Professional Paper

The Utility Value of Solar Water Heating Systems in New York State

FSEC-PF-332-98

Tim Merrigan
Carlos Colon

Florida Solar Energy Center
1679 Clearlake Road
Cocoa, Florida 32922

Presented at
The 1998 ASME International Solar Energy Conference
Albuquerque, New Mexico, June 15-17, 1998

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Tim Merrigan
Carlos Colón

Florida Solar Energy Center
University of Central Florida
1679 Clearlake Road
Cocoa, Florida 32922 USA
(407) 638-1000

ABSTRACT

The Florida Solar Energy Center (FSEC), under contract to the New York State Energy Research and Development Authority, installed 12 solar domestic hot water (SDHW) systems in single-family residences in downstate New York and instrumented them to determine energy consumption and time-of-day electrical demand. Annual performance data was collected on both the SDHW systems and the original electric resistance water heaters and has been analyzed to determine energy efficiency, cost effectiveness, and the impact on electrical utility peak demand.

During the summer months, a typical New York State SDHW system is able to reduce weekday electrical demand by 90 percent (when compared to the weekday demand of electric resistance water heaters) at times that coincide with utility system peak demand. Furthermore, a SDHW system was able to reduce coincident demand by 88 percent on the 1995 Long Island Lighting Company (LILCO) summer peak day and by 92 percent on the Consolidated Edison Company of New York summer peak day. In addition, SDHW systems do not adversely impact the utility system by decreasing the load factor for electric water heating, since the annual weekday load factor for both the SDHW systems and the electric resistance water heaters was 60 percent.

The average New York SDHW system installed during this program also operated with approximately a 63 percent higher annual electrical energy efficiency than the average electric resistance water heater. The energy savings due to a New York SDHW system ranged from approximately 900 to 3,100 kWh per year, with a mean of 1,980 kWh per year -- based on an average electric resistance water heater usage of 4,623 kWh per year for the twelve original electric water heaters. Therefore, at the 1995 residential electricity rates of the three New York utilities -- LILCO, Con Edison, and Orange & Rockland Utilities -- in whose service areas the systems were installed, the average utility customer could save approximately $325 per year due to a typical SDHW system. The average installed cost for a SDHW system in this program was $3,850, so the average tax-free rate of return for the 12 SDHW systems was approximately 8 percent. However, if the utility owned the SDHW system and sold the hot water to the customer for a monthly fee, the after-tax internal rate of return to the utility for installing 1,550 SDHW systems over five years at an investment of approximately $4 million could be 11.8 percent per system. Therefore, it appears that the potential exists for a utility to generate revenue from a SDHW program without taking into account the ancillary benefits of good customer relations, environmental incentives, possible renewable energy credits, or the 90 percent reduction in summer peak demand.

INTRODUCTION

In 1992, the New York State Energy Research and Development Authority (NYSERDA) contracted with the Florida Solar Energy Center (FSEC) to evaluate the current technology of solar domestic hot water (SDHW) systems available in the United States and then conduct a field demonstration using the four most promising systems for New York State. The objective of the field demonstration was to determine the performance, cost effectiveness, and utility value of SDHW systems in New York State.

The results of a preliminary SDHW system review indicated that there were two solar system designs appropriate for New York State -- pressurized antifreeze (indirect) systems and drainback systems. Since the project's field demonstration was designed to install four system types in each of the three participating utilities' service areas -- Consolidated Edison Company of New York, Inc. (Con Edison), Long Island Lighting Company (LILCO), and Orange and Rockland Utilities, Inc. (O&R) -- it was recommended that two drainback systems and two pressurized antifreeze systems be included in the program. The following four separate SDHW system models were recommended for the field demonstration:

A1. Single-phase pressurized antifreeze with a photovoltaic-powered circulating pump,
A2. Two-phase pressurized antifreeze with a patented self-pumping mechanism,
D1. Drainback system with a photovoltaic-powered pump, and
D2. Drainback system with a conventional AC-powered pump.

METHODOLOGY

Through the cooperation of the participating electric utilities, more than 90 single-family residences were identified whose owners agreed to allow the installation of both a SDHW system and performance monitoring equipment for at least a 16-month period. Table 1 lists the location of the selected project sites by utility service area and the installed SDHW system type, as well as the existing electric water heater size, the wattage of the existing water heater's electrical elements, its energy factor (EF) rating (U.S. Department of Energy, 1990) and the temperature settings (in degrees Fahrenheit) of the element thermostats. The project's Advisory Panel also recommended that the project sites have a family size of four or more, so eight of the selected residences had a family size of four people and four sites had a family size of five.

The first solar system was installed in November 1993 at the home located in Huntington Station (Nassau County). The twelfth solar system was installed in December 1994 at the last selected site (A1) in Warwick (Orange County). Both SDHW system types A1 and D1 used two conventional 4 feet (1.2 meters) by 8 feet (2.5 meters) solar collectors with coated metal absorber plates. System type A2 -- the two-phase, pressurized antifreeze system -- also used two solar collectors with coated metal absorbers of approximately 32 square feet (3 square meters) each; however, each collector incorporated a self-pumping manifold at one end that occupied an additional eight square feet. Finally, system type D2 used two 4 feet (1.2 meters) by 12 feet (3.6 meters) collectors with a nonmetallic absorber made of an ethylene-propylene-diene monomer (EPDM) that was manufactured in New York State.

Instrumentation

In order to evaluate the system performance as well as the utility value of the 12 SDHW systems, the electrical energy input to each system and the hot water energy output from each system was measured. Determination of the heat output in conjunction with the energy input furnished the system's electrical efficiency on a daily, monthly, or annual basis. The electrical energy input was also measured on a 15-minute interval basis to determine the time-of-day impact on the total utility system load profile.

Figure 1 displays a schematic of the monitoring equipment installed on each water heating system. A two-tank SDHW system was installed in order to retain the original electric resistance water heater and meter its energy consumption on a periodic basis. Furthermore, a combination mixing/anti-scald valve was installed on the hot water outlet of the existing water heater to ensure that the temperature of the water supplied to the house would remain relatively constant. The actual instrumentation used at each site included the following:

- Kilowatt-hour meter,
- Heat (Btu) meter with an additional volume indicator, and
- Solid-state data recorder (with its own telephone line).

The kilowatt-hour (kWh) meter was a standard item with ±2 percent rated accuracy. It measured not only the 230 volts AC (VAC) electric consumption of the storage tank's electric resistance element(s) but also, by splitting a 115 VAC outlet off one of the three-wire legs, the electrical consumption of any AC pumps and controllers that were used in some of the systems. Standard single-phase 30-amp meters were used with a pulse initiator that had a resolution of one watthour.

To measure the hot water energy delivered by both the solar tank and the total hot water system, a heat or Btu meter was installed at each site. This thermal energy meter used an electronic circuit to integrate the signal from a standard water meter installed in the cold water supply line

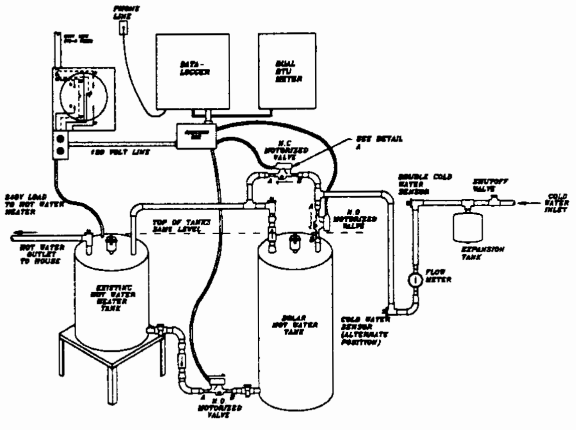

Figure 1. Electric Resistance and SDHW System Monitoring Instrumentation

Table 1
SDHW System Locations and Electric Water Heater Features

System Type	Site Location	Tank Volume gal (liters)	Element Size (kW)	Rated EF	Thermostat Upper/ Lower
LILCO - Long Island (Nassau and Suffolk Counties)					
A1	Southampton	50 (190)	4.5	.86	120/110
A2	Shirley	40 (150)	3.8	.89	120/130
D1	Lake Grove	50 (190)	4.5	.88	140/140
D2	Huntington Stn.	40 (150)	4.5	.88	115/110
Consolidated Edison - Westchester County					
A1	Croton-Hudson	66 (250)	5.5	.85	140/120
A2	Mohegan Lake	85 (320)	3.8	.95	120/120
D1	Yorktown Hgts.	52 (200)	5.5	.88	140/120
D2	Ossining	50 (190)	4.5	.88	130/130
O&R - Orange and Rockland Counties					
A1	Warwick	40 (150)	4.5	.89	130/120
A2	Warwick	52 (200)	3.8	.88	Unreported
D1	Spring Valley	82 (310)	4.5	.87	140/130
D2	Florida	50 (190)	4.5	.88	120/120

with the temperature difference signals from sensors installed in the cold water inlet and both the hot water output to the house as well as the hot water output from the solar tank. Laboratory tests on the flow meter have indicated flow accuracies within 2.3 percent of the true mass flow over long time periods. Similar tests on the heat calculation have indicated an accuracy of within 5 percent of the true energy flow, with resolutions of 1,000 Btus (0.3 kWh) and 1 gallon (3.8 liters) (Merrigan and Wang, 1981).

The solid-state data recorder accumulated contact closure pulses from the kWh, heat, and flow meters and stored them in 15-minute totals in its internal memory. These totals were routinely acquired by the FSEC computer system through telephone interrogation of the recorders and then stored in this same raw pulse format for eventual data reduction. The data recorders also had the ability to open or close relays and thus energize three motorized valves that were installed in each system. These valves were capable of isolating the solar system from the electric water heater and, hence, permitted the collection of periodic energy data on the original electric resistance water heater. The solar heat collection process itself was allowed to keep operating during these periods; however, the solar tank was not permitted to supply solar-heated water to the auxiliary electric water heater. Therefore, the electric resistance elements in the original water heater were the only source of hot water for each residence during these times.

Annual performance data was collected on both the SDHW systems and the original electric resistance water heaters and was analyzed to determine the water heating system's energy efficiency, or coefficient of performance (COP), defined as:

$$\text{COP} = \frac{\text{Hot water energy delivered}}{\text{Electrical energy consumed}}$$

as well as cost effectiveness and impact on electrical utility peak demand.

RESULTS

Table 2 presents the annual daily average of the four measured quantities as well as the calculated coefficient of performance (COP) for each system during the twelve months from March 1995 through February 1996. This is the one-year period when data was being collected from all 12 SDHW systems simultaneously.

Table 3 next lists the SDHW system group annual daily averages of electric use, hot water use, hot water energy use, energy drawn from the solar tank, and COP, as well as the range of these values for the 12 systems over the twelve-month period from March 1995 through February 1996.

Figures 2 to 5 present average daily 15-minute profiles of the four measured quantities for the group of 12 SDHW systems over the 12-month period from March 1995 through February 1996 as well as for a three-month summer season (June - August 1995) and a three-month winter season (December 1995 - February 1996). These annual and seasonal profiles include both weekdays and weekends, a distinction that will be investigated more in the analysis section. Also, all times displayed in the profiles are clock times, i.e., Eastern Standard Time (EST) from the end of October through the beginning of April, and Eastern Daylight-saving Time (EDT) during the rest of the year. This approach was taken since the use of household hot water generally corresponds to actual clock time, as discussed below.

The profiles of average hot water use (Fig. 3) reveal the characteristic double peak of morning and evening use throughout the year and the two seasons. This double peak is characteristic of typical residential hot water use patterns -- washing or showering in the morning and then food preparation and clean-up in the evening (ASHRAE, 1995). The hot water energy consumption profiles (Fig. 4) as well as the energy drawn from the solar tank profiles (Fig. 5) follow the hot water volume profiles fairly closely, since the hot water volume is integrated with the cold and hot water temperature difference to determine the energy content of the water.

Table 2
Annual Daily Averages (March 1995 - February 1996)

System Type	Electricity (kWh)	Hot Water gal (liters)	Hot Water (kWh)	Solar Tank (kWh)	COP
LILCO - Long Island (Nassau and Suffolk Counties)					
A1	9.6	60.6 (230)	10.7	5.8	1.11
A2	7.9	48.0 (182)	9.0	3.6	1.15
D1	9.6	84.5 (320)	15.3	7.9	1.58
D2	4.6	58.0 (220)	9.8	7.3	2.12
Consolidated Edison - Westchester County					
A1	15.3	81.4 (308)	18.4	6.2	1.20
A2	5.6	50.0 (189)	9.1	4.8	1.62
D1	4.6	39.5 (150)	7.0	4.1	1.57
D2	5.9	45.4 (172)	5.9	2.7	1.00
O&R - Orange and Rockland Counties					
A1	8.4	49.6 (188)	9.9	4.7	1.17
A2	3.4	43.9 (166)	6.2	3.9	1.83
D1	5.7	37.8 (143)	7.6	5.4	1.32
D2	6.0	52.5 (199)	8.6	4.8	1.45

Table 3
Group Annual Daily Averages (March 1995 - February 1996)

	Annual Average	Annual Range
Daily SDHW Electric Use	7.1 kWh	3.4 - 15.3 kWh
Daily Hot Water Use	53.5 gal 202.5 liters	37.8 - 84.5 gal 143 - 320 liters
Daily Hot Water Energy Use	9.7 kWh	5.9 - 18.4 kWh
Daily Energy Drawn from the Solar Tank	5.1 kWh	2.7 - 7.9 kWh
Daily COP	1.36	1.00 - 2.12

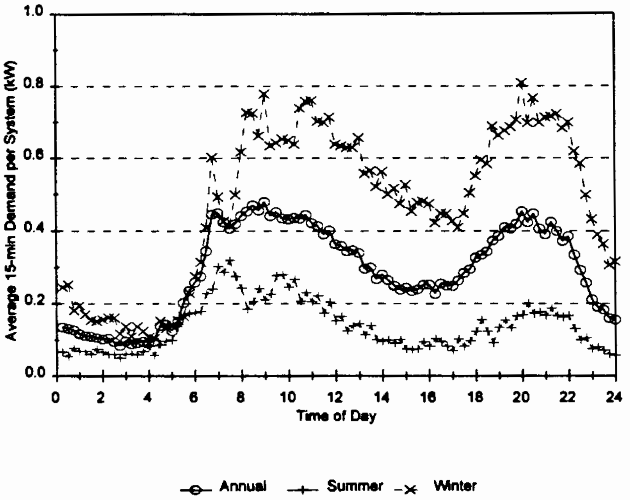

Figure 2. Avg. Daily 15-min Electrical Demand per System

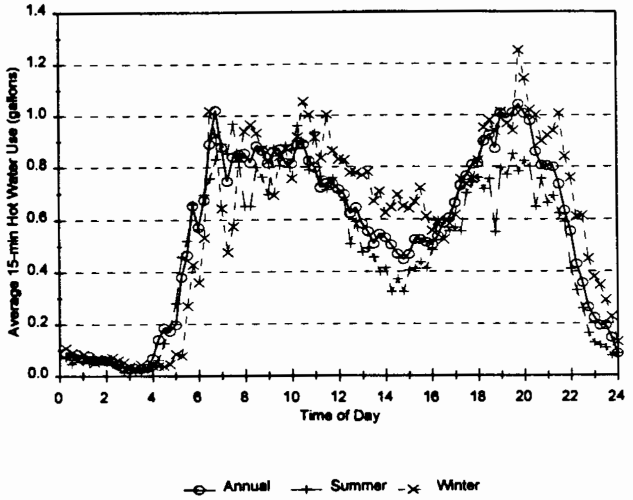

Figure 3. Average Daily 15-min Hot Water Use per System

Furthermore, the profiles of average 15-minute electrical demand (Fig. 2) for a SDHW system also follow the hot water consumption profiles fairly closely; however, the magnitude of the profiles depends both on the time of the day and on the season of the year. For a SDHW system is able to produce solar-heated water throughout the day and thus meet the evening hot water demand with less electrical input to the auxiliary element. In the summer, this effect is even more pronounced than during the rest of the year.

ANALYSIS

In order to determine the cost effectiveness and utility value of SDHW systems in New York State, it is first necessary to determine the energy consumption and time-of-day demand of typical New York electric resistance water heaters for the purpose of comparison. Fortunately, both the two-tank arrangement and the instrumentation used in this project permitted the collection of periodic energy data on the performance of the original electric resistance water heater in each of the 12 residences selected for this program. This data was collected during various times of the year by isolating the solar tank from the electric water heater for periods of two or more days. The solar heat collection process was allowed to keep operating during this period; however, the solar tank was not permitted to supply solar-heated water to the auxiliary electric water heater. Furthermore, in order to eliminate any potential "carry-over" of previously solar-heated water in the auxiliary electric water heater, the first day of tank isolation was omitted from the analysis of electric resistance element operation that is presented here.

Analogously, when the isolation valves between the solar and auxiliary tanks were eventually opened and the system returned to normal two-tank solar operation, there was very often more hot water

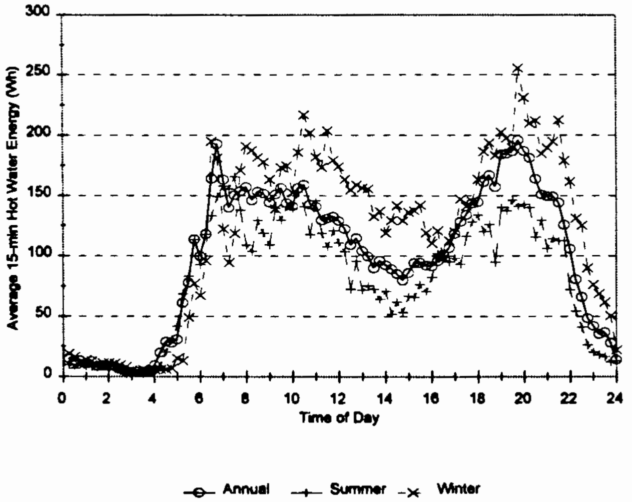

Figure 4. Average Daily 15-minute Hot Water Energy Use per System

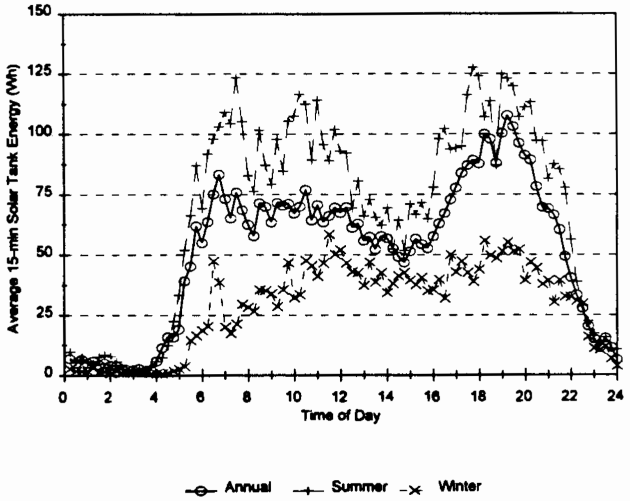

Figure 5. Average Daily 15-minute Energy Drawn from the Solar Tank

Table 4
Electric Resistance Water Heater Daily Averages (March 1995 - February 1996)

System Type	Electricity Use (kWh)	Hot Water Use gal (liters)	Hot Water Energy (kWh)	Electric COP	Rated EF	Heat Loss (kWh)
LILCO - Long Island (Nassau and Suffolk Counties)						
A1	13.8	61.1 (231)	10.8	0.78	0.86	3.0
A2	12.4	42.2 (160)	9.6	0.77	0.89	2.8
D1	18.1	88.8 (336)	16.7	0.92	0.88	1.4
D2	11.2	68.5 (259)	10.0	0.90	0.88	1.2
Consolidated Edison - Westchester County						
A1	23.9	92.2 (349)	19.9	0.84	0.85	4.0
A2	11.6	51.5 (195)	10.3	0.88	0.95	1.3
D1	6.8	31.4 (119)	5.9	0.86	0.88	0.9
D2	11.3	45.3 (171)	6.5	0.58	0.88	4.8
O&R - Orange and Rockland Counties						
A1	13.0	52.8 (200)	10.5	0.81	0.89	2.5
A2	6.4	39.5 (150)	5.8	0.91	0.88	0.6
D1	11.8	51.4 (195)	10.4	0.88	0.87	1.4
D2	11.3	55.8 (211)	9.9	0.87	0.88	1.4

Table 5
Annual Energy Savings (March 1995 - February 1996)

System Type	Daily Base Electricity (kWh)	Annual Base Electricity (kWh)	Daily SDHW Electricity (kWh)	Annual SDHW Electricity (kWh)	Energy Savings (kWh)
LILCO - Long Island (Nassau and Suffolk Counties)					
A1	13.8	5060	9.6	3532	1528
A2	12.4	4534	7.9	2873	1661
D1	18.1	6641	9.6	3528	3113
D2	11.2	4097	4.6	1701	2396
Consolidated Edison - Westchester County					
A1	23.9	8733	15.3	5598	3135
A2	11.6	4268	5.6	2065	2203
D1	6.8	2491	4.6	1632	859
D2	11.3	4121	5.9	2174	1947
O&R - Orange and Rockland Counties					
A1	13.0	4745	8.4	3082	1663
A2	6.4	2334	3.4	1247	1087
D1	11.8	4309	5.7	2096	2213
D2	11.3	4144	6.0	2184	1960

than usual in the solar tank. Although this hot water was provided by the solar system, it was not subject to the normal usage patterns of the residence during the days of solar tank isolation and electric resistance element-only operation. Hence, when presenting the solar system performance data, the first day following the isolation valve switch-over is also omitted from the solar system results.

Energy Savings

Electric Water Heater Performance. Table 4 presents the daily average of the measured quantities as well as the calculated COP for each electric water heater during the periods of solar storage tank isolation from March 1995 through February 1996. These periods represent a total of 34 days spread out over the data year, or approximately one month of data collection on each original electric water heater. For ease of comparison, Table 4 also lists the rated energy factor (EF) of the electric water heater (from Table 1) as well as the calculated daily average storage tank heat loss. (Since the solar tank was isolated during the periods of data collection on the electric water heater, the solar tank energy supplied is not listed in Table 4.)

The annual average COP for the group of twelve original electric resistance water heaters was determined to be 0.83. Table 4 also reveals that system type D2 in Westchester County has an electric water heater with a measured COP that is considerably lower than what would be expected from its rated energy factor. Furthermore, this relatively new water heater (installed in 1993) has the highest daily average heat loss of all the 12 systems, perhaps due to voids in the foam insulation around the tank but concealed under the sheet metal housing. This low electric COP, however, explains why the annual COP for this solar system was reported in Table 2 as just 1.0 -- the lowest of all the 12 SDHW systems. It also strongly emphasizes the need for a fair basis of comparison when determining the energy savings of SDHW systems.

SDHW System Energy Savings. Table 5 presents the calculated annual energy savings of each SDHW system during the 12 months from March 1995 through February 1996. The individual system savings are determined by first multiplying the daily average electrical use for both the base electric resistance water heater and the SDHW system (presented in Tables 4 and 2, respectively, and also provided in Table 5) by 366 days in a year (1996 was a leap year). The calculated annual energy savings, listed in the last column of Table 5, are simply the differences between the two annual electricity consumptions.

Table 5 indicates that the energy savings due to a New York SDHW system ranges from approximately 900 to 3,100 kWh per year, with a calculated mean of 1,980 kWh per year, based on an average electric resistance water heater usage of 4,623 kWh per year for the twelve original electric water heaters. The rather large variability in energy savings among only 12 systems can almost entirely be explained by an 80 percent correlation between savings and hot water use at each site.

Cost Effectiveness

At the 1995 residential electricity rates of the three New York utilities -- LILCO, Con Edison, and Orange & Rockland -- in whose service areas the systems were installed, the average utility customer could save approximately $325 per year due to a typical SDHW system. The average maintenance cost for each system was determined over 245 months (20.4 years) of system operation to be $19.74 per year. The average installed cost for a SDHW system in this program was $3,850, so the average tax-free rate of return for the 12 SDHW systems was approximately 8 percent. To achieve a simple rate of return greater than 10 percent typically requires that a SDHW system customer have a hot water use of approximately 70 gallons per day or more.

In addition to examining the energy savings and cost effectiveness for the utility customer, a SDHW system also can be analyzed as a revenue-generating business for the utility itself. In fact, the analysis of a SDHW system as a distributed-generation or end-use pricing business for a utility (or one of its unregulated subsidiaries) opens up a number of financial options that are not available to its residential customers. For example, if the utility owns the SDHW system and sells the hot water energy generated by it to its customer, then an investor-owned utility could take advantage of two corporate income tax incentives -- depreciation of the equipment and the federal 10 percent investment credit for solar energy. Furthermore, environmental credits are also available from the Environmental Protection Agency (EPA) Conservation and Renewable Energy Reserve in the form of sulfur dioxide (SO_2) allowances under EPA's Acid Rain Program. (LILCO, Con Edison, and Orange & Rockland are already participants in this reserve program and have been awarded allowances for their commercial and residential efficiency programs (EPA, 1996).) Finally, if a percentage of utility energy generation is required to be supplied by renewable energy in any of the number of national electric utility restructuring bills that are currently being debated in the U.S. Congress (e.g., H.R. 655 - "Electric Consumers' Power to Choose Act of 1997" introduced by Representative Dan Schaefer of Colorado), a utility SDHW system business would contribute to that renewable portfolio.

However, to analyze the financial impact to the utility of providing solar hot water services to its customers, it is necessary to use a fairly sophisticated economic model to account for all the financial parameters and relevant cash flows. Fortunately, one investor-owned utility, Wisconsin Public Service Company, in conjunction with its energy services consultant, Energy Alliance Group (1997), has recently developed the Solar Thermal Financial Model to compute the net present value (NPV) and internal rate of return (IRR) not only to the utility and to the utility customer but also to an unregulated, third-party energy services company (ESCO), if necessary. Table 6 presents a summary sheet from this model that lists the data inputs and outputs for an example using the average New York SDHW system performance and costs from this project as well as the 1995 energy costs, tax rates, and discount rate of Con Edison (1996). Con Edison's 1995 discount rate or weighted-average cost of capital of 8.64 percent is based on its capitalization ratios and costs as presented in Table 7. (For comparison, LILCO's and O&R's 1995 discount rates are 7.59 percent and 8.82 percent, respectively (LILCO, 1996; O&R, 1996).) For the purposes of this example analysis, systems are only installed by the utility in the first five years (50 systems in the first year and doubling every year for the next four years) in order to capture their cash flow effects over time. Finally, even though the project's SDHW system maintenance costs averaged $19.74 per system per year, the example analysis uses a maintenance cost of $25 per system per year in order to provide extra funds for possible replacement of the solar storage tank during the 20-year period. (All the remaining SDHW system equipment -- solar collector, heat exchanger, circulating pump, controller and wiring, valves and piping -- has an expected service life greater than 20 years.)

Table 7
1995 Discount Rate Calculation
for Consolidated Edison Company of New York, Inc.
(Source: 1995 Con Edison Annual Report)

Capitalization	Ratio (%)	Cost (%)	Composite (%)
Debt	38.9	7.71	3.00
Preferred Stock	6.3	5.56	0.35
Common Equity	54.8	11.6	6.36
Total	100.0		9.71
Effective Tax Rate	35.5		
After-Tax Discount Rate			8.64

Table 6 indicates that the after-tax internal rate of return to the utility for installing 1,550 SDHW systems over five years at an investment of approximately $6 million would be a modest 4.15 percent per system. However, it must be emphasized that this example used the project's average installed SDHW system cost of $3,850 for just 12 systems (that were purchased in lots of three). The equipment cost would most certainly be less if the utility was purchasing 1,550 SDHW systems over five years. In fact, if the lowest of the four SDHW systems' equipment and installation costs are used in the example analysis -- for a total installed system cost of $3,141 -- then the utility's after-tax rate of return increases to 6.2 percent on a total five-year investment of approximately $5 million. Lowering the installed system cost to $2,500 increases the rate of return to 8.7 percent -- which is higher than the utility's discount rate -- on an investment of less than $4 million.

Furthermore, this example also used the project's average energy savings of 1,980 kWh per year, or approximately $30 per month, to determine the customer monthly payment of $28.00 or a discount to the customer of approximately 5 percent. However, in a market research study of a proposed SDHW leasing program commissioned by Jersey Central Power & Light in 1996, 28 percent of the utility customers surveyed said that they would be "very likely" to participate in the program even if their cost increased $5 per month (Energy Alliance

Table 6
Solar Thermal Financial Model Summary Sheet

NEW YORK STATE SOLAR WATER HEATER UTILITY ANALYSIS
Data Inputs and Summary Outputs

Scenario: DISTRIBUTED GENERATION **Owned By: CON EDISON (Example)**

NAMES AND TITLES	
Scenario	ISTRIBUTED GENERATION
Technology Name	SOLAR WATER HEATER
Utility Name	CON EDISON (Example)
ESCO Name	ESCO
Customer Name	CUSTOMER

CUSTOMER SAVINGS		
Monthly Savings	29.86	$/month
Annual Savings	358.33	$/yr

ENVIRONMENTAL CREDIT		
Environmental Credit	0.00000	$/kWh
Environmental Credit	0.00	$/month
Env. Credit Goes To	CON EDISON (Example)	

COSTS PER SYSTEM	
Equipment	$2,500
Installation	$1,350
Margin	$0
Total System	$3,850

OWNERSHIP	
System Owned By	CON EDISON (Example)

PERF. BONUS FACTOR		
Percentage	0%	
Goes To	CONTRACTOR	
Payout Term	0	months

MAINTENANCE COST SCHEDULE	
At 0 months	$0.00
At 12 months	$25.00
At 24 months	$25.00
At 36 months	$25.00
At 48 months	$25.00
At 60 months	$25.00
At 72 months	$25.00
At 84 months	$25.00
At 96 months	$25.00
At 108 months	$25.00
At 120 months	$25.00
At 132 months	$25.00
At 144 months	$25.00
At 156 months	$25.00
At 168 months	$25.00
At 180 months	$25.00
At 192 months	$25.00
At 204 months	$25.00
At 216 months	$25.00
At 228 months	$25.00
At 240 months	$25.00
TOTAL	$500.00

CUSTOMER LUMP SUM PAYMENTS		
Down Payment	$0	
End of Term Buyout	$0	
CUSTOMER MONTHLY PAYMENTS		
Customer Payment	28.00	$/month
O&M Escrow	2.08	$/month
Performance Bonus	0.00	$/month
Sales Tax	1.12	$/month
Net System/Program Payment	24.80	$/month
Contract Term	240	months
Equipment Life	240	months

FINANCING		
Rebate	☐ Taxable	$0
Financed By		CON EDISON (Example
Financed Amount		$0
Annual Interest Rate		6.50%
Amortization Term		0 months
Finance Payment		Not Applicable (N/A)
Escrow Interest Rate		4.00%

DEPRECIATION SCHEDULE	
Amount Depreciable	$3,850
Depreciation Schedule	Modified ACRS -- 7 Year
For St. Line Depreciation	8 years

DISCOUNT RATE (Excluding General Inflation)	
CON EDISON (Example)	8.64%
ESCO	10.00%
CUSTOMER	8.00%

TAX DEDUCTIONS AND CREDITS	
Federal Solar Tax Deduction	0.00%
Tax Deduction Amount	$0
State Solar Tax Deduction*	0.00%
Tax Deduction Amount	$0
Tax Credit	10.00%

TAX RATES	
CON EDISON (Example) Corp	35.000%
ESCO Corporate Tax Rate	40.000%
CUSTOMER Tax Rate	36.000%
Sales Tax Rate	4.000%
Gross Receipts Tax Rate	8.297%

ANNUAL ESCALATION RATE (Excluding General Inflation)	
Electric Price	0.00%
Gas Price	0.00%
Oil Price	0.00%

ANNUAL SYSTEMS INSTALLED AND FIXED COSTS			
	Systems Installed In	Fixed Costs For	
		CON EDISON (Example)	ESCO
Set-Up		$100,000	$0
Year 1 of Program	50	150,000 $/yr	0 $/yr
Year 2 of Program	100	150,000 $/yr	0 $/yr
Year 3 of Program	200	150,000 $/yr	0 $/yr
Year 4 of Program	400	150,000 $/yr	0 $/yr
Year 5 of Program	800	150,000 $/yr	0 $/yr

RESULTS: FOR SINGLE SYSTEM	
Payback w/o Rebate	10.81 years
Payback with Rebate	10.81 years
Utility Pre Tax NPV	($1,361)
Utility After Tax NPV	($849)
Utility Pre Tax IRR	3.20%
Utility After Tax IRR	4.15%
ESCO Pre Tax NPV	$0
ESCO After Tax NPV	$0
ESCO Pre Tax IRR	N/A
ESCO After Tax IRR	N/A
Customer Pre Tax NPV	$221
Customer After Tax NPV	$141
Customer Pre Tax IRR	N/A
Customer After Tax IRR	N/A

* Feature Not Implemented In This Version

SEE "ERRORS" SHEET FOR ERRORS AND WARNINGS

VARIABLE, PER SYSTEM COSTS		
Insurance	6.00	$/yr
CON EDISON (Example) Admi	0.25	$/month
ESCO Admin Cost	0.00	$/month

RESULTS: MULTIPLE SYSTEMS MULTIPLE YEARS	
Utility Pre Tax NPV	($2,316,066)
Utility After Tax NPV	($1,462,823)
Utility Pre Tax IRR	1.74%
Utility After Tax IRR	2.74%
ESCO Pre Tax NPV	$0
ESCO After Tax NPV	$0
ESCO Pre Tax IRR	N/A
ESCO After Tax IRR	N/A
Total # of Systems	1,550
Total Undisc. Value	$5,967,500

Group, 1997). Hence, if the customer's payment were increased to $35 a month and the system cost kept at $2,500, the example analysis reveals that the rate of return to the utility would increase to 11.8 percent per system -- higher than Con Edison's 1995 rate of return on common equity of 11.6 percent (from Table 7). Therefore, it appears that the potential exists for a utility to generate revenue from a SDHW program, without taking into account the ancillary benefits of good customer relations, long-term customer retention, environmental incentives, possible renewable energy credits, or time-of-day electrical demand impact -- which will be discussed in the next section.

Time-of-Day Impact

Annual and Seasonal Comparisons. The electrical demand profiles of the 12 SDHW systems also need to be compared to demand profiles of the 12 original electric resistance water heaters as well as to utility system loads in order to determine the time-of-day utility impact. Figure 6 presents the average daily electrical demand profiles (based on hourly intervals) both for the sample group of 12 SDHW systems and for the group of 12 electric resistance water heaters (during the periods of solar storage tank isolation) over the 12-month period from March 1995 through February 1996. As indicated at the beginning of this analysis section, the diversified annual demand profile for the electric resistance

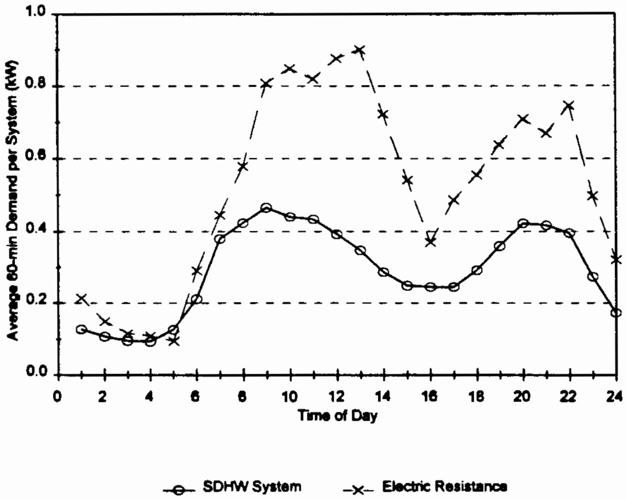

Figure 6. Average Daily 60-minute Electrical Demand per System

water heaters represents a total of approximately 34 days for each system spread over the data year. Hence, the profile is somewhat more "jagged" than the diversified annual demand profile of the SDHW systems which is averaged over more than 300 days for each system. Nevertheless, the overall shape and magnitude of the 34-day profile is still representative of the diversified demand of an electric water heater, for averaging over a longer time period only serves to reduce the uncertainty in the individual data points, resulting in a "smoother" curve. Both annual profiles in Fig. 6 also include all days of the week, so their shapes are somewhat influenced by the later morning use of hot water on weekends. Therefore, Figures 7 and 8 display data similar to that in Fig. 6, but for weekdays and weekends, respectively.

Figures 9 and 10 present the average 60-minute demand profiles for both the SDHW systems and the electric resistance water heaters during three months of summer (June - August 1995) for weekdays and weekends, respectively. However, while the weekday SDHW profile is diversified over all operating systems for approximately 60 summer days in Fig. 9, the weekday electric resistance profile represents the average demand of eleven water heaters during just two days of storage tank isolation (June 7-8) plus one system that was operating on its electric resistance element only for 26 days (June 14 - July 9). Similarly, the weekend electric resistance profile in Fig. 10 represents the average demand of all 12 electric water heaters during one late summer weekend (September 9-10), while the SDHW system profile is averaged over 13 weekends for all the systems. Hence, the summer electric resistance profiles appear to incorporate more uncertainty than the summer SDHW system profiles and therefore, require further statistical analysis to test for significance in their differences.

Figures 11 and 12 present the average 60-minute demand profiles for both the SDHW systems and the electric resistance water heaters during three months of winter (December 1995 - February 1996) on weekdays and weekends, respectively. These profiles appear to be more comparable than the summer profiles in the previous two figures, since the electric resistance profiles have been averaged over many more days.

One means of quantifying the differences between the electric resistance and SDHW system profiles in Figures 7 to 12 is the calculation of "load factor." Load factor is the ratio, expressed as a percent, of the average demand over a designated period of time to the peak demand occurring in that period. It is therefore a measure of how well the electrical capacity demanded from the utility is utilized by the load over a period of time. A utility would generally prefer a high load factor for all of its loads, to enable better load management and system planning; however, a load factor greater than 40 percent for any residential appliance is typically considered good.

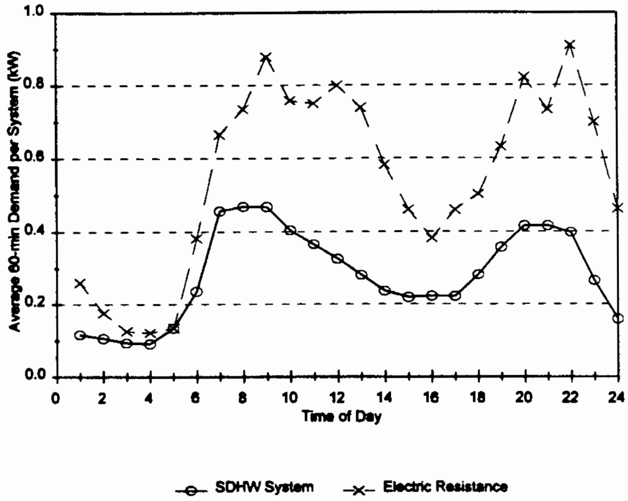

Figure 7. Average Weekday 60-minute Electrical Demand per System

Table 8 lists the average 60-minute demand, the peak 60-minute demand, and the load factor for both the sample group of 12 SDHW systems and the electric resistance water heaters on weekdays during the three months of both summer and winter and during the whole year. Table 9 presents similar information for weekends during the same periods.

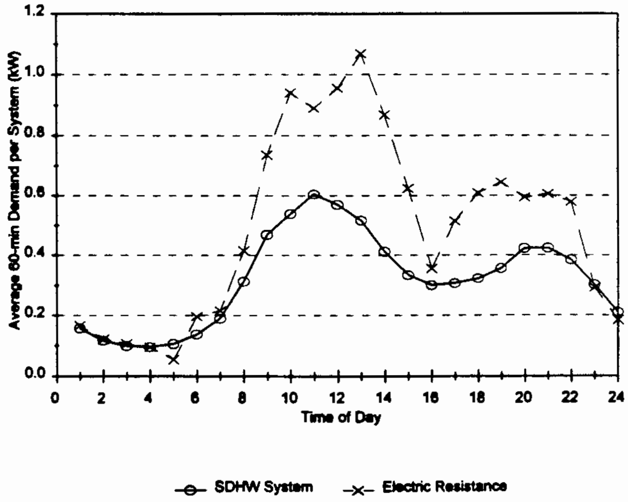

Figure 8. Average Weekend 60-minute Electrical Demand per System

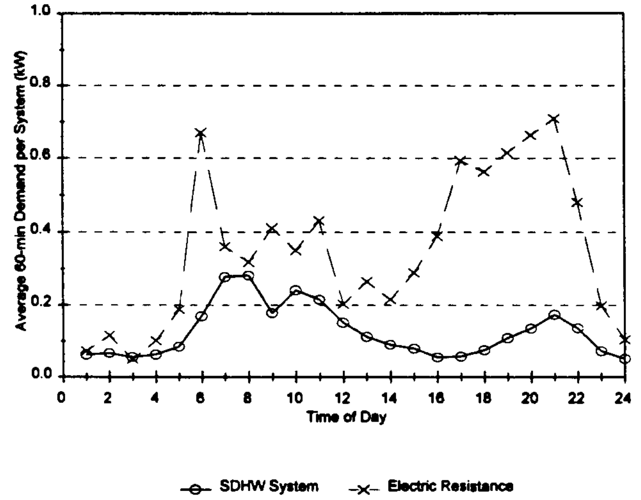

Figure 9. Average Weekday 60-minute Electrical Demand in Summer

Table 8
Weekday Average 60-minute Demands, Peak 60-minute Demands, and Load Factors

	Summer (Jun 95-Aug 95)		Winter (Dec 95-Feb 96)		Year (Mar 95-Feb 96)	
	SDHW	Electric	SDHW	Electric	SDHW	Electric
Average kW	0.13	0.35	0.46	0.55	0.28	0.55
Peak kW	0.28	0.71	0.82	0.97	0.47	0.91
Load Factor %	44	49	56	57	60	60

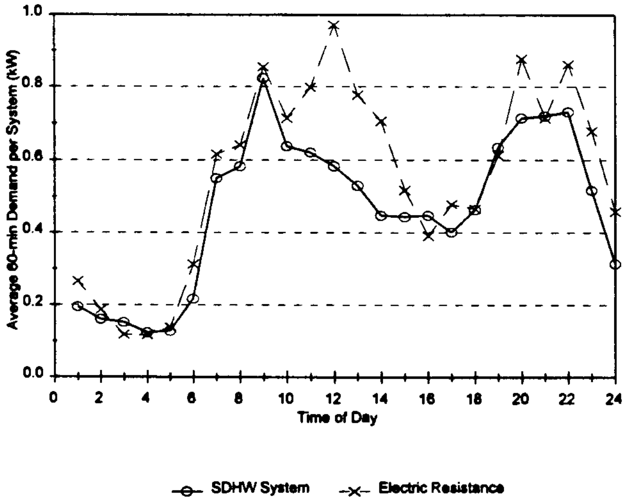

Figure 11. Average Weekday 60-minute Electrical Demand in Winter

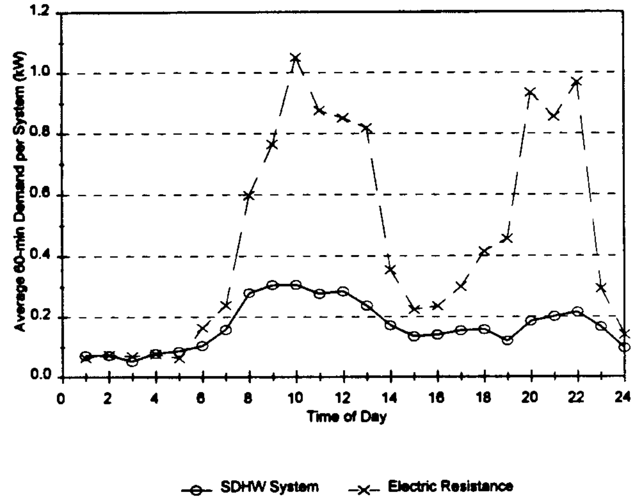

Figure 10. Average Weekend 60-minute Electrical Demand in Summer

Table 9
Weekend Average 60-minute Demands, Peak 60-minute Demands, and Load Factors

	Summer (Jun 95-Aug 95)		Winter (Dec 95-Feb 96)		Year (Mar 95-Feb 96)	
	SDHW	Electric	SDHW	Electric	SDHW	Electric
Average kW	0.17	0.45	0.52	0.52	0.32	0.49
Peak kW	0.31	1.05	0.96	1.29	0.61	1.07
Load Factor %	55	43	54	41	53	46

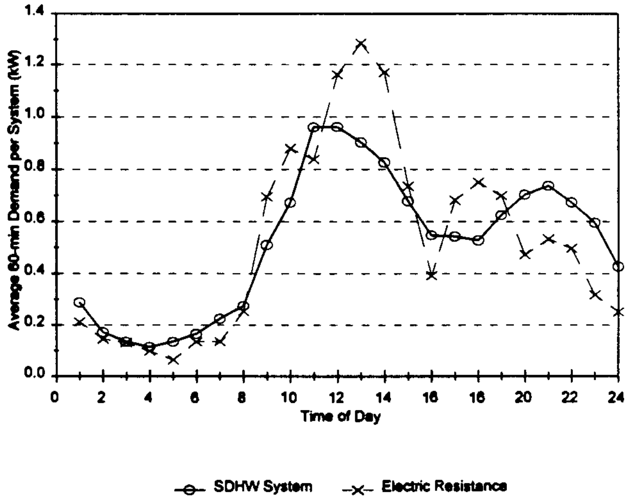

Figure 12. Average Weekend 60-minute Electrical Demand in Winter

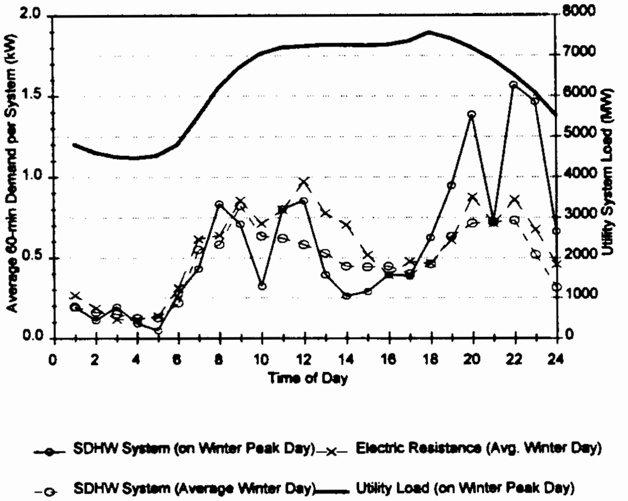

Figure 13. 60-minute Electrical Demand on the LILCO and Con Edison Winter Peak Day

It is evident from Tables 8 and 9 that SDHW systems are able to reduce residential water heating electrical demand on both weekdays and weekends in the summer and the winter, and over the full year. This reduction is especially evident on summer weekdays, when SDHW system average demand is only 37 percent of the average demand of electric resistance water heaters. Furthermore, weekday load factors for the SDHW systems are nearly equivalent to the load factors for electric resistance water heaters, with both types of systems displaying a 60 percent load factor for annual weekdays. On weekends -- when people typically use hot water later in the morning -- the load factors for SDHW systems exceed the load factors for electric water heaters on both a seasonal and an annual basis.

Utility Peak Days. The time-of-day use of electricity for water heating is especially important on those days when electric utilities experience their peak demand for power. System peak demands usually occur on the hottest weekdays during the summer and the coldest weekdays during the winter. Based on information supplied by the three utilities in whose service areas the SDHW systems were located, Table 10 lists both the times and the integrated hourly magnitudes of 1994-95 winter and summer system peak loads.

Table 10
1994-95 New York Utility Peak Days and System Loads

Electric Utility	Winter Peak Day			Summer Peak Day		
	Date	Time	MW	Date	Time	MW
LILCO	6 Feb 95	19:00	2924	4 Aug 95	17:00	4077
Con Edison	6 Feb 95	18:00	7576	2 Aug 95	16:00	10805
O&R	13 Dec 94	18:00	733	15 Jul 95	15:00 16:00	1068 1068

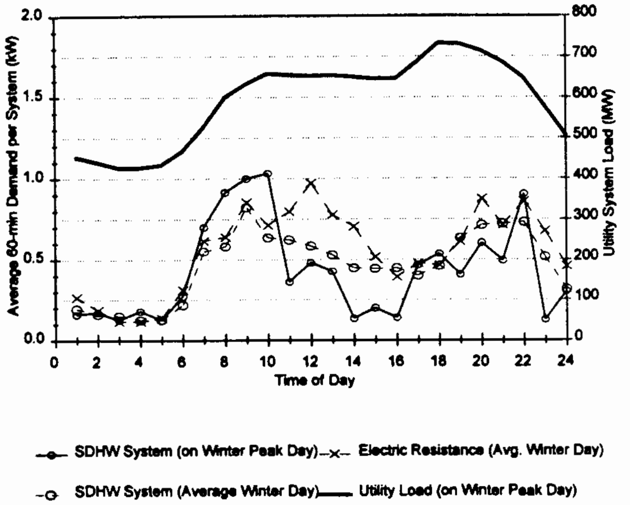

Figure 14. 60-minute Electrical Demand on the Orange & Rockland Winter Peak Day

Figures 13 to 17 present the average 60-minute electrical demand profiles for the sample group of 12 SDHW systems that occurred on the peak days listed in Table 10. These figures also display the utility integrated hourly load profiles (in bold) for the Con Edison and Orange & Rockland winter peak and summer peak days. (LILCO did not provide their peak day integrated hourly loads.) Figures 13 and 14 also present the average 60-minute demand profiles of both the 12 original electric resistance water heaters and the 12 SDHW systems during an average winter weekday, for comparison to the peak day load profiles. Similarly, Figures 15 and 16 present the average 60-minute demand profiles for the 12 electric resistance water heaters and the 12 SDHW systems during an average summer weekday, while Fig. 17 presents the average 60-minute demand profile for both groups during a summer weekend. (Orange & Rockland's 1995 summer peak load occurred on

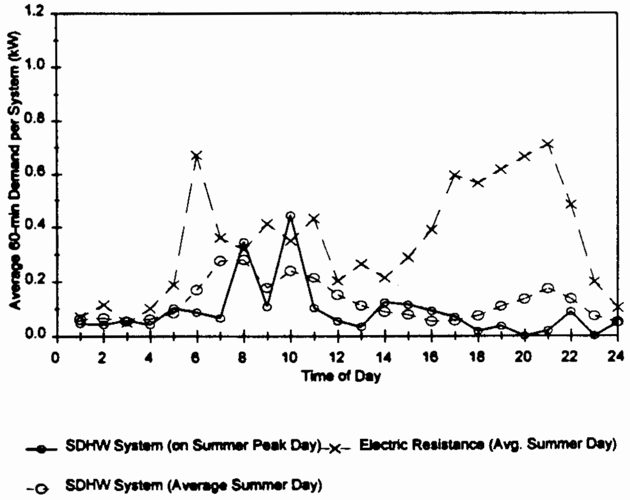

Figure 15. 60-minute Electrical Demand on the LILCO Summer Peak Day

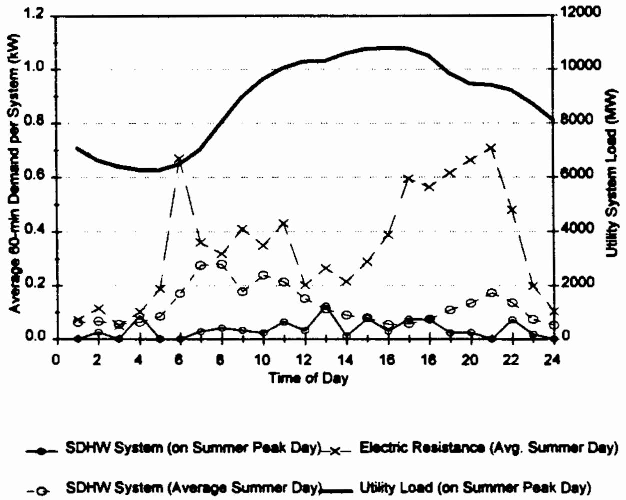

Figure 16. 60-minute Electrical Demand on the Con Edison Summer Peak Day

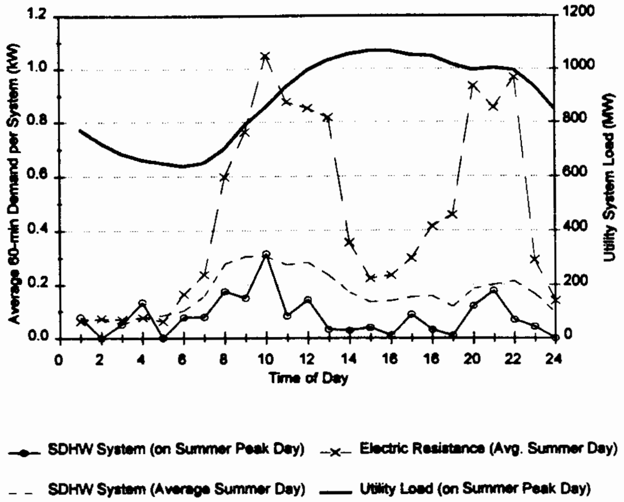

Figure 17. 60-minute Electrical Demand on the Orange & Rockland Summer Peak Day

a Saturday.) Finally, it is important to note that the SDHW system peak day profiles are averaged over only one day in each figure, rather than over a number of days as in the average winter and summer day profiles for both groups. (It was not possible to determine both the SDHW and the electric resistance profiles on the peak day for each system.) Hence, it is again not possible to accurately compare the peak day profile to the average day profiles without further quantitative analysis.

In addition to the calculation of load factor, another means of quantitative comparison between time-of-day electrical use on utility peak days is the calculation of "coincidence factor." This is the ratio, in percent, of the load's average electrical demand occurring at the time of the utility system peak demand to the load's peak demand occurring within a specified period regardless of the time of occurrence. Demand occurring at the time of the utility system peak demand is termed "coincident peak demand" and the peak demand occurring in the specified period regardless of time is called "noncoincident peak demand." The coincidence factor, therefore, indicates the percentage of the load's peak demand that coincides with the utility system peak. Hence, a utility would prefer a low coincidence factor for any load.

Table 11 presents the average 60-minute demand, the noncoincident peak demand, the coincident peak demand, the load factor, and the coincidence factor for the sample group of 12 SDHW systems on the utility system peak days listed in Table 10. Since LILCO's winter peak day occurred on the same day as Con Edison's winter peak (February 6, 1995), the average demand, peak demand, and load factor are the same for the SDHW systems on that day. However, the coincident demand and coincidence factor are different, since LILCO's system peak occurred one hour later than Con Edison's peak.

Table 12 lists the same demands and calculated factors as in Table 11 for the electric resistance water heaters on the average seasonal weekdays and weekends presented in Figures 13 to 17. These values are presented to allow comparison to the utility system peak day values for the SDHW systems listed in Table 11. Again, since LILCO's winter and summer peaks occurred one hour later than Con Edison's peaks, the coincident demands and coincidence factors are different for the electric water heaters on the average winter and summer weekdays. Furthermore, Orange & Rockland's 1995 summer peak occurred on a Saturday, so an average summer weekend for the electric resistance water heaters is listed in Table 12.

It is evident from Tables 11 and 12 that SDHW systems are able to reduce the utility peak day electrical demand due to residential water heating in the summer -- when utility system peak loads are highest -- but not necessarily in the winter -- when utility peak loads were approximately 30 percent lower. The summer reduction due to SDHW systems is especially evident on weekdays, when SDHW system coincident demand is no more than 12 percent of the coincident demand of electric resistance water heaters, resulting in a minimum 0.3 kW reduction per customer. On summer weekends, the SDHW system coincident demand is 0.2 kW less than the coincident demand of electric resistance water heaters. Furthermore, summer weekday coincidence factors for the SDHW systems are less than half the coincidence factors of electric resistance water heaters.

CONCLUSIONS

The average New York State SDHW system installed during this program operated with approximately a 63 percent higher annual electrical energy efficiency than the average electric resistance water heater. The typical New York State SDHW system installed during this program also operated with a modest degree of reliability, with seven service calls required in more than 245 system months or 20.4 years or operation. Furthermore, nine of the 12 SDHW systems did not require any maintenance during the program. Hence, it was the program's experience that the SDHW system owner would have an average maintenance cost of $19.74 per year.

During the summer months, a typical New York State SDHW system is able to reduce weekday electrical demand by 90 percent (when compared to the weekday demand of electric resistance water heaters) at times that coincide with the utility system peak demand. Furthermore, a SDHW system was able to reduce coincident demand by 88 percent on the 1995 Long Island Lighting Company summer peak day and by 92 percent on the Consolidated Edison Company of New York summer

Table 11
SDHW System 60-minute Demands and Factors on the Utility Peak Days

	Winter Peak Day			Summer Peak Day		
	LILCO	ConEd	O&R	LILCO	ConEd	O&R
Average kW	0.58		0.43	0.09	0.04	0.08
Peak kW	1.57		1.03	0.44	0.12	0.32
Coincident kW	0.95	0.63	0.54	0.07	0.03	0.04
Load Factor %	37		41	20	29	26
Coincidence %	60	40	52	16	23	13

Table 12
Electric Resistance 60-minute Demands and Factors on Average Seasonal Days

	Winter Weekday			SummerWeekday		End
	LILCO	ConEd	O&R	LILCO	ConEd	O&R
Average kW	0.55			0.35		0.45
Peak kW	0.97			0.71		1.05
Coincident kW	0.61	0.47		0.59	0.39	.24
Load Factor %	57			49		43
Coincidence %	63	48		84	55	22

peak day. On the 1995 Orange & Rockland Utilities summer peak day (which occurred on a weekend), the SDHW systems were able to reduce the coincident peak demand by 83 percent. This reduction in both peak day and average summer weekday coincident demand is consistent with the demand reduction reported in previous SDHW system studies, particularly a 1984-86 study performed by Connecticut Power and Light (Johnson, 1987). In addition, SDHW systems do not adversely impact the utility system by decreasing the load factor for electric water heating, since the annual weekday load factor for both the SDHW systems and the electric resistance water heaters was 60 percent.

The program's average SDHW system costs and energy savings as well as the 1995 energy costs, tax rates, and Con Edison discount rate were input to the Solar Thermal Financial Model (Energy Alliance Group, 1997) developed for utility end-use pricing analysis. This model assumes that the utility or its unregulated subsidiary would own the SDHW system and would sell the hot water to the customer for a monthly fee. The analysis revealed that the after-tax internal rate of return to the utility for installing 1,550 SDHW systems over five years at an investment of approximately $6 million would be a modest 4.15 percent per system. However, lowering the installed system cost to $2,500 and increasing the customer payment to $35 a month increased the rate of return to the utility to 11.8 percent per system -- higher than Con Edison's 1995 rate of return on common equity of 11.6 percent -- on a total five-year investment of less than $4 million. Therefore, it appears that the potential exists for a utility to generate revenue from a SDHW program, without taking into account the ancillary benefits of good customer relations, environmental incentives, possible renewable energy credits, or the 90 percent reduction in summer peak demand.

Therefore, instead of focusing on the cost-effectiveness of SDHW systems to the individual New York State homeowner, emphasis should be put on the revenue-generation potential of SDHW systems to New York State utilities. For it has been demonstrated that when the utility owns the SDHW system and sells the hot water energy generated by it to its customers, then an investor-owned utility can take advantage of federal income tax incentives that are not available to residential customers -- depreciation and the 10 percent investment tax credit for solar energy. The combination of these two tax incentives, coupled with the utility's knowledge and ability in purchasing bulk quantities of energy equipment -- like SDHW systems -- results in potentially higher rates of return to the utility than for the sale of conventionally-generated electricity. Furthermore, the incorporation of SDHW systems into a utility's energy generation and distribution portfolio underscores the investor-owned utility's environmental commitment not only to its customers but also to its shareholders. Hence, New York State utilities should be encouraged to investigate the revenue-generation potential of SDHW systems as a new residential service using end-use pricing techniques.

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