Summary of Cool Roof Monitoring and Analysis at Three Sites

Prepared for:

San Diego Gas & Electric
8335 Century Park Court, CP12B
San Diego, California 92123-1569

Prepared by:

Architectural Energy Corporation
2540 Frontier Avenue, Suite 201
Boulder, Colorado 80301

October 21, 2002

Summary of Cool Roof Monitoring and Analysis at Three Sites

Table of Contents

Table of Tables

Attachments

Introduction

This project was intended to evaluate the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems. Three sites were selected for evaluation. A report was created for each site. The reports include details of monitoring and analysis. This document is a brief summary of the results, with observations on the effectiveness of the cool roof coatings.

Site Summaries

The analytic approach for each of the three sites is summarized in Table 1.

The best site for evaluating the roof coating is reported as Site A. Here we measured the roof performance before the cool roof coating was applied, and then performed a side-by-side comparison of the treated and untreated sections of the roof surfaces that were subjected to the same indoor and outdoor conditions.

At Site B, two roofs, a cool roof and a standard mineral surfaced cap sheet were evaluated for comparison. However, since the roofs were on different buildings, the internal loads were potentially different. Furthermore, the location of the roof insulation was different, which affected heat flow into the buildings. The building with the treated roof has insulation attached to the roof deck, while the building with the untreated roof has insulation laid on the suspended ceiling, as much as ten feet below the roof deck. Because of these differences, an attempt to compare heat flows through the two different roofs was not attempted. Instead, measurements were taken on the untreated roof to characterize the roof surface temperature, and then used to estimate the performance of a standard roof.

The roof structure at the third site, Site C, had been retrofitted over the years to accommodate the various tenants that had used that building. As a result, the insulation was not as effective as if it had been installed during the original construction. Insulation was laid in on top of the suspended ceiling, rather than stapled to the roof joists. This caused increased heat gain to the ducts, since they were in an uninsulated portion of the building, above the insulation. Furthermore, air leaks allowed conditioned air to mix with the air in the unconditioned airspace, further increasing the load. The HVAC system at this site was undersized for the load. This situation may have existed from the day it was installed, or it may be a result of additional internal load in the building that was not anticipated when the original HVAC unit was installed. Another possibility is that the unit may not be performing to specification and require maintenance.

Table 1. Site Evaluation Summary

Site Designation	Original Roof Condition	Cool Roof Coating Applied	Evaluation Approach
Site A	Conventional Mineral Surface Cap Sheet	Applied Acu-Flex Energy-Seal Elastomer 3/15/02	Side-by-side comparison of existing roof surface to a portion of roof with cool roof coating.
Site B	Treated Roof: Coated with Uniflex Elastomer Untreated Roof: Conventional Mineral Surface Cap Sheet	The cool roof coating was applied to the treated roof prior to evaluation period	Side-by-side comparison of existing cool roof surface on one building to a standard mineral cap sheet on another building. Issue: • Roof insulation was different for the two buildings. Untreated roof had lay-in insulation; treated roof had insulation between joists next to roof deck.
Site C	Tar and Gravel Built-up	Replaced roof with built-up construction. Coating applied 8/7/02	Comparison of original roof to new roof with cool roof coating. Issues: • Not side-by-side comparison. • HVAC system was slightly undersized for building loads. • Lay-in insulation was less effective, due to air leakage and duct heat loss/gains. • Coating did not appear to be performing to specification

The data collection periods are shown in Table 2 for sites A and B, and Table 3 for Site C. Data collection period three was delayed at Site C due to a delay in the roof replacement schedule. This delay extended the monitoring period a few weeks, and did not adversely affect the evaluation of the roof.

Table 2. Data Collection Periods – Site A and Site B

Data Collection Period	Begin	End	Notes
1	2/6/2002	3/18/2002	Roof coated at Site A on 3/15/2002
2	3/18/2002	4/24/2002	
3	6/12/2002	8/2/2002	

Table 3. Data Collection Periods – Site C

Data Collection Period	Begin	End	Notes
1	2/6/2002	3/18/2002	Original Tar/Gravel Roof
2	3/18/2002	4/24/2002	Original Tar/Gravel Roof
3a	7/9/2002	7/30/2002	New roof, but uncoated (black tar surface)
3b	8/7/02	8/23/02	Roof Coated 8/7/02

The annual savings are compared in Table 4. The lowest savings, and the highest installation costs, were achieved at Site A. The savings were low because the roof insulation was very good, and so reducing the roof temperature had less effect on reducing heat flow into the building. However, the effectiveness of the roof coating in reducing roof temperatures was greatest at this site.

The greatest savings were realized at Site C. The savings were higher because of less efficient roof insulation. However, the roof coating did not reduce the roof temperatures as much as expected. When the published coating specifications were examined, it appeared that the coating was not performing to specification, possibly due to a problem with the way it was applied, or the material quantity. The cost provided by the contractor for applying the coating was very low compared to the installation costs at the other sites.

The performance at Site B was between that at the other two sites. The coating effectiveness was similar to the coating at Site A; the roof temperature reductions were similar. The energy savings were greater at Site B primarily because the insulation was not as effective as the insulation at Site A.

Monthly performance estimates are shown in Table 5 through Table 7 for the individual locations.

Table 4. Annual Savings Summary

Site Designation	Original Roof Condition	Coating Applied During Evaluation	Annual Savings (kWh/sf)	Annual Savings ($/sf)	Installation Cost ($/sf)
Site A	Conventional Mineral Surface Cap Sheet	Applied Acu-Flex Energy-Seal Elastomer 3/15/02	0.415	$0.067	$1.95
Site B	Treated Roof: Coated with Uniflex Elastomer Untreated Roof: Conventional Mineral Surface Cap Sheet	The cool roof coating was applied to the treated roof prior to evaluation period	0.618	$0.071	$1.45
Site C	Tar and Gravel Built-up	Replaced roof with built-up construction. Coating applied 8/7/02	0.624	$0.100	$0.45 (coating only)

Table 5. Site A HVAC Energy Impacts

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 sf			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	2,101	2,096	-5	-0.2%	$239	$237	-$2	-0.8%
Feb	2,035	2,029	-6	-0.3%	$235	$235	$0	0.0%
Mar	2,076	2,060	-16	-0.8%	$240	$238	-$3	-1.3%
Apr	1,869	1,835	-33	-1.8%	$224	$220	-$5	-2.2%
May	1,922	1,875	-47	-2.4%	$278	$270	-$8	-2.9%
Jun	2,001	1,940	-60	-3.0%	$293	$284	-$9	-3.1%
Jul	2,308	2,228	-80	-3.5%	$330	$318	-$13	-3.9%
Aug	2,256	2,189	-68	-3.0%	$322	$311	-$11	-3.4%
Sep	2,056	1,997	-60	-2.9%	$300	$291	-$10	-3.3%
Oct	2,049	2,012	-37	-1.8%	$248	$243	-$5	-2.0%
Nov	1,959	1,951	-8	-0.4%	$229	$227	-$2	-0.9%
Dec	2,333	2,338	6	0.3%	$262	$262	$0	0.0%
Annual	24,965	24,551	-415	-1.7%	$3,202	$3,135	-$67	-2.1%

Table 6. Site B HVAC Energy Impacts

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 sf			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	1,717	1,689	-28	-1.6%	$184	$181	($3)	-1.6%
Feb	1,544	1,507	-37	-2.4%	$169	$165	($4)	-2.4%
Mar	1,723	1,672	-51	-3.0%	$183	$178	($5)	-2.7%
Apr	1,736	1,678	-58	-3.3%	$189	$182	($7)	-3.7%
May	1,817	1,763	-54	-3.0%	$193	$187	($6)	-3.1%
Jun	1,858	1,804	-54	-2.9%	$207	$200	($7)	-3.4%
Jul	2,139	2,052	-87	-4.1%	$237	$227	($11)	-4.6%
Aug	2,108	2,026	-82	-3.9%	$227	$219	($9)	-4.0%
Sep	1,978	1,911	-67	-3.4%	$215	$207	($8)	-3.7%
Oct	1,901	1,863	-38	-2.0%	$205	$201	($4)	-2.0%
Nov	1,695	1,661	-33	-1.9%	$183	$179	($4)	-2.2%
Dec	1,712	1,684	-28	-1.6%	$182	$179	($3)	-1.6%
Annual	21,929	21,311	-618	-2.8%	$2,375	$2,304	($71)	-3.0%

Table 7. Site C HVAC Energy Impacts

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 sf			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	1,311	1,276	-35	-2.7%	$192	$187	($5)	-2.6%
Feb	1,187	1,148	-40	-3.4%	$175	$169	($6)	-3.4%
Mar	1,385	1,330	-55	-4.0%	$204	$195	($9)	-4.4%
Apr	1,456	1,393	-63	-4.3%	$214	$205	($9)	-4.2%
May	1,585	1,518	-67	-4.2%	$279	$267	($12)	-4.3%
Jun	1,755	1,691	-64	-3.6%	$309	$298	($11)	-3.6%
Jul	2,126	2,060	-66	-3.1%	$374	$362	($12)	-3.2%
Aug	2,119	2,058	-61	-2.9%	$373	$362	($11)	-2.9%
Sep	1,948	1,895	-52	-2.7%	$343	$333	($10)	-2.9%
Oct	1,720	1,671	-50	-2.9%	$252	$246	($7)	-2.8%
Nov	1,373	1,333	-40	-2.9%	$202	$196	($6)	-3.0%
Dec	1,276	1,245	-31	-2.4%	$187	$183	($5)	-2.7%
Annual	19,243	18,618	-624	-3.2%	$3,103	$3,003	($100)	-3.2%

Conclusions

The general findings from this cool roof study can be summarized as follows:

- The savings from cool roofs on buildings with good insulation are minimal, and the paybacks are long.
- The best targets for cool roof applications are buildings with poor insulation.
- The installation costs can vary dramatically. Note that the costs for the jobs in this study were not based on a common specification, but were quoted based on each job.
- The performance of the coating should be checked to ensure that it performs to specification. Although measurements would be the most accurate method of performing this check, a simple visual inspection might be adequate; the coating at Site C, the worst performing coating, appeared darker than those at the other locations.
- Buildings with undersized HVAC systems will not benefit greatly from reduced energy consumption, but may be more comfortable due to reducing the roof heating load.
- For all of the buildings in this study, the percentage savings in energy consumption is three percent or less, which will likely not be noticeable on a utility bill.

Attachment 1

Cool Roof Monitoring and Analysis at Site A

Cool Roof Monitoring and Analysis at Site A

Prepared for:

San Diego Gas & Electric
8335 Century Park Court, CP12B
San Diego, California 92123-1569

Prepared by:

Architectural Energy Corporation
2540 Frontier Avenue, Suite 201
Boulder, Colorado 80301

October 21, 2002

Cool Roof Monitoring and Analysis at Site A

Table of Contents

Table of Figures

Table of Tables

Executive Summary

This project is intended to evaluate the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems.

The facility selected for monitoring is operated by a manufacturing company located in El Cajon, California. The area selected for this study is a manufacturing area that is maintained at constant temperature and relative humidity to provide stability for the manufacturing materials. This area was selected because of the highly stable interior temperature and the ease of access to the underside of the roof. The roof structure over the manufacturing area consists of waferboard decking over 2"x6" wood joists spaced two feet apart, supported every eight feet by steel joists. R-19 fiberglass insulation batts are stapled to the 2"x6" wood joists.

The occupants at Site A contracted with their roofing contractor to install a cool roof product on a portion of its building roof covering the manufacturing area. The roofing contractor applied Acu-Flex Energy-Seal coating on March 15, 2002.

The overall approach for evaluating the performance of the cool roof product was to perform a side-by-side comparison of the existing roof with mineral cap sheet, to a portion of the same roof coated with the cool roof coating. A side-by-side comparison is useful so that the conventional and cool roof surfaces are compared under the same ambient conditions.

Instrumentation was installed on February 6, 2002 to monitor ambient conditions, roof structure temperatures, and heat flux through the roof structure. The instrumentation was placed on two areas of the roof, one to be coated in mid-March, and the other to remain uncoated. The monitoring ended in early August.

After collecting performance data, a simulation model was developed using DOE-2.1 and calibrated using the measured data to estimate the annual performance of the roof coating.

Annual simulated savings from the cool roof coating were estimated at 0.415 kWh/sf, or on a dollar basis, $0.067/sf. The installation cost for the roof was $1.95/sf, leading to a simple payback of 29 years. Based on the energy savings alone, the cost-effectiveness of the cool roof coating was quite low, although there are other non-energy considerations that may make a cool roof coating a good investment. Prior to applying the roof coating, the daily roof surface temperature swings were as great as 120°F. After the coating was applied on March 15, the temperature swing was reduced to 30-40°F on sunny days. This reduced temperature swing will reduce the thermal expansion and contraction of the roof, which could increase the lifetime of the roof. Considering the increased roof lifetime would improve the cost-effectiveness of the roof coating.

1.0 Project Overview

This project is intended to evaluate the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems. The facility selected for monitoring is operated by a manufacturing company located in El Cajon, California. The evaluation was performed by first monitoring the thermal performance of the facility to understand the actual performance characteristics of the roof. Next, to determine the annual performance of the building a simulation model was created and calibrated using the actual performance data. The calibrated simulation results were then used to evaluate the cost-effectiveness of the cool roof system.

2.0 Site Description

The facility selected for monitoring is operated by a manufacturing company located in El Cajon, California. The area selected for this study is a manufacturing area maintained at constant temperature and relative humidity to provide stability for the wood used for the product. This area was selected because of the highly stable interior temperature and the ease of access to the underside of the roof.

The space conditioning for this area is provided by a DataAire 10-ton computer room style HVAC unit. This unit provides highly stable temperature and humidity control. The room is maintained at constant temperature and relative humidity to maintain product stability.

The roof structure over the manufacturing area consists of waferboard decking over 2"x6" wood joists spaced two feet apart, supported every eight feet by steel joists. R-19 fiberglass insulation batts are stapled to the 2"x6" wood joists. A picture of the underside of the roof is shown in Figure 1. A diagram showing the cross-section of the roof is shown in Figure 10.

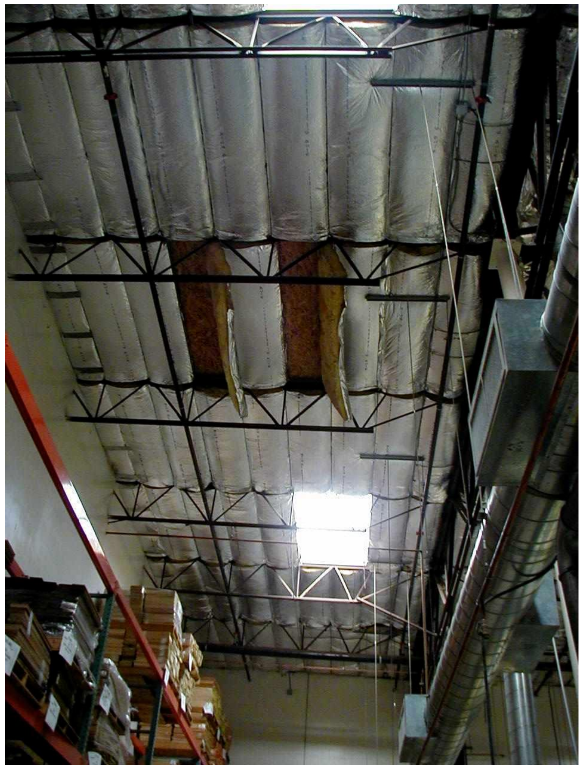

Figure 1. Site A Ceiling

The original roof surface is conventional mineral surfaced cap sheet roll roofing. A picture of the roof prior to coating is shown in Figure 2.

Figure 2. Site A Roof

Site A personnel contracted with their roofing contractor to install a cool roof product on a portion of its roof. The contractor applied Acu-Flex Energy-Seal coating.[1]

3.0 Project Approach

3.1 General Approach

The overall approach for evaluating the performance of the cool roof product was to perform a side-by-side comparison of the existing roof with mineral cap sheet, to a portion of the same roof coated with the cool roof coating. A side-by-side comparison is useful so that the conventional and cool roof surfaces are compared under the same ambient conditions.

Prior to applying the coating, the roof was monitored for five weeks to ensure that there were no differences in the roof structures that could affect the thermal performance of the roof. No significant differences were observed between the roof areas, and so the differences observed between the coated and uncoated roof portions could be attributed completely to the roof coating.

After collecting performance data, a simulation model was developed, based on the measured data, to estimate the annual performance of the roof coating. A simulation model allows annual projections of performance using a shorter monitoring period. Furthermore, the weather data used to drive the simulation are based on long-term observations, and so are typical of the weather for a region, rather than for a specific year. This also allows a better indication of what performance could be expected over the long term, rather than relying on extrapolating the results of a specific period of time.

The steps for evaluating the performance of the cool roof product were as follows:

- Install instrumentation as listed in Table 1.
- Monitor the performance of the roof for a period prior to the roof coating procedure to determine if there is any bias in the measurements at different roof locations.
- Coat the portion of the roof targeted for treatment with the roof coating.
- Continue to monitor the roof throughout the spring and into the summer.
- Develop models of the heat transfer through the roof using DOE-2. Calibrate the models using measured data.

[1] Information sources: http://www.energy-seal.com/es-web.nsf/products/Acu-Flex

http://yosemite1.epa.gov/estar/consumers.nsf/attachments/RoofProdList2.21.01.PDF/$File/RoofProdList2.21.01.PDF?OpenElement

- Run simulations of the manufacturing area to compare the annual effects of the roof coating on roof heat transfer and the subsequent effects on the HVAC system.
- Perform a cost / benefit analysis of the roof coating.

3.2 Data Collection

Instrumentation was installed on February 6, 2002, according to the measurement list shown in Table 1. The data collection was performed in three time periods, as shown in Table 2. Phase 1 and 2 are consecutive, and are differentiated only by the need to remove the old loggers for download and install new loggers with fresh batteries. After a seven-week hiatus in data collection between mid-April and mid-June, loggers were reinstalled and data collection proceeded into the summer, until August 2, 2002.

Table 1. Measurement List

Measurement Points	Units
Ambient Temperature	°F
Solar Insolation	watts/m^2
Wind Speed	mph
RTU Current	amps
Roof T 1 (Coated)	°F
Roof T 2 (Coated)	°F
Roof T 3 (Uncoated)	°F
Roof T 4 (Uncoated)	°F
Deck T 1 (Coated)	°F
Deck T 2 (Coated)	°F
Deck T 3 (Uncoated)	°F
Deck T 4 (Uncoated)	°F
Under Deck Heat Flux A603 (Coated)	BTU/hr-sf
Room Temp (Under Coated Portion of Roof)	°F
Heat Flux A604 (Uncoated)	BTU/hr-sf

Table 2. Data Collection Periods

Data Collection Period	Begin	End	Notes
1	2/6/2002	3/18/2002	Roof coated 3/15/02
2	3/18/2002	4/24/2002	
3	6/12/2002	8/2/2002	

The roof temperature sensors were anchored to the roof with epoxy adhesive and covered with the mineral surface coating that was covering the cap sheet. Applying the mineral material was done to ensure that the temperature sensor was “shaded” from the direct sun with the same material covering the roof so that the sensor would respond to solar radiation similarly to the actual roof to accurately sense the roof temperature,. A picture of a typical sensor installation is shown in Figure 3. Tape was used to strain-relief the sensor cable to minimize stress on the sensor bonding.

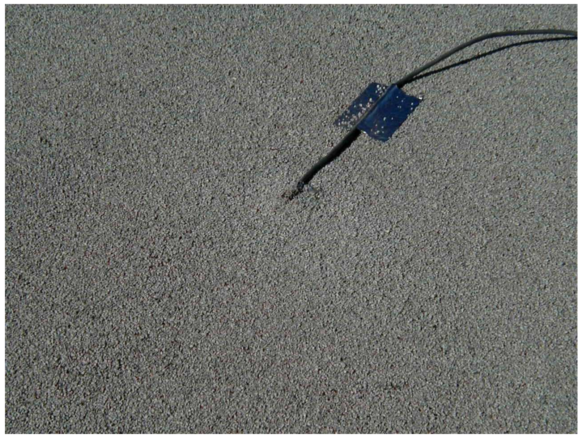

Figure 3. Roof Temperature Sensor

The heat flux transducers and deck temperature sensors were attached to the underside of the roof deck, as shown in Figure 4. Heat transfer compound was applied between the sensors and the roof deck to minimize resistance to heat flow between the sensors and the roof deck. High strength tape was used to attach the sensors. After the sensors were attached, the insulation was replaced, further holding the sensors in place. The completed logger installation is shown in Figure 5. This picture shows that the insulation has been replaced and the logger and associated equipment has been attached to the metal roof joist.

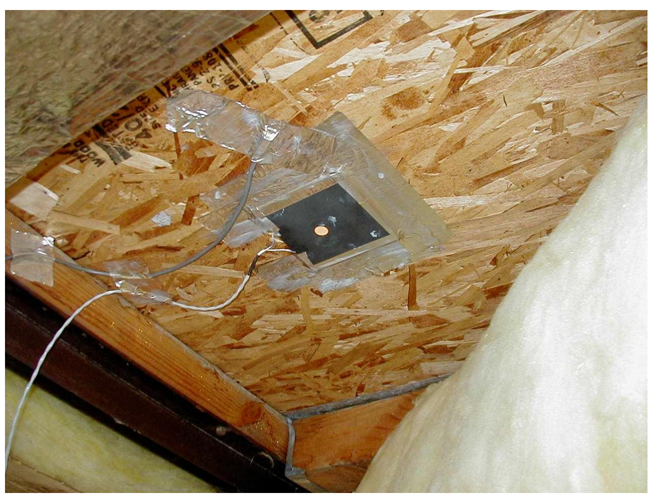

Figure 4. Deck Instrumentation

Figure 5. Deck Logger Installation

Solar radiation, ambient temperature, and wind speed were also monitored to have a record of the ambient conditions affecting the roof.

Daily summaries of the all measurements are included in Appendix A.

4.0 Analysis and Results

The first step in the analysis was to ensure that, prior to roof coating, the roof temperature and heat flux measurements were similar between the two roof sections. The measurements for both sections of the roof prior to coating showed little significant difference in performance. All of the roof surface temperatures compared very closely, as did the deck temperatures. There is a small shift in the heat flux measurements, but the maximum and minimum values compare closely, as well as the total daily heat flux. The other key comparison is the heat flux during the night, when the roof heat flow is at steady-state conditions. Based on these comparisons, the differences in the roof performance after the coating was applied could be attributed totally to the coating.

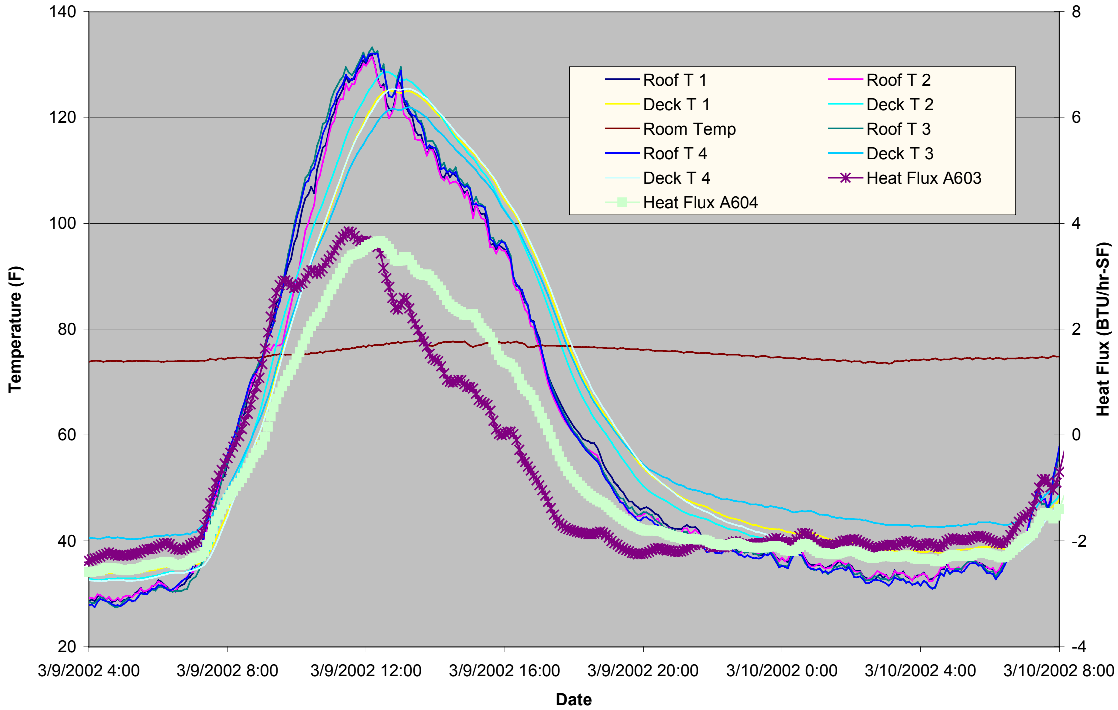

Figure 6. Pre-Coat Measurement Comparison

The roof was coated on March 15, 2002. Figure 7 shows the temperature history before and after the roof was coated. Notice the dramatic drop in roof temperature just after 12:00, when the roof is coated. Prior to roof coating, the roof temperatures in both the uncoated area and the area targeted for roof coating tracked very closely. After the roof was coated, the uncoated roof temperature is as much as 40°F higher than the coated roof. At night, the roof coating has no effect on roof temperature, as expected. Another observation, unrelated to the coating, is that the roof temperature is below the ambient temperature when the sky is clear at night. This is due to the roof radiating to the cool night sky. On cloudy nights, the roof temperature is essentially the same as the ambient temperature. As expected, the reduced nighttime temperature is the same for both the coated and uncoated roof sections.

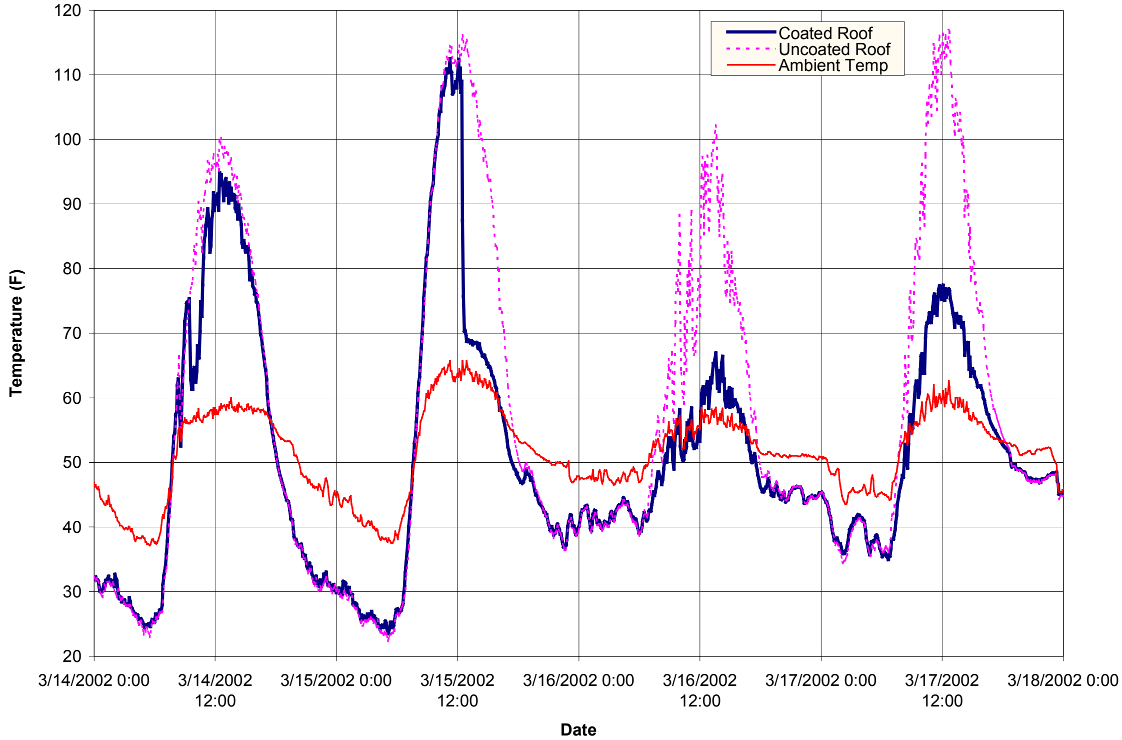

Figure 7. Temperature History During Roof Coating

4.1 Description of Roof Thermal Behavior

The heat flow through the entire roof structure is affected by the temperatures of the roof surface, the deck temperature, the air temperature in the conditioned space, and the heat stored in the roof structure components. Figure 8 shows a one-day history of the temperatures and heat flux in the uncoated portion of the roof. Until approximately 7:30 in the morning, the heat flux is constant at about –1.1 BTU/hr-sf, meaning that heat is traveling from the conditioned space to the roof deck, and out of the building. After this time, the heat flux changes to positive and increases rapidly until it peaks around 12:30 pm at 4.0 BTU/hr-sf. During this morning “warm-up” period, the temperature of the roof top surface (measured by the roof temperature sensor) is greater than the lower surface (measured by the deck temperature sensor), meaning that heat is being conducted into the building. Since both the roof and deck temperatures are increasing, this indicates that the overall roof structure is heating up, i.e., storing heat. In the afternoon, this situation is reversed: the upper roof surface is cooler than the interior roof deck, and both the roof and deck temperatures are decreasing, i.e., the roof is cooling off, and the stored heat in the roof structure is being released. During this period, heat is being rejected by the roof surface through radiation and convection to the outdoor sky, and is also being conducted from the bottom of the roof deck, through the insulation, to the conditioned space. Finally, at about 20:00 (8 pm), after the sun has set, the heat flux becomes negative as heat flows out of the building. After a few hours, the heat flux stabilizes.

The coated roof has a similar temperature and heat flux history, although less pronounced due to the lower roof temperatures, as shown in Figure 9.

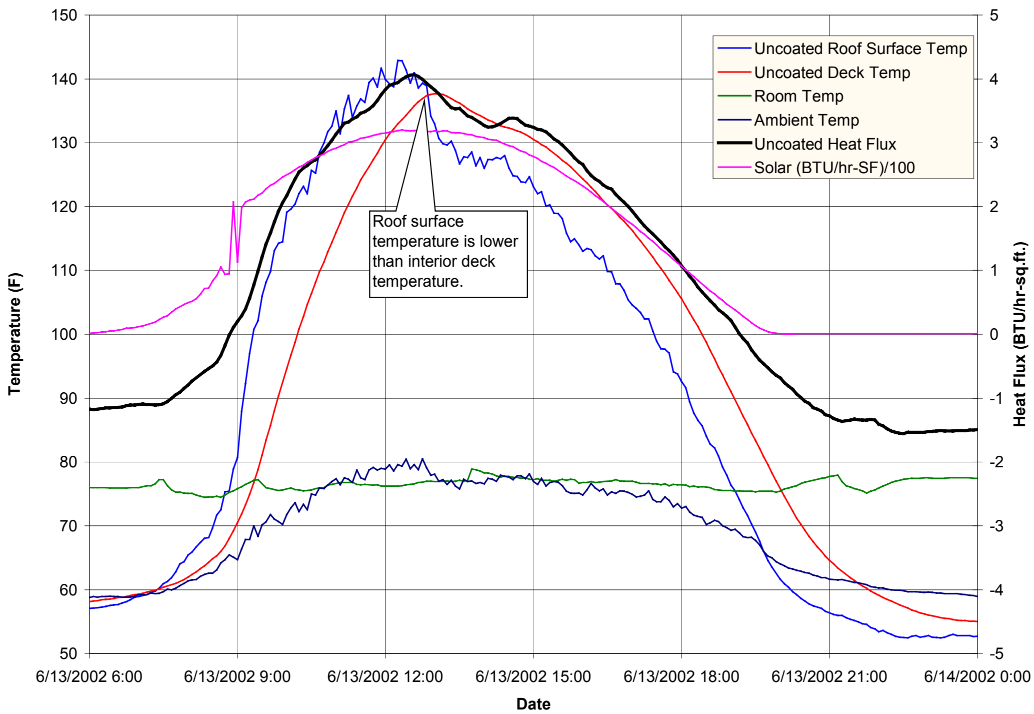

Figure 8. Uncoated Roof Temperature and Heat Flux History

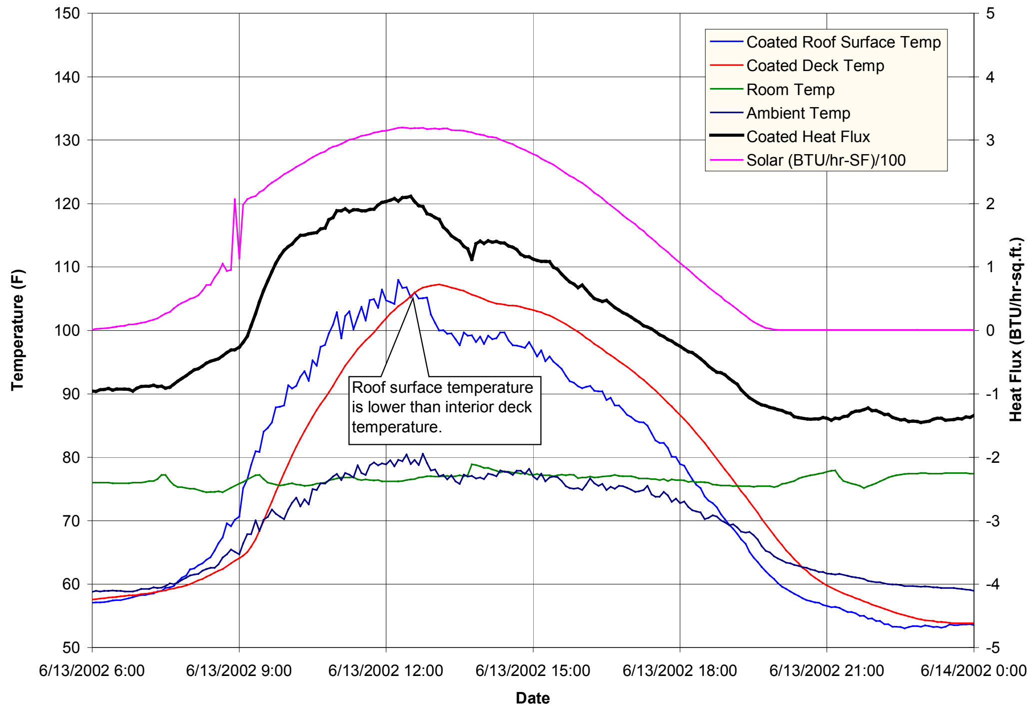

Figure 9. Coated Roof Temperature and Heat Flux History

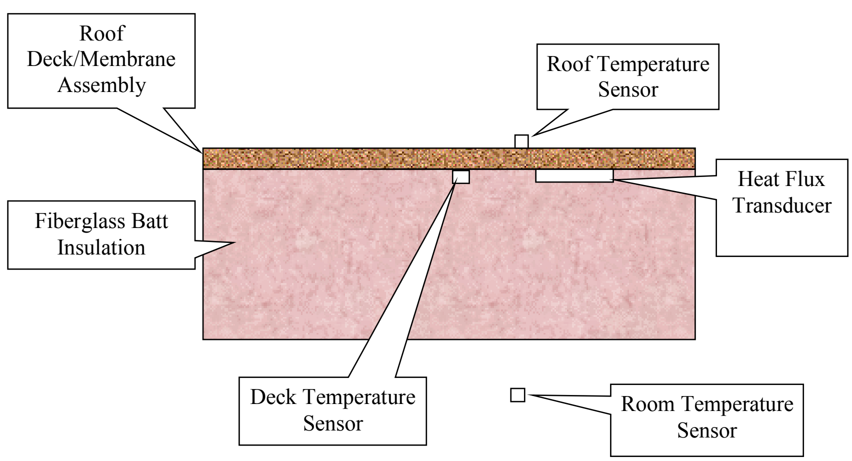

Figure 10. Roof Structure Schematic

4.2 Simulation Model Development

An annual building energy simulation was performed using DOE-2.1 v133 to model the operating and building characteristics of the space. The simulation was run with Riverside Climate Zone (CTZ10) weather data. This weather data is recommended by the California Energy Commission for the El Cajon area. For the modeled space, annual savings were calculated using initial and coated roof characteristics.

Table 3. Site A Site Characteristics

Characteristic	Observed Site Characteristic	Simulation Input
Utilities		
Electric Rate	Utility meter measured consumption for entire building. Only part of building was coated and modeled.	SDG&E AL-TOU (Jan 1, 2002) with commodity rates (July 1, 2002)[2]
Gas Rate	No gas used in this building space	None
Simulation Weather Data	El Cajon address	CTZ10
Envelope		
Space and Roof Area	48 lf x 70 lf	3360 sf
Initial Roof Absorptance	Asphalt roll roofing. Mineral cap sheet.	70%, based on measurements
Roof Construction	Roll roofing over waferboard over insulated joists. No interior finish.	DOE-2 asphalt shingle, 5/8" plywood, R-14 including bypasses
Wall Height	16'	16'
Wall Construction	Tilt-up concrete without insulation	6" heavy concrete
Wall Exposure	Two interior walls and two exterior walls.	Two interior walls and two exterior walls.
Internal Loads		
Connected Lighting	26 x F42LL	1.0 W/sf used.
Occupied Equipment Load	Various large equipment.	1.5 W/sf for 50% of occupied hours.
Schedules	Occupied about 80 hrs per week.	Equipment and lights to 5% during unoccupied hours indicated on survey memo.
HVAC		
Type	DX constant volume Liebert type	Packaged single zone
Sizing	10 tons	10 tons
Cooling Efficiency	EER = 8 Btu/Wh, including fan. Estimated for old computer room system	EER = 8.5 Btu/Wh for compressor and condenser (without fan)
Heat Source	Electric	Electric
Humidification	Electric steam	Minimum humidity setpoint of 46%
Dehumidification	From cooling	From cooling
Outside Air	From adjacent spaces. No economizer.	Constant @ 5%
Air Flow	As balanced	450 cfm/ton.
Schedule	For humidity control, 24/7 operation	Continuous fan operation and temperature control
Return Air	Direct. No plenum.	Direct. No plenum.

[2] All SDG&E tariffs are available at the following website: http://www.sdge.com/tariff/elec_commercial.shtml

Hourly outputs from the simulation and hourly monitored data were compared to verify and calibrate the assumptions in the model. The key assumptions that affect roof heat gain are shown in Table 4.

Table 4. Calibrated Inputs

Characteristic	Default or Catalog Value	Calibrated Value
Insulating batt thermal resistance (R-value)	15 sf-F/Btuh	13 sf-F/Btuh
Overall insulation layer thermal resistance (R-value)	14 sf-F/Btuh	12 sf-F/Btuh
Original roof surface solar absorptance	80%	70%
White roof surface solar absorptance (Energy Seal Acu-Flex)	11%	20%

The insulation R-value was verified using night time heat flux to eliminate the effects of surface absorptance as shown in Figure 11. The insulation appeared to be nominal 6" batts stapled to the rafters spaced 2 feet on center. Assuming some degradation from installation imperfections, the initial model assumption was an effective R-15. This was calibrated to R-13, by matching the measured and simulated heat fluxes as a function of temperature. The heat flux sensor was installed in the center of the batt, and would not include the effects of thermal bypasses through the studs. Further adjustment for this effect yields an effective overall roof R-value of about 12.

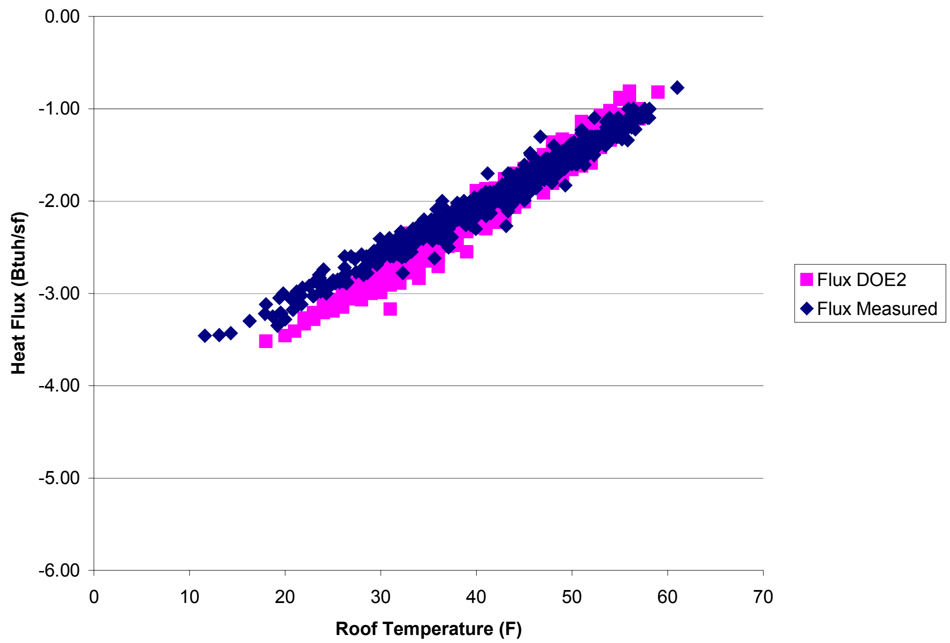

Figure 11. Heat Flux as a Function of Roof Temperature on Cool Nights for R-13 Batt, 74°F Average Zone Temperature (Negative heat flux is heat loss from warm room to ambient.)

Other calibration and parameter verification was accomplished by charting the daytime heat gains and roof surface temperatures against solar insolation. Given a well-insulated roof such as this, the surface temperatures should be very sensitive to the roof absorptance.

The DOE-2 simulation program predicted slightly different exterior roof temperatures than were measured. The comparisons for the uncoated roof, shown in Figure 12, are very good, but the simulation predicted somewhat lower temperature rise for the coated roof than was observed, as shown in Figure 13. This could be due to slightly different humidity or wind conditions for the corresponding insolation levels between the simulation weather file and the conditions encountered during the monitored period.

Because of the fairly consistent indoor conditions beneath the sensors, and simple construction, the heat flux could be used to calibrate the simulation more exactly. The important changes in cooling energy consumption will be governed by the heat flux, more than the surface temperature. Because of this, the next step in the calibration process was to compare heat flux as a function of insolation levels. These results are shown in Figure 14 for the uncoated roof, and Figure 15 for the coated roof. These plots show good comparison between the modeled and observed results, although the model results have more scatter than those observed. Because of the good comparison of heat flux and the greater importance of heat flux on the annual results, the model inputs were not adjusted further in an attempt to improve the temperature results.

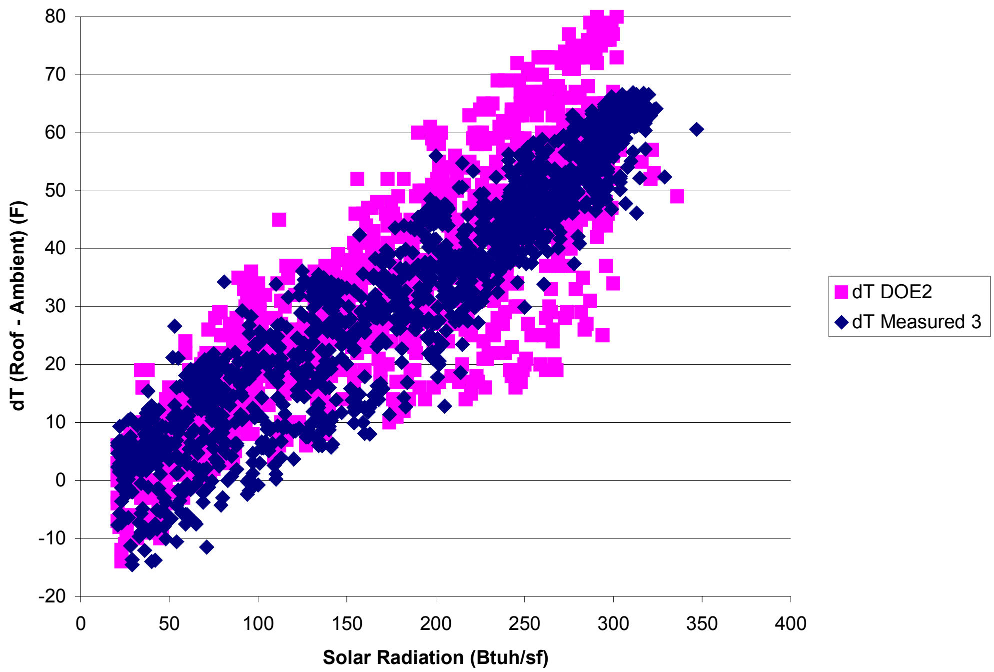

Figure 12. Original Roof: Ambient Temperature -- Roof Temperature vs. Solar Radiation

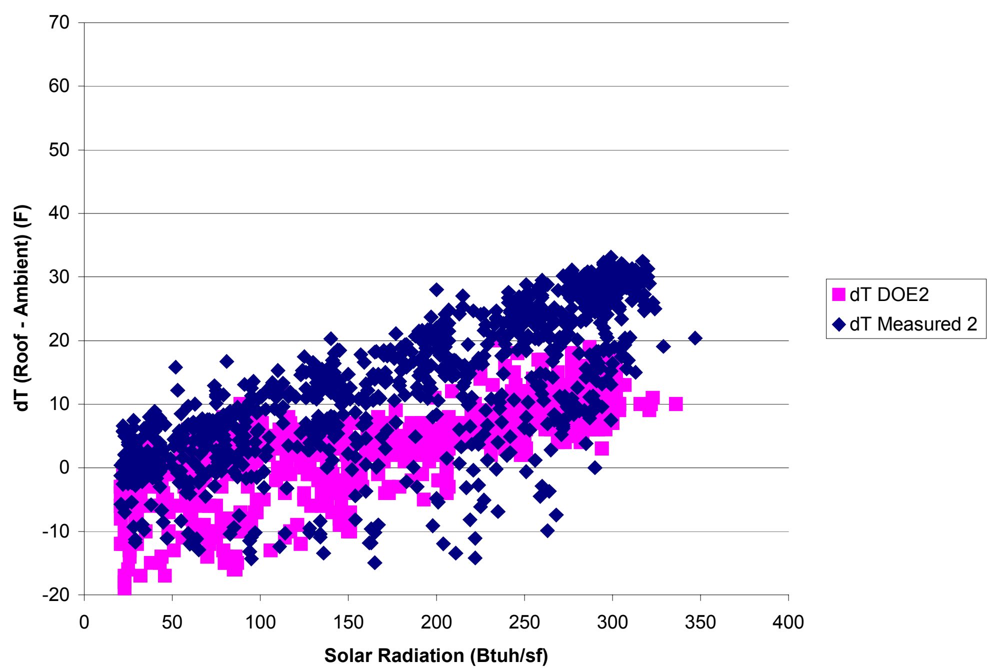

Figure 13. White Coated Roof: Ambient Temperature -- Roof Temperature vs. Solar Radiation

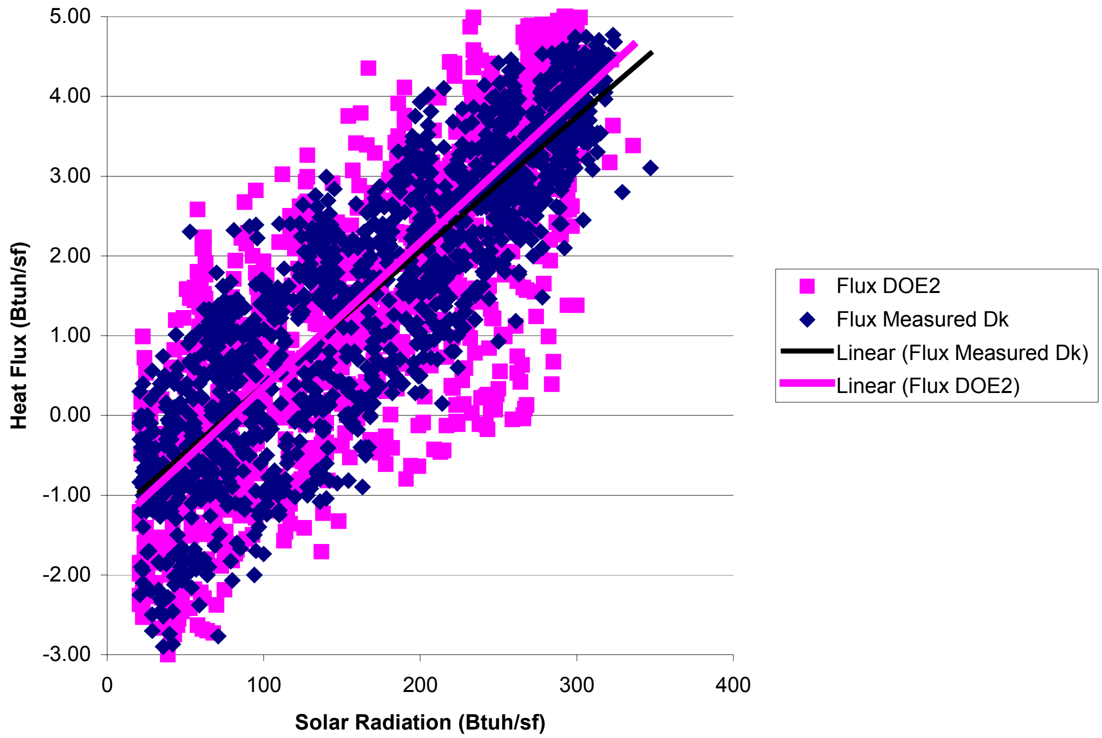

Figure 14. Original Roof: Heat Flux vs. Solar Radiation

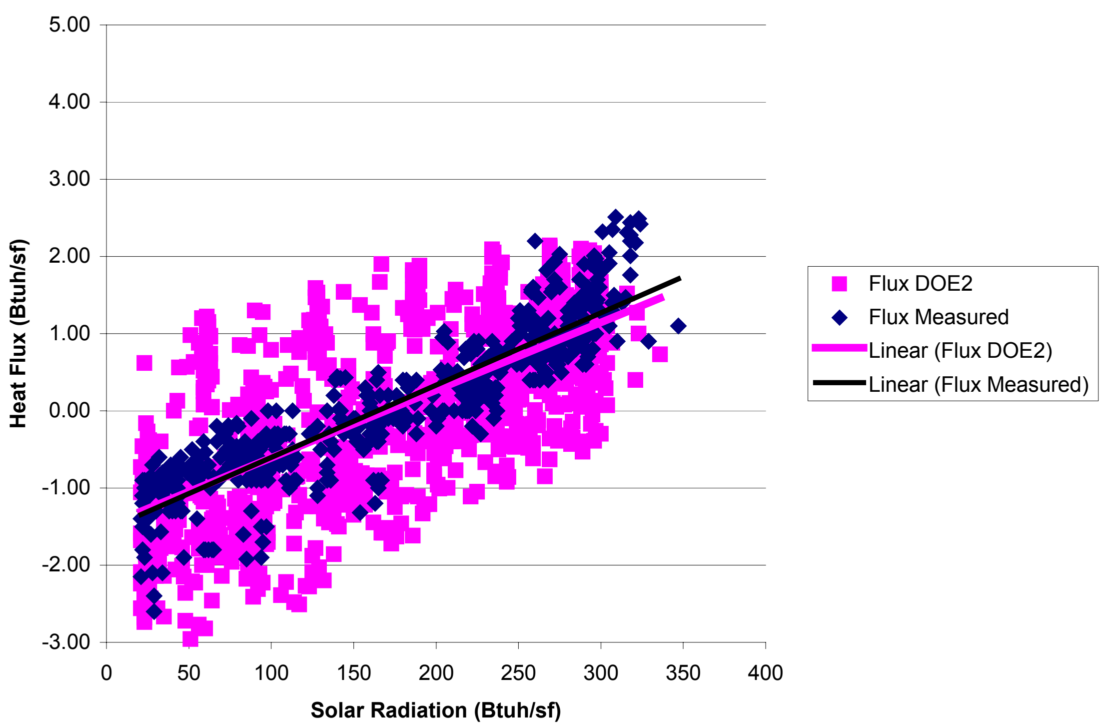

Figure 15. White Coated Roof: Heat Flux vs. Solar Radiation

4.3 Simulation Model Results

Using the initial assumptions listed in Table 3 and the calibrated inputs shown in Table 4, the simulation produced the results listed in Table 5 for the roof heat flux and Table 6, showing the impact on the HVAC system. Results are normalized per 1000 sf to facilitate comparison with the other sites. Roof heating and cooling fluxes are output from DOE-2 assuming a constant space temperature. For this case, 77°F was used, as that was the average measured space temperature. The simulated heat gains and losses shown are slightly high because the space temperature actually floats between 74° and 79°F, somewhat in concert with the ambient conditions. Although the simulated heat gains may be slightly high, these errors will essentially cancel out when comparing the difference in heat flow between the original and coated roofs. Therefore, the change in heat flux is essentially not affected by the issue mentioned above.

Table 5. Monthly Roof Loads

	Roof Heat Flux (Million BTU/1,000 sf)		
	Original	**Coated**	**Change**
Jan	-0.70	-1.18	-0.48
Feb	-0.53	-0.95	-0.42
Mar	-0.40	-0.97	-0.57
Apr	-0.18	-0.76	-0.58
May	-0.01	-0.57	-0.56
Jun	0.26	-0.35	-0.62
Jul	0.57	-0.19	-0.76
Aug	0.47	-0.18	-0.65
Sep	0.22	-0.37	-0.59
Oct	-0.20	-0.67	-0.47
Nov	-0.64	-1.04	-0.39
Dec	-0.79	-1.26	-0.47
Annual	-1.93	-8.50	-6.57

The change in heat flux through the roof leads to the changes in electrical energy consumption shown in Table 6. The percentage decrease in energy use due to the roof coating is small since this space has substantial energy consumption unrelated to the roof heat transfer. This includes two shifts of manufacturing, and a computer-room style HVAC system with electrical humidification. Also, the roof insulation at this site was reasonably good, which limited the impact of the cool roof coating on energy reduction.

Annual simulated savings from the cool roof coating were estimated at 0.415 kWh/sf, or on a dollar basis, $0.067/sf. This corresponds to $216 per year if the entire roof over the monitored manufacturing area was coated. Detailed simulated savings are presented in Table 6.

Table 6. Monthly HVAC Energy Impacts

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 SF			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	2,101	2,096	-5	-0.2%	$239	$237	-$2	-0.8%
Feb	2,035	2,029	-6	-0.3%	$235	$235	$0	0.0%
Mar	2,076	2,060	-16	-0.8%	$240	$238	-$3	-1.3%
Apr	1,869	1,835	-33	-1.8%	$224	$220	-$5	-2.2%
May	1,922	1,875	-47	-2.4%	$278	$270	-$8	-2.9%
Jun	2,001	1,940	-60	-3.0%	$293	$284	-$9	-3.1%
Jul	2,308	2,228	-80	-3.5%	$330	$318	-$13	-3.9%
Aug	2,256	2,189	-68	-3.0%	$322	$311	-$11	-3.4%
Sep	2,056	1,997	-60	-2.9%	$300	$291	-$10	-3.3%
Oct	2,049	2,012	-37	-1.8%	$248	$243	-$5	-2.0%
Nov	1,959	1,951	-8	-0.4%	$229	$227	-$2	-0.9%
Dec	2,333	2,338	6	0.3%	$262	$262	$0	0.0%
Annual	24,965	24,551	-415	-1.7%	$3,202	$3,135	-$67	-2.1%

The normalized area is net roof area, not floor area.

4.4 Cost / Benefit Analysis

To determine the value of applying a cool roof coating, the costs of applying the coating should be compared to the benefits. For this analysis, the dollar benefits will be limited to the energy savings, although there may be other considerations that would affect a decision to apply a roof coating.

Costs for applying the roof coating were provided by the roofing contractor. According to the roofing contractor, although it is possible to apply a roof coating over an existing roof without performing any roof maintenance, it is unwise to do so. Sealing flashing and other tasks should be done prior to coating the roof to extend the roof life and to minimize the amount of repair that might be required in the future.

The roofing contractor performed the roof maintenance and applied the roof coating for $1.95/sf. If roof maintenance is not performed, the cost would be $1.25/sf. This cost includes sweeping, power washing, and other surface preparation prior to applying the roof coating. The manufacturer's cost for the material is about $0.30/sf, but does not include any labor or other materials that might be required for finishing the roof coating. Using these costs, and the cost savings attributable to reduced energy consumption, the simple payback is shown in Table 7. Using the actual cost of installation, the payback is 29 years, longer than the probable life of the roof. Using a minimal application cost (without roof maintenance), the simple payback is about 19 years. If the labor to prepare the roof and apply the roof coating was free, and no maintenance is performed when applying the roof, the simple payback would be about five years. It is unlikely that the installation labor would ever be free, but is an indication of the minimum payback possible with this material at this location. Simple payback analysis results in the shortest payback possible; it assumes no time-value of money. If a present value analysis was used, the payback periods would lengthen.

Table 7. Payback Analysis

Description	Cost ($/sf)	Energy Savings ($/sf)	Simple Payback (yrs)
Cost includes • Roof Maintenance • Roof Preparation • Coating and Coating Labor	$1.95	$0.067	29.1
Cost includes • Roof Preparation • Coating and Coating Labor	$1.25	$0.067	18.7
Cost includes • Coating Material Only (no labor or roof prep)	$0.30	$0.067	4.5

There are other non-energy considerations that may make a cool roof coating a good investment. One consideration is extended roof life. Although studying the effects of roof coating on roof lifetime was not part of this analysis, the cool roof coating substantially decreased the roof diurnal temperature swing, as shown in Figure 16. The uncoated roof daily temperature swing could be as great as 120°F. After the coating was applied on March 15, the temperature swing was reduced by 30-40°F on sunny days. Reducing this temperature swing will reduce the thermal expansion and contraction of the roof, which could conceivably increase the longevity of the roof. Considering the increased roof longevity could improve the cost-effectiveness of the roof coating.

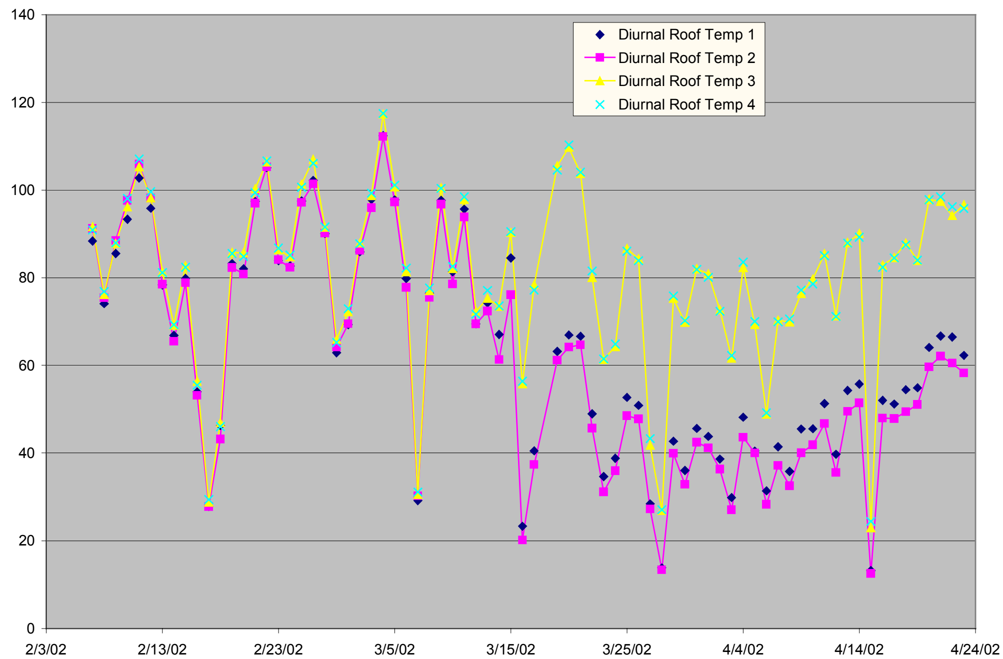

Figure 16. Diurnal Temperature Swing

5.0 Conclusions

The cool roof reduced the cooling requirements and reduced the energy consumption at the facility. However, the impact was reduced because of the reasonably good roof insulation.

The payback period of the cool roof coating at Site A is longer than the lifetime of the roof, when using the actual installation costs. Again, the long payback period is due to the good insulation already present at the facility.

Energy should not be the only consideration for applying a cool roof coating. Effects on roof lifetime should be investigated, and should be included in any roof coating cost / benefit analysis.

Appendix A: Daily Data Summary

Date	Daily Solar Insolation (BTU/SF)	Average Amb Temp (F)	Max Amb Temp (F)	Min Amb Temp (F)	Average Room Temp (F)	Max Room Temp (F)	Min Room Temp (F)	Daily Coated Heat Flux (BTU/SF)	Average Roof T 1 (F)	Max Roof T 1 (F)	Min Roof T 1 (F)	Average Roof T 2 (F)	Max Roof T 2 (F)	Min Roof T 2 (F)	Average Deck T 1 (F)	Max Deck T 1 (F)	Min Deck T 1 (F)
2/7/2002	1,499.87	50.39	69.86	33.76	75.21	77.84	72.99	-28.66	51.52	108.49	20.13	51.30	111.19	19.99	54.79	106.96	26.60
2/8/2002	1,476.48	51.76	68.11	37.93	75.88	78.36	73.78	-21.92	56.90	107.23	33.16	56.48	108.12	32.68	59.89	106.53	37.41
2/9/2002	1,534.87	59.06	80.81	40.55	75.21	77.67	73.54	-19.05	59.86	116.01	30.48	59.82	118.83	30.34	62.63	114.57	35.31
2/10/2002	1,598.99	58.67	81.61	41.41	75.16	77.74	73.42	-22.22	58.58	119.35	26.04	58.78	122.46	24.83	60.85	117.61	30.10
2/11/2002	1,608.31	57.50	82.30	36.00	75.93	79.03	73.32	-23.19	56.75	121.47	18.73	56.55	123.99	18.08	58.85	119.50	24.73
2/12/2002	1,562.12	55.76	78.00	36.71	75.69	78.71	73.26	-23.79	55.82	115.26	19.42	55.57	116.86	18.69	58.40	114.81	24.81
2/13/2002	1,260.87	55.80	77.56	39.28	75.88	78.42	73.64	-21.10	57.37	104.27	25.90	56.96	103.75	25.22	59.47	106.26	30.60
2/14/2002	1,230.80	55.52	67.71	46.89	76.14	78.39	73.63	-18.62	60.85	104.86	37.99	60.08	103.03	37.56	63.21	102.37	42.56
2/15/2002	1,426.50	56.16	75.47	44.23	76.12	78.46	73.95	-20.12	60.60	114.04	34.21	59.62	113.23	34.38	63.09	110.64	38.63
2/16/2002	1,029.71	55.35	66.15	48.90	74.68	76.20	73.52	-15.84	61.37	99.03	45.07	60.60	98.59	45.43	63.29	98.20	44.67
2/17/2002	466.13	53.40	57.03	48.32	73.86	74.35	73.38	-28.23	53.11	68.58	40.72	53.00	68.23	40.44	55.29	68.20	43.65
2/18/2002	863.54	49.45	57.64	41.80	74.16	75.34	73.46	-32.08	49.64	77.44	31.15	48.72	74.31	31.11	52.70	78.43	36.93
2/19/2002	1,576.68	51.04	66.13	37.71	75.49	77.96	73.47	-23.41	56.04	111.04	27.81	55.25	110.36	28.05	58.74	109.69	32.76
2/20/2002	1,604.56	55.33	72.18	41.63	75.88	78.07	73.57	-17.76	60.79	114.96	32.95	59.90	113.80	32.97	63.21	112.59	37.11
2/21/2002	1,645.04	66.44	91.73	44.62	76.01	78.32	73.51	-10.68	68.17	132.47	35.09	67.17	132.24	35.26	70.00	129.26	38.80
2/22/2002	1,699.62	68.03	95.89	45.80	76.19	78.06	73.80	-11.97	68.28	134.20	29.07	67.88	134.35	29.08	69.74	132.18	33.61
2/23/2002	1,483.69	58.54	76.31	47.10	75.49	76.75	74.01	-14.04	62.24	116.04	32.11	62.07	115.93	31.84	63.90	114.19	36.97
2/24/2002	1,700.10	60.50	74.61	47.92	75.59	76.79	74.31	-7.65	68.66	120.60	37.90	67.87	119.69	37.36	70.36	117.76	43.17
2/25/2002	1,702.89	61.02	84.04	43.54	75.63	77.65	73.48	-10.57	65.49	128.36	30.85	64.50	128.13	30.93	67.95	126.01	35.19
2/26/2002	1,686.25	64.78	89.95	42.85	76.29	78.45	73.74	-11.56	67.23	131.62	29.39	66.13	131.37	29.97	69.11	127.72	33.75
2/27/2002	1,470.10	62.21	84.37	47.04	76.11	77.94	73.45	-14.40	64.92	123.33	33.27	64.47	123.64	33.48	66.49	114.66	37.90
2/28/2002	1,582.52	56.86	64.86	50.42	76.48	77.49	74.59	-9.00	68.09	109.81	46.90	67.80	110.63	46.47	70.33	112.00	48.84
3/1/2002	1,581.79	59.13	72.28	50.94	76.45	77.80	74.70	-11.57	67.64	111.07	41.77	67.28	110.92	41.43	69.93	112.21	45.30
3/2/2002	1,768.90	59.11	73.20	45.14	75.35	77.22	73.75	-17.24	61.99	117.78	31.86	61.30	118.27	32.06	65.08	117.75	37.02
3/3/2002	1,875.50	55.61	72.24	36.35	74.66	76.11	73.59	-23.37	56.46	115.81	17.97	55.63	113.88	17.90	59.24	115.35	23.96
3/4/2002	1,921.91	54.97	80.70	32.49	75.58	77.86	73.44	-24.12	55.31	123.93	11.54	55.01	123.81	11.61	58.45	121.54	18.86
3/5/2002	1,759.48	54.44	74.08	36.85	76.08	78.24	73.93	-18.70	59.33	119.05	21.31	59.20	118.50	21.25	62.29	118.59	27.65
3/6/2002	1,329.41	56.00	71.77	42.63	75.97	77.96	73.98	-15.12	61.35	113.49	33.66	60.30	111.67	33.90	63.36	110.02	37.58
3/7/2002	658.05	57.43	62.14	53.55	76.27	77.23	74.80	-20.37	58.88	75.72	46.54	58.60	76.34	46.13	61.24	80.44	49.37
3/8/2002	1,620.94	55.22	64.38	46.40	76.06	77.96	73.90	-14.61	64.04	112.81	36.33	63.10	112.09	36.64	67.18	113.77	40.44
3/9/2002	1,869.88	57.76	79.78	40.29	75.49	77.46	73.74	-14.87	63.38	126.54	28.85	62.50	125.98	29.19	66.25	123.87	33.78
3/10/2002	1,904.53	57.38	71.71	44.82	75.53	77.30	73.76	-15.14	62.60	114.78	33.41	61.31	111.96	33.40	65.18	114.51	37.89
3/11/2002	1,900.55	59.76	78.54	42.64	76.19	78.62	73.76	-11.25	66.49	127.03	31.41	65.48	125.69	31.85	68.92	124.71	36.42
3/12/2002	1,862.71	60.01	73.17	47.91	76.07	77.99	74.58	-4.26	71.89	117.43	47.92	70.85	116.92	47.47	74.07	120.28	49.48
3/13/2002	1,255.55	57.82	66.60	47.98	75.33	77.66	72.98	-14.80	63.30	107.20	32.93	62.47	105.70	33.32	66.19	107.38	38.19
3/14/2002	1,974.16	49.86	58.75	37.66	74.13	77.07	68.98	-25.91	51.27	92.07	25.00	50.36	87.02	25.69	55.15	96.31	30.26
3/15/2002	**1,956.64**	**51.90**	**64.21**	**38.02**	**75.61**	**76.98**	**74.11**	**-25.75**	**52.76**	**109.36**	**24.86**	**52.45**	**102.51**	**26.40**	**55.81**	**110.26**	**30.63**
3/16/2002	1,527.09	51.92	57.27	47.07	74.27	75.07	73.66	-27.36	48.69	63.76	40.44	48.31	61.30	41.12	52.69	66.58	43.66
3/17/2002	1,786.38	52.17	60.38	44.52	74.85	75.99	73.53	-23.05	52.20	76.16	35.68	51.53	73.93	36.57	57.91	78.90	47.16

Date	Daily Solar Insolation (BTU/SF)	Average Amb Temp (F)	Max Amb Temp (F)	Min Amb Temp (F)	Average Room Temp (F)	Max Room Temp (F)	Min Room Temp (F)	Daily Coated Heat Flux (BTU/SF)	Average Roof T 1 (F)	Max Roof T 1 (F)	Min Roof T 1 (F)	Average Roof T 2 (F)	Max Roof T 2 (F)	Min Roof T 2 (F)	Average Deck T 1 (F)	Max Deck T 1 (F)	Min Deck T 1 (F)
3/19/2002	2,095.74	54.80	73.23	36.46	75.65	76.97	73.86	-31.52	49.61	86.10	22.92	49.96	84.72	23.54	52.93	86.08	30.10
3/20/2002	2,115.80	60.08	82.64	39.43	75.69	78.03	73.77	-27.21	53.58	92.53	25.62	54.09	91.09	26.94	56.35	90.96	32.89
3/21/2002	1,795.64	61.94	86.07	44.05	75.70	77.19	73.72	-23.53	56.10	95.22	28.57	56.51	93.98	29.27	58.37	92.93	35.28
3/22/2002	1,921.15	57.07	69.64	44.71	75.82	77.09	73.90	-27.24	53.67	82.71	33.76	54.00	80.52	34.86	56.48	82.67	39.04
3/23/2002	1,446.77	56.61	64.85	49.41	74.97	76.10	73.77	-20.15	57.08	79.23	44.58	56.77	76.59	45.45	59.11	78.36	45.75
3/24/2002	1,577.51	54.71	60.88	46.58	74.67	75.51	73.78	-26.34	52.78	73.10	34.30	52.60	71.36	35.41	55.72	75.26	39.82
3/25/2002	2,059.37	55.22	67.56	41.98	75.74	77.03	73.69	-27.76	52.83	82.88	30.19	53.08	80.26	31.74	55.39	82.53	36.08
3/26/2002	1,985.59	57.23	72.27	44.50	76.09	77.16	74.18	-26.88	54.46	85.80	34.92	54.56	83.62	35.85	57.24	85.20	40.50
3/27/2002	463.91	54.53	60.70	47.08	76.04	77.22	74.23	-25.68	53.38	65.61	37.17	53.34	65.59	38.37	55.64	65.77	42.78
3/28/2002	509.56	55.77	58.89	52.74	76.26	77.49	74.75	-24.87	55.63	64.08	50.26	55.34	63.58	50.20	57.94	64.28	53.30
3/29/2002	1,487.24	56.67	66.75	49.36	76.01	77.23	74.32	-23.87	56.89	83.70	41.00	56.58	80.92	40.97	59.51	82.80	45.30
3/30/2002	1,710.96	58.27	70.53	52.62	75.38	76.86	74.20	-16.29	61.21	87.06	51.02	60.51	84.09	51.21	63.31	87.00	53.21
3/31/2002	1,950.50	59.89	73.62	53.49	75.29	76.61	74.23	-14.56	63.26	92.51	46.87	62.53	90.10	47.64	65.28	91.74	51.10
4/1/2002	2,043.32	60.45	73.29	54.22	75.96	77.75	74.27	-14.34	64.19	92.61	48.80	63.53	90.09	48.90	66.22	92.53	54.25
4/2/2002	1,889.55	59.10	69.31	55.00	76.39	77.74	75.18	-16.16	63.27	89.61	50.98	62.56	86.92	50.62	65.51	89.72	55.44
4/3/2002	1,701.27	58.09	66.01	54.47	76.20	77.16	75.08	-17.20	62.18	83.70	53.83	61.31	80.77	53.71	64.43	85.23	56.33
4/4/2002	2,112.75	59.01	69.66	49.90	76.13	77.37	74.86	-18.71	61.64	89.35	41.19	60.79	85.89	42.32	65.08	89.13	47.17
4/5/2002	984.91	55.78	67.74	48.10	75.82	77.04	74.03	-24.84	54.04	76.64	36.18	54.01	76.20	36.18	58.56	80.89	42.87
4/6/2002	980.34	56.50	62.14	50.88	75.00	75.75	74.00	-21.11	56.36	74.43	43.02	56.05	72.09	43.79	61.01	70.84	53.55
4/7/2002	1,757.09	58.82	66.96	52.14	75.49	76.83	73.78	-11.48	63.46	88.30	46.86	62.31	84.48	47.34	67.16	88.87	54.13
4/8/2002	1,930.06	61.53	70.38	56.31	76.09	77.33	74.68	-8.19	65.75	90.12	54.30	64.64	86.70	54.18	71.02	92.76	58.81
4/9/2002	2,156.34	62.31	73.19	55.60	76.38	77.46	75.51	-12.44	65.98	93.36	47.86	64.81	88.99	48.94	68.25	93.50	52.29
4/10/2002	2,152.02	62.28	74.70	54.06	76.41	77.16	75.25	-13.66	66.48	95.32	49.80	65.49	92.04	50.17	67.56	94.55	51.18
4/11/2002	2,277.05	63.49	76.62	56.01	76.49	77.29	75.85	-12.68	67.63	99.81	48.55	66.50	95.04	48.33	68.73	96.24	51.88
4/12/2002	1,872.59	61.58	70.96	55.85	76.26	77.40	75.55	-12.50	66.51	93.24	53.50	65.43	89.19	53.63	67.71	91.75	55.49
4/13/2002	2,217.64	64.23	81.44	55.93	76.01	76.77	75.36	-10.77	69.00	104.39	50.11	67.91	100.68	51.18	70.25	100.69	53.21
4/14/2002	2,076.90	61.85	77.11	52.38	75.92	76.62	75.26	-13.21	65.65	99.52	43.77	64.74	96.06	44.63	66.82	97.45	48.10
4/15/2002	621.48	56.99	60.48	55.09	76.39	77.74	75.57	-22.36	57.88	66.37	53.18	57.47	65.73	53.19	59.99	67.89	55.96
4/16/2002	2,082.15	57.91	65.61	49.33	76.21	77.48	74.62	-21.11	59.86	89.80	37.80	59.06	86.25	38.25	61.77	89.38	42.40
4/17/2002	1,972.61	58.13	66.65	52.80	76.06	77.14	74.93	-18.72	61.32	92.41	41.21	60.44	89.05	41.19	63.36	91.93	45.60
4/18/2002	2,377.01	57.15	66.20	47.12	75.65	77.44	73.74	-22.43	58.52	90.82	36.38	57.85	86.85	37.43	60.38	89.69	41.83
4/19/2002	2,191.61	56.39	66.07	46.51	75.65	76.99	73.60	-24.77	55.94	88.08	33.19	55.23	84.63	33.57	58.24	87.54	40.46
4/20/2002	2,384.54	57.17	70.98	45.81	75.32	76.88	73.84	-20.93	58.14	94.50	30.41	57.63	90.82	31.19	60.17	94.13	36.96
4/21/2002	2,432.02	59.62	75.33	43.21	75.32	76.77	73.90	-19.48	59.18	96.93	30.26	58.72	92.46	30.35	60.46	93.28	36.54
4/22/2002	2,463.10	64.43	80.46	46.04	75.69	77.29	73.97	-16.94	62.84	99.47	32.97	62.50	94.86	34.37	63.86	95.77	38.95
4/23/2002	2,360.24	65.78	82.90	53.31	75.86	77.12	74.59	-11.75	67.30	106.80	44.50	66.57	103.20	44.92	67.72	103.77	47.94

Date	Daily Solar Insolation (BTU/SF)	Average Amb Temp (F)	Max Amb Temp (F)	Min Amb Temp (F)	Average Room Temp (F)	Max Room Temp (F)	Min Room Temp (F)	Daily Coated Heat Flux (BTU/SF)	Average Roof T 1 (F)	Max Roof T 1 (F)	Min Roof T 1 (F)	Average Roof T 2 (F)	Max Roof T 2 (F)	Min Roof T 2 (F)	Average Deck T 1 (F)	Max Deck T 1 (F)	Min Deck T 1 (F)
6/13/2002	2,543.78	66.22	79.27	56.65	76.31	77.76	74.82	-6.68	72.05	110.17	47.23	71.01	105.31	48.37	73.04	104.61	51.84
6/14/2002	2,542.36	68.21	83.56	57.34	77.08	78.16	75.87	-5.75	74.36	113.37	48.94	73.30	109.28	49.87	75.22	108.95	54.09
6/15/2002	2,765.18	71.34	87.73	53.86	76.24	77.63	75.06	-4.25	74.98	118.72	42.98	74.12	115.04	43.71	75.51	115.29	48.66
6/16/2002	2,680.12	71.35	88.65	54.33	76.23	77.53	74.97	-2.02	76.45	121.06	41.59	75.48	116.71	42.53	77.05	116.99	48.66
6/17/2002	2,651.64	72.15	85.36	59.49	77.34	78.52	76.03	4.90	78.30	116.22	51.99	77.29	112.36	52.41	81.18	113.22	55.87
6/18/2002	2,632.50	71.60	85.87	60.03					78.81	117.22	51.63	77.58	113.25	51.85			
6/19/2002	2,494.55	66.99	75.51	61.30					76.35	106.70	54.82	74.88	101.99	55.03			
6/20/2002	2,212.64	64.74	71.83	61.12					74.90	104.21	61.11	73.37	100.08	60.72			
6/21/2002	2,198.51	66.22	75.33	60.35					74.44	110.89	51.34	73.18	106.57	52.24			
6/22/2002	2,686.70	69.14	80.58	60.50					78.07	112.87	52.41	76.71	108.28	53.29			
6/23/2002	2,480.93	68.53	81.90	59.19					77.12	116.67	50.51	75.73	112.09	51.99			
6/24/2002	2,489.23	67.63	81.78	56.55					75.15	114.89	48.62	74.01	110.71	49.32			
6/25/2002	2,608.02	69.33	86.01	55.93					77.14	120.46	48.40	75.84	116.05	50.08			
6/26/2002	2,518.75	68.93	85.05	58.74					76.26	118.53	51.76	75.04	114.29	52.83			
6/27/2002	2,580.82	67.04	80.82	57.31					75.63	116.10	50.40	74.41	111.46	51.33			
6/28/2002	2,620.59	68.02	81.40	58.80					77.33	116.60	54.03	75.96	112.08	54.30			
6/29/2002	2,562.64	67.61	81.41	59.96					77.09	116.14	52.06	75.60	111.64	52.47			
6/30/2002	2,591.74	69.31	82.37	57.66					77.18	116.23	48.97	76.11	112.13	50.28			
7/1/2002	2,536.15	70.83	90.14	57.45					77.59	123.58	50.74	76.82	119.93	51.73			
7/2/2002	2,506.99	71.35	90.14	57.15					78.08	123.51	46.12	77.15	119.47	46.71			
7/3/2002	2,501.65	68.40	79.42	61.06					76.48	112.96	53.77	74.94	107.66	54.45			
7/4/2002	2,451.54	66.81	77.24	60.48					76.83	114.15	54.55	75.27	109.33	54.42			
7/5/2002	2,319.47	66.83	75.99	61.55					76.63	109.83	56.04	75.17	105.02	55.78			
7/6/2002	2,314.21	67.46	78.20	58.95					75.67	110.26	50.27	74.41	105.97	51.06			
7/7/2002	2,551.69	70.26	82.71	60.02					79.05	118.79	51.97	77.64	113.96	52.68			
7/8/2002	2,528.42	73.65	91.01	61.64					82.02	122.92	54.02	80.84	119.88	54.90			
7/9/2002	2,409.64	74.48	87.64	61.08					80.21	118.69	52.18	79.29	114.72	53.31			
7/10/2002	1,253.21	73.80	81.31	66.45					76.07	103.55	57.56	75.44	101.26	57.79			
7/11/2002	1,554.60	74.70	86.91	65.58					80.04	116.05	60.91	79.13	112.43	61.24			
7/12/2002	1,793.39	75.59	89.92	64.96					80.84	124.30	56.97	79.84	120.13	57.34			
7/13/2002	2,445.56	74.54	87.01	63.31					82.20	119.50	58.59	80.52	115.26	59.23			
7/14/2002	2,287.90	73.17	87.27	63.19					81.43	121.90	57.26	80.06	116.55	58.06			
7/15/2002	1,876.63	71.83	84.64	62.98					77.81	119.62	55.46	76.76	115.26	55.77			
7/16/2002	2,429.65	71.63	82.89	62.13					79.99	118.38	55.41	78.78	113.20	56.83			
7/17/2002	2,358.07	71.53	84.07	62.86					81.36	120.45	55.77	79.82	115.32	56.57			
7/18/2002	2,318.40	71.39	82.48	63.19					81.46	118.34	55.98	79.86	113.55	56.46			
7/19/2002	2,236.90	69.41	81.16	62.62					78.53	116.23	56.68	77.21	111.01	56.73			
7/20/2002	2,110.41	67.59	78.48	60.91					75.99	113.27	53.08	74.70	108.44	54.13			
7/21/2002	2,289.60	67.81	78.63	60.41					77.33	115.33	53.57	75.68	109.08	54.42			
7/22/2002	2,337.40	69.52	79.76	59.40					76.40	112.64	51.51	75.09	106.60	53.11			
7/23/2002	2,402.77	74.06	86.16	61.37					80.79	118.75	54.30	79.43	112.75	55.38			
7/24/2002	2,385.12	80.48	95.01	66.87					87.17	129.92	58.84	86.11	124.98	59.94			
7/25/2002	2,495.26	78.08	92.22	64.90					83.68	125.82	54.09	82.47	121.09	54.50			
7/26/2002	2,439.05	72.39	83.44	63.45					80.30	119.29	56.67	79.05	114.58	56.91			
7/27/2002	2,318.87	68.59	79.91	62.56					78.58	118.14	55.90	77.00	113.04	55.80			
7/28/2002	2,528.24	70.85	83.17	61.77					80.54	119.88	53.73	78.78	114.76	54.54			
7/29/2002	2,483.75	68.54	81.05	56.89					74.04	111.89	47.92	72.96	106.11	49.62			
7/30/2002	2,319.60	70.38	84.41	60.75					77.96	119.96	52.84	76.72	114.78	53.48			
7/31/2002	1,634.04	70.22	84.49	60.49					73.97	113.80	53.61	73.26	109.18	54.78			
8/1/2002	2,323.85	71.91	83.73	64.03					82.19	121.27	58.84	80.62	116.22	59.25			
8/2/2002	82.25	65.70	67.92	65.04					65.16	73.47	63.04	65.15	73.25	63.19			

Appendix B: SDG&E Schedule AL-TOU

SCHEDULE AL-TOU

Sheet 1

GENERAL SERVICE - TIME METERED

APPLICABILITY

Applicable to all metered non-residential customers whose monthly maximum demand equals, exceeds, or is expected to equal or exceed 20 kW. This schedule is optionally available to three-phase residential service, including common use, and to metered non-residential customers whose Monthly Maximum Demand is less than 20 kW. Any customer whose Maximum Monthly Demand has fallen below 20 kW for three consecutive months may, at their option, elect to continue service under this schedule or be served under any other applicable schedule. This schedule is the utility's standard tariff for commercial and industrial customers with a Monthly Maximum Demand equaling or exceeding 20 kW.

Non-profit group living facilities taking service under this schedule may be eligible for a 20% California Alternate Rates for Energy (CARE) discount on their bill, if such facilities qualify to receive service under the terms and conditions of Schedule E-LI.

Agricultural Employee Housing Facilities, as defined in Schedule E-LI, may qualify for a 20% CARE discount on the bill if all eligibility criteria set forth in Form 142-4032 is met.

TERRITORY

Within the entire territory served by the Utility.

RATES

Description	Transm	Distr	PPP	ND	FTA	TTA Credit	Restruc	CTC	RMR	UDC Total	
Basic Service Fees											
($/month)											
0-500 kW											
Secondary		46.14								**46.14**	
Primary		46.14								**46.14**	
Secondary Substa.		13,179.65								**13,179.65**	
Primary Substation		13,179.65								**13,179.65**	
Transmission		50.75								**50.75**	I
> 500 kW											
Secondary		184.55								**184.55**	
Primary		184.55								**184.55**	
Secondary Substa.		13,179.65								**13,179.65**	
Primary Substation		13,179.65								**13,179.65**	
Transmission		203.01								**203.01**	I
> 12 MW											
Secondary Substa.		20,752.11								**20,752.11**	
Primary Substation		20,752.11								**20,752.11**	
Distance Adjust. Fee											
Secondary - OH		1.17								**1.17**	
Secondary - UG		3.02								**3.02**	
Primary - OH		1.16								**1.16**	
Primary - UG		2.98								**2.98**	

(Continued)

SCHEDULE AL-TOU

Sheet 2

GENERAL SERVICE - TIME METERED

RATES (Continued)

Description	Transm	Distr	PPP	ND	FTA	Restruc	CTC	RMR	UDC Total
Demand Charges ($/kW)									
Non-Coincident									
Secondary	0.35	5.78					0.39	0.19	**6.71**
Primary	0.33	5.69					0.35	0.19	**6.56**
Secondary Substation	0.35						0.39	0.19	**0.93**
Primary Substation	0.33						0.03	0.18	**0.54**
Transmission	0.32						0.03	0.18	**0.53**
Maximum On-Peak									
Summer									
Secondary	3.15	3.80					1.71	1.76	**10.42**
Primary	3.02	3.66					1.67	1.69	**10.04**
Secondary Substation	3.15						1.71	1.76	**6.62**
Primary Substation	2.96						1.22	1.66	**5.84**
Transmission	2.94						1.21	1.65	**5.80**
Winter									
Secondary	0.77	3.23					0.40	0.43	**4.83**
Primary	0.74	3.22					0.39	0.41	**4.76**
Secondary Substation	0.77						0.40	0.43	**1.60**
Primary Substation	0.72						0.25	0.40	**1.37**
Transmission	0.72						0.25	0.40	**1.37**
Power Factor ($/kvar)									
Secondary		0.24							**0.24**
Primary		0.24							**0.24**
Secondary Substation		0.24							**0.24**
Primary Substation		0.24							**0.24**
Transmission									**0.00**

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

RATES (Continued)

Description	Transm	Distr	PPP	ND	FTA	Restruc	CTC	RMR	UDC Total
Energy Charges ($/kWh)									
On-Peak - Summer									
Secondary	(.00001)	.00082	.00302	.00065		.00067	.00660	.00036	**.01211**
Primary	(.00004)	.00079	.00302	.00065		.00067	.00643	.00035	**.01187**
Secondary Substation	(.00001)		.00302	.00065		.00067	.00660	.00036	**.01129**
Primary Substation	(.00005)		.00302	.00065		.00067	.00621	.00034	**.01084**
Transmission	(.00005)		.00302	.00065		.00067	.00617	.00034	**.01080**
Semi-Peak - Summer									
Secondary	(.00002)	.00082	.00302	.00065		.00067	.00385	.00036	**.00935**
Primary	(.00004)	.00079	.00302	.00065		.00067	.00377	.00035	**.00921**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00385	.00036	**.00853**
Primary Substation	(.00005)		.00302	.00065		.00067	.00366	.00034	**.00829**
Transmission	(.00005)		.00302	.00065		.00067	.00363	.00034	**.00826**
Off-Peak - Summer									
Secondary	(.00002)	.00048	.00302	.00065		.00067	.00303	.00036	**.00819**
Primary	(.00004)	.00047	.00302	.00065		.00067	.00298	.00035	**.00810**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00303	.00036	**.00771**
Primary Substation	(.00005)		.00302	.00065		.00067	.00293	.00034	**.00756**
Transmission	(.00005)		.00302	.00065		.00067	.00291	.00034	**.00754**
On-Peak - Winter									
Secondary	(.00001)	.00066	.00302	.00065		.00067	.00552	.00036	**.01087**
Primary	(.00004)	.00064	.00302	.00065		.00067	.00538	.00035	**.01067**
Secondary Substation	(.00001)		.00302	.00065		.00067	.00552	.00036	**.01021**
Primary Substation	(.00005)		.00302	.00065		.00067	.00520	.00034	**.00983**
Transmission	(.00005)		.00302	.00065		.00067	.00517	.00034	**.00980**
Semi-Peak - Winter									
Secondary	(.00002)	.00066	.00302	.00065		.00067	.00387	.00036	**.00921**
Primary	(.00004)	.00064	.00302	.00065		.00067	.00378	.00035	**.00907**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00387	.00036	**.00855**
Primary Substation	(.00005)		.00302	.00065		.00067	.00368	.00034	**.00831**
Transmission	(.00005)		.00302	.00065		.00067	.00365	.00034	**.00828**
Off-Peak - Winter									
Secondary	(.00002)	.00048	.00302	.00065		.00067	.00306	.00036	**.00822**
Primary	(.00004)	.00048	.00302	.00065		.00067	.00301	.00035	**.00814**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00306	.00036	**.00774**
Primary Substation	(.00005)		.00302	.00065		.00067	.00296	.00034	**.00759**
Transmission	(.00005)		.00302	.00065		.00067	.00294	.00034	**.00757**

Notes: Transmission Energy charges include the Transmission Revenue Balancing Account Adjustment (TRBAA) of ($.0007) per kWh, the Transmission Access Charge Balancing Account Adjustment (TACBAA) of $.00007 per kWh and a Supplemental Surcharge (SS) of $.00007 per kWh. Restructuring Implementation Rate is comprised of rates for Internally Managed Costs (IMC) and Externally Managed Costs (EMC).

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

RATES (Continued)

Rate Components
The Utility Distribution Company Total Rates (UDC Total) shown above are comprised of the following components (if applicable): (1) Transmission (Trans) Charges, (2) Distribution (Distr) Charges, (3) Public Purpose Program (PPP) Charges, (4) Nuclear Decommissioning (ND) Charge, (5) Trust Transfer Amount (TTA), sometimes referred to as Fixed Transition Amount (FTA), (6) Restructuring Implementation Rate (Restruc) which is the sum of the rates for Internally Managed Costs and Externally Managed Costs (7) Ongoing Competition Transition Charges (CTC), and (8) Reliability Must Run Generation Rates (RMR).

Utility Distribution Company (UDC) Total Rate shown above excludes any applicable commodity charges associated with Schedule EECC (Electric Energy Commodity Cost). T T

Fixed Transition Amount Adjustment
For residential and small commercial customers as defined in Rule 1 – Definitions, and as described in Public Utilities Code Section 331(h), the rates shown above will be adjusted in accordance with the rates set forth in Schedule FTA.

Time Periods
All time periods listed are applicable to local time. The definition of time will be based upon the date service is rendered.

	Summer May 1 - Sept 30	Winter All Other
On-Peak	11 a.m. - 6 p.m. Weekdays	5 p.m. - 8 p.m. Weekdays
Semi-Peak	6 a.m. - 11 a.m. Weekdays	6 a.m. - 5 p.m. Weekdays
	6 p.m. - 10 p.m. Weekdays	8 p.m. - 10 p.m. Weekdays
Off-Peak	10 p.m. - 6 a.m. Weekdays	10 p.m. - 6 a.m. Weekdays
	Plus Weekends & Holidays	Plus Weekends & Holidays

Non-Standard Seasonal Changeover
Customers may select on an optional basis to start the summer billing period on the first Monday of May and to start the winter billing period on the first Monday of October. Customers electing this option will be charged an additional $100 per year for metering equipment and programming.

Franchise Fee Differential
A Franchise Fee Differential of 1.9% will be applied to the monthly billings calculated under this schedule for all customers within the corporate limits of the City of San Diego. Such Franchise Fee Differential shall be so indicated and added as a separate item to bills rendered to such customers.

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

SPECIAL CONDITIONS

1. Definitions: The Definitions of terms used in this schedule are found either herein or in Rule 1.

2. Voltage: Service under this schedule normally will be supplied at a standard available Voltage in accordance with Rule 2.

3. Voltage Regulators: Voltage Regulators, if required by the customer, shall be furnished, installed, owned, and maintained by the customer.

4. Reconnection Charge: In the event that a customer terminates service under this schedule and re-initiates service under this or any other schedule at the same location within 12 months, there will be a Reconnection Charge equal to the greater of the Minimum Charge or the Basic Service Fee which would have been billed had the customer not terminated service. T

5. Non-Coincident Demand Charge: The Non-Coincident Demand Charge shall be based on the higher of the Maximum Monthly Demand or 50% of the Maximum Annual Demand.

6. On-Peak Period Demand Charge: The On-Peak Period Demand Charge shall be based on the Maximum On-Peak Period Demand.

7. Power Factor: The Power Factor rate shall apply to those customers that have a Power Factor Test Failure and will be based on the Maximum Kilovar billing demand. Those customers that have a Power Factor Test Failure will be required to pay for the Power Factor Metering that the utility will install.

8. Parallel Generation Limitation. This schedule is not applicable to standby, auxiliary service or service operated in parallel with a customer's generating plant, except as specified in Rule 1 under the definition of Parallel Generation Limitation.

9. Seasonal Changeover Switching Limitation. Customers who elect the nonstandard Seasonal Changeover option of this schedule will be prohibited from switching service to the regular seasonal changeover for a 12-month period.

10. Limitation on Non-Standard Seasonal Changeover Availability. At the utility's sole option, the optional non-standard seasonal changeover provision is available to no more than ten additional Schedule AL-TOU and Schedule A6-TOU customers annually and; service will be provided in the order in which requests are received.

11. Terms of Optional Service. A customer receiving service under this schedule may elect to change to another applicable rate schedule, but only after receiving service on this schedule for at least 12 consecutive months. If a customer elects to discontinue service on this schedule, the customer will not be permitted to return to this schedule for a period of one year.

12. Basic Service Fee Determination. The basic service fee will be determined each month based on the customer's Maximum Annual Demand. T L T L

(Continued)

SPECIAL CONDITIONS (Continued)

L

13. Billing. A customer's bill is first calculated according to the total rates and conditions listed above. The following adjustments are made depending on the option applicable to the customer:

a. **UDC Bundled Service Customers** receive supply and delivery services solely from SDG&E. The customer's bill is based on the Total Rates set forth above. The EECC component is determined by multiplying the EECC price for this schedule during the last month by the customer's total usage.

b. **Direct Access Customers** purchase energy from an energy service provider (ESP) and continue to receive delivery services from SDG&E. The bill for a Direct Access Customer will be calculated as if it were a UDC Bundled Service Customer, then crediting the bill by the amount of the EECC component, as determined for a UDC Bundled Customer.

c. **Virtual Direct Access Customers** receive supply and delivery services solely from SDG&E. A customer taking Virtual Direct Access service must have a real-time meter installed at its premises to record hourly usage, since EECC change hourly. The bill for a Virtual Direct Access Customer will be calculated as if it were a UDC Bundled Service Customer, then crediting the bill by the amount of the EECC component, as determined for a UDC Bundled Customer, then adding the hourly EECC component, which is determined by multiplying the hourly energy used in the billing period by the hourly cost of energy.

Nothing in this service schedule prohibits a marketer or broker from negotiating with customers the method by which their customer will pay the CTC charge.

14. Temporary Service. When service is turned on for cleaning and/or showing of an unoccupied premise above 20 kW facility, the minimal usage shall be billed under Schedule A, until a new tenant begins service. Should usage exceed 20kW at any time for cleaning and/or showing, the customer shall be billed the rates on this schedule. T T N

15. Multiple Meters on Single Premise. When a single corporate entity owns a contiguous property, not divided by any public right of way or property owned by another entity, and the utility has more than one meter serving that property, then, at the customer's request the utility will for the additional fees set forth in this Special Condition bill all of the usage at some, or all, of the meters as though the whole premise were served through a single meter. Meter data will be combined for the purpose of billing Distribution charges, as listed in the Rates Section of this tariff. The customer must pay for the utility to install and maintain meters to record consumption in 15 minute intervals for all involved meters. The customer must also pay a distance adjustment fee determined by that utility that is based on the distance between each of the meters involved using normal utility position to determine that distance. The rate applied will be the Distance Adjustment Fee from the Rate Section of this tariff times 0.121. When Secondary level and Primary level services are combined, the usage measured at the Secondary level will be increased by 4% for losses, prior to being added to the usage measured at the Primary level. When Primary level and Transmission level services are combined, usage measured at the Primary Level will be increased by 3% for losses, prior to being added to the usage measured at the Transmission level. L–L

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

SPECIAL CONDITIONS (Continued)

L

16. Electric Emergency Load Curtailment Plan: As set forth in CPUC Decision 01-04-006, all transmission level customers except essential use customers, OBMC participants, net suppliers to the electrical grid, or others exempt by the Commission, are to be included in rotating outages in the event of an emergency. A transmission level customer who refuses or fails to drop load shall be added to the next curtailment block so that the customer does not escape curtailment. If the transmission level customer fails to cooperate and drop load at SDG&E's request, automatic equipment controlled by SDG&E will be installed at the customer's expense per Electric Rule 2. A transmission level customer who refuses to drop load before installation of the equipment shall be subject to a penalty of $6/kWh for all load requested to be curtailed that is not curtailed. The $6/kWh penalty shall not apply if the customer's generation suffers a verified, forced outage and during times of scheduled maintenance. The scheduled maintenance must be approved by both the ISO and SDG&E, but approval may not be unreasonably withheld.

17. One Time Bill Change Limitation: Pursuant to D.02-09-034, the Utility will, between November 1, 2003 and January 1, 2004, perform a calculation that may lead to bill credits for some customers on this rate schedule. The calculation shall be based on twelve consecutive billing periods of usage for each customer on this rate schedule, commencing with the customers first billing period after October 1, 2002. The calculation shall determine the annual bill at total adopted rates less the annual bill at total present rates, divided by the annual bill at total present rates, to arrive at each customer's annual percentage change in bill. Total rates shall include all applicable rates that a bundled customer taking service under this rate schedule would be billed, including Schedule EECC rates. Based on the result of this calculation, any customer who has experienced an annual bill increase that exceeds 7.5% shall be eligible for a bill credit equal to that portion of their bill increase that causes them to exceed a 7.5% increase. Present rates will be those rates in effect on September 30, 2002. All customers eligible for a bill credit under the provisions of this Special Condition shall receive such bill credits by February 1, 2004. N

18. Other Applicable Tariffs: Rules 21, 23 and Schedule E-Depart apply to customers with generators. N

Attachment 2:

Cool Roof Monitoring and Analysis at Site B

Cool Roof Monitoring and Analysis at Site B

Prepared for:

San Diego Gas & Electric
8335 Century Park Court, CP12B
San Diego, California 92123-1569

Prepared by:

Architectural Energy Corporation
2540 Frontier Avenue, Suite 201
Boulder, Colorado 80301

October 21, 2002

Cool Roof Monitoring and Analysis at Site B

Table of Contents

Table of Figures

Table of Tables

Executive Summary

This project was intended to evaluate the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems.

The facilities selected for monitoring are operated by a property management company and are located in a shopping center in Oceanside, California. Two buildings were monitored. One had a cool roof coating; and the other had a standard mineral cap sheet roof surface.

The evaluation was performed by first monitoring the thermal performance of the two roof surfaces to understand their actual performance characteristics. Next, to determine the annual performance of the building, a simulation model was created and calibrated using the actual performance data. The calibrated simulation results were then used to evaluate the energy impact and cost effectiveness of the cool roof system.

The roof structure on the coated store consists of plywood decking over wood joists spaced two feet apart. Fiberglass insulation batts are stapled to the wood joists. The roof coating is Uniflex Roofing Systems 41-300 elastomeric roof coating.

At the uncoated store, the roof and insulation design is substantially different. The plywood decking is placed over wood joists, as on the building with the coated roof; but instead of insulation batts attached between the joists, the insulation is laid over the suspended ceiling. Since the goal was to only monitor the roof surface at the uncoated store, this difference will not substantially affect the results.

The approach used to evaluate the cool roof performance was to compare the performance of the cool roof surface on one building to the standard mineral cap sheet surface on the other building. This evaluation was performed through monitoring temperatures and heat flows, as well as ambient conditions for a period of several months. Next, a simulation model was developed to model the performance of the store with the coated roof. The monitored data was then used to calibrate the simulation model so that it accurately represented the roof performance. The data collected on the uncoated roof was used to calibrate the model of the uncoated roof so that the savings attributable to the cool roof coating could be calculated.

Instrumentation was installed at the shopping center on February 6, 2002 to monitor ambient conditions, roof structure temperatures, and heat flux; and HVAC system inlet temperatures. The monitoring was completed by the end of July.

After collecting performance data, a simulation model was developed using DOE-2.1, based on the measured data, to estimate the annual performance of the roof coating.

Annual simulated savings from the cool roof coating were estimated at 0.618 kWh/sf, or on a dollar basis, $0.071/sf. The installation cost for the roof was $1.45/sf, leading to a simple payback of 20 years. Based on the energy savings alone, the cost-effectiveness of the cool roof coating was quite low, although there are other non-energy considerations that may make a cool roof coating a good investment. The daily roof surface temperature swing for the uncoated roof was as great as 90°F. With the coated roof, the temperature swing was reduced as much as 30°F on sunny days. This reduced temperature swing will reduce the thermal expansion and contraction of the roof, which could increase the lifetime of the roof. Considering the increased roof lifetime could improve the cost-effectiveness of the roof coating.

1.0 Project Overview

This project is intended to evaluate the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems. The facilities selected for monitoring is operated by a property management company and is located in a shopping center in Oceanside, California. Two buildings were monitored. One had a cool roof coating; and the other had a standard mineral cap sheet roof surface.

The evaluation was performed by first monitoring the thermal performance of the two roof surfaces to understand their actual performance characteristics. Next, to determine the annual performance of the building a simulation model was created and calibrated using the actual performance data. The calibrated simulation results were then used to evaluate the cost-effectiveness of the cool roof system.

2.0 Site Description

The facilities selected for monitoring are operated by a property management company, and are located in a shopping center in Oceanside, California. Two buildings were monitored. One had a cool roof coating; and the other had a standard mineral cap sheet roof surface.

2.1 Coated Store Description

The space conditioning for the coated store is provided by standard single-zone rooftop HVAC units, generally without economizers. The building has 13 rooftop HVAC units, ranging from 3.5 to 13 tons.

The roof and insulation structure at the coated roof store consists of plywood decking on 2"x6" wood joists spaced two feet apart, with larger wooden beams supporting the wood joists. Fiberglass insulation batts are held in place between the wood joists by wire. A picture of the underside of the roof is shown in Figure 1. A diagram showing the cross-section of the roof, with the approximate sensor locations, is shown in Figure 2.

The roof coating is Uniflex Roofing Systems 41-300 elastomeric roof coating.[1] A picture of the coated roof is shown in Figure 3.

[1] http://www6.inetba.com/koolsealinc/index2.ivnu

Figure 1. Coated Store Ceiling and Insulation

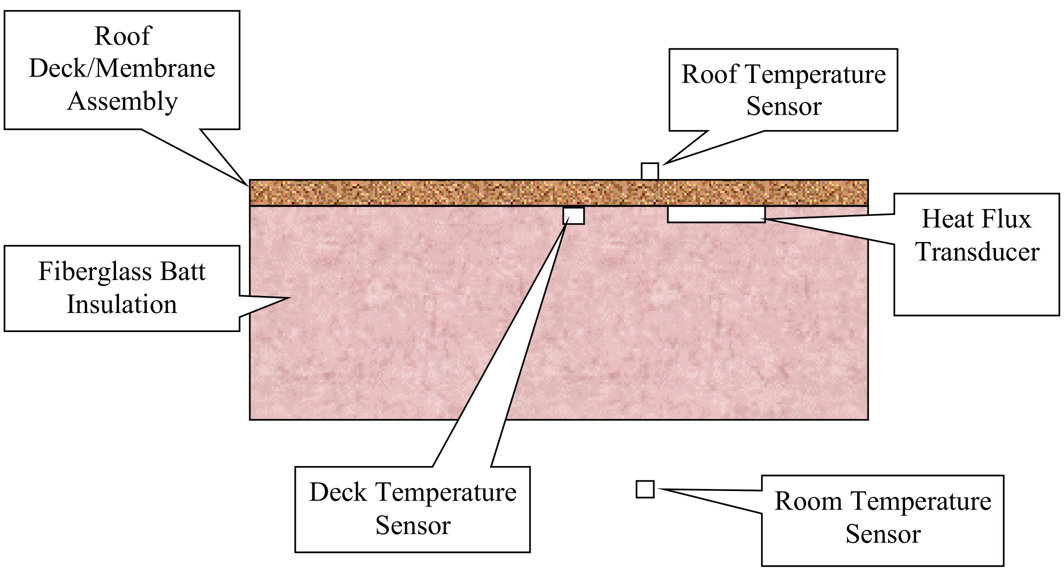

Figure 2. Roof Structure Schematic

2.2 Uncoated Store Description

At the uncoated store, the roof and insulation design is substantially different. The plywood decking is placed over wood joist, as at the coated store, but instead of insulation batts attached between the joists, the insulation is laid over the suspended ceiling. This provides an uninsulated, largely unconditioned space between the roof deck and the insulation on top of the suspended ceiling. The heat flow through the roof and to the conditioned space is substantially different than when the insulation is attached to the roof deck, due to radiation, duct leakage, and uncontrolled air flow between the conditioned space and the hot, unconditioned space above the lay-in insulation.

The roof surface at the uncoated store is conventional mineral surfaced cap sheet roll roofing. A picture of the roof is shown in Figure 3.

The space conditioning for uncoated store is provided by standard single-zone rooftop HVAC units, without economizers. There are eight five-ton HVAC units located on the roof. All of these units have fixed outside air intakes, i.e., the percentage of outside air entering the unit remains the same, regardless of ambient conditions.

Figure 3. Coated Store Roof

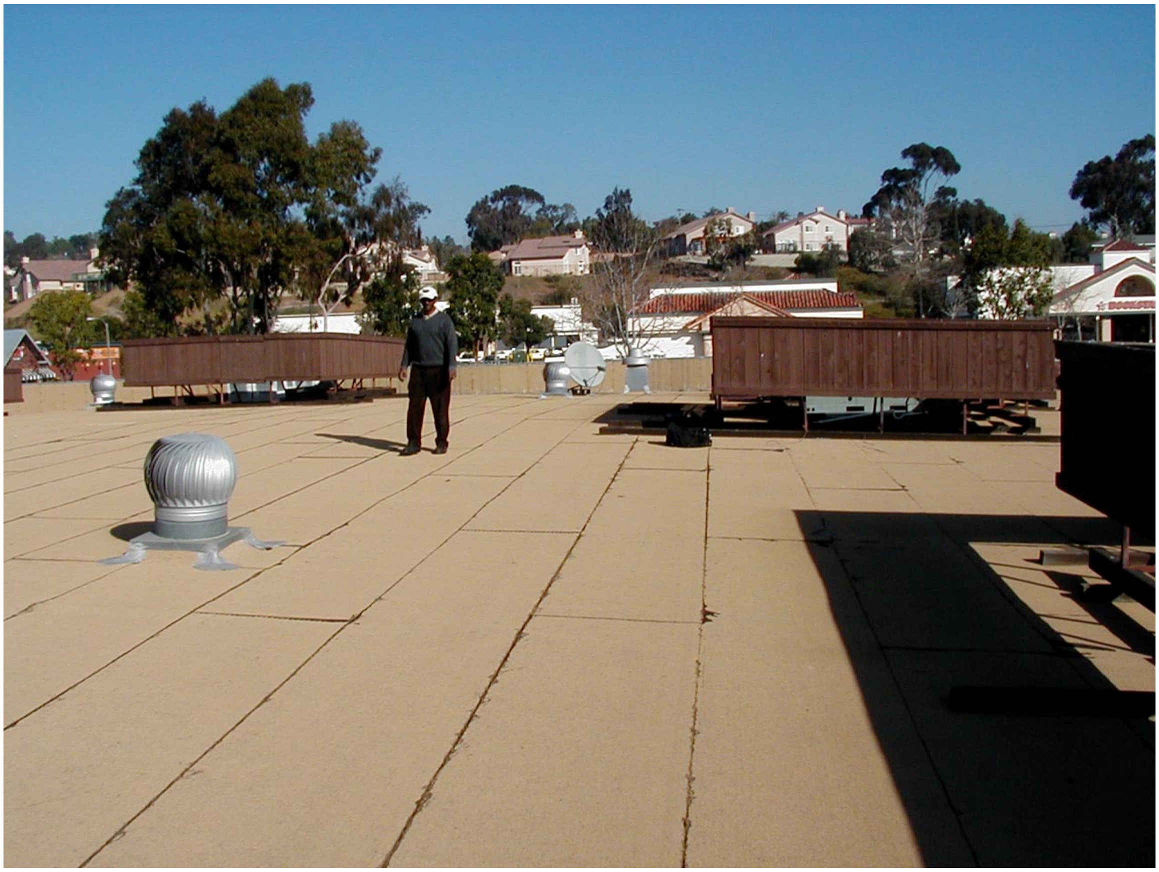

Figure 4. Uncoated Store Roof

3.0 Project Approach

3.1 General Approach

The approach used to evaluate the cool roof performance at the coated store was to compare the performance of the cool roof surface at the coated store to the standard mineral cap sheet surface at the uncoated store. This evaluation was performed through monitoring temperatures and heat flows, as well as ambient conditions for a period of several months. Next, a simulation model was developed to model the performance of the coated store. The monitored data was then used to calibrate the simulation model so that it accurately represented the performance at The coated store. The data at the uncoated store was used to estimate the performance of an uncoated roof so that the savings attributable to the cool roof coating at The coated store could be calculated.

Because the roof was coated prior to the start of this project, it was not possible to compare the performance of the two roofs while they had conventional roof surfaces. Also, because the insulation at the two buildings was installed differently the measurement approach used at the uncoated store was to focus on the roof surface temperatures, as well as the air temperatures entering the

HVAC units, rather than try to characterize the heat flow through the roof deck and the subsequent impact on the heating and cooling loads.
The general measurement categories for the two stores were as follows:

Coated Store Measurements
- Heat flow through roof deck
- Roof surface temperature
- Deck temperature
- Inlet temperature to HVAC units
- Zone temperature

Uncoated Store Measurements
- Heat flow through roof deck
- Roof surface temperature
- Inlet temperature to HVAC units

After collecting performance data, a simulation model was developed, based on the measured data, to estimate the annual performance of the roof coating. A simulation model allows annual projections of performance using a relatively short monitoring period. Furthermore, the weather data used to drive the simulation are based on long-term observations, and so are typical of the weather for a region, rather than for a specific year. This also allows a better indication of what performance could be expected over the long term, rather than relying on extrapolating the results of a specific period of time.

The steps for evaluating the performance of the cool roof product were as follows:

- Install instrumentation as listed in Table 1.
- Monitor the roof throughout the spring and into the summer.
- Develop models of the heat transfer through the roof using DOE-2. Calibrate the models using measured data.
- Run simulations to compare the annual effects of the roof coating on roof heat transfer and the subsequent effects on the HVAC system.
- Perform a cost / benefit analysis of the roof coating.

3.2 Data Collection

Instrumentation was installed on February 6, 2002, according to the measurement list shown in Table 1 for the coated store and Table 2 at The uncoated store. The data collection was performed in three time periods, as shown in Table 3. Phase 1 and 2 are consecutive, and are differentiated only by the need to remove the old loggers for download and install new loggers with fresh batteries. After a seven-week hiatus in data collection between mid-April and mid-June, loggers were reinstalled and data collection proceeded into the summer, until August 2, 2002.

Table 1. Coated Store Measurement List

Measurement Points	Units	Notes
Ambient Temperature	°F	
Solar Insolation	watts/m^2	
Wind Speed	mph	
Auxiliary Amb Temp	°F	Installed 6/15/02
Corner HVAC Amps	°F	
Corner HVAC Input Temp	°F	
Corner Roof Temp	°F	
AHU-a Current	amps	Installed 6/15/02
AHU-a Inlet Temp	°F	Installed 6/15/02
AHU-b Current	amps	Installed 6/15/02
AHU-b Inlet Temp	°F	Installed 6/15/02
AHU-c Current	amps	Installed 6/15/02
AHU-c Inlet Temp	°F	Installed 6/15/02
SM2 HVAC Amps	amps	
SM2 HVAC Input Temp	°F	
SM2 Roof Temp	°F	
SM2 Return Temp	°F	
A601 Heat Flux	BTU/hr-sf	
Deck Temp 1	°F	
Deck Temp 2	°F	
Space Temp	°F	

Table 2. Uncoated Store Measurement List

Measurement Points	Units
Roof Temp 1	°F
Roof Temp 2	°F
Roof Temp 3	°F
Roof Temp 4	°F
AHU2 Crnp Amps	amps
AH2 OA Inlet	°F
AHU4 Crnp Amps	amps
AHU4 OA Inlet	°F

Table 3. Data Collection Periods

Data Collection Period	Begin	End
1	2/6/2002	3/18/2002
2	3/18/2002	4/24/2002
3	6/12/2002	7/30/2002

At The coated store, the roof temperature sensors were first anchored to the roof with epoxy adhesive and then covered with a small amount of cool roof coating, similar to that found on the roof. The sensor was covered to ensure that the temperature sensor was “shaded” from the direct sun with the same material covering the roof so that the sensor would respond to solar radiation similarly to the actual roof to accurately sense the roof temperature. A picture of a typical sensor installation is shown in Figure 5. Tape was used to strain-relief the sensor cable to minimize stress on the sensor bonding.

Figure 5. Coated Store Roof Temperature Sensor

At the uncoated store, the roof temperature sensors were also anchored to the roof with epoxy adhesive and covered with the mineral coating that was covering the roof. Applying the mineral coating was done to ensure that the temperature sensor was “shaded” from the direct sun with the same material covering the roof so that the sensor would respond to solar radiation similarly to the actual roof to accurately sense the roof temperature. A picture of a typical sensor installation is shown in Figure 6. Tape was used to strain-relief the sensor cable to minimize stress on the sensor bonding.

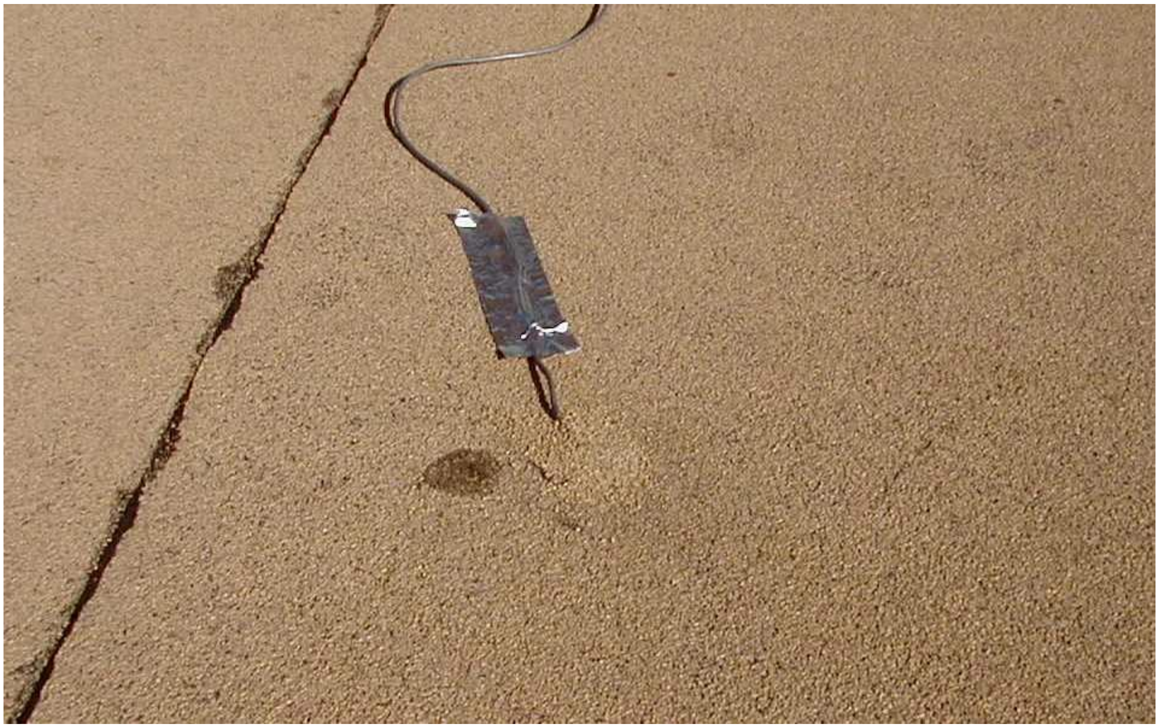

Figure 6. Uncoated Roof Temperature Sensor

The heat flux transducers and deck temperature sensors were attached to the underside of the roof deck at The coated store. These sensors were placed in a second-story non-retail conditioned storage area at the rear of the store to minimize impact to the store operations. The roof construction and insulation in this area was comparable to the rest of the store. Heat transfer compound was applied between the sensors and the roof deck to minimize resistance to heat flow between the sensors and the roof deck. High strength tape was used to attach the sensors. After the sensors were attached, the insulation was replaced, further holding the sensors in place. The completed logger installation is shown in Figure 7.

Figure 7. Deck Logger Installation

Solar radiation, ambient temperature, and wind speed were also monitored to provide a record of the ambient conditions affecting the roof. The ambient measurement station is shown in Figure 8. One of the goals is to determine if the air temperature entering the HVAC condensers and outside air inlet is higher for a standard roof, as compared to the cool roof. Therefore, one of the key measurements for this study is ambient temperature. To have a reasonable test, the ambient sensor must be in a location where it is not affected by the roof surface. To meet this requirement, the ambient temperature sensor, located in the radiation shield in Figure 8, is located several feet above the roof.

Figure 8. Ambient Measurement Station

Daily summaries of the all measurements are included in Appendix A.

4.0 Analysis and Results

The heat flow through the entire roof structure is affected by the temperatures of the roof surface, the deck temperature, the air temperature in the conditioned space, and the heat stored in the roof structure components. Figure 9 shows a one-day history of the temperatures and heat flux in the uncoated portion of the roof. Until approximately 7:30 in the morning, the heat flux is constant at about –2.5 BTU/hr-sf, meaning that heat is traveling from the conditioned space to the roof deck, and out of the building. After this time, the heat flux changes to positive and increases rapidly until it peaks shortly around noon at 2.0 BTU/hr-sf. During this morning “warm-up” period, the temperature of the roof-top surface (measured by the roof temperature sensor) is greater than the lower surface (measured by the deck temperature sensor), meaning that heat is being conducted into the building. Since both the roof and deck temperatures are increasing, this indicates that the overall roof structure is heating up, i.e., storing heat. In the afternoon, this situation is reversed: the upper roof surface is cooler than the interior roof deck, and both the roof and deck temperatures are decreasing, i.e., the roof is cooling off, and the stored heat in the roof structure is being released. During this period, heat is being rejected by the roof surface through radiation and convection to the outdoor sky, and is also being conducted from the bottom of the roof deck, through the insulation, to the conditioned space. Finally, at the end of the day, the heat flux becomes negative as heat flows out of the building.

Notice that the peak temperature for the uncoated roof is about 120°F, while the coated roof peaks about 92°F, a difference of 28°F.

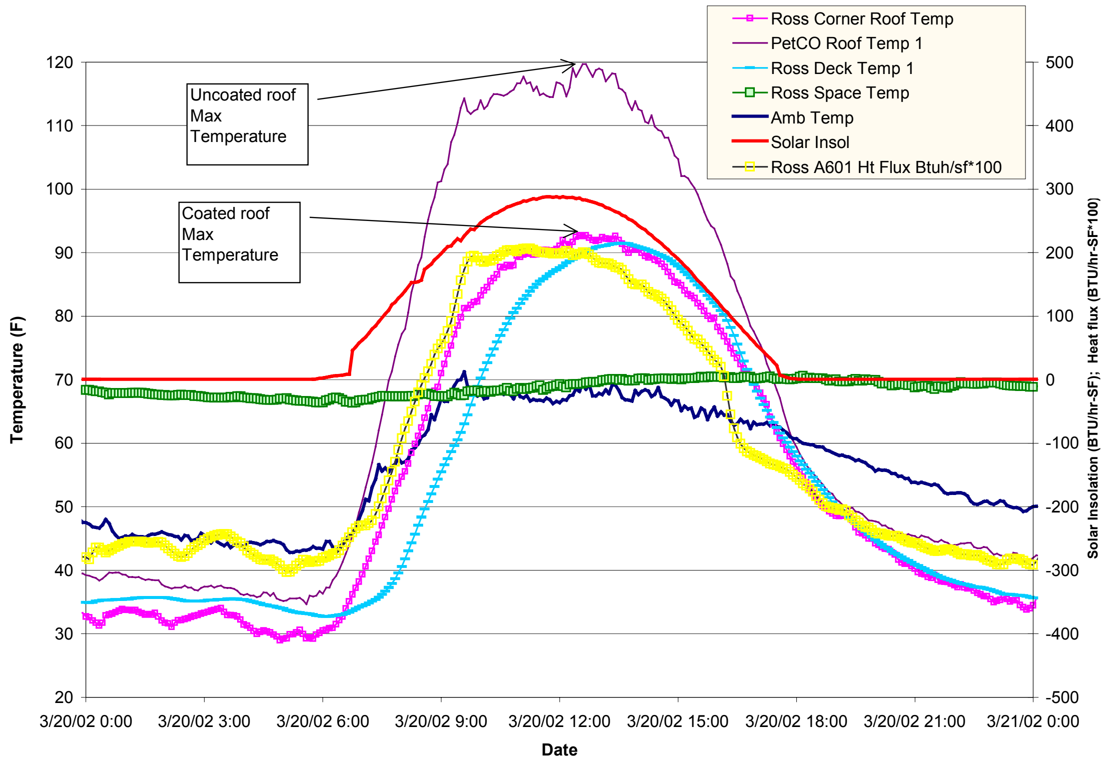

Figure 9. Roof Temperature and Heat Flux History

4.1 Simulation Model Development

Two large spaces in a shopping center were monitored to different degrees. One had a standard mineral cap sheet roof surface, and the other had a coated roof surface. Since it was desired to determine the actual savings for the stores that installed the cool roofs, the coated store was simulated. The uncoated roof data was examined to calibrate the original, uncoated, roof absorptance, and to provide AHU inlet air temperature data.

An annual building energy simulation was performed using DOE-2.1 v133 to model the operating and building characteristics of the space. The simulation was run with San Diego Climate Zone (CTZ07) weather data. This weather data is recommended by the California Energy Commission for the Oceanside area. For the modeled space, annual savings were calculated using the coated roof characteristics at The coated store, as compared to the standard mineral cap sheet surface at the uncoated store.

Hourly outputs from the simulation and hourly monitored data were compared to verify and calibrate the assumptions in the model. The key assumptions that effect roof heat gain are shown in Table 5.

Table 4. Coated Store Site Characteristics

Characteristic	Observed Site Characteristic	Simulation Input
Utilities		
Electric Rate	Utility meter measured consumption for entire building. Only part of metered area modeled.	SDG&E AL-TOU (Jan 1, 2002) with commodity rates (July 1, 2002)[2]
Gas Rate	No gas modeled in this building space	None
Simulation Weather Data	Oceanside address	CTZ07
Envelope		
Initial Roof Absorptance	Tan mineral cap sheet or "roll roofing"	80% (to be calibrated)
Roof Construction	"wood deck, R-19" surveyed. Pictures show poor insulation installation.	DOE-2 asphalt shingle, 5/8" plywood, R-14 including bypasses (to be calibrated)
Wall Height	18'	18'
Wall Construction	"concrete masonry w/o insulation"	DOE-2 8" partially filled heavy concrete block
Wall Exposure	From survey	2 of 4 exterior
Internal Loads		
Connected Lighting	1.1 W/sf	Surveyed value.
Occupied Equipment Load	Main: 0.2 W/sf. Offices: 1.5 W/sf	As observed
Schedules	Equipment to 30% during unoccupied hours indicated on survey memo. Lights to 5%.	As observed
HVAC		
Type	DX constant volume	As observed
Cooling Efficiency	EER = 9 Btu/Wh, including fan.	EER = 10 Btu/Wh for compressor and condenser (without fan)
Sizing	250 sf/ton overall	As observed
Heat Source	Heat pump.	Heat Pump. Minimal resistance heat in central zone areas.
Reheat	None	None
Outside Air	Constant @ 10%	As observed
SAT Control	Usual PSZ.	Variable temperature to meet load.
Air Flow	375 cfm/ton.	As observed
Schedule	Seven days, 12 hours/day.	Follow occupancy.
Return	In hung ceiling. Roof is insulated.	Modeled as direct.

[2] All SDG&E tariffs are available at the following website: http://www.sdge.com/tariff/elec_commercial.shtml. Specific rate included in Appendix.

Table 5. Calibrated Inputs

Characteristic	Default or Catalog Value	Calibrated Value
Insulating batt thermal resistance (R-value)	19 sf-F/Btuh (supposedly nominal 6" batts)	12 sf-F/Btuh
Overall insulation layer thermal resistance (R-value)	17 sf-F/Btuh	10 sf-F/Btuh
Original roof surface solar absorptance	80%	Calibrated to 70%
White roof surface solar absorptance (Uniflex Roofing Systems 41-300)	12%	Calibrated to 30%

In addition to roof temperatures and heat fluxes, air temperatures were measured at the outside air inlets of the HVAC units. This allowed us to test the hypothesis that roof coatings reduced the environmental temperatures at the HVAC unit condensers and air inlets. Figure 10 shows a correlation between the increase of the inlet temperature above ambient versus the solar insolation level for mid-day conditions. Mid-day conditions were used because it became apparent during the data analysis that sun shining directly on the side of the HVAC units also affects the temperature of the air entering the unit. To isolate the effect of the roof surface on air temperature, hours with low sun angles were not used in this evaluation. Using the data with high sun angles, the analysis indicated that the coated roof reduces condensing and OA inlet temperatures about 2-3°F during sunny midday conditions. Both AHU inlet temperature sensors on the dark roofs showed very similar trends, and the one AHU sensor with good inlet air flow on the white roof measured consistently lower temperatures.

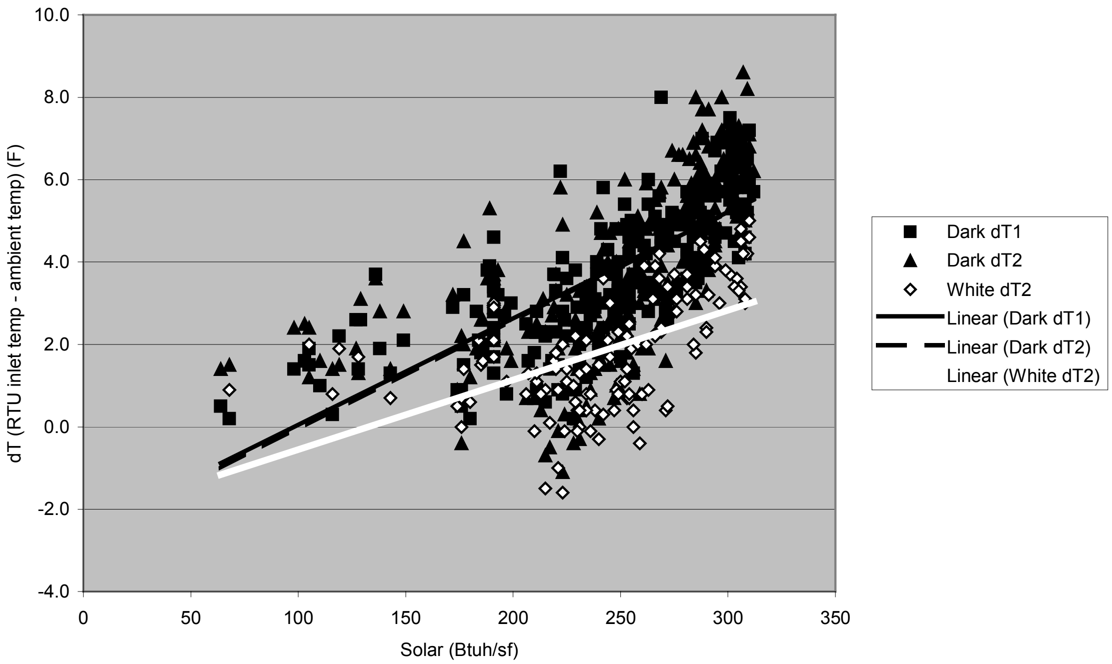

Figure 10. Correlation of Midday HVAC Inlet Temperatures to Solar Radiation for Ambient Temperatures Above 70°F, Light Winds

Calculations indicate the savings from this change in air temperatures due to coated roofs will increase the annual savings about $10 / 1,000 SF. The savings are dependent on the sensitivity of the compressor to condensing temperatures, and the amount of outside air being brought in.

The coated roof on the coated store performed very well, greatly reducing roof temperatures during sunny periods. The performance of the actual insulation layer performance was compared to the surveyed value. This insulation was surveyed as R-19; however, it did not perform at that level. Simulated and measured center-of-batt heat flux is compared in Figure 11. Simulated center-of-batt insulation is R-12.

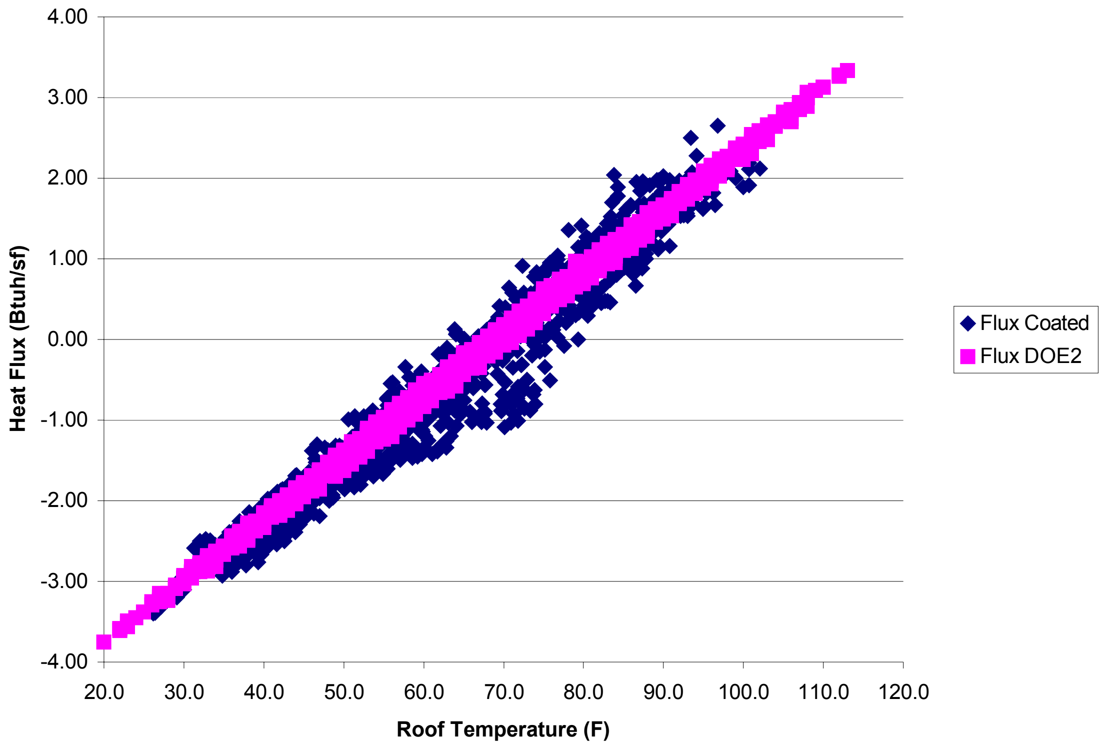

Figure 11. Heat Flux vs. Coated Roof Temperature (Measured data is filtered showing only points when space temperature is between 67° and 71°F. Simulated zone temperature is 69°F.)

The savings were calculated using a more degraded overall insulating layer R-value of 10. The degraded overall insulating value was used to account for heat transfer through the joists and air leakage around the insulation. The heat flux sensor was installed where the insulation was installed well. However, the insulation in general is potentially leaky, as shown in Figure 1 and Figure 7. Air can circulate around the ends and sides of the batts.

The roof temperature rise data are shown in Figure 12 for the uncoated roof and Figure 13 for the coated roof. The correlation between the model and the measured data are quite close for the uncoated roof. The simulation predicts somewhat lower surface temperatures for the coated roof.

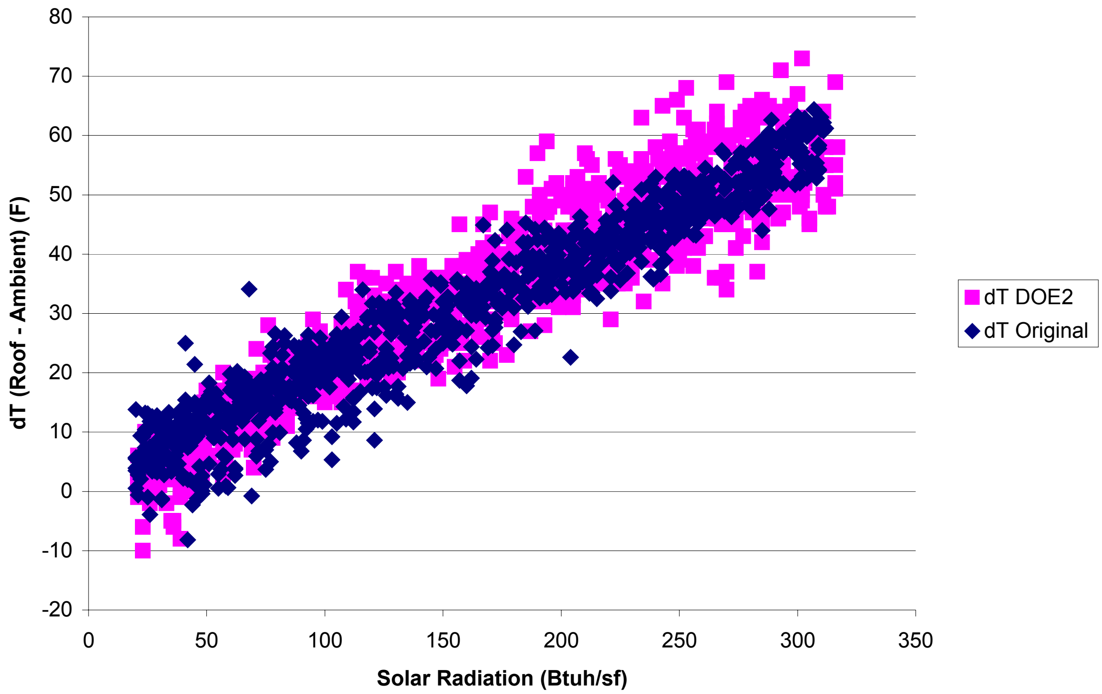

Figure 12. Uncoated Roof: Ambient Temperature – Roof Temperature vs. Solar Radiation

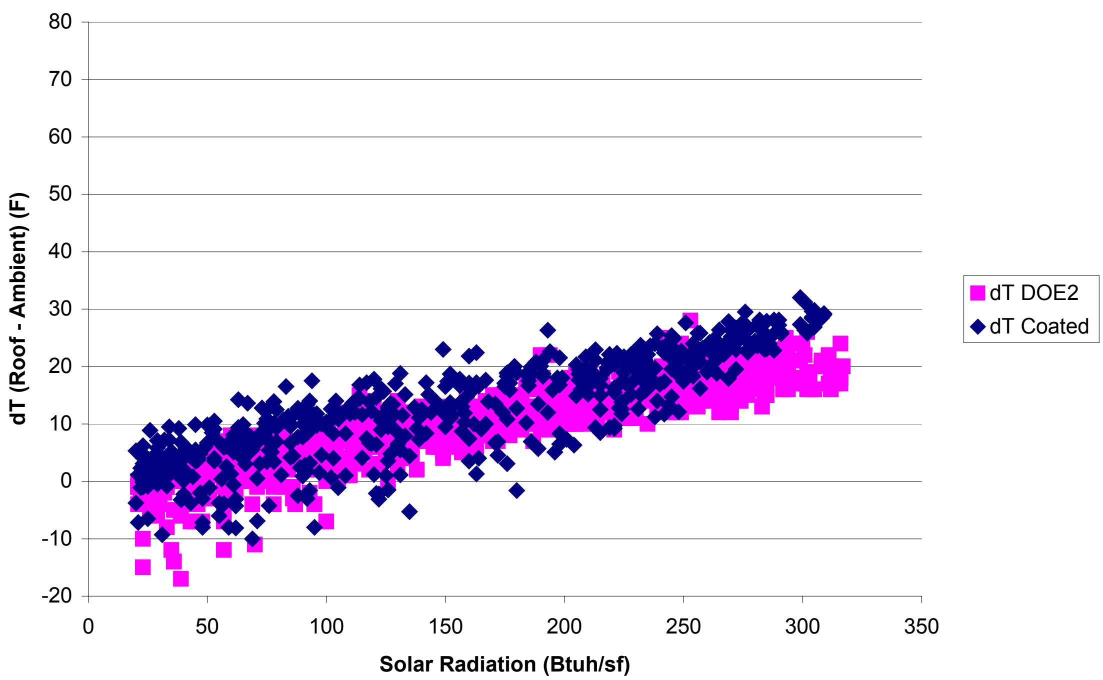

Figure 13. Coated Roof: Ambient Temperature – Roof Temperature vs. Solar Radiation

No heat flux sensor was installed under the "original" roof area over the uncoated store. That roof was of significantly different construction, and would not have been comparable. The flux measurements accumulated from the coated roof are shown in Figure 14.

The simulated roof temperatures appear slightly low, although the flux shown in Figure 14 shows excellent agreement between measurements and simulated data. Adjusting the roof absorptance would improve the agreement between the measured and simulated roof temperature, but it would also worsen the heat flux comparison. Since heat flux, rather than roof temperature, is the preferred comparison variable, the absorptance was not increased in the coated roof model to better calibrate the roof temperatures.

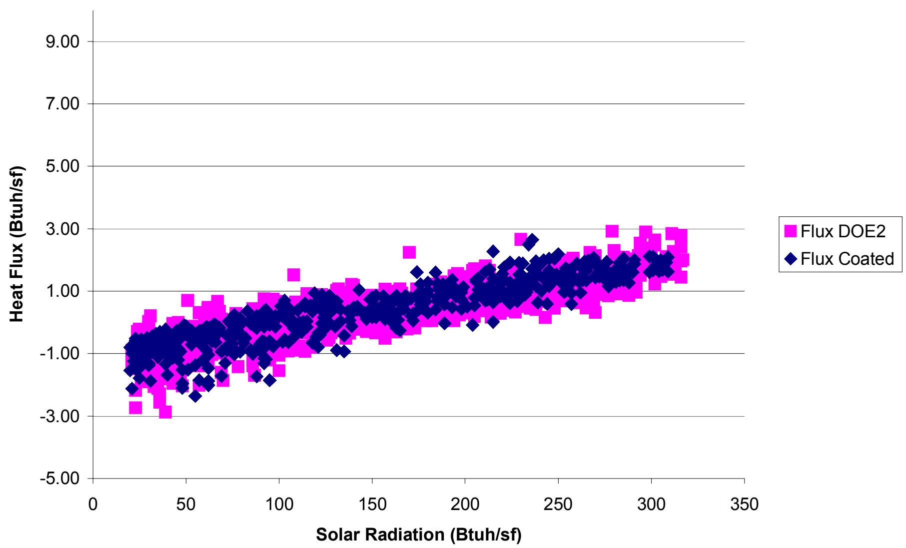

Figure 14. Coated Roof: Heat Flux vs. Solar Radiation for Periods where Interior Temperatures were between 67° and 71°F

4.2 Simulation Model Results

Using the initial assumptions listed in Table 4 and the calibrated inputs shown in Table 5, the simulation produced the results listed in Table 6 for the roof heat flux and Table 7, showing the impact of the cool roof coating on the HVAC system. Results are normalized in these tables per 1,000 sf, to facilitate comparison with other sites. Roof heating and cooling fluxes are output from DOE-2 assuming a constant space temperature. During the calibration phase, 69°F was used, as that was the average measured space temperature in the office / storage space near the heat flux sensor. This was not a typical temperature for the overall conditioned retail space. For the energy savings calculations, a more typical zone temperature cooling setpoint of 72°F was used, set up to 78°F during unoccupied periods.

Table 6. Monthly Roof Loads

	Roof Heat Flux (Million BTU/1,000 sf)		
	Uncoated	**Coated**	**Change**
Jan	-0.54	-0.92	-0.38
Feb	-0.32	-0.76	-0.44
Mar	-0.07	-0.67	-0.60
Apr	0.23	-0.42	-0.65
May	0.37	-0.27	-0.64
Jun	0.63	-0.01	-0.64
Jul	1.05	0.26	-0.79
Aug	0.96	0.25	-0.71
Sep	0.69	0.11	-0.58
Oct	0.22	-0.27	-0.49
Nov	-0.23	-0.63	-0.40
Dec	-0.59	-0.96	-0.37
Annual	2.41	-4.28	-6.68

The change in heat flux through the roof leads to the changes in electrical energy consumption shown in Table 7. The percentage decrease in energy use due to the roof coating is only 2-3%. The savings shown do not include the reduction in condensing and OA temperatures that probably saves an additional $10 / 1000 sf per year.

Annual simulated savings from the cool roof coating were estimated at 0.618 kWh/sf, or on a dollar basis, $0.071/sf. Final simulated savings from the white roof coating were $1600 per year for the coated store. Detailed simulated savings are presented in Table 7.

Table 7. Monthly HVAC Energy Impacts

	Energy Use (kWh/ 1,000 sf)				**Energy Cost $/1,000 sf**			
	Original	**Coated**	**Change kWh/1,000 sf**	**Change (percent)**	**Original**	**Coated**	**Change $/1,000 sf**	**Change (percent)**
Jan	1,717	1,689	-28	-1.6%	$184	$181	($3)	-1.6%
Feb	1,544	1,507	-37	-2.4%	$169	$165	($4)	-2.4%
Mar	1,723	1,672	-51	-3.0%	$183	$178	($5)	-2.7%
Apr	1,736	1,678	-58	-3.3%	$189	$182	($7)	-3.7%
May	1,817	1,763	-54	-3.0%	$193	$187	($6)	-3.1%
Jun	1,858	1,804	-54	-2.9%	$207	$200	($7)	-3.4%
Jul	2,139	2,052	-87	-4.1%	$237	$227	($11)	-4.6%
Aug	2,108	2,026	-82	-3.9%	$227	$219	($9)	-4.0%
Sep	1,978	1,911	-67	-3.4%	$215	$207	($8)	-3.7%
Oct	1,901	1,863	-38	-2.0%	$205	$201	($4)	-2.0%
Nov	1,695	1,661	-33	-1.9%	$183	$179	($4)	-2.2%
Dec	1,712	1,684	-28	-1.6%	$182	$179	($3)	-1.6%
Ann	21,929	21,311	-618	-2.8%	$2,375	$2,304	($71)	-3.0%

4.3 Cost / Benefit Analysis

To determine the value of applying a cool roof coating, the costs of applying the coating should be compared to the benefits. For this analysis, the dollar benefits will be limited to the energy savings, although there may be other considerations that would affect a decision to apply a roof coating.

Costs for applying the roof coating were provided by the contractor, who applied the roof coating for $1.45/sf. This cost includes sweeping, power washing, and other surface preparation prior to applying the roof coating. The manufacturer's cost for the material is about $0.45/sf, but does not include any labor or other materials that might be required for finishing the roof coating. Using these costs, and the cost savings attributable to reduced energy consumption, the simple payback is shown in Table 8. Using the actual cost of installation, the payback is 20 years. If the labor to prepare the roof and apply the roof coating was free, and no maintenance is performed when applying the roof, the simple payback would be about 6 years. It is unlikely that the installation labor would ever be free, but is an indication of the minimum payback possible with this material at this location. Simple payback analysis results in the shortest payback possible; it assumes no time-value of money. If a present value analysis was used, the payback periods would lengthen.

Table 8. Payback Analysis

Description	Cost ($/sf)	Energy Savings ($/sf)	Simple Payback (yrs)
Cost includes • Roof Preparation • Coating and Coating Labor	$1.45	$0.071	20.3
Cost includes • Coating Material Only (no labor or roof prep)	$0.45	$0.071	6.3

There are other non-energy considerations that may make a cool roof coating a good investment. One consideration is extended roof life. Although studying the effects of roof coating on roof longevity was not part of this analysis, the cool roof coating resulted in a significantly decreased roof diurnal temperature swing, as shown in Figure 15. The uncoated roof daily temperature swing was as great as 90°F, while the corresponding daily temperature swing on the coated roof was about 65°F. Reducing this temperature swing reduces the thermal expansion and contraction of the roof, which could conceivably increase the longevity of the roof. Considering the increased roof longevity would improve the cost-effectiveness of the roof coating.

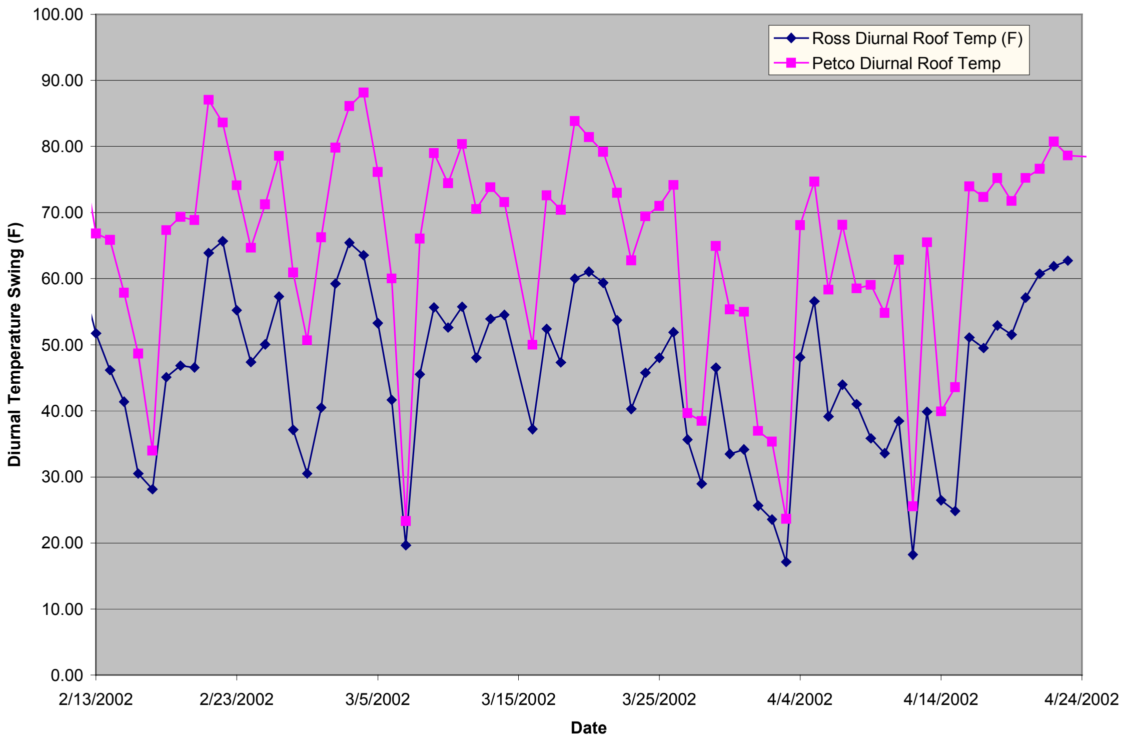

Figure 15. Diurnal Temperature Swing

5.0 Conclusions

The cool roof reduced the cooling requirements and reduced the energy consumption at the coated store.

The payback period of the cool roof coating is probably longer than the lifetime of the roof, when using the actual installation costs.

Energy should not be the only consideration for applying a cool roof coating. Effects on roof lifetime should be investigated, and should be included in any roof coating cost / benefit analysis.

Appendix A: Daily Data Summary

Coated Store, Period 1

Date	Solar Insolation	Average Amb Temp	Max Amb Temp	Min Amb Temp	Average Corner Roof Temp	Max Corner Roof Temp	Min Corner Roof Temp	Average SM2 Roof Temp	Max SM2 Roof Temp	Min SM2 Roof Temp	Daily A601 Ht Flux	Average Deck Temp 1	Max Deck Temp 1
	BTU/SF	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	BTU/SF	(F)	(F)
2/7/2002	763.00	55.41	60.57	49.40	56.01	78.52	39.88	55.21	76.15	39.33	-10.64	58.22	79.20
2/8/2002	917.98	53.52	63.71	46.15	53.16	80.72	38.59	52.50	80.22	38.03	-24.27	53.44	79.51
2/9/2002	1,564.68	61.80	80.16	42.97	57.55	96.82	33.01	56.89	94.80	31.59	-16.68	55.51	93.13
2/10/2002	1,629.08	61.41	79.38	44.89	53.24	91.25	27.75	52.26	89.13	27.33	-27.66	51.48	89.25
2/11/2002	1,576.62	59.87	75.82	44.94	54.52	93.04	28.89	53.41	88.09	28.28	-25.25	52.20	89.64
2/12/2002	1,514.67	56.55	71.45	42.73	52.61	91.00	30.03	51.06	87.57	28.48	-29.24	50.89	87.38
2/13/2002	1,112.24	54.37	69.84	42.54	51.75	83.15	30.95	50.43	80.53	29.29	-29.89	50.65	79.40
2/14/2002	1,300.00	55.37	65.31	47.11	55.80	84.94	37.62	54.83	81.77	36.80	-23.15	55.40	81.78
2/15/2002	1,158.09	55.93	64.83	47.82	55.68	82.51	40.22	54.67	80.20	39.76	-22.71	55.45	81.52
2/16/2002	1,040.82	57.12	63.01	53.86	59.97	82.02	51.09	59.21	80.47	50.41	-14.83	59.62	80.14
2/17/2002	521.87	54.35	60.13	48.91	52.28	68.84	39.54	51.47	66.12	39.19	-27.74	52.28	64.17
2/18/2002	1,555.18	52.57	61.22	44.25	50.91	80.47	33.48	50.10	77.50	34.30	-28.71	49.80	77.82
2/19/2002	1,575.88	52.66	62.27	42.28	52.12	82.27	34.01	50.83	78.97	33.55	-26.13	50.31	79.11
2/20/2002	1,577.41	54.95	64.44	44.80	54.88	84.76	36.97	53.38	81.31	35.96	-23.81	53.25	82.17
2/21/2002	1,453.53	66.22	85.54	46.30	62.17	100.72	35.95	60.97	97.87	34.85	-17.00	59.22	95.44
2/22/2002	1,557.14	70.46	88.24	56.07	64.65	105.39	37.81	63.32	101.65	37.90	-17.37	61.29	99.56
2/23/2002	1,408.29	59.07	72.64	50.14	59.28	92.98	36.91	58.35	91.08	36.71	-20.90	57.55	87.25
2/24/2002	1,608.06	59.59	66.04	52.06	61.54	87.75	39.10	60.49	83.92	37.83	-21.17	60.34	85.22
2/25/2002	1,579.09	56.92	67.41	46.82	58.36	88.57	37.64	57.29	85.95	36.77	-21.43	57.05	84.75
2/26/2002	1,704.51	59.74	71.70	46.32	59.12	92.88	34.32	58.42	89.88	33.81	-21.29	57.85	87.96
2/27/2002	1,278.15	58.19	65.67	48.78	60.77	80.53	41.78	60.20	78.20	42.72	-17.94	59.11	75.97
2/28/2002	1,104.07	57.35	62.16	53.40	62.26	83.96	53.10	61.67	82.85	52.69	-13.22	62.32	82.33
3/1/2002	1,226.64	58.72	66.76	54.64	59.72	87.85	44.65	58.66	83.20	45.43	-20.76	59.14	81.24
3/2/2002	1,800.86	58.31	70.15	47.78	56.32	91.52	30.05	55.02	86.77	29.80	-27.33	54.47	86.62
3/3/2002	1,927.68	55.51	71.55	40.03	50.86	91.03	23.94	49.54	85.89	22.12	-34.95	48.64	85.86
3/4/2002	1,964.85	57.12	73.12	42.97	53.57	95.42	28.52	52.46	87.31	27.09	-29.86	50.63	89.19
3/5/2002	1,770.39	54.64	65.94	42.68	54.17	88.63	32.04	53.04	82.66	32.71	-28.81	52.67	85.56
3/6/2002	1,224.51	55.88	63.08	45.63	57.39	83.89	39.15	56.32	79.06	40.51	-21.03	56.44	79.01
3/7/2002	299.52	58.14	61.56	56.18	57.21	67.63	47.58	56.82	66.84	47.59	-23.04	57.93	66.94
3/8/2002		55.82	60.99	47.85	56.94	82.97	35.75	55.65	79.41	35.59	-23.58	56.37	81.45
3/9/2002		56.24	69.07	42.21	55.21	91.51	32.11	53.52	84.64	32.73	-26.16	54.11	88.54
3/10/2002		57.09	67.80	46.17	56.32	89.81	34.79	54.98	83.79	33.61	-25.10	55.41	88.16
3/11/2002		57.70	68.89	45.81	58.50	94.54	35.22	57.10	87.64	35.50	-22.34	57.31	91.69
3/12/2002		57.79	66.03	50.58	62.98	91.32	40.73	61.66	85.98	40.51	-12.43	61.66	89.08
3/13/2002		60.05	66.15	53.02	62.19	91.20	35.05	60.99	86.38	34.74	-19.68	61.11	86.77
3/14/2002		53.01	61.21	39.69	51.10	83.42	26.20	49.23	76.45	24.63	-32.50	50.07	81.46

Coated Store, Period 2

Date	Solar Insolation	Average Amb Temp	Max Amb Temp	Min Amb Temp	Average Corner Roof Temp	Max Corner Roof Temp	Min Corner Roof Temp	Average SM2 Roof Temp	Max SM2 Roof Temp	Min SM2 Roof Temp	Daily A601 Ht Flux	Average Deck Temp 1	Max Deck Temp 1
	BTU/SF	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	BTU/SF	(F)	(F)
3/16/2002	1,560.31	54.76	59.61	49.52	55.79	77.55	39.89	54.49	75.31	38.53	-22.74	55.42	77.69
3/17/2002	1,753.80	53.23	60.33	45.84	56.70	86.96	34.08	55.72	85.36	33.45	-20.86	56.46	86.05
3/18/2002	2,036.36	53.14	61.48	44.52	54.64	83.14	34.88	53.03	79.72	33.34	-27.21	54.16	81.76
3/19/2002	2,081.42	54.03	65.30	40.21	53.13	89.39	28.18	51.38	86.48	27.70	-29.25	52.16	87.34
3/20/2002	2,095.48	56.38	68.43	43.26	55.44	91.99	29.74	53.34	88.78	28.95	-26.54	54.24	91.26
3/21/2002	1,774.14	57.95	71.72	45.19	57.73	93.45	33.46	56.06	90.75	31.99	-22.07	57.00	89.67
3/22/2002	1,988.42	56.27	64.05	47.75	57.07	89.84	35.07	55.88	88.07	35.45	-25.14	56.69	89.87
3/23/2002	1,769.35	57.89	64.21	53.18	62.69	87.69	46.44	61.19	84.96	45.65	-14.53	62.39	87.18
3/24/2002	1,787.73	56.58	62.22	50.42	58.88	87.03	39.89	57.71	84.37	39.96	-21.34	58.92	85.72
3/25/2002	2,011.68	55.62	64.05	46.23	58.37	88.39	39.19	56.84	85.59	38.74	-23.34	57.22	86.86
3/26/2002	2,091.05	56.00	64.30	45.94	56.87	89.19	36.25	55.24	86.22	35.37	-26.66	56.27	88.64
3/27/2002	708.34	55.06	59.82	47.17	55.01	71.62	36.01	54.07	70.57	34.86	-24.79	54.84	71.49
3/28/2002	717.78	57.47	60.30	52.89	59.36	73.24	44.71	58.57	72.87	43.42	-20.12	59.47	73.43
3/29/2002	1,411.49	56.40	64.49	48.82	58.67	88.08	41.49	57.41	87.00	40.53	-22.86	57.85	86.90
3/30/2002	1,301.75	57.82	64.25	54.50	63.80	89.08	54.78	62.79	86.77	54.10	-13.31	63.70	86.92
3/31/2002	1,226.67	56.90	62.13	54.14	63.75	89.69	54.78	62.78	87.72	54.34	-13.55	64.10	87.01
4/1/2002	850.56	56.30	60.50	53.62	61.08	79.35	53.68	60.24	78.81	53.20	-17.38	61.57	78.55
4/2/2002	736.74	56.61	60.19	54.61	60.62	77.40	53.83	59.75	76.65	53.08	-17.98	60.91	77.28
4/3/2002	633.07	56.79	59.17	54.34	60.00	71.01	53.65	58.98	69.51	52.65	-18.40	60.19	70.66
4/4/2002	2,109.32	58.56	64.30	53.42	64.27	91.95	43.56	62.83	88.66	40.88	-14.51	63.83	91.20
4/5/2002	1,393.95	57.06	65.76	47.87	58.69	93.64	36.55	57.45	91.56	35.50	-21.21	58.36	89.60
4/6/2002	1,700.18	59.05	64.29	54.92	64.01	89.68	50.53	63.03	88.73	49.57	-13.08	63.81	89.48
4/7/2002	2,015.80	59.80	64.86	54.00	67.71	92.99	48.74	67.14	91.71	48.04	-7.54	67.30	92.86
4/8/2002	1,519.22	60.80	66.15	58.02	65.85	92.31	50.92	64.91	89.98	49.38	-12.08	65.37	91.21
4/9/2002	1,792.38	60.55	65.76	57.10	68.00	93.87	56.95	66.83	90.52	55.80	-8.68	67.68	92.18
4/10/2002	1,585.52	58.85	63.84	55.65	67.19	90.23	56.52	66.46	89.23	55.78	-9.45	67.15	89.30
4/11/2002	1,755.48	59.93	65.24	56.83	68.92	96.10	57.30	68.11	94.66	56.57	-7.33	68.71	95.05
4/12/2002	761.71	59.15	62.10	56.82	63.94	75.42	57.40	63.24	74.89	56.49	-15.15	64.03	75.11
4/13/2002	1,667.88	60.09	65.67	57.00	69.21	97.68	57.45	68.25	96.07	56.59	-6.69	69.18	96.20
4/14/2002	814.34	59.02	64.12	56.36	64.55	83.82	57.06	63.87	82.65	56.48	-14.03	64.89	83.97
4/15/2002	898.16	58.02	61.96	56.25	61.14	80.85	55.07	60.48	78.59	54.70	-17.91	61.74	79.39
4/16/2002	1,872.66	57.55	63.76	48.04	60.63	89.59	38.64	60.22	88.35	37.14	-19.73	60.17	89.62
4/17/2002	2,159.18	58.79	64.02	53.32	64.42	93.63	43.86	63.38	91.49	42.28	-15.70	64.09	92.17
4/18/2002	2,284.07	55.93	63.44	46.03	58.82	90.85	37.72	57.98	89.77	37.08	-23.36	58.25	90.78
4/19/2002	2,290.57	57.53	64.99	49.06	59.68	90.86	38.14	59.11	89.68	39.39	-21.41	58.70	90.63
4/20/2002	2,259.60	57.90	65.53	50.86	61.15	95.10	37.71	60.75	93.25	36.39	-21.27	60.32	93.23
4/21/2002	2,396.07	58.32	67.65	47.41	61.05	96.19	34.78	59.83	93.95	33.91	-21.21	60.35	94.73
4/22/2002	2,421.08	60.02	69.41	48.21	62.38	99.00	36.29	61.48	96.39	35.35	-19.40	61.56	96.72
4/23/2002	2,356.91	61.59	70.12	54.12	66.44	102.08	38.89	65.47	99.84	37.56	-12.78	65.50	99.22

Coated Store, Period 3

Date	Solar Insolation	Average Amb Temp	Max Amb Temp	Min Amb Temp	Average Corner Roof Temp	Max Corner Roof Temp	Min Corner Roof Temp	Average SM2 Roof Temp	Max SM2 Roof Temp	Min SM2 Roof Temp	Daily A601 Ht Flux	Average Deck Temp 1	Max Deck Temp 1
	BTU/SF	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	BTU/SF	(F)	(F)
6/12/2002	1,577.04	66.55	70.08	62.16	79.70	106.51	52.34	78.96	105.05	52.02			
6/13/2002	2,260.85	65.18	69.67	60.49	74.39	104.73	56.06	73.49	101.40	55.68			
6/14/2002	2,471.28	65.69	70.29	61.02	75.72	107.79	46.09	75.77	105.66	61.57			
6/15/2002	2,658.27	64.74	71.71	55.30	70.26	108.54	43.35						
6/16/2002	2,466.40	65.75	71.29	58.02	75.09	109.42	47.94						
6/17/2002	2,457.39	66.19	71.09	60.87	76.18	109.93	50.35						
6/18/2002	2,423.32	66.62	70.89	62.23	77.73	111.28	50.14						
6/19/2002	1,885.84	65.73	70.11	62.43	76.31	101.35	62.47						
6/20/2002	850.79	63.70	67.49	61.91	69.16	87.25	61.56						
6/21/2002	1,625.41	65.17	70.21	61.79	73.57	105.94	61.11						
6/22/2002	2,476.38	67.08	72.03	63.27	78.87	108.36	59.03						
6/23/2002	2,169.90	66.18	71.90	62.50	77.42	110.21	59.13						
6/24/2002	2,260.53	64.59	69.15	61.09	75.86	108.01	52.30						
6/25/2002	2,219.20	65.87	72.76	60.36	77.47	111.87	58.33						
6/26/2002	2,101.36	65.41	70.57	62.58	76.76	109.06	58.40						
6/27/2002	2,333.85	64.84	69.50	61.30	76.27	109.36	52.14						
6/28/2002	2,314.26	65.49	70.87	61.05	77.15	109.63	58.16						
6/29/2002	2,002.52	65.57	71.10	61.77	76.10	109.92	54.66						
6/30/2002	1,703.38	64.97	69.59	61.12	72.78	103.57	49.59						
7/1/2002	2,289.19	66.25	72.76	61.63	78.14	113.80	53.13						
7/2/2002	2,208.56	67.45	74.11	62.07	80.04	113.52	61.92						
7/3/2002	1,752.09	66.90	72.08	64.38	77.92	110.84	63.84						
7/4/2002	1,729.36	64.79	68.94	61.72	75.06	107.06	60.65						
7/5/2002	1,762.37	65.29	70.15	62.50	75.63	105.20	61.76						
7/6/2002	1,234.49	65.44	68.86	63.24	73.74	97.61	62.58						
7/7/2002		66.77	72.25	63.48	76.67	107.64	63.34						
7/8/2002		66.85	72.52	63.01	79.88	113.54	64.17						
7/9/2002		66.90	72.86	62.91	77.49	104.56	56.29				0.34	82.79	100.29
7/10/2002		67.66	72.47	62.79	74.56	99.14	56.11				-5.98	73.90	95.55
7/11/2002		68.18	74.07	64.52	78.63	114.07	62.31				-0.12	77.77	107.74
7/12/2002		69.23	74.63	65.71	79.16	112.27	60.97				-1.76	78.31	106.60
7/13/2002		69.97	74.05	66.48	81.31	110.98	60.94				1.81	80.81	109.07
7/14/2002		69.32	73.95	65.75	79.55	111.32	58.91				0.40	79.53	108.88
7/15/2002		69.55	74.91	63.48	79.34	109.95	56.38				0.05	78.61	105.70
7/16/2002		69.56	74.68	66.08	79.65	112.27	57.80				1.11	79.38	109.42
7/17/2002		68.92	73.85	66.01	78.42	112.39	57.82				-0.18	77.96	108.88
7/18/2002		68.86	72.32	66.74	78.64	107.22	63.54				0.72	78.67	106.57
7/19/2002		67.73	71.20	63.56	75.37	98.74	63.43				-3.92	75.53	96.81
7/20/2002		65.77	71.24	63.21	72.34	104.40	55.54				-7.04	72.93	101.94
7/21/2002		66.12	71.19	62.77	73.71	105.26	58.21				-5.57	73.56	102.60
7/22/2002		69.00	73.30	64.79	79.39	109.70	61.50				1.22	78.64	106.57
7/23/2002		70.32	76.64	62.40	79.35	114.00	53.49				-1.51	78.40	109.99
7/24/2002		72.69	79.20	65.97	82.04	117.28	58.30				-1.13	80.84	112.71
7/25/2002		71.90	77.58	66.44	80.69	114.12	57.88				-2.16	80.24	111.67
7/26/2002		68.93	73.51	65.44	79.31	114.13	56.89				-2.07	78.09	108.44
7/27/2002		67.33	71.56	65.05	79.38	112.26	64.17				-0.22	78.51	106.85
7/28/2002		68.20	73.25	63.49	79.26	115.39	50.80				-2.67	78.02	108.78
7/29/2002		67.07	73.56	59.62	76.69	113.47	49.84				-5.36	74.90	107.92
7/30/2002		66.40	72.73	64.41	72.92	109.38	61.11				-6.86	67.03	85.63

Uncoated Store, Period 1

Date	Average Roof Temp 1	Max Roof Temp 1	Min Roof Temp 1	Average Roof Temp 2	Max Roof Temp 2	Min Roof Temp 2	Average Roof Temp 3	Max Roof Temp 3	Min Roof Temp 3	Average Roof Temp 4	Max Roof Temp 4	Min Roof Temp 4
	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
2/7/2002	66.224	104.456	44.498	66.895	105.248	44.912	65.978	102.506	44.114	67.687	105.656	44.906
2/8/2002	59.89625	102.428	43.622	60.10175	102.8	44.078	59.7715	100.61	43.442	59.884	100.46	44.546
2/9/2002	67.08375	124.49	36.86	67.958	126.584	37.43	65.664	122.102	36.134	66.52125	119.642	36.722
2/10/2002	63.955	113.852	34.004	65.27475	116.798	34.772	62.35275	110.414	33.32	63.0015	106.76	34.67
2/11/2002	63.99675	115.85	34.59	65.48	119.84	35.41	63.61	116.01	33.50	64.37	113.65	35.14
2/12/2002	63.866	116.00	35.32	64.58	116.95	35.73	62.54	113.63	34.50	63.27	112.79	35.53
2/13/2002	60.4105	104.42	36.03	60.73	103.72	36.57	59.91	102.42	35.48	60.16	101.09	36.21
2/14/2002	64.2325	110.16	42.36	64.56	110.88	42.85	63.61	107.17	42.35	63.73	105.70	42.99
2/15/2002	63.11275	102.76	44.19	63.48	103.00	44.47	62.82	102.10	43.78	62.74	100.29	44.25
2/16/2002	65.87375	104.16	54.36	66.07	103.83	54.44	65.89	102.49	54.18	65.43	101.53	54.54
2/17/2002	56.4125	79.96	44.59	56.27	78.81	44.89	55.91	77.59	44.09	56.22	77.82	44.68
2/18/2002	61.49125	107.03	37.80	61.81	107.21	38.64	60.40	104.59	37.62	61.01	103.39	38.92
2/19/2002	62.086	107.98	37.68	62.79	108.44	38.09	61.53	107.07	37.29	61.78	105.24	38.31
2/20/2002	64.6655	109.33	40.02	65.45	110.34	40.41	64.46	109.87	39.63	64.36	106.63	40.69
2/21/2002	72.6305	128.09	39.93	73.72	129.30	40.63	71.82	126.28	39.22	72.51	124.36	40.08
2/22/2002	75.44275	130.39	45.69	76.82	132.15	46.67	74.90	129.77	45.46	75.46	126.91	46.98
2/23/2002	68.61875	118.77	43.66	68.78	119.16	44.13	68.10	117.37	42.72	68.09	115.64	43.95
2/24/2002	70.73225	111.02	45.40	71.43	111.55	46.13	70.37	110.89	44.75	70.14	107.35	45.90
2/25/2002	68.28525	113.31	41.08	68.51	113.56	41.68	67.64	112.50	40.54	67.57	110.23	41.33
2/26/2002	69.89925	119.33	39.49	70.35	119.82	40.11	68.66	118.51	39.00	69.35	115.39	40.19
2/27/2002	68.66025	106.83	44.28	68.63	106.83	44.67	68.24	105.42	43.86	68.09	102.55	45.09
2/28/2002	67.979	106.19	54.37	67.70	105.60	54.51	67.89	104.55	54.25	67.53	103.65	54.23
3/1/2002	66.23375	116.95	48.90	66.43	117.67	49.26	66.13	115.78	48.78	65.87	111.47	49.95
3/2/2002	67.0755	119.06	37.39	67.95	118.80	38.44	66.30	116.38	36.36	66.76	115.09	37.86
3/3/2002	62.791	116.93	30.43	63.92	118.81	31.00	61.74	114.96	28.19	62.20	113.25	29.89
3/4/2002	64.093	118.20	31.18	65.52	121.52	31.92	63.88	120.95	29.73	64.18	116.40	31.66
3/5/2002	65.17025	114.67	36.15	65.60	113.79	36.64	64.20	111.62	35.89	64.52	110.02	37.03
3/6/2002	64.88325	103.85	42.21	64.76	102.90	42.39	64.41	102.31	41.62	64.26	99.91	42.70
3/7/2002	59.9625	74.55	50.29	59.51	72.91	50.18	59.59	73.53	49.77	59.69	73.15	50.62
3/8/2002	66.424	108.33	41.31	66.50	108.35	41.83	65.75	106.91	40.60	66.02	106.17	41.84
3/9/2002	66.60525	116.15	36.54	67.24	117.43	37.01	65.95	116.28	35.92	65.99	112.61	37.03
3/10/2002	67.61825	115.69	40.07	68.25	115.78	40.42	67.14	114.62	39.34	67.28	111.80	40.37
3/11/2002	69.95625	121.09	39.75	70.51	121.32	40.15	69.03	120.49	38.83	69.27	117.31	40.04
3/12/2002	72.04825	118.10	45.73	71.99	117.78	46.26	71.47	116.26	45.11	71.27	113.37	46.21
3/13/2002	68.451	116.00	40.42	68.62	115.47	41.16	68.58	114.18	39.78	68.35	112.26	41.29
3/14/2002	59.91375	100.53	31.32	61.64	104.70	31.89	60.87	105.57	30.43	60.62	100.94	31.77

Uncoated Store, Period 2

Date	Average Roof Temp 1 (F)	Max Roof Temp 1 (F)	Min Roof Temp 1 (F)	Average Roof Temp 2 (F)	Max Roof Temp 2 (F)	Min Roof Temp 2 (F)	Average Roof Temp 3 (F)	Max Roof Temp 3 (F)	Min Roof Temp 3 (F)	Average Roof Temp 4 (F)	Max Roof Temp 4 (F)	Min Roof Temp 4 (F)
3/16/2002	61.8045	91.33	43.08	62.38	94.32	43.66	62.12	95.14	42.21	61.66	91.41	43.25
3/17/2002	65.01375	113.07	39.37	65.16	113.49	39.93	64.50	111.85	38.69	64.02	109.39	39.51
3/18/2002	64.825	110.86	39.13	65.48	111.02	39.75	64.64	109.87	38.29	64.28	106.68	39.64
3/19/2002	66.0925	118.34	33.02	66.91	118.45	33.57	65.44	116.63	32.02	65.45	113.53	33.05
3/20/2002	68.13625	117.79	35.59	69.02	118.06	36.08	67.71	118.07	34.78	67.60	114.29	36.13
3/21/2002	68.216	119.88	39.32	68.54	119.77	39.70	67.95	119.02	38.68	67.59	115.51	39.74
3/22/2002	67.89425	115.28	41.13	68.68	115.42	41.71	67.83	114.78	40.41	67.58	111.43	41.73
3/23/2002	70.90675	113.38	49.21	70.83	113.18	49.71	70.48	112.48	48.57	69.90	108.93	49.47
3/24/2002	67.3705	113.58	43.71	67.68	114.47	44.08	67.31	114.24	43.02	66.99	110.71	44.64
3/25/2002	69.056	115.48	42.94	69.75	115.58	43.32	68.78	114.42	42.70	68.40	111.07	43.67
3/26/2002	68.5615	115.90	40.76	69.46	116.41	41.19	68.34	115.67	39.91	67.98	111.21	40.73
3/27/2002	60.34125	81.33	40.99	60.15	80.37	41.52	60.35	82.15	40.95	59.87	79.53	41.41
3/28/2002	63.78275	86.10	46.65	63.50	84.19	47.30	63.74	86.31	46.48	63.16	84.51	46.94
3/29/2002	66.028	110.53	44.85	66.19	109.77	45.28	66.08	110.91	44.11	65.70	107.59	44.85
3/30/2002	69.52575	111.76	55.87	69.51	112.44	56.04	69.41	111.07	55.55	68.70	109.08	55.49
3/31/2002	69.284	113.19	56.71	69.32	113.38	56.73	69.20	111.09	56.43	68.38	108.48	56.31
4/1/2002	65.76	92.84	54.84	65.37	91.60	54.84	65.45	92.04	54.51	64.91	89.92	54.48
4/2/2002	64.616	91.97	55.57	64.34	90.40	55.66	64.46	91.05	55.26	63.88	89.56	55.29
4/3/2002	63.45025	78.57	55.06	63.29	78.30	55.18	63.50	79.80	54.70	62.84	77.56	54.69
4/4/2002	73.5505	116.29	47.43	74.33	117.92	48.10	73.62	115.89	46.99	72.91	112.48	47.68
4/5/2002	66.31175	117.84	42.64	66.39	118.29	43.02	66.16	118.31	41.89	65.69	114.57	42.78
4/6/2002	71.72475	113.17	53.63	71.53	112.63	53.89	71.25	111.58	52.90	70.95	109.82	53.48
4/7/2002	77.6482609	119.50	50.12	77.72	119.76	50.59	77.06	117.57	49.21	76.84	115.41	49.84
4/8/2002	72.476	112.25	54.44	72.70	114.28	54.69	72.71	114.68	54.01	72.12	110.84	54.88
4/9/2002	74.93275	117.86	58.88	75.40	119.64	58.98	75.29	118.75	58.51	74.30	114.72	58.39
4/10/2002	74.48525	113.79	57.73	74.41	114.19	57.84	74.24	111.70	57.46	73.57	109.82	57.30
4/11/2002	77.349	123.06	58.50	77.34	123.52	58.58	76.68	120.03	58.23	76.14	118.23	58.18
4/12/2002	67.92225	84.40	58.49	67.52	83.28	58.54	67.84	84.95	58.16	67.25	82.86	58.14
4/13/2002	76.4095	125.74	58.45	76.42	125.81	58.59	76.04	122.62	58.17	75.25	121.03	58.03
4/14/2002	68.384	98.44	57.70	68.00	96.91	57.78	68.22	98.76	57.51	67.60	95.98	57.44
4/15/2002	65.306	102.38	56.37	64.77	97.69	56.43	64.92	99.17	56.14	64.84	100.09	56.22
4/16/2002	69.8185	117.54	42.40	69.93	116.94	42.88	69.44	116.08	41.83	69.76	114.95	42.65
4/17/2002	73.857	121.35	47.80	74.16	121.77	48.23	73.65	120.39	47.29	73.46	117.51	48.36
4/18/2002	70.54675	118.39	41.65	70.88	117.70	41.95	70.10	116.34	41.22	70.35	115.27	42.06
4/19/2002	70.73275	116.04	42.82	71.25	115.27	43.01	70.59	114.01	42.12	70.88	113.12	43.54
4/20/2002	72.1965	121.63	44.73	72.33	121.10	44.97	71.61	119.60	43.80	71.74	117.73	45.64
4/21/2002	72.6555	120.20	42.10	73.15	120.37	42.45	71.71	117.82	41.49	72.06	116.41	42.33
4/22/2002	74.8035	123.25	41.59	75.41	123.70	41.83	73.72	121.54	40.35	74.39	119.43	41.20
4/23/2002	77.81925	127.12	46.92	78.25	127.38	47.55	76.67	124.36	46.28	77.17	123.70	47.30

Uncoated Store, Period 3

Date	Average Roof Temp 1	Max Roof Temp 1	Min Roof Temp 1	Average Roof Temp 2	Max Roof Temp 2	Min Roof Temp 2	Average Roof Temp 3	Max Roof Temp 3	Min Roof Temp 3	Average Roof Temp 4	Max Roof Temp 4	Min Roof Temp 4
	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)	(F)
6/12/2002	90.2755	129.71	56.91	90.56	130.66	57.08	88.22	128.33	56.15	90.84	129.76	57.20
6/13/2002	82.1435	122.61	59.92	82.49	125.06	59.97	81.50	124.14	59.24	82.34	123.76	60.10
6/14/2002	85.0135	130.39	52.57	85.26	131.26	53.17	83.43	128.71	51.76	85.05	129.78	53.07
6/15/2002	82.57325	133.83	47.44	83.40	133.98	47.94	80.66	129.99	47.11	83.03	133.00	47.90
6/16/2002	85.7915	135.33	55.80	85.76	135.09	56.28	83.48	130.73	55.03	85.55	133.57	55.84
6/17/2002	86.03575	131.25	56.52	86.20	132.61	56.98	84.19	128.99	55.74	86.17	130.80	56.63
6/18/2002	87.05325	132.27	57.55	87.32	133.87	57.88	85.55	130.53	56.52	87.20	131.51	57.42
6/19/2002	82.57225	117.68	64.24	82.59	119.35	64.30	82.30	117.66	63.82	83.04	118.74	64.07
6/20/2002	72.4535	96.29	63.16	72.16	95.36	63.25	72.12	95.95	62.76	72.43	96.27	63.03
6/21/2002	79.20475	125.26	62.44	79.20	125.86	62.53	78.34	123.44	62.09	79.40	124.32	62.26
6/22/2002	86.383	127.17	61.94	86.95	128.71	62.01	85.93	126.00	61.66	86.82	126.73	62.67
6/23/2002	84.8925	130.44	62.37	85.04	131.94	62.53	84.21	128.29	61.95	85.11	130.09	62.83
6/24/2002	84.01175	129.43	56.83	84.16	130.11	57.18	82.76	126.65	56.23	84.16	129.42	57.07
6/25/2002	84.893	131.86	61.84	85.15	133.24	62.01	83.92	130.94	61.39	85.14	131.50	61.65
6/26/2002	83.78725	129.73	61.54	83.95	130.74	61.62	82.82	127.74	60.93	83.61	128.49	61.93
6/27/2002	84.794	130.63	56.74	85.17	132.25	57.09	83.39	128.52	56.08	84.73	129.32	57.15
6/28/2002	85.53825	129.66	62.26	85.91	131.88	62.35	84.85	129.33	61.83	85.53	129.44	62.10
6/29/2002	82.99475	132.00	58.63	83.15	132.54	58.84	82.13	129.70	57.88	82.66	131.35	58.77
6/30/2002	79.74775	122.28	56.78	79.57	122.56	57.06	78.31	120.75	55.86	79.61	122.40	56.94
7/1/2002	86.10675	132.39	59.99	86.64	134.13	60.02	85.82	133.16	59.20	86.45	132.92	60.07
7/2/2002	85.8685	129.58	62.59	86.43	132.13	62.56	86.15	131.37	62.73	86.77	130.68	63.13
7/3/2002	81.79175	126.69	64.24	82.14	129.31	64.16	82.53	128.24	64.41	82.48	127.13	64.87
7/4/2002	79.75725	121.03	61.16	79.49	120.95	61.20	79.81	121.00	61.18	80.20	120.92	61.57
7/5/2002	80.95325	122.44	62.56	80.88	122.94	62.61	81.18	122.88	62.40	81.40	122.78	62.75
7/6/2002	77.032	109.71	63.28	76.66	108.52	63.27	77.31	109.89	63.36	77.48	110.21	63.78
7/7/2002	79.3855	116.43	63.69	79.33	117.46	63.72	80.14	118.17	63.73	79.94	116.46	64.06
7/8/2002	84.624	132.82	64.83	84.63	133.23	64.75	84.51	131.56	65.07	85.01	131.74	65.64
7/9/2002	82.29075	118.12	59.77	82.53	117.87	59.89	81.77	116.23	59.81	83.07	118.43	60.61
7/10/2002	79.92	109.38	58.20	79.89	108.12	58.32	79.27	106.94	57.85	80.77	110.25	58.32
7/11/2002	83.2295	132.56	63.90	82.92	132.34	63.97	82.44	130.45	63.84	83.68	132.57	64.96
7/12/2002	84.01775	126.93	63.20	83.95	128.07	63.30	83.03	126.01	62.95	84.66	127.12	63.93
7/13/2002	88.4485	130.42	63.39	88.88	131.28	63.62	88.07	129.02	63.38	89.41	130.98	64.38
7/14/2002	86.70125	129.84	62.17	87.04	131.28	62.43	86.28	129.62	61.89	87.62	131.60	62.87
7/15/2002	86.264	126.54	59.34	86.64	127.95	59.61	85.98	126.10	58.62	87.02	127.01	59.26
7/16/2002	87.48	130.66	61.70	87.90	131.62	61.99	86.69	128.82	61.32	88.31	131.60	62.04
7/17/2002	85.53025	131.45	61.45	85.69	132.63	61.65	84.89	128.37	61.02	86.30	132.33	61.80
7/18/2002	84.248	125.66	65.85	84.15	126.36	65.92	83.80	124.45	65.74	84.95	127.08	66.78
7/19/2002	79.36	109.21	64.87	79.05	108.40	64.91	78.99	108.90	64.81	79.80	109.84	65.49
7/20/2002	77.573	121.39	58.39	77.38	121.63	58.67	76.59	121.05	58.39	78.32	122.50	59.56
7/21/2002	79.057	124.21	61.92	79.04	125.25	61.93	78.88	124.10	61.40	79.77	126.02	62.39
7/22/2002	84.94475	123.39	64.65	85.52	126.21	64.61	84.99	124.95	64.50	85.99	125.06	65.11
7/23/2002	86.633	127.37	56.73	87.49	129.50	57.01	86.31	128.35	56.26	87.60	128.47	56.91
7/24/2002	90.465	134.19	61.75	91.27	135.70	62.02	89.48	133.08	61.02	91.54	134.79	61.66
7/25/2002	89.48175	134.24	61.62	90.30	135.34	63.27	88.59	131.81	61.63	90.37	135.10	62.45
7/26/2002	85.82625	130.22	63.25	86.00	131.94	63.48	85.04	128.62	62.56	86.59	130.99	63.56
7/27/2002	85.38525	126.92	65.65	85.62	128.75	65.74	84.78	125.57	65.27	85.92	127.39	65.66
7/28/2002	85.9925	131.52	56.59	86.94	133.02	56.95	85.43	130.51	55.81	86.87	132.38	57.18
7/29/2002	83.6315	125.56	55.15	84.70	127.80	55.30	83.64	126.53	54.31	84.50	126.55	55.08

Appendix B: SDG&E Schedule AL-TOU

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

APPLICABILITY

Applicable to all metered non-residential customers whose monthly maximum demand equals, exceeds, or is expected to equal or exceed 20 kW. This schedule is optionally available to three-phase residential service, including common use, and to metered non-residential customers whose Monthly Maximum Demand is less than 20 kW. Any customer whose Maximum Monthly Demand has fallen below 20 kW for three consecutive months may, at their option, elect to continue service under this schedule or be served under any other applicable schedule. This schedule is the utility's standard tariff for commercial and industrial customers with a Monthly Maximum Demand equaling or exceeding 20 kW.

Non-profit group living facilities taking service under this schedule may be eligible for a 20% California Alternate Rates for Energy (CARE) discount on their bill, if such facilities qualify to receive service under the terms and conditions of Schedule E-LI.

Agricultural Employee Housing Facilities, as defined in Schedule E-LI, may qualify for a 20% CARE discount on the bill if all eligibility criteria set forth in Form 142-4032 is met.

TERRITORY

Within the entire territory served by the Utility.

RATES

Description	Transm	Distr	PPP	ND	FTA	TTA Credit	Restruc	CTC	RMR	UDC Total	
Basic Service Fees											
($/month)											
0-500 kW											
Secondary		46.14								**46.14**	
Primary		46.14								**46.14**	
Secondary Substa.		13,179.65								**13,179.65**	
Primary Substation		13,179.65								**13,179.65**	
Transmission		50.75								**50.75**	I
> 500 kW											
Secondary		184.55								**184.55**	
Primary		184.55								**184.55**	
Secondary Substa.		13,179.65								**13,179.65**	
Primary Substation		13,179.65								**13,179.65**	
Transmission		203.01								**203.01**	I
> 12 MW											
Secondary Substa.		20,752.11								**20,752.11**	
Primary Substation		20,752.11								**20,752.11**	
Distance Adjust. Fee											
Secondary - OH		1.17								**1.17**	
Secondary - UG		3.02								**3.02**	
Primary - OH		1.16								**1.16**	
Primary - UG		2.98								**2.98**	

(Continued)

SCHEDULE AL-TOU

Sheet 2

GENERAL SERVICE - TIME METERED

RATES (Continued)

Description	Transm	Distr	PPP	ND	FTA	Restruc	CTC	RMR	UDC Total
Demand Charges ($/kW)									
Non-Coincident									
Secondary	0.35	5.78					0.39	0.19	**6.71**
Primary	0.33	5.69					0.35	0.19	**6.56**
Secondary Substation	0.35						0.39	0.19	**0.93**
Primary Substation	0.33						0.03	0.18	**0.54**
Transmission	0.32						0.03	0.18	**0.53**
Maximum On-Peak									
Summer									
Secondary	3.15	3.80					1.71	1.76	**10.42**
Primary	3.02	3.66					1.67	1.69	**10.04**
Secondary Substation	3.15						1.71	1.76	**6.62**
Primary Substation	2.96						1.22	1.66	**5.84**
Transmission	2.94						1.21	1.65	**5.80**
Winter									
Secondary	0.77	3.23					0.40	0.43	**4.83**
Primary	0.74	3.22					0.39	0.41	**4.76**
Secondary Substation	0.77						0.40	0.43	**1.60**
Primary Substation	0.72						0.25	0.40	**1.37**
Transmission	0.72						0.25	0.40	**1.37**
Power Factor ($/kvar)									
Secondary		0.24							**0.24**
Primary		0.24							**0.24**
Secondary Substation		0.24							**0.24**
Primary Substation		0.24							**0.24**
Transmission									**0.00**

(Continued)

SCHEDULE AL-TOU

Sheet 3

GENERAL SERVICE - TIME METERED

RATES (Continued)

Description	Transm	Distr	PPP	ND	FTA	Restruc	CTC	RMR	UDC Total
Energy Charges ($/kWh)									
On-Peak - Summer									
Secondary	(.00001)	.00082	.00302	.00065		.00067	.00660	.00036	**.01211**
Primary	(.00004)	.00079	.00302	.00065		.00067	.00643	.00035	**.01187**
Secondary Substation	(.00001)		.00302	.00065		.00067	.00660	.00036	**.01129**
Primary Substation	(.00005)		.00302	.00065		.00067	.00621	.00034	**.01084**
Transmission	(.00005)		.00302	.00065		.00067	.00617	.00034	**.01080**
Semi-Peak - Summer									
Secondary	(.00002)	.00082	.00302	.00065		.00067	.00385	.00036	**.00935**
Primary	(.00004)	.00079	.00302	.00065		.00067	.00377	.00035	**.00921**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00385	.00036	**.00853**
Primary Substation	(.00005)		.00302	.00065		.00067	.00366	.00034	**.00829**
Transmission	(.00005)		.00302	.00065		.00067	.00363	.00034	**.00826**
Off-Peak - Summer									
Secondary	(.00002)	.00048	.00302	.00065		.00067	.00303	.00036	**.00819**
Primary	(.00004)	.00047	.00302	.00065		.00067	.00298	.00035	**.00810**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00303	.00036	**.00771**
Primary Substation	(.00005)		.00302	.00065		.00067	.00293	.00034	**.00756**
Transmission	(.00005)		.00302	.00065		.00067	.00291	.00034	**.00754**
On-Peak - Winter									
Secondary	(.00001)	.00066	.00302	.00065		.00067	.00552	.00036	**.01087**
Primary	(.00004)	.00064	.00302	.00065		.00067	.00538	.00035	**.01067**
Secondary Substation	(.00001)		.00302	.00065		.00067	.00552	.00036	**.01021**
Primary Substation	(.00005)		.00302	.00065		.00067	.00520	.00034	**.00983**
Transmission	(.00005)		.00302	.00065		.00067	.00517	.00034	**.00980**
Semi-Peak - Winter									
Secondary	(.00002)	.00066	.00302	.00065		.00067	.00387	.00036	**.00921**
Primary	(.00004)	.00064	.00302	.00065		.00067	.00378	.00035	**.00907**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00387	.00036	**.00855**
Primary Substation	(.00005)		.00302	.00065		.00067	.00368	.00034	**.00831**
Transmission	(.00005)		.00302	.00065		.00067	.00365	.00034	**.00828**
Off-Peak - Winter									
Secondary	(.00002)	.00048	.00302	.00065		.00067	.00306	.00036	**.00822**
Primary	(.00004)	.00048	.00302	.00065		.00067	.00301	.00035	**.00814**
Secondary Substation	(.00002)		.00302	.00065		.00067	.00306	.00036	**.00774**
Primary Substation	(.00005)		.00302	.00065		.00067	.00296	.00034	**.00759**
Transmission	(.00005)		.00302	.00065		.00067	.00294	.00034	**.00757**

Notes: Transmission Energy charges include the Transmission Revenue Balancing Account Adjustment (TRBAA) of ($.0007) per kWh, the Transmission Access Charge Balancing Account Adjustment (TACBAA) of $.00007 per kWh and a Supplemental Surcharge (SS) of $.00007 per kWh. Restructuring Implementation Rate is comprised of rates for Internally Managed Costs (IMC) and Externally Managed Costs (EMC).

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

RATES (Continued)

Rate Components
The Utility Distribution Company Total Rates (UDC Total) shown above are comprised of the following components (if applicable): (1) Transmission (Trans) Charges, (2) Distribution (Distr) Charges, (3) Public Purpose Program (PPP) Charges, (4) Nuclear Decommissioning (ND) Charge, (5) Trust Transfer Amount (TTA), sometimes referred to as Fixed Transition Amount (FTA), (6) Restructuring Implementation Rate (Restruc) which is the sum of the rates for Internally Managed Costs and Externally Managed Costs (7) Ongoing Competition Transition Charges (CTC), and (8) Reliability Must Run Generation Rates (RMR).

Utility Distribution Company (UDC) Total Rate shown above excludes any applicable commodity charges associated with Schedule EECC (Electric Energy Commodity Cost). T T

Fixed Transition Amount Adjustment
For residential and small commercial customers as defined in Rule 1 – Definitions, and as described in Public Utilities Code Section 331(h), the rates shown above will be adjusted in accordance with the rates set forth in Schedule FTA.

Time Periods
All time periods listed are applicable to local time. The definition of time will be based upon the date service is rendered.

	Summer May 1 - Sept 30	Winter All Other
On-Peak	11 a.m. - 6 p.m. Weekdays	5 p.m. - 8 p.m. Weekdays
Semi-Peak	6 a.m. - 11 a.m. Weekdays	6 a.m. - 5 p.m. Weekdays
	6 p.m. - 10 p.m. Weekdays	8 p.m. - 10 p.m. Weekdays
Off-Peak	10 p.m. - 6 a.m. Weekdays	10 p.m. - 6 a.m. Weekdays
	Plus Weekends & Holidays	Plus Weekends & Holidays

Non-Standard Seasonal Changeover
Customers may select on an optional basis to start the summer billing period on the first Monday of May and to start the winter billing period on the first Monday of October. Customers electing this option will be charged an additional $100 per year for metering equipment and programming.

Franchise Fee Differential
A Franchise Fee Differential of 1.9% will be applied to the monthly billings calculated under this schedule for all customers within the corporate limits of the City of San Diego. Such Franchise Fee Differential shall be so indicated and added as a separate item to bills rendered to such customers.

(Continued)

SPECIAL CONDITIONS

1. Definitions: The Definitions of terms used in this schedule are found either herein or in Rule 1.

2. Voltage: Service under this schedule normally will be supplied at a standard available Voltage in accordance with Rule 2.

3. Voltage Regulators: Voltage Regulators, if required by the customer, shall be furnished, installed, owned, and maintained by the customer.

4. Reconnection Charge: In the event that a customer terminates service under this schedule and re-initiates service under this or any other schedule at the same location within 12 months, there will be a Reconnection Charge equal to the greater of the Minimum Charge or the Basic Service Fee which would have been billed had the customer not terminated service. T

5. Non-Coincident Demand Charge: The Non-Coincident Demand Charge shall be based on the higher of the Maximum Monthly Demand or 50% of the Maximum Annual Demand.

6. On-Peak Period Demand Charge: The On-Peak Period Demand Charge shall be based on the Maximum On-Peak Period Demand.

7. Power Factor: The Power Factor rate shall apply to those customers that have a Power Factor Test Failure and will be based on the Maximum Kilovar billing demand. Those customers that have a Power Factor Test Failure will be required to pay for the Power Factor Metering that the utility will install.

8. Parallel Generation Limitation. This schedule is not applicable to standby, auxiliary service or service operated in parallel with a customer's generating plant, except as specified in Rule 1 under the definition of Parallel Generation Limitation.

9. Seasonal Changeover Switching Limitation. Customers who elect the nonstandard Seasonal Changeover option of this schedule will be prohibited from switching service to the regular seasonal changeover for a 12-month period.

10. Limitation on Non-Standard Seasonal Changeover Availability. At the utility's sole option, the optional non-standard seasonal changeover provision is available to no more than ten additional Schedule AL-TOU and Schedule A6-TOU customers annually and; service will be provided in the order in which requests are received.

11. Terms of Optional Service. A customer receiving service under this schedule may elect to change to another applicable rate schedule, but only after receiving service on this schedule for at least 12 consecutive months. If a customer elects to discontinue service on this schedule, the customer will not be permitted to return to this schedule for a period of one year.

12. Basic Service Fee Determination. The basic service fee will be determined each month based on the customer's Maximum Annual Demand. T L T L

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

SPECIAL CONDITIONS (Continued)

13. Billing. A customer's bill is first calculated according to the total rates and conditions listed above. The following adjustments are made depending on the option applicable to the customer: L

a. **UDC Bundled Service Customers** receive supply and delivery services solely from SDG&E. The customer's bill is based on the Total Rates set forth above. The EECC component is determined by multiplying the EECC price for this schedule during the last month by the customer's total usage.

b. **Direct Access Customers** purchase energy from an energy service provider (ESP) and continue to receive delivery services from SDG&E. The bill for a Direct Access Customer will be calculated as if it were a UDC Bundled Service Customer, then crediting the bill by the amount of the EECC component, as determined for a UDC Bundled Customer.

c. **Virtual Direct Access Customers** receive supply and delivery services solely from SDG&E. A customer taking Virtual Direct Access service must have a real-time meter installed at its premises to record hourly usage, since EECC change hourly. The bill for a Virtual Direct Access Customer will be calculated as if it were a UDC Bundled Service Customer, then crediting the bill by the amount of the EECC component, as determined for a UDC Bundled Customer, then adding the hourly EECC component, which is determined by multiplying the hourly energy used in the billing period by the hourly cost of energy.

Nothing in this service schedule prohibits a marketer or broker from negotiating with customers the method by which their customer will pay the CTC charge.

14. Temporary Service. When service is turned on for cleaning and/or showing of an unoccupied premise above 20 kW facility, the minimal usage shall be billed under Schedule A, until a new tenant begins service. Should usage exceed 20kW at any time for cleaning and/or showing, the customer shall be billed the rates on this schedule. T T N

15. Multiple Meters on Single Premise. When a single corporate entity owns a contiguous property, not divided by any public right of way or property owned by another entity, and the utility has more than one meter serving that property, then, at the customer's request the utility will for the additional fees set forth in this Special Condition bill all of the usage at some, or all, of the meters as though the whole premise were served through a single meter. Meter data will be combined for the purpose of billing Distribution charges, as listed in the Rates Section of this tariff. The customer must pay for the utility to install and maintain meters to record consumption in 15 minute intervals for all involved meters. The customer must also pay a distance adjustment fee determined by that utility that is based on the distance between each of the meters involved using normal utility position to determine that distance. The rate applied will be the Distance Adjustment Fee from the Rate Section of this tariff times 0.121. When Secondary level and Primary level services are combined, the usage measured at the Secondary level will be increased by 4% for losses, prior to being added to the usage measured at the Primary level. When Primary level and Transmission level services are combined, usage measured at the Primary Level will be increased by 3% for losses, prior to being added to the usage measured at the Transmission level. L – L

(Continued)

SCHEDULE AL-TOU

GENERAL SERVICE - TIME METERED

SPECIAL CONDITIONS (Continued) L

16. Electric Emergency Load Curtailment Plan: As set forth in CPUC Decision 01-04-006, all transmission level customers except essential use customers, OBMC participants, net suppliers to the electrical grid, or others exempt by the Commission, are to be included in rotating outages in the event of an emergency. A transmission level customer who refuses or fails to drop load shall be added to the next curtailment block so that the customer does not escape curtailment. If the transmission level customer fails to cooperate and drop load at SDG&E's request, automatic equipment controlled by SDG&E will be installed at the customer's expense per Electric Rule 2. A transmission level customer who refuses to drop load before installation of the equipment shall be subject to a penalty of $6/kWh for all load requested to be curtailed that is not curtailed. The $6/kWh penalty shall not apply if the customer's generation suffers a verified, forced outage and during times of scheduled maintenance. The scheduled maintenance must be approved by both the ISO and SDG&E, but approval may not be unreasonably withheld.

17. One Time Bill Change Limitation: Pursuant to D.02-09-034, the Utility will, between November 1, 2003 and January 1, 2004, perform a calculation that may lead to bill credits for some customers on this rate schedule. The calculation shall be based on twelve consecutive billing periods of usage for each customer on this rate schedule, commencing with the customers first billing period after October 1, 2002. The calculation shall determine the annual bill at total adopted rates less the annual bill at total present rates, divided by the annual bill at total present rates, to arrive at each customer's annual percentage change in bill. Total rates shall include all applicable rates that a bundled customer taking service under this rate schedule would be billed, including Schedule EECC rates. Based on the result of this calculation, any customer who has experienced an annual bill increase that exceeds 7.5% shall be eligible for a bill credit equal to that portion of their bill increase that causes them to exceed a 7.5% increase. Present rates will be those rates in effect on September 30, 2002. All customers eligible for a bill credit under the provisions of this Special Condition shall receive such bill credits by February 1, 2004. N

18. Other Applicable Tariffs: Rules 21, 23 and Schedule E-Depart apply to customers with generators. N

Attachment 3:

Cool Roof Monitoring and Analysis at Site C

Cool Roof Monitoring and Analysis at Site C

Prepared for:

San Diego Gas & Electric
8335 Century Park Court, CP12B
San Diego, California   92123-1569

Prepared by:

Architectural Energy Corporation
2540 Frontier Avenue, Suite 201
Boulder, Colorado   80301

October 21, 2002

Cool Roof Monitoring and Analysis at Site C

Table of Contents

Table of Figures

Table of Tables

Executive Summary

This project is intended to monitor the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems.

The facility selected for monitoring is a small retail store located in La Mesa, California.

The evaluation was performed by first monitoring the thermal performance of the existing roof, removing all instrumentation for a complete roof installation, and then reinstalling instrumentation for data collection with the new roof and cool roof surface. Next, to determine the annual performance of the building, a simulation model was created and calibrated using the actual performance data. The calibrated simulation results were then used to evaluate the cost-effectiveness of the cool roof system.

The roof and insulation structure at this store has been retrofitted over the years to serve different store needs. Originally, this building was used for drive-in car tune-ups. The ceiling consisted of sheet rock attached to the ceiling joists. No insulation was installed in the ceiling because the building was essentially unconditioned in the automobile bays. The building now houses a retail establishment. When insulation was added, instead of attaching it between the ceiling joists (which were inaccessible because of the sheet rock), insulation was laid on top of a suspended ceiling. In July 2002, the roof was replaced with a new built-up roof suitable for the cool roof coating, and in August, the roof was coated with APOC 252 coating.

The approach used to evaluate the cool roof performance at this site was to compare the performance of the original and uncoated roof to the new roof and cool roof coating. This evaluation was performed through monitoring temperatures and heat flows, as well as ambient conditions, for a period of several months. Next, a simulation model was developed to model the performance of the store. The monitored data was then used to calibrate the simulation model so that it accurately represented the roof performance.

Instrumentation was installed on February 6, 2002 to monitor ambient conditions, roof structure temperatures, and heat flux, and HVAC system inlet temperatures. The monitoring was completed in late August 2002.

After collecting performance data, a simulation model was developed using DOE-2.1, based on the measured data, to estimate the annual performance of the roof coating. The measured performance data showed that the roof coating was less reflective than expected, and that the HVAC cooling capacity was not completely meeting the load during peak cooling days. Therefore, several models were created to model not only the observed roof and building characteristics, but to

model the building with increased HVAC capacity, and to model the performance with a more reflective roof surface.

From the model used to predict the performance of the building, the annual savings from the cool roof coating were estimated at 0.624 kWh/sf, or on a dollar basis, $0.10/sf. The cost of the coating was $0.45/sf, leading to a simple payback of less than 5 years, which may be a reasonable payback period.

Although the roof coating did reduce roof temperatures, it was not as effective as had been observed on other roofs. One non-energy benefit of cool roofs is a reduction in peak roof temperatures, which can result in increased roof lifetime. The effect was not dramatic at this location. The peak daily asphalt roof temperatures, prior to the application of the roof coating, are greater than the original gravel roof. The coating reduced the maximum roof temperature by about 15°F as compared to the asphalt roof, but only about 5°F as compared to the original gravel roof.

1.0 Project Overview

This project is intended to monitor the thermal impact of a cool roof system on a commercial building roof and its heating and cooling systems. The facility selected for monitoring is a small retail store located in La Mesa, California.

The evaluation was performed by first monitoring the thermal performance of the existing roof, removing all instrumentation for a complete roof installation, and then reinstalling instrumentation for data collection with the new roof and cool roof surface. Next, to determine the annual performance of the building a simulation model was created and calibrated using the actual performance data. The calibrated simulation results were then used to evaluate the cost-effectiveness of the cool roof system.

2.0 Site Description

The facility selected for monitoring is a small retail store located in La Mesa, California. The building is relatively small single-story building, with a total square footage of about 1,200 square feet, about 970 of which is conditioned.

The space conditioning for the store is provided by one standard single-zone three-ton rooftop HVAC unit, without economizer.

The roof and insulation structure at this site has been retrofitted over the years to serve different store needs. Originally, this building was used for drive-in car tune-ups. The ceiling consisted of sheet rock attached to the ceiling joists. No insulation was installed in the ceiling because the building was essentially unconditioned in the automobile bays. The building now houses a retail establishment. When insulation was added, instead of attaching it between the ceiling joists (which were inaccessible because of the sheet rock), insulation was laid on top of a suspended ceiling. A cross-section of the facility is shown in Figure 1.

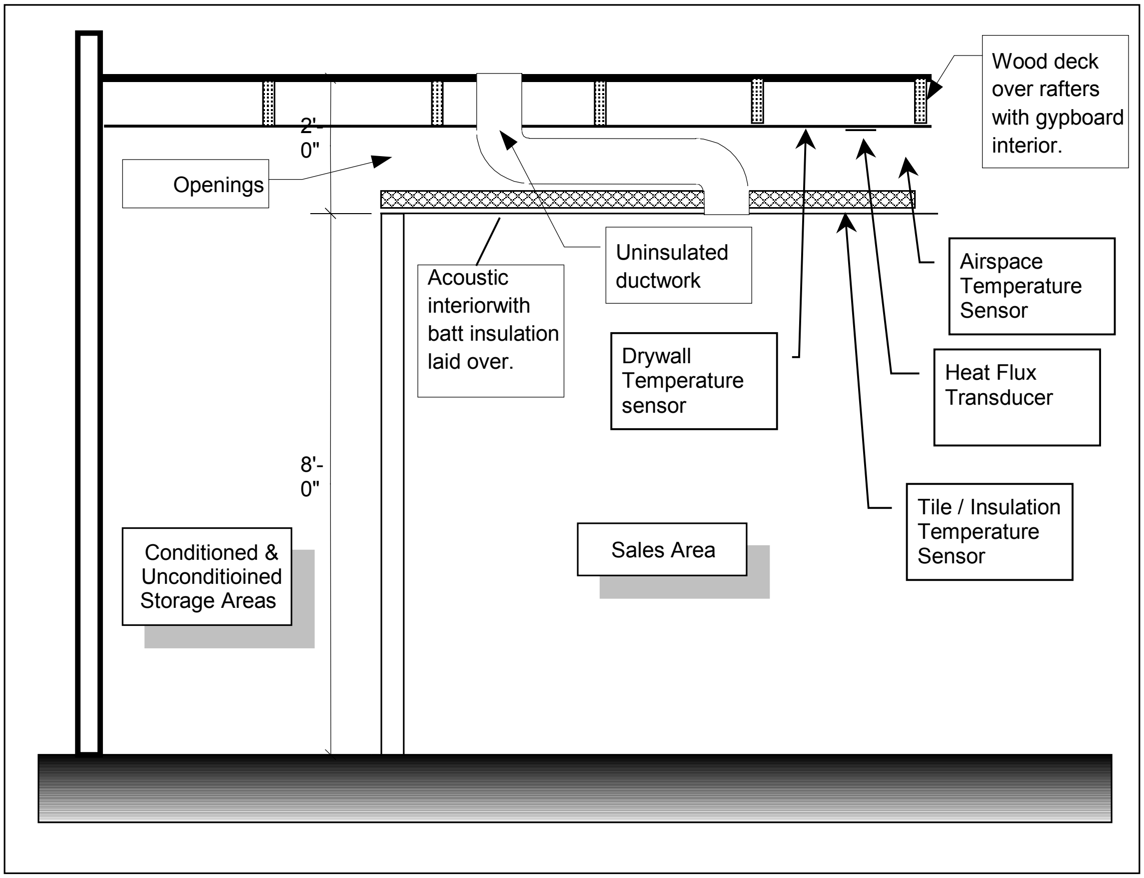

Figure 1. Approximate Section Through Building

The original roof surface used a tar and gravel built-up roofing system. Since the roof was near the end of its life, a new built-up roof was scheduled to be installed during the monitoring period.

A picture of the original roof is shown in Figure 2.

The roofing contractor installed a new roof during the late spring, but due to miscommunication, the cool roof coating was not applied until early August, near the end of the monitoring period. They applied APOC 252 Ultra White Elastomeric Roof Coating[1], manufactured by Gardner Asphalt.

[1] http://www.apoc.com/Apoc-new/frames/252-d.htm

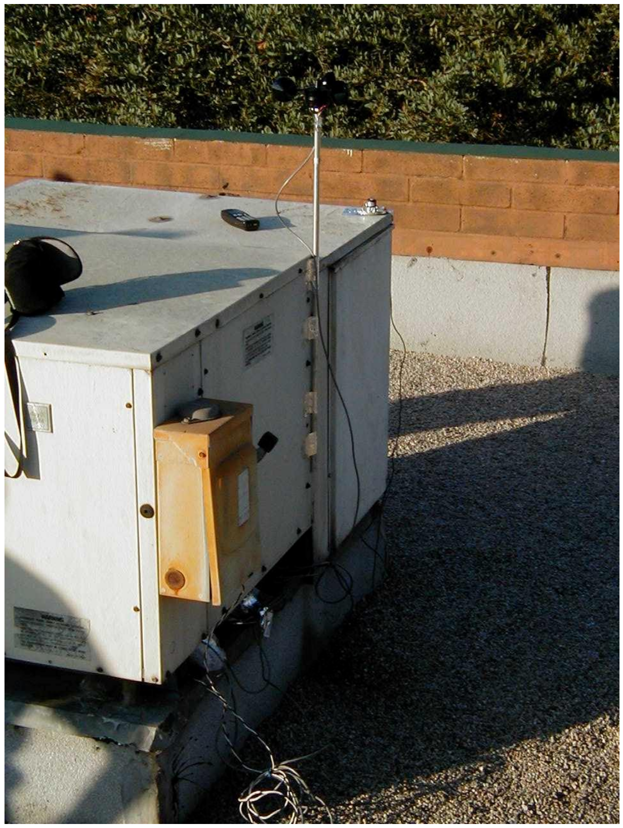

Figure 2. Original Roof and HVAC Unit

3.0 Project Approach

3.1 General Approach

The approach used to evaluate the cool roof performance at this site was to compare the performance of the original and uncoated roof to the new roof and cool roof coating. This evaluation was performed through monitoring temperatures and heat flows, as well as ambient conditions for a period of several months. Next, a simulation model was developed to model the performance of the building. The monitored data was then used to calibrate the simulation model so that it accurately represented the roof performance.

Because a completely new roof was installed during the monitoring period, there was concern that some of the performance difference might be attributable to the new roof, and not just the roof coating. However, since there was a period of several weeks during which the roof had been replaced, but had not yet been coated, it was possible to observe and compare the performance of the uncoated new roof to the original tar and gravel roof.

After collecting performance data, a simulation model was developed, based on the measured data, to estimate the annual performance of the roof coating. A simulation model allows annual projections of performance using a relatively short monitoring period. Furthermore, the weather data used to drive the simulation are based on long-term observations, and so are typical of the weather for a region, rather than for a specific year. This also allows a better indication of what performance could be expected over the long term, rather than relying on extrapolating the results of a specific period of time.

The steps for evaluating the performance of the cool roof product were as follows:

- Install instrumentation as listed in Table 1.
- Monitor the roof throughout the spring and into the summer.
- Develop models of the heat transfer through the roof using DOE-2. Calibrate the models using measured data.
- Run simulations to compare the annual effects of the roof coating on roof heat transfer and the subsequent effects on the HVAC system.
- Perform a cost / benefit analysis of the roof coating.

3.2 Data Collection

Instrumentation was installed on February 6, 2002, according to the measurement list shown in Table 1. The data collection was performed in three time periods, as shown in Table 2. Phase 1 and 2 are consecutive, and are differentiated only by the need to remove the old loggers for download and install new loggers with fresh batteries. After an eleven-week hiatus in data collection between mid-April and early July, during which the roof was replaced, loggers were reinstalled and data collection proceeded into the summer, until August 23, 2002.

Table 1. Measurement List

Measurement Points	Units
Ambient Temperature	°F
Solar Insolation	watts/m^2
Wind Speed	mph
Roof Temperature 1	°F
Roof Temperature 2	°F
HVAC Outdoor Inlet Temp	°F
HVAC Amps	amps
Drywall Temperature	°F
Airspace between Drywall and Insulation Temperature	°F
Ceiling Tile / Insulation Temperature	°F
Drywall Heat Flux	BTU/hr-sf

Table 2. Data Collection Periods

Data Collection Period	Begin	End	Notes
1	2/6/2002	3/18/2002	Original Tar/Gravel Roof
2	3/18/2002	4/24/2002	Original Tar/Gravel Roof
3a	7/9/2002	7/30/2002	New roof, but uncoated (black tar surface)
3b	8/7/02	8/23/02	Roof Coated 8/7/02

The roof temperature sensors were first anchored to the tar roof surface under the gravel with epoxy adhesive and then covered with gravel, similar to that found on the roof. The sensor was covered to ensure that the temperature sensor was “shaded” from the direct sun with the same material covering the roof so that the sensor would respond to solar radiation similarly to the actual roof to accurately sense the roof temperature. A picture of a typical sensor installation is shown in Figure 3. The sensor is almost indistinguishable from the surrounding roof.

Figure 3. Roof Temperature Sensor

The heat flux transducers and sheet rock temperature sensors were attached to the underside of the sheet rock. These sensors were placed in the sales area of the store. Heat transfer compound was applied between the sensors and the sheet rock to minimize resistance to heat flow between the sensors and the roof deck. High strength tape was used to attach the sensors. The completed logger installation is shown in Figure 4.

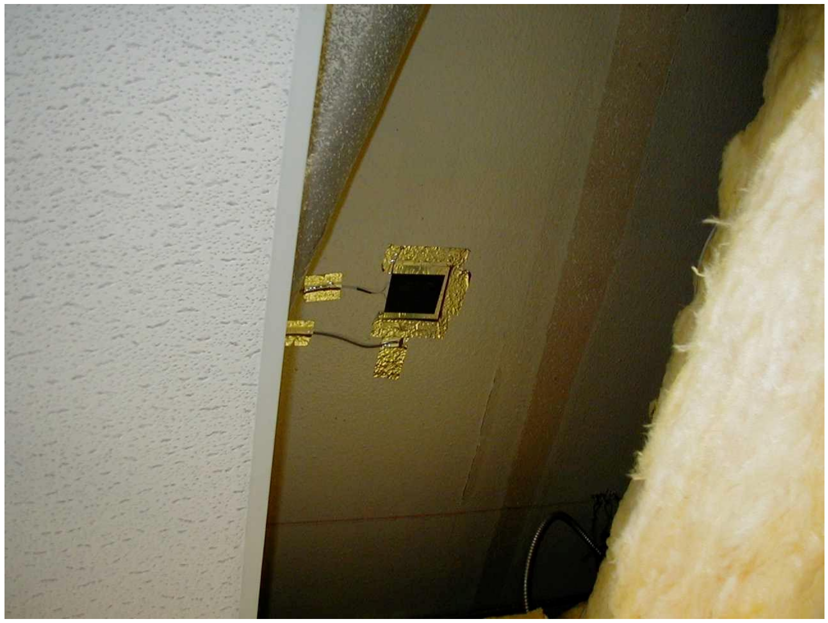

Figure 4. Sheet Rock Instrumentation

Solar radiation, ambient temperature, and wind speed were also monitored to have a record of the ambient conditions affecting the roof.

Daily summaries of the all measurements are included in Appendix A.

4.0 Analysis and Results

4.1 Measured Performance

The heat flow through the entire roof structure is affected by the temperatures of the roof surface, the deck temperature, the air temperature in the conditioned space, and the heat stored in the roof structure components. Furthermore, because of the location of the insulation and the multiple airspaces in the structure, the heat flows can be high, with time delays. Figure 5 shows a one-day history of the temperatures and heat flux in the uncoated portion of the roof. Until approximately 7:30 in the morning, the heat flux has over-ranged the instrumentation amplifier in the negative direction. Since negative heat flows (out of the building) are not affected by a cool roof coating, it was considered more important to record heat flux into the building with high accuracy, at the expense of measuring negative heat flow. Due to the very low insulation levels, heat flow out of the building during nighttime hours was greater than anticipated, and so the instrumentation was over-ranged. However, this did not affect the analysis of the cool roof.

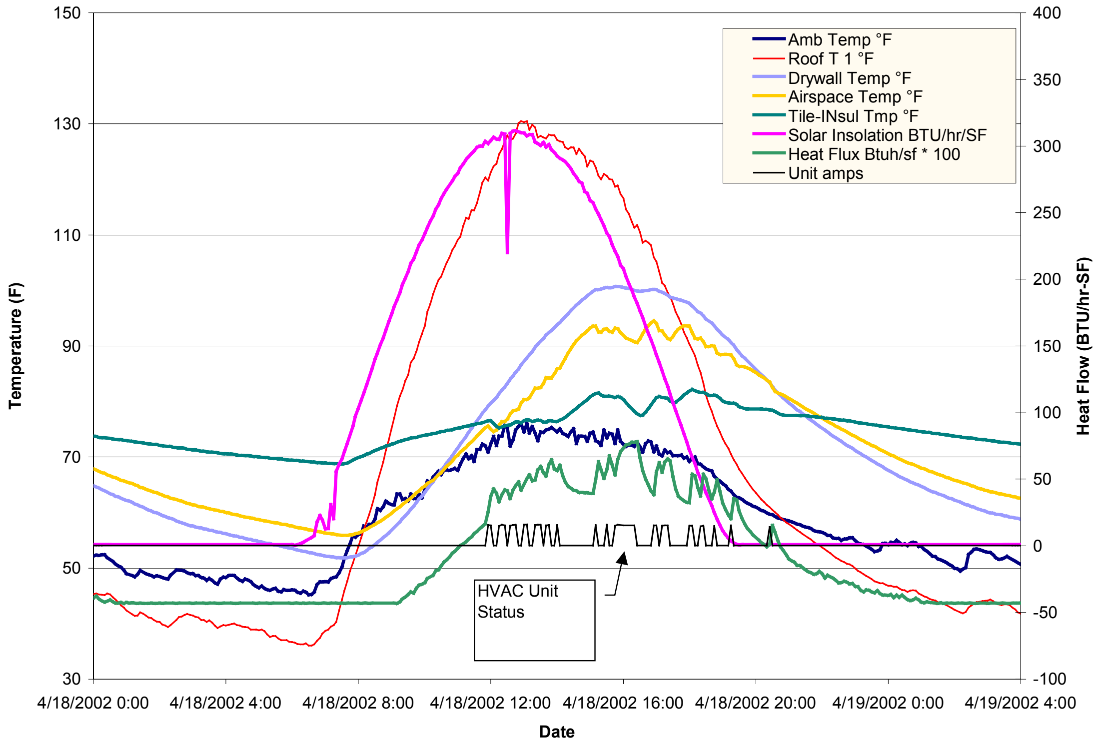

Figure 5. Roof Temperature and Heat Flux History – Original Roof

During the early morning hours, all of the temperatures are decreasing. Notice that the ambient temperature drops to about 45°F. The roof surface temperature has dropped to about 37°F, due to night-sky radiation. Airspace temperature above the insulation has dropped to about 55°F, and the actual drywall temperature is about 52°F.

As the sun rises at about 6:15, all of the temperatures start to increase. The heat flux sensor starts to register shortly after 9:00 am. The roof temperature reached a peak of 130°F shortly after noon. However, the roof structure temperatures and heat flux do not reach their peaks until around 16:00. At this time, the heat flux peaks at 7.0 BTU/hr-sf.

During this morning “warm-up” period, the temperature of the roof-top surface (measured by the roof temperature sensor) is greater than the lower surface (measured by the drywall temperature sensor), meaning that heat is being conducted into the building. Since both the roof and drywall temperatures are increasing, this indicates that the overall roof structure is heating up, i.e., storing heat. In the late afternoon, this situation is reversed: the upper roof surface is cooler than the interior drywall temperature, and both the roof and drywall temperatures are decreasing, i.e., the roof is cooling off, and the stored heat in the roof structure is being released. During this period, heat is being rejected by the roof surface through radiation and convection to the outdoor sky, and is also being conducted from the bottom of the drywall, through the insulation, to the conditioned space. Finally, at the end of the day, the heat flux becomes negative as heat flows out of the building.

The status of the HVAC unit is also shown in Figure 5. Notice when the HVAC unit cycles on in the early morning before sunrise, the heat flux tends to increase, i.e., becomes less negative. Leaks or other losses in the ductwork above the insulation lowers the air temperature in the airspace, which reduces the temperature difference across the roof structure, and therefore decreases the heat flow out of the building. Although it is difficult to see in these plots, a similar behavior occurs during the day, when the roof surface is hotter than the building interior: when the HVAC unit is running, it cools the airspace, which increases the temperature difference between the drywall and the roof, and increases the heat flow into the building. In essence, during the day, since the ducts run through an area that is essentially uninsulated the building cooling load is increased.

Similar plots are shown for the new roof, prior to coating, in Figure 6, and after the roof was coated, in Figure 7. The addition of the coating decreased roof temperatures somewhat, as well as the heat flux, but the results are not as dramatic as have been observed at other locations.

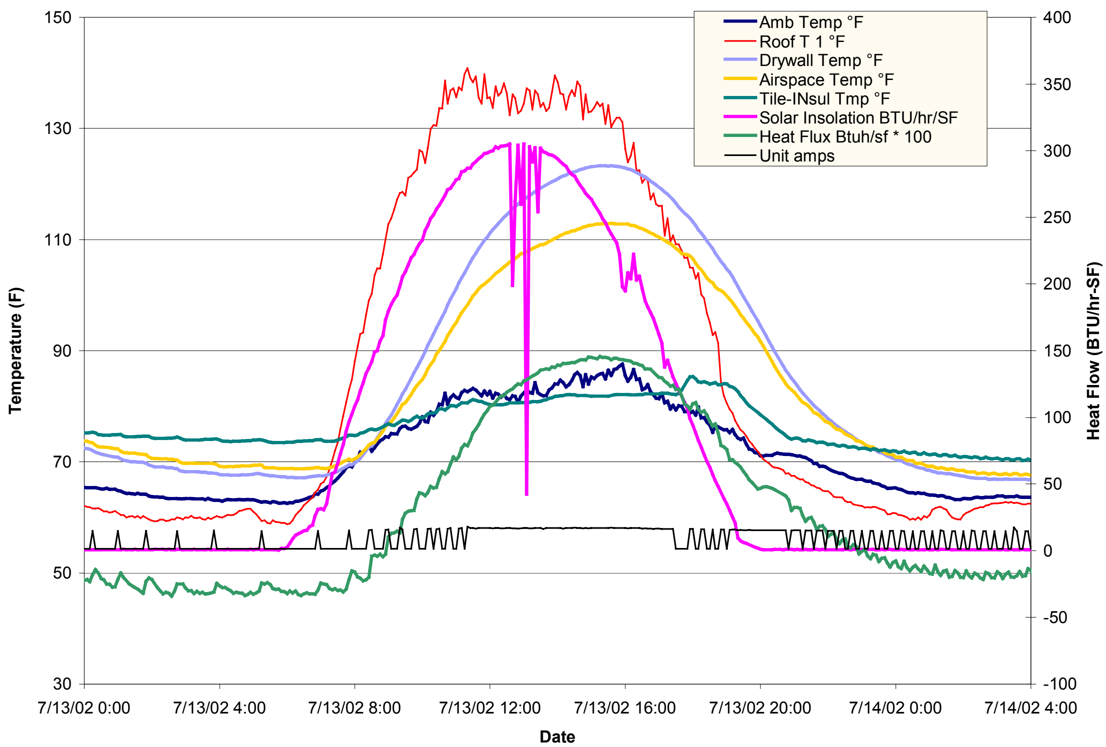

Figure 6. Temperature History – New Roof Prior to Coating

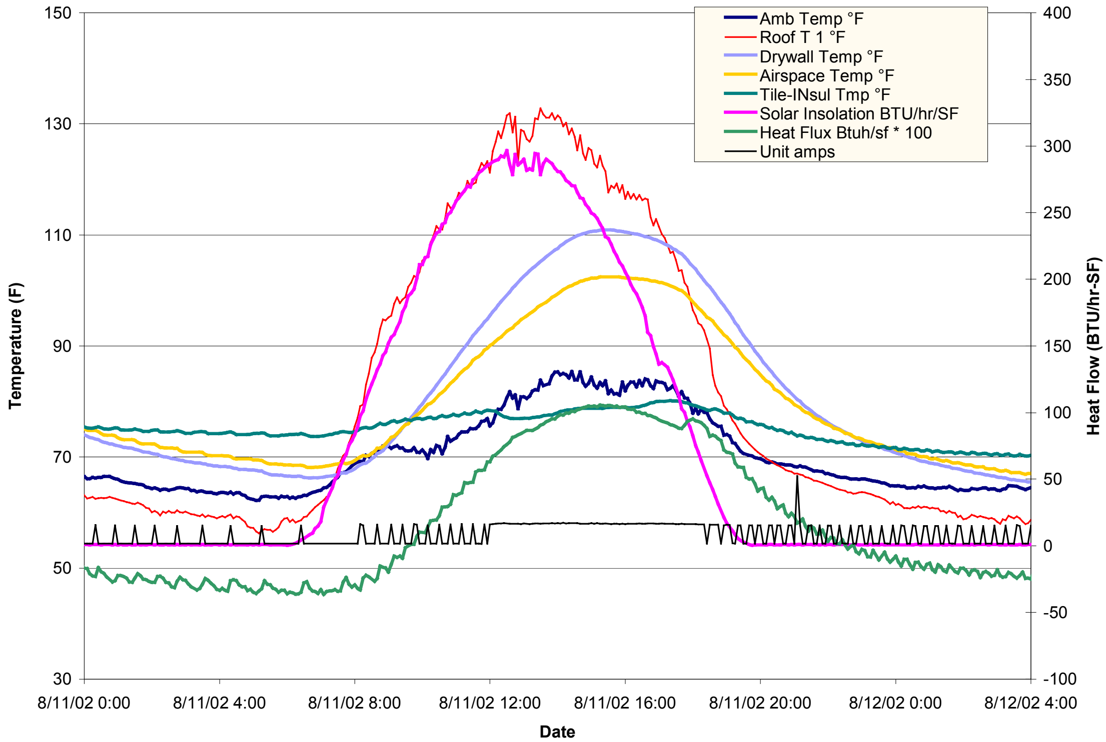

Figure 7. Temperature History – New Roof After Coating

Figure 8 shows the temperatures and roof heat flux before and after the roof coating. There is a small drop in heat flux, and a less pronounced drop in roof temperatures.

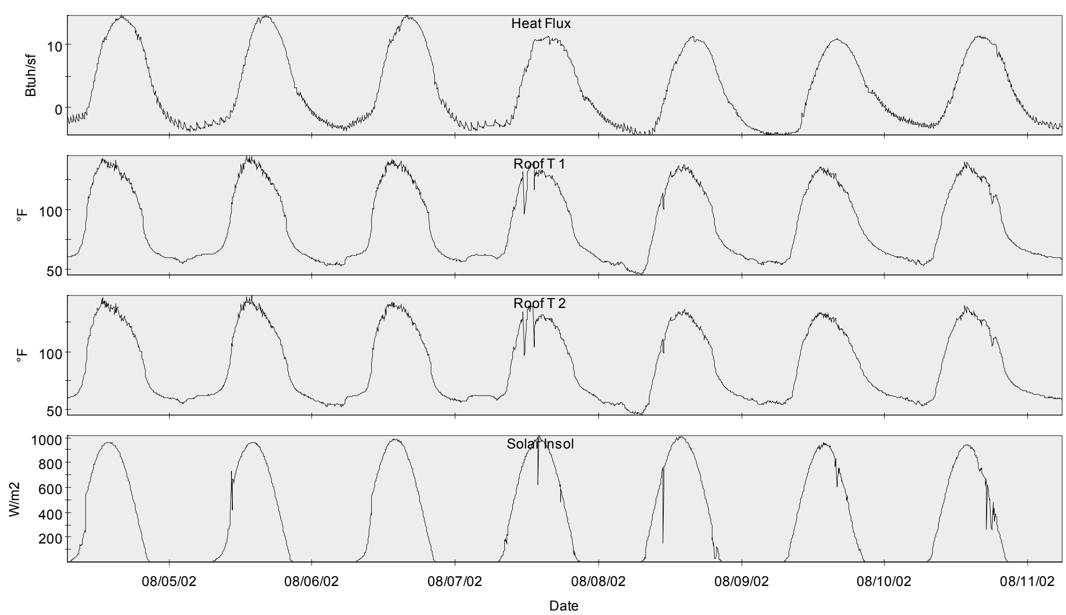

Figure 8. History During Roof Coating

Figure 9 shows the roof temperature rise for the original roof, the new roof prior to coating, the new roof after coating, and a recently applied cool roof coating at another site. The original roof has greater scatter, which is probably caused by the greater thermal mass of the gravel. The new uncoated roof actually has slightly higher temperature rise, which is not unexpected, because of the fresh black surface. The coated roof has a slightly decreased temperature rise, although not dramatic, especially when compared to a recently applied cool roof at another location. During a final inspection at the site while the instrumentation was removed, it was observed that the roof surface was not as "white" as was expected.

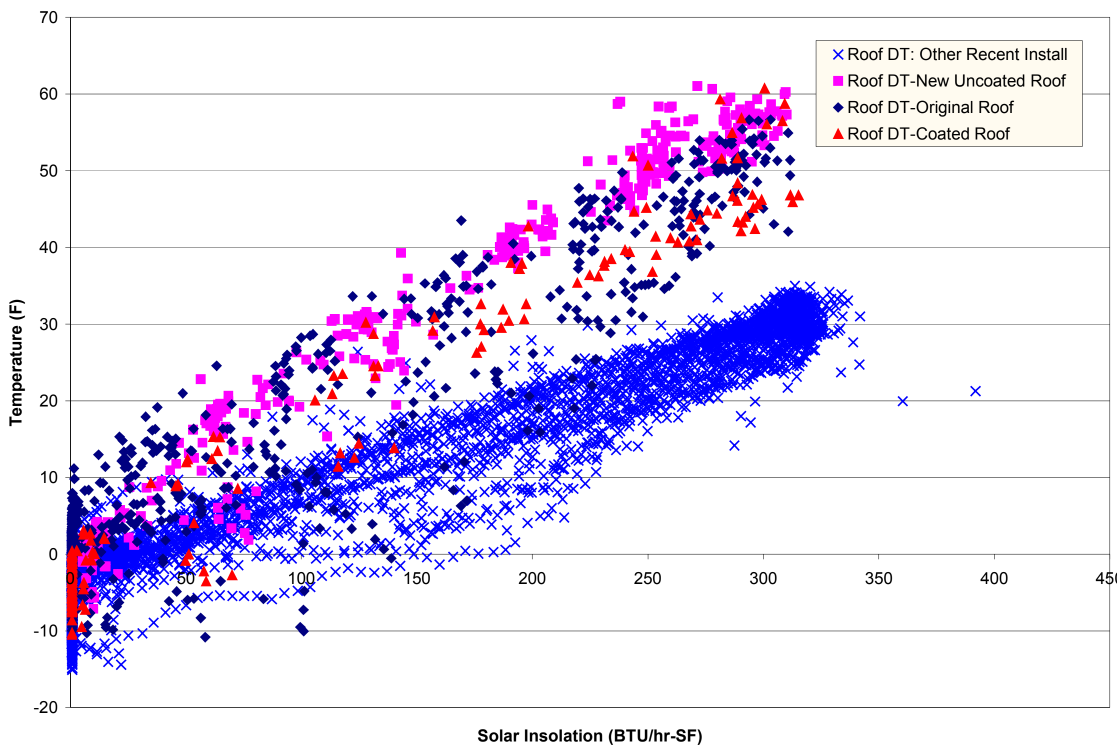

Figure 9. Comparison of Roof Temperature Rise

Finally, Figure 10 shows a comparison of the relative daily energy consumption of the HVAC unit versus the daily ambient temperature.. The original roof was in place when the daily ambient temperature was cooler, but was replaced by the new asphalt roof when the days were warmer. Notice that as the daily average ambient temperature increases, the daily HVAC energy consumption also increases, as would be expected. However, notice that the data showing the energy consumption after the cool roof coating was applied does not result in dramatic energy savings, even though other data shows that the roof temperatures were lowered and the heat flux through the roof had decreased. The most likely reason for this is that the HVAC unit is undersized for the current building load. This hypothesis is substantiated when looking at the HVAC system status in Figure 6 and Figure 7. Notice that the HVAC system is running constantly from noon until 6 pm, and that the "Tile-Insul Temp," which is a reasonable indicator of zone temperature, is increasing during this entire period. Minimal energy savings will be realized during peak cooling days if the system cannot meet the load during mid-day. The cool roof coating will result in less heat transferred to the roof, which will probably result in shorter run times in the late afternoon and evening, especially during days with lower cooling requirements than were observed during the July and August monitoring period.

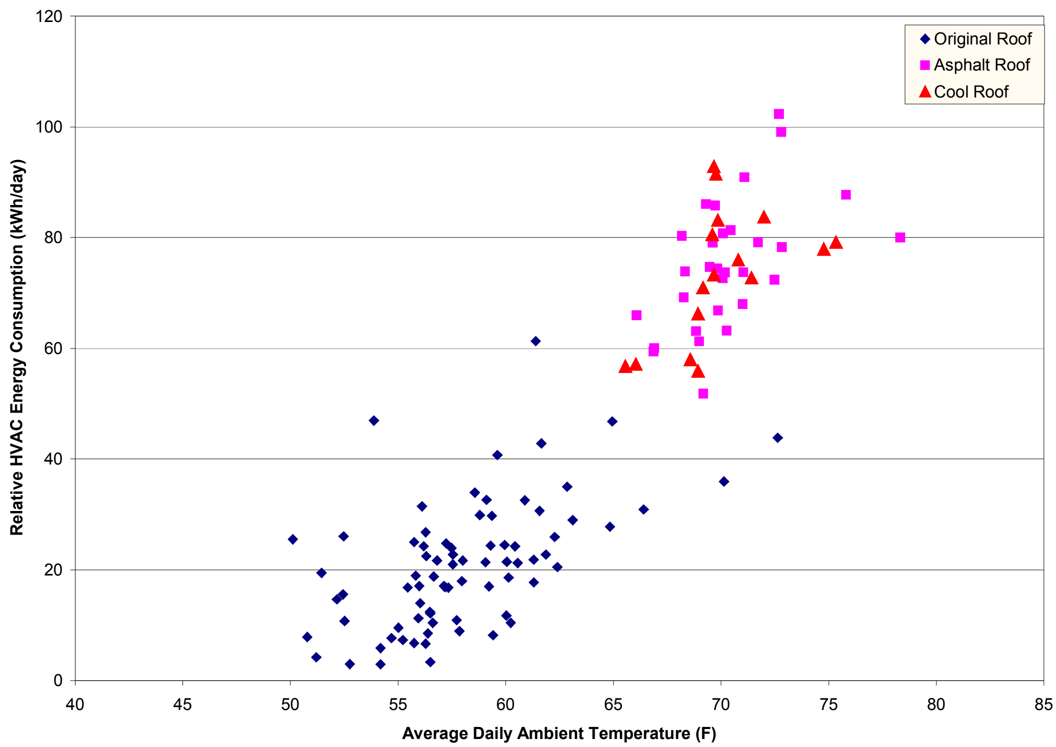

Figure 10. Daily HVAC Energy Consumption vs. Ambient Temperature

4.2 Simulation Model Development

An annual building energy simulation was performed using DOE-2.1 v133 to model the operating and building characteristics of the space. The simulation was run with San Diego Climate Zone (CTZ07) weather data. This weather data is recommended by the California Energy Commission for the La Mesa area. Annual savings were calculated by comparing the performance of the original roof to the new coated roof.

Several models were created to estimate the annual performance of the cool roof product. The cases that were modeled are as follows:

Case 1:	Building and roof as observed
Case 2:	Building and roof with adequate HVAC sizing
Case 3:	Building and roof with adequate HVAC sizing and improved roof reflectivity

As was discussed previously, the HVAC system ran continuously during hot days in August. This is often due to a load that is greater than can be met with the current HVAC system. It can also be due to an occupant adjusting the thermostat so that the unit runs continuously. It can also be caused by other maintenance issues associated with in the HVAC system. The good news is that an undersized system will always use less energy than a larger system. The bad news is that occasionally the zone temperature will rise during hot days. Also, in the case of this cool roof analysis, the savings that can be achieved through a cool roof coating may be reduced, since reducing the roof thermal load will first result in a more comfortable zone temperature, and then, after the zone temperature setpoint is achieved, will result in energy savings.

The next case is intended to model the roof and structure as observed, but with increased cooling capacity in the HVAC system. With increased cooling capacity, the zone temperature will not increase during peak cooling days, and the cool roof will result in more energy savings.

The final case builds on the previous case by increasing the reflectivity of the roof. Recall that the measurements indicated that the cool roof coating did not reduce roof temperatures as much as had been observed at other sites. This case estimates what the effects would be with an improved roof coating.

Hourly outputs from the simulation and hourly monitored data were compared to verify and calibrate the assumptions in the model. The key assumptions that affect roof heat gain are shown in Table 4.

Table 3. Site Characteristics

Characteristic	Observed Site Characteristic	Simulation Input
Site		
Utility Rate	Utility meter measured consumption for entire building.	SDG&E Schedule A plus EECC (July 2002)[2]
Simulation Weather Data	La Mesa address	CTZ07
Envelope		
Initial Roof Absorptance	Calibrated to 75%.	
Roof Construction	Tar/gravel, wood deck, airspace, gypboard.	DOE2 shingles, wood deck, airspace, gypboard.
Ceiling Construction	Insulation and acoustic tile	As surveyed.
Wall Height	8' conditioned 2' unconditioned	As surveyed.
Wall Construction	Surveyed as mix of light and heavy types.	DOE2 8" partially filled heavy concrete block with some insulation.
Wall Exposure	All exterior	As surveyed.
Internal Loads		
Connected Lighting	2.0 W/sf	As surveyed.
Occupied Equipment Load	Main: 0.2 W/sf. Offices: 1.5 W/sf	As surveyed.
Schedules	Equipment to 30% during unoccupied hours indicated on survey memo. Lights to 5%. Seven days, average 10 hrs/day.	As surveyed.
HVAC		
Type	DX constant volume	Small package unit.
Sizing	3 tons guessed. No nameplate.	4 tons for properly sized runs. 3 tons for undersized runs.
Heat Source	Not noted.	Heat pump assumed.
Reheat	No	None
Outside air	Constant @ 10%	As surveyed.
SAT Control	Usual PSZ.	Variable temperature to meet load.
Air Flow	375 cfm/ton.	As surveyed.
Schedule	Interview says continuous fans. 60F heating, 70°F cooling setpoints.	Monitored data shows intermittent fan and compressor operation.
Return	Unknown.	DOE-2.1 does not model return ducts.
Supply	Uninsulated ducts in ceiling space	Modeled duct heat gain of 3°F at design conditions, and duct leakage of 2%.

[2] All SDG&E tariffs are available at the following website: http://www.sdge.com/tariff/elec_commercial.shtml. Specific rate included in Appendix.

At this site, insulation is placed on the ceiling tiles, instead of the under the roof. Ductwork runs in the space between the roof and ceiling. This configuration has greater heat transfer than in buildings where the ducts run through an insulated space. The uncoated roof was monitored, then an initial coating applied, but not until August, near the end of the monitoring period. This was thought to be a thin coating because it did not appear very white.

Table 4. Calibrated Inputs

Characteristic	Default or Catalog Value	Calibrated Value
Insulating batt thermal resistance (R-value)	19 sf-F/Btuh	Not meaningful
Overall insulation layer thermal resistance (R-value)	Not determined.	9 sf-F/Btuh
Original roof surface solar absorptance	80%	75%
Initial installed white roof surface solar *absorptance* (APOC 252 Ultra-white elastomeric acrylic)	19%	50%
Re-coated Initial white roof surface solar *absorptance* (APOC 252 Ultra-white elastomeric acrylic)	19%	30% (estimate from catalog.)

The measured heat fluxes at this site are much greater than in a more conventional construction. This is illustrated in Figure 11. The greater scatter is due to the mass of the gravel and the thermal lags associated with the air cavity between the roof deck and the sheet rock surface, where the heat flux transducer is located. The greater heat flux is due to the decreased overall insulating value of the roof and ceiling, despite the thick batts laid over the hung ceiling.

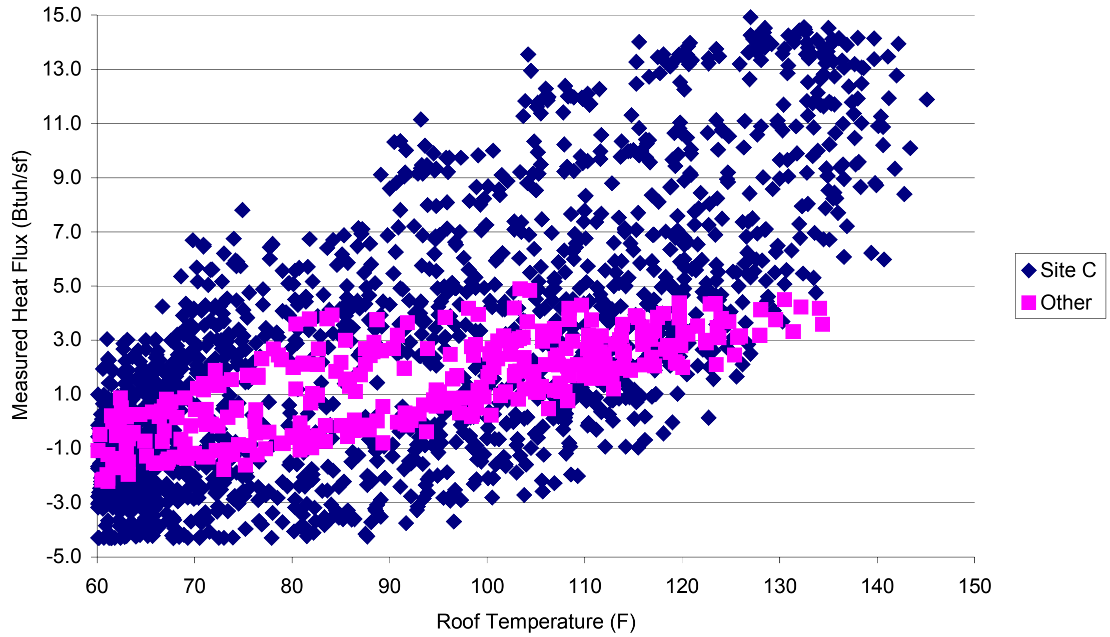

Figure 11. Measured Heat Flux vs. Roof Temperature for Uncoated Roofs

Because of the configuration of the roof and ceiling spaces, it was difficult to calibrate the effective thermal resistance using monitored heat fluxes. The configuration is pictured in Figure 4 and diagrammed in Figure 1. As mentioned previously, the heat flux sensor was attached to the roof sheet rock, separated from the roof deck by an air cavity. Directly below the sheet rock is an unconditioned airspace. Since the airspace contained ductwork and communicated with other spaces, this cannot be simulated precisely in the DOE-2.x family of simulation programs. Also, the monitored heat flux data is not a very linear function of roof temperature due to the thermal lag through the airspace and the variable temperature in the airspace so cannot be compared directly to the simulated heat flux. Because of these difficulties, calibration was accomplished by examining roof temperature response, as shown in the following figures.

Figure 12 shows the comparison between the simulated and measured roof temperature rise prior to roof coating. The simulation predicts a somewhat higher temperature rise than observed with the intermediate asphalt roof. The original roof has greater scatter due to the thermal lag effect of the gravel.

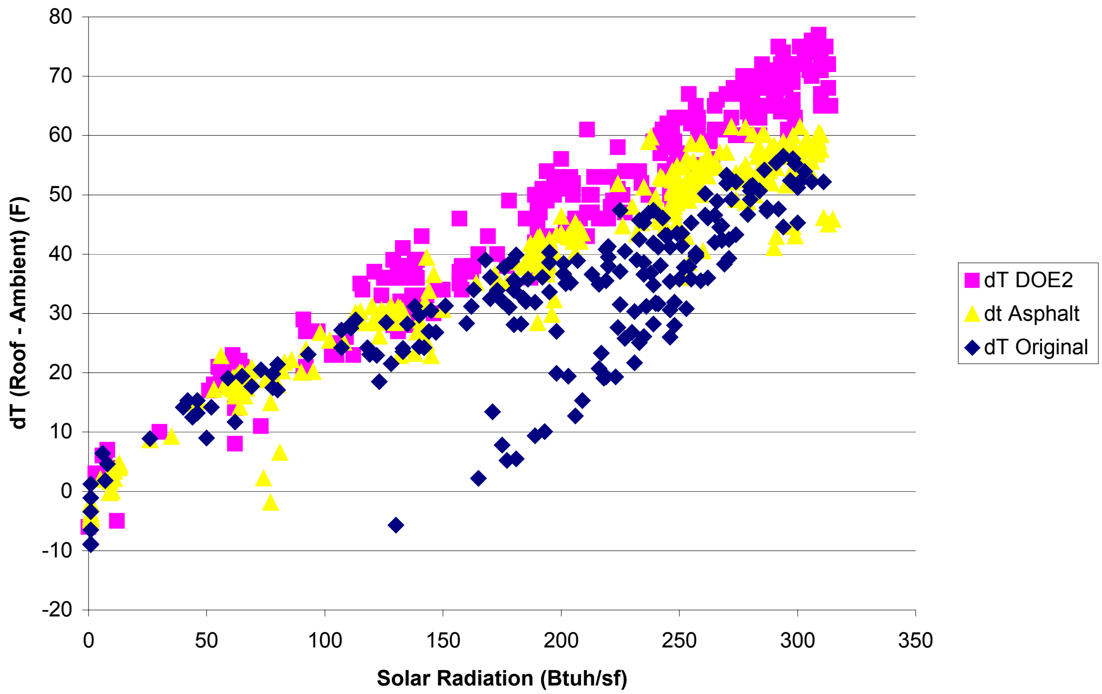

Figure 12. Roof Temperature as a Function of Solar Radiation for the Original Roof and the New Asphalt Roof Before the White Coating

Figure 13 shows the comparison between the simulated and measured roof temperature rise with the cool roof coating. The simulation predicts a slightly lower temperature rise than observed at low insolation levels, and very close agreement at high insolation levels.

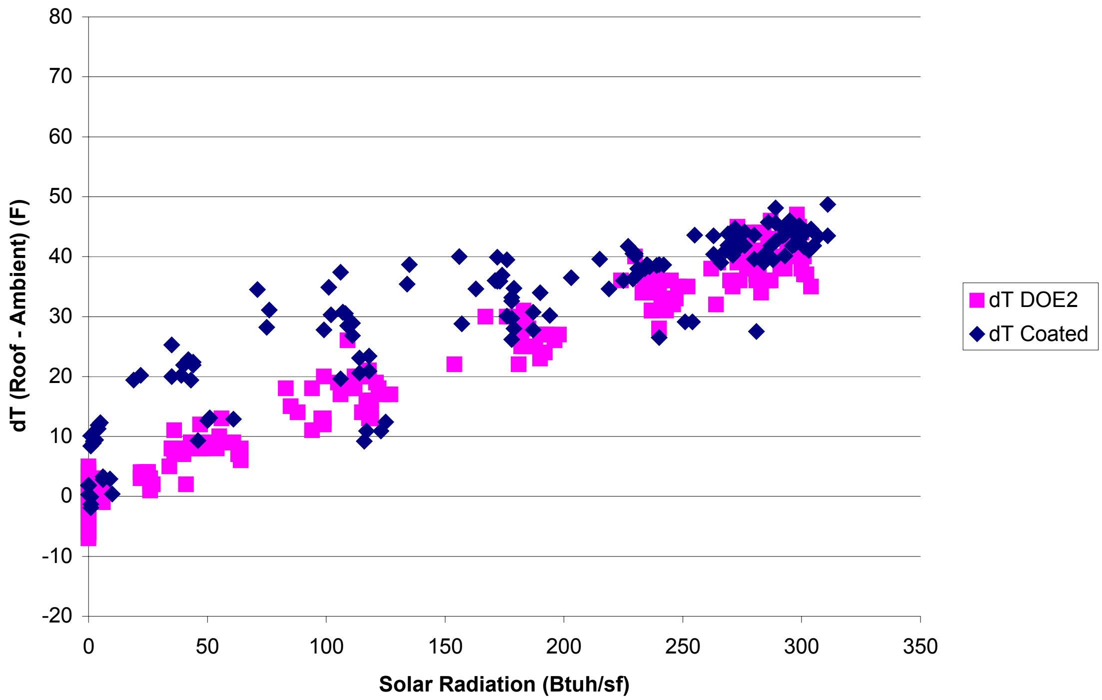

Figure 13. Roof Temperature as a Function of Solar Radiation for the White Coated Roof. Simulated Values for 50% Roof Solar Absorptance.

4.3 Simulation Model Results

Using the initial assumptions listed in Table 3 and the calibrated inputs shown in Table 4, the simulation produced the results listed in the following tables, showing the impact on the HVAC system. Results are normalized in these tables per 1,000 sf, to facilitate comparison with the other sites.

4.3.1 Case 1: As-Observed Model

Simulated savings from the cool roof coating are projected to be 0.624 kWh/sf, or on a dollar basis, $0.10/sf of roof per year. This corresponds to about $110/year for the entire building. Detailed simulated savings are presented in Table 5.

The savings during August are less than three percent. This can be compared to the plot shown in Figure 10, which shows the daily HVAC energy consumption versus daily ambient temperature. The average daily temperature in August is about 71°F. It would be difficult to detect a three percent reduction in energy consumption in this graph, considering that the variation in daily energy consumption at this temperature is about 75 kWh/day, plus or minus 15 kWh, a 20 percent variation.

Table 5. Monthly HVAC Energy Impacts with 50% Roof Absorptance – Observed HVAC Capacity

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 sf			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	1,311	1,276	-35	-2.7%	$192	$187	($5)	-2.6%
Feb	1,187	1,148	-40	-3.4%	$175	$169	($6)	-3.4%
Mar	1,385	1,330	-55	-4.0%	$204	$195	($9)	-4.4%
Apr	1,456	1,393	-63	-4.3%	$214	$205	($9)	-4.2%
May	1,585	1,518	-67	-4.2%	$279	$267	($12)	-4.3%
Jun	1,755	1,691	-64	-3.6%	$309	$298	($11)	-3.6%
Jul	2,126	2,060	-66	-3.1%	$374	$362	($12)	-3.2%
Aug	2,119	2,058	-61	-2.9%	$373	$362	($11)	-2.9%
Sep	1,948	1,895	-52	-2.7%	$343	$333	($10)	-2.9%
Oct	1,720	1,671	-50	-2.9%	$252	$246	($7)	-2.8%
Nov	1,373	1,333	-40	-2.9%	$202	$196	($6)	-3.0%
Dec	1,276	1,245	-31	-2.4%	$187	$183	($5)	-2.7%
Annual	19,243	18,618	-624	-3.2%	$3,103	$3,003	($100)	-3.2%

4.3.2 Case 2: As-Observed Model with Increased HVAC Cooling Capacity

Using the observed cool roof coating but with increased HVAC cooling capacity, the projected savings are 0.94 kWh/sf, or on a dollar basis, $0.15/sf of roof per year. This corresponds to about $160/year for the entire building. Detailed simulated savings are presented in Table 6.

Table 6. Monthly HVAC Energy Impacts with 50% Roof Absorptance – Increased HVAC Capacity

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 sf			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	1,374	1,333	-41	-3.1%	$202	$196	($6)	-3.1%
Feb	1,240	1,188	-51	-4.3%	$183	$175	($8)	-4.6%
Mar	1,464	1,389	-75	-5.4%	$216	$204	($12)	-5.9%
Apr	1,557	1,468	-89	-6.1%	$229	$216	($14)	-6.5%
May	1,701	1,607	-94	-5.8%	$299	$283	($17)	-6.0%
Jun	1,907	1,809	-98	-5.4%	$336	$318	($17)	-5.3%
Jul	2,376	2,256	-119	-5.3%	$418	$397	($21)	-5.3%
Aug	2,364	2,253	-111	-4.9%	$416	$396	($19)	-4.8%
Sep	2,144	2,052	-91	-4.4%	$378	$361	($17)	-4.7%
Oct	1,854	1,778	-77	-4.3%	$273	$261	($12)	-4.6%
Nov	1,440	1,385	-54	-3.9%	$212	$204	($8)	-3.9%
Dec	1,322	1,283	-39	-3.0%	$194	$188	($6)	-3.2%
Annual	20,743	19,803	-940	-4.7%	$3,354	$3,199	($155)	-4.8%

4.3.3 Case 3: As-Observed Model with Increased HVAC Cooling Capacity and Reduced Roof Solar Absorptance

Using the observed cool roof coating but with increased HVAC cooling capacity and an assumed roof absorptance closer to what has been observed on other cool roofs, the projected savings are 1.70 kWh/sf, or on a dollar basis, $0.285/sf of roof per year. This corresponds to about $300/year for the entire building. Detailed simulated savings are presented in Table 7.

Table 7. Monthly HVAC Energy Impacts with 30% Roof Absorptance – Increased HVAC Capacity

	Energy Use (kWh/ 1,000 sf)				Energy Cost $/1,000 sf			
	Original	Coated	Change kWh/1,000 sf	Change (percent)	Original	Coated	Change $/1,000 sf	Change (percent)
Jan	1,374	1,297	-77	-5.9%	$202	$190	($12)	-6.3%
Feb	1,240	1,145	-95	-8.3%	$183	$168	($15)	-8.9%
Mar	1,464	1,326	-138	-10.4%	$216	$195	($20)	-10.3%
Apr	1,557	1,392	-165	-11.9%	$229	$205	($24)	-11.7%
May	1,701	1,527	-174	-11.4%	$299	$269	($30)	-11.2%
Jun	1,907	1,725	-182	-10.6%	$336	$304	($32)	-10.5%
Jul	2,376	2,153	-222	-10.3%	$418	$379	($40)	-10.6%
Aug	2,364	2,158	-206	-9.5%	$416	$380	($36)	-9.5%
Sep	2,144	1,975	-169	-8.6%	$378	$348	($30)	-8.6%
Oct	1,854	1,714	-141	-8.2%	$273	$251	($21)	-8.4%
Nov	1,440	1,342	-98	-7.3%	$212	$197	($15)	-7.6%
Dec	1,322	1,250	-72	-5.8%	$194	$183	($11)	-6.0%
Ann	20,743	19,005	-1,738	-9.1%	$3,354	$3,069	($285)	-9.3%

4.4 Cost / Benefit Analysis

To determine the value of applying a cool roof coating, the costs of applying the coating should be compared to the benefits. For this analysis, the dollar benefits will be limited to the energy savings, although there may be other considerations that would affect a decision to apply a roof coating.

Costs for replacing the roof and applying the roof coating were provided by the roofing contractor. The roof replacement and coating total cost was $2.95/sf. The cost of the coating was $0.45/sf, which was the cost used for performing the cost benefit analysis. This was a relatively small roof, and so the unit costs were higher than those for a larger roof. For a larger roof, the coating could be applied for $0.30/sf.

The Case 1 savings values (as observed) are used for the cost / benefit analysis.

Using the actual installation costs, and the cost savings attributable to reduced energy consumption, the simple payback is shown in Table 8. The payback for the coating is less than five years, which may be a suitable payback period. Simple payback analysis results in the shortest payback possible; it assumes no time-value of money. If a present value analysis was used, the payback periods would increase.

Table 8. Payback Analysis

Description	Cost ($/sf)	Energy Savings ($/sf)	Simple Payback (years)
Cost includes • Roof Preparation • Coating and Coating Labor	$0.45	$0.10	4.5

This site had a reasonable payback because of the relatively low cost of the coating, and the effectiveness of the coating in reducing the energy consumption of the site. The coating was effective because of the reduced insulating characteristics of the roof. If the cooling capacity of the HVAC system had been greater, the savings would have increased, and the payback period would have been even less.

There are other non-energy considerations that may make a cool roof coating a good investment. One consideration is extended roof life. Although there can often be a substantial reduction in diurnal roof temperature swing, this was not a noticeable effect at this site, as shown in Figure 14. This plot shows the daily roof temperature swing as a function of daily solar radiation. There is little improvement with the cool roof coating. Figure 15 shows the daily maximum roof temperature rise as a function of daily solar insolation. The asphalt roof temperatures are greater than the original gravel roof. The coating reduced the maximum roof temperature by about 15°F as compared to the asphalt roof, but only about 5°F as compared to the original gravel roof.

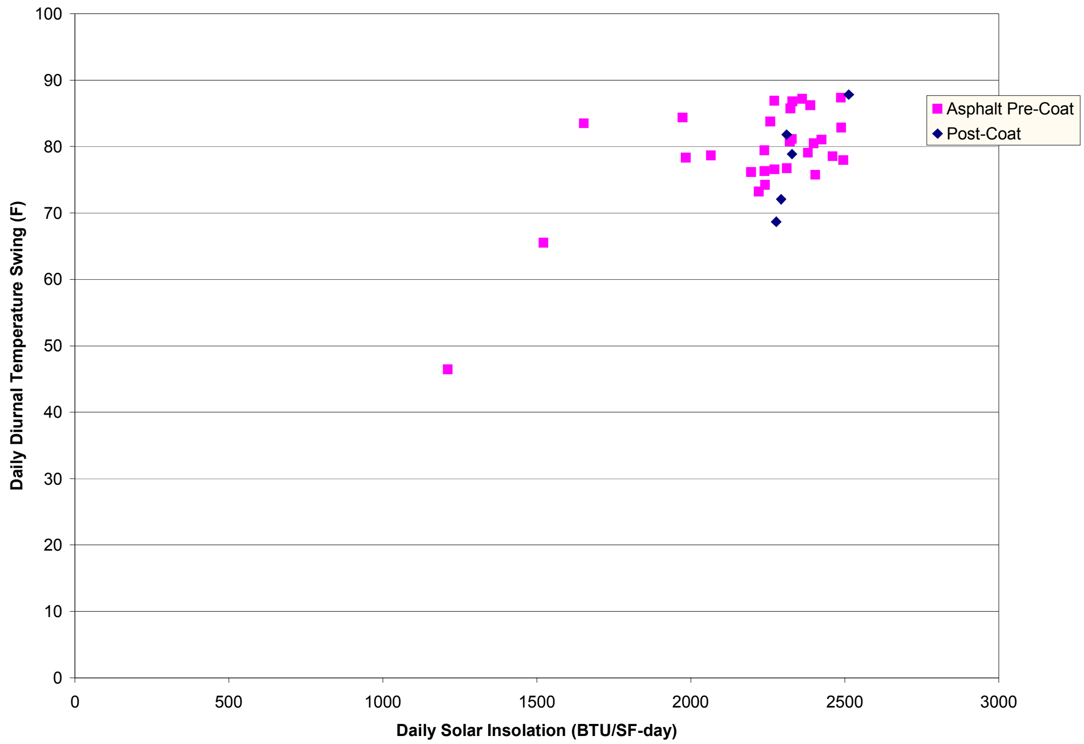

Figure 14. Diurnal Temperature Swing

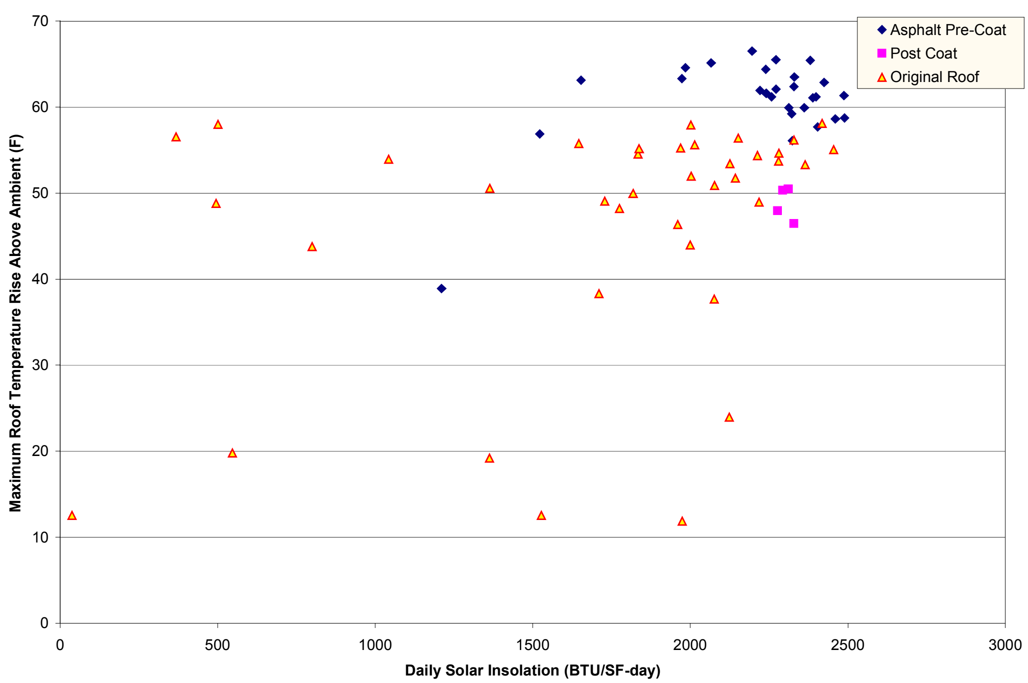

Figure 15. Daily Maximum Roof Temperature Rise (°F)

5.0 Conclusions

The cool roof coating reduced the cooling requirements and reduced the energy consumption at the facility. Its impact was relatively high, mainly because the insulation effectiveness of the roof structure and insulation was low. The heat transfer through the roof is directly related to the difference between the roof and indoor temperatures. By reducing the roof temperatures the energy consumption of the building is reduced.

The effectiveness of the coating was reduced because the cooling capacity of the HVAC unit was such that the unit ran continuously from noon until 6 pm during the hottest days of the monitoring period, indicating that the load in the building may be greater than can be met by the unit. If the HVAC unit capacity had been greater, the effectiveness of the coating in reducing energy consumption would have been increased.

Because of the low roof insulation value and the low cost of the coating, the simple payback period at this site is less than five years, which may be a good investment.

The effectiveness of the cool roof coating in reducing roof temperatures was not as great as has been observed at other roofs. The cause of this is unclear, as the published initial solar reflectance of the coating is 0.81, which is similar to other products. Further study of this may be warranted.

Energy should not be the only consideration for applying a cool roof coating. Effects on roof lifetime should be investigated, and should be included in any roof coating cost / benefit analysis.

Appendix A: Daily Data Summary

Date	Daily Solar Insolation	Average Amb Temp	Max Amb Temp	Min Amb Temp	Average Roof T 1	Max Roof T 1	Min Roof T 1	Average Roof T 2	Max Roof T 2	Min Roof T 2	Average Drywall Temp	Max Drywall Temp	Min Drywall Temp	Average Airspace Temp	Max Airspace Temp	Min Airspace Temp	Average Tile-Insul Tmp
	BTU/SF	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
2/6/2002	4.867237	50.777	57.134	45.122	47.725	57.692	39.842	47.653	56.816	40.088	69.352	78.74	60.188	71.751	79.016	63.644	74.378
2/7/2002	1528.716	52.16125	67.844	38.378	56.7065	102.128	29.618	55.613	99.998	30.212	63.0145	84.326	45.29	64.6355	79.838	49.772	71.6795
2/8/2002	1454.668	53.8785	68.24	42.398	60.45025	105.032	36.902	59.51375	102.95	37.316	64.44875	85.13	50.072	65.2875	79.586	53.792	70.55475
2/9/2002	1558.105	61.391	82.838	46.232	65.00525	116.858	38.51	63.7615	114.488	38.606	67.408	93.05	50.378	67.9015	87.722	53.756	71.9595
2/10/2002	1609.828	61.30625	80.252	44.552	62.2765	115.826	33.356	60.8405	112.25	33.794	66.684	90.896	48.542	67.72575	86.198	53.018	72.5995
2/11/2002	1618.295	61.29575	82.976	43.214	63.7895	121.094	31.682	62.333	118.652	31.898	67.82325	93.662	47.846	68.765	86.654	52.412	73.2605
2/12/2002	1576.856	59.0635	75.29	44.75	63.0795	111.62	35.636	61.76925	109.256	35.762	67.6155	89.696	50.486	68.60975	84.416	54.638	73.3155
2/13/2002	1259.134	57.54375	75.728	45.404	62.388	100.256	36.86	61.88	99.362	37.094	66.9295	85.43	52.646	67.97125	80.894	56.906	71.41575
2/14/2002	1274.8	55.8175	65.9	47.534	64.158	100.982	43.304	63.706	100.232	43.484	68.27775	85.058	57.728	68.9105	80.972	60.434	72.11625
2/15/2002	1387.871	56.28525	71.426	45.134	63.13875	106.364	39.2	62.40825	105.188	39.296	67.183	86.852	52.766	67.8685	82.022	56.318	71.53925
2/16/2002	1022.6	55.22275	64.334	50.546	63.90025	95.882	48.446	63.7765	94.448	49.028	67.97725	83.678	59.474	68.9845	80.576	62.348	72.158
2/17/2002	442.0899	52.43675	56.486	46.904	54.04125	64.226	41.834	54.29775	64.628	42.2	63.6065	70.652	58.622	65.86075	72.368	61.634	72.3605
2/18/2002	1168.837	50.11	58.298	42.782	51.80075	76.238	37.166	51.35	74.468	37.586	62.4475	73.79	55.19	65.43475	74.588	59.966	74.0415
2/19/2002	1598.64	52.4685	64.856	41.456	59.86225	104.18	36.17	58.52125	100.106	36.518	65.94075	85.004	53.852	67.574	82.226	57.752	74.63425
2/20/2002	1633.167	56.385	71.432	43.43	64.97	113.264	38.126	63.762	111.62	38.198	68.255	90.524	51.128	69.05425	86.12	54.836	73.36025
2/21/2002	1687.231	70.13625	91.826	47.738	73.17975	121.874	41.18	71.62975	118.808	41.132	72.71925	95.966	53.75	72.4105	87.68	57.314	74.00125
2/22/2002	1738.489	72.6375	95.102	54.752	75.99875	134.096	45.662	74.6865	131.222	45.77	76.696	101.762	58.496	76.2915	92.972	61.982	76.05525
2/23/2002	1475.726	60.04925	73.97	50.666	66.73975	110.768	42.188	66.63675	110.222	42.656	70.76775	89.876	56.618	71.72125	84.344	60.518	74.52075
2/24/2002	1722.501	60.02475	71.366	49.22	70.724	113.828	45.2	69.62075	112.052	45.404	73.27325	92.348	59.216	73.50975	87.164	62.414	75.65275
2/25/2002	1731.678	61.8575	80.306	45.614	69.438	121.7	38.186	68.3035	120.182	38.462	72.0705	96.362	53.408	72.48825	90.362	57.404	75.3135
2/26/2002	1749.001	66.4095	87.878	47.384	71.78075	126.464	36.968	70.631	124.046	37.25	73.18625	97.892	52.784	73.28375	90.986	57.08	75.485
2/27/2002	1430.408	62.2765	79.574	50.09	68.69975	113.234	41.624	68.2895	113.024	42.176	71.705	89.198	56.222	72.2885	85.358	60.146	74.70675
2/28/2002	1422.905	56.11275	62.522	51.926	68.913	106.22	54.092	68.87875	105.686	54.278	71.4185	87.068	63.026	71.5395	81.872	65.156	72.875
3/1/2002	1517.41	58.796	70.316	53.378	69.066	109.928	49.958	68.25425	107.498	50.384	70.75325	90.284	59.888	70.758	85.196	61.652	71.9385
3/2/2002	1782.742	60.23625	74.012	48.458	68.67625	118.562	41.468	67.5105	114.962	41.948	71.537	96.596	54.056	71.975	91.76	57.59	74.59475
3/3/2002	1895.989	56.028	71.294	37.196	60.997	114.536	23.09	59.95225	112.004	23.774	66.50825	90.524	44.21	67.567	84.578	49.568	73.1675
3/4/2002	1924.339	57.5465	80.576	38.822	61.50125	121.79	24.626	60.4105	119.15	25.034	66.307	94.124	43.418	67.26075	87.326	48.572	72.5835
3/5/2002	1806.3	55.9825	71.654	41.192	63.378	115.154	29.918	62.60875	113.366	30.974	67.48725	92.558	47.888	68.37675	86.006	52.31	73.1235
3/6/2002	1324.892	56.47725	69.83	44.762	64.34675	106.736	39.218	64.175	106.766	39.644	68.0435	86.726	52.52	69.031	82.604	56.156	72.8995
3/7/2002	507.3243	56.27625	59.714	52.886	58.13525	66.89	49.472	58.49175	67.808	49.676	66.48125	72.29	61.562	68.32325	73.628	63.98	72.95125
3/8/2002	1613.166	54.188	61.46	47.342	61.55775	98.054	41.918	60.97275	96.842	41.924	67.17225	84.134	57.662	68.76225	82.586	60.146	73.064
3/9/2002	1903.07	59.22125	76.802	41.948	67.40525	121.646	33.692	66.29475	119.834	33.608	69.189	94.376	49.178	69.50125	88.226	53.252	73.489
3/10/2002	1938.823	59.40725	72.218	47.66	68.2695	115.514	39.578	67.2015	112.544	39.926	71.3445	94.646	53.81	71.93375	90.332	57.578	75.26525
3/11/2002	1914.385	60.552	77.192	47.342	70.68275	125.642	38.786	69.76675	124.55	39.44	72.70575	96.92	52.91	72.9115	89.366	56.93	75.29875
3/12/2002	1886.703	59.30075	69.404	49.856	73.88625	114.542	49.052	73.103	112.814	49.184	74.9825	93.818	61.43	74.8235	87.188	64.406	75.6335
3/13/2002	957.9654	57.19125	64.316	50.024	63.81225	92.936	41.768	63.9385	92.456	42.26	70.15075	81.878	60.26	71.25825	80.378	63.386	73.748
3/14/2002	1937.378	51.442	60.002	41.264	56.97175	96.284	30.902	55.95775	93.248	30.998	63.23825	82.052	47.06	64.64975	77.57	51.506	70.93525
3/15/2002	1929.95	52.51425	62.852	42.62	62.16725	106.328	35.42	61.45625	104.72	36.26	66.11925	87.5	48.668	66.99825	82.598	52.544	71.806
3/16/2002	1605.409	51.19375	57.392	45.8	54.87025	80.102	40.988	54.13925	78.02	41.228	62.325	75.392	52.976	64.41925	75.494	56.156	71.321
3/17/2002	1897.401	52.7545	59.864	46.604	63.9045	104.408	41.03	62.843	102.11	40.868	67.00675	87.56	52.76	67.68675	84.2	55.958	71.99525

Date	Daily Solar Insolation	Average Amb Temp	Max Amb Temp	Min Amb Temp	Average Roof T 1	Max Roof T 1	Min Roof T 1	Average Roof T 2	Max Roof T 2	Min Roof T 2	Average Drywall Temp	Max Drywall Temp	Min Drywall Temp	Average Airspace Temp	Max Airspace Temp	Min Airspace Temp	Average Tile-Insul Tmp
	BTU/SF	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
3/19/2002	2123.668	56.19025	66.03775	70.892	41.594	121.562	32.336	64.7995	120.146	32.552	67.6355	92.426	46.502	67.6945	85.574	50.612	71.55275
3/20/2002	2142.722	62.393	72.0435	79.928	46.952	127.508	37.544	70.89675	126.782	37.91	72.721	98.27	51.692	72.555	91.43	55.616	74.3955
3/21/2002	1818.578	63.107	71.8745	81.296	47.642	124.436	38.66	71.5495	122.534	39.392	73.131	96.098	54.014	73.031	87.758	58.124	74.30175
3/22/2002	1999.9	57.13025	67.50525	70.13	45.32	120.278	35.996	66.504	117.896	36.608	71.91375	94.388	53.636	72.44875	88.742	57.926	75.009
3/23/2002	1363.585	56.606	65.85225	64.004	51.656	96.878	48.992	65.685	95.6	49.538	70.078	85.268	60.518	70.96625	81.872	63.248	74.09025
3/24/2002	1710.393	54.69525	63.561	61.088	48.884	97.718	43.496	62.7645	95.27	43.916	68.2805	83.816	58.58	69.27825	81.128	61.364	73.4725
3/25/2002	2075.874	55.93925	68.43975	68.198	43.772	118.004	37.55	67.3745	115.934	37.862	70.63825	94.244	51.206	70.92425	87.842	54.968	74.0215
3/26/2002	2002.697	57.722	69.24975	70.55	47.132	117.212	40.148	68.469	116.012	40.706	72.1225	94.604	53.804	72.48175	88.55	57.62	75.1045
3/27/2002	494.2774	54.18625	58.71925	58.064	48.104	75.482	41.96	59.0675	75.392	42.53	66.1165	74.246	58.298	68.1175	75.068	61.808	73.0455
3/28/2002	546.5327	55.01475	60.9445	58.34	51.32	73.994	50.054	61.25	74.138	50.204	66.81925	73.712	60.134	68.07025	74.132	62.498	72.0695
3/29/2002	1362.428	56.4935	66.8775	65.822	48.626	111.686	43.91	66.82	110.876	44.096	70.214	88.1	57.368	70.751	83.222	60.176	73.2045
3/30/2002	1728.391	58.00225	73.6375	69.686	52.01	122.336	54.344	73.43275	122.09	54.698	73.81375	97.052	62.324	73.37625	91.148	64.52	73.50775
3/31/2002	1969.454	59.34925	76.08075	71.438	53.576	125.582	55.094	75.76875	125.24	55.112	74.006	93.842	63.284	72.94575	86.306	65.372	72.9655
4/1/2002	2013.901	59.1075	76.73175	70.004	53.132	123.752	55.298	76.66225	123.086	55.718	75.646	95.648	63.014	74.71775	87.824	64.964	73.546
4/2/2002	1834.27	57.95925	74.76225	66.404	54.152	120.74	56.03	74.59825	119.834	56.354	75.72075	94.85	64.262	75.36375	87.374	66.398	74.43225
4/3/2002	1646.451	57.33375	72.388	64.754	53.438	114.296	55.304	72.1855	113.486	55.616	73.811	90.782	63.614	73.61975	84.152	65.654	73.834
4/4/2002	2076.905	58.563	74.26025	67.772	52.478	119.558	49.28	74.00375	118.706	50.126	74.9765	94.802	63.638	74.2365	87.548	65.78	74.12025
4/5/2002	1042.542	55.74475	62.88	66.926	47.054	106.166	39.428	63.15625	105.38	40.148	67.21	83.804	55.196	68.16275	80.762	58.958	71.6045
4/6/2002	799.6794	55.74075	58.61825	59.93	51.782	69.338	46.586	58.48225	69.056	46.562	66.0815	72.752	59.558	68.04025	74.462	62.582	72.55875
4/7/2002	1527.144	57.84957	69.71365	64.256	53.342	107.822	50.678	69.40348	107.066	50.912	70.50383	88.634	59.426	70.92617	86.132	61.964	73.26487
4/8/2002	1959.973	60.4345	77.1545	68.756	55.346	122.708	56.198	77.1585	123.158	56.498	76.19825	96.656	63.626	75.355	90.416	65.744	74.41575
4/9/2002	2152.533	61.56525	77.4185	71.318	55.298	122.012	53.222	76.89825	121.406	53.798	77.27	96.086	65.912	76.31875	90.218	67.958	75.1895
4/10/2002	2125.797	60.8865	78.763	72.062	53.798	122.198	54.962	78.5715	120.152	55.652	77.14525	97.388	64.148	76.05725	89.648	66.434	74.74
4/11/2002	2279.571	61.6585	80.18175	71.114	55.124	123.92	57.374	79.7005	123.518	57.83	78.419	98.36	65.786	76.87025	89.246	67.958	74.835
4/12/2002	1837.414	59.944	77.1705	66.758	55.082	117.362	57.536	77.2515	117.65	57.908	77.23725	95.654	65.564	76.60775	89.312	67.67	75.18675
4/13/2002	2213.044	62.8565	81.3095	76.802	55.514	132.884	52.934	81.29325	133.73	53.504	79.74475	101.618	65.948	78.27275	93.596	68.168	76.19025
4/14/2002	2002.054	59.618	76.42025	70.928	53.714	126.302	47.846	76.71275	126.41	48.53	75.18825	96.416	61.742	74.1205	90.074	65.102	73.77025
4/15/2002	501.0037	55.449	58.2185	57.044	53.816	66.734	53.042	58.91225	67.712	53.492	66.66125	72.416	61.472	68.7165	74.138	63.26	72.6715
4/16/2002	1974.879	56.658	67.88125	62.858	49.616	107.822	42.494	67.55275	106.76	42.83	69.60075	87.722	55.136	70.14925	82.79	58.526	72.95775
4/17/2002	1775.365	57.23	69.29325	64.742	52.874	111.266	49.922	69.21625	110.18	50.474	71.06875	87.836	62.318	71.23275	82.658	64.52	72.7645
4/18/2002	2217.953	56.805	71.477	65.222	48.632	115.13	43.178	70.954	114.554	43.622	72.4685	93.374	56.288	72.233	86.81	59.546	73.7525
4/19/2002	2280.645	56.305	69.3705	65.294	47.984	116.072	40.526	68.8445	115.514	40.946	71.787	92.954	54.104	71.717	86.492	57.674	73.725
4/20/2002	2328.81	57.4825	72.07675	68.096	48.596	123.638	40.904	72.04825	123.53	41.696	72.593	96.974	54.92	72.1555	88.7	58.358	73.77675
4/21/2002	2418.363	60.13325	73.58125	74.708	46.046	128.606	36.602	72.41	126.722	36.98	73.68075	100.31	51.962	73.28875	92.942	56.072	75.05075
4/22/2002	2454.512	64.84225	78.0765	79.478	50.372	130.868	39.986	76.91075	129.362	40.232	77.4865	103.04	54.908	76.71175	95.258	58.898	76.62625
4/23/2002	2364.705	64.9475	80.154	80.642	54.014	135.782	48.554	79.32475	134.528	48.932	78.599	102.224	60.716	77.2485	92.192	64.052	75.9535
4/24/2002	359.3047	56.4944	57.0012	62.132	53.24	71.168	48.14	57.2472	71.282	48.494	65.1512	70.682	60.416	67.7724	72.536	63.662	73.6588

Date	Daily Solar Insolation	Average Amb Temp	Max Amb Temp	Min Amb Temp	Average Roof T 1	Max Roof T 1	Min Roof T 1	Average Roof T 2	Max Roof T 2	Min Roof T 2	Average Drywall Temp	Max Drywall Temp	Min Drywall Temp	Average Airspace Temp	Max Airspace Temp	Min Airspace Temp	Average Tile-Insul Tmp
	BTU/SF	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
7/9/02	211.0655	72.69971	79.094	66.896	77.96171	109.67	62.57	78.476	110.144	62.672	91.74114	114.722	72.86	88.53714	106.562	72.914	75.93886
7/10/02	1210.817	70.27375	78.38	64.31	79.811	104.978	58.832	79.7315	105.446	58.766	79.55975	96.128	64.37	78.2555	92.372	65.444	74.179
7/11/02	1522.277	71.72925	82.028	63.824	84.46125	125.306	60.476	84.92275	126.758	60.566	83.06125	107.924	66.56	81.05575	100.508	67.844	75.1745
7/12/02	1973.493	72.80525	85.25	64.232	87.88025	142.652	58.436	88.15575	142.754	58.238	86.104	122.162	63.554	83.69925	112.94	64.778	76.052
7/13/02	2460.613	72.838	86.054	62.792	91.12925	137.72	59.51	91.19625	138.278	59.408	89.595	123.194	67.244	86.5075	112.79	68.804	77.37675
7/14/02	2381.267	71.09625	83.99	63.158	90.02825	137.666	59.096	90.4475	138.638	59.114	87.193	122.168	66.26	83.75125	111.644	67.172	74.015
7/15/02	1983.904	69.312	79.604	61.784	85.04875	134.384	57.134	85.08425	136.61	57.206	83.8005	113.882	63.056	81.257	104.726	64.34	72.929
7/16/02	2404.26	69.48275	79.73	61.322	87.772	131.912	56.816	88.19375	133.316	56.912	86.57125	119.66	63.836	83.75025	109.58	65.24	74.2015
7/17/02	2312.307	69.8365	81.14	62.498	89.50125	134.882	58.46	89.78125	135.578	58.604	88.164	120.788	67.994	85.1635	110.54	69.398	75.43425
7/18/02	2272.219	69.7365	80.084	63.164	88.6755	136.628	60.272	88.90975	137.12	60.356	87.0165	120.398	66.626	83.94875	110.09	67.496	73.765
7/19/02	2241.157	68.185	78.356	61.976	86.373	134.396	60.074	86.7995	134.222	60.14	85.56825	119.732	67.352	82.897	109.502	68.192	73.6175
7/20/02	2066.165	66.07525	76.988	60.278	83.35775	134.264	55.916	83.55875	135.08	56.126	82.993	118.022	65.462	80.518	107.984	66.254	72.677
7/21/02	2239.476	66.865	76.742	60.944	85.3455	135.104	55.478	85.441	134.816	55.58	84.26925	119.204	65.054	81.64925	109.28	66.368	73.6785
7/22/02	2321.754	68.9945	80.84	58.916	86.19725	132.956	52.1	85.946	132.896	52.22	85.0075	118.082	61.436	82.3555	108.242	63.398	74.727
7/23/02	2362.145	72.48225	85.778	60.44	89.894	139.49	52.466	89.646	139.88	52.544	88.50475	122.432	63.902	85.6975	112.028	65.912	77.158
7/24/02	2324.323	78.3325	90.956	65.27	95.68725	145.148	59.474	95.423	145.136	59.36	91.603	124.046	66.302	88.302	113.996	67.772	77.2695
7/25/02	2489.099	75.8125	89.282	64.874	92.995	140.264	57.878	92.9125	141.206	57.92	90.665	124.886	66.122	87.66225	114.662	67.958	77.2585
7/26/02	2425.073	70.4535	80.486	62.726	89.438	138.446	58.466	90.06075	140.576	58.502	88.71625	121.58	68.192	85.94525	111.662	69.872	76.04825
7/27/02	2196.304	66.893	76.232	61.634	85.62975	134.786	59.276	86.07125	136.232	59.492	85.24125	117.914	66.782	82.68325	108.218	67.688	74.6555
7/28/02	2399.173	69.18075	80.036	60.842	88.97225	135.512	55.34	88.92325	136.532	55.7	87.6555	119.06	67.628	84.85875	108.878	68.726	77.214
7/29/02	2487.907	68.33575	81.482	56.51	85.5795	136.688	49.562	85.14975	136.472	48.908	85.6155	120.686	60.824	83.1535	110.18	63.32	76.33475
7/30/02	2258.328	68.27875	79.346	59.612	84.9735	134.762	51.5	85.274	135.71	51.512	84.415	117.884	61.292	81.9545	108.236	63.206	74.2435
7/31/02	1653.481	68.849	83.312	60.014	81.5025	137.894	54.29	81.55	137.81	54.428	81.28825	115.4	62.048	79.43925	106.1	63.764	73.73475
8/1/02	2239.949	70.09875	81.302	62.762	90.2685	138.428	62.774	90.5405	139.676	62.732	87.58975	121.16	67.466	84.522	110.528	68.114	74.5995
8/2/02	2221.029	70.08175	80.414	63.944	89.573	137.57	64.688	89.86825	138.092	64.556	87.9315	121.166	68.846	85.12775	111.14	69.608	75.4495
8/3/02	2328.598	69.62575	79.058	61.442	88.21775	136.694	56.018	88.4275	137.732	56.144	86.95	119.978	68.108	83.91075	109.76	69.302	74.325
8/4/02	2330.263	69.8695	83.906	59.942	87.2635	139.526	53.084	87.38675	140.426	53.276	85.16825	120.368	62.672	82.3885	109.964	64.454	74.421
8/5/02	2271.527	71.04425	83.486	61.814	87.93425	142.016	55.718	88.21525	143.378	55.91	87.03525	121.514	66.23	84.45	111.158	68.03	75.8495
8/6/02	2388.72	70.18075	83.468	60.098	86.4855	139.55	53.666	86.88525	140.126	53.618	85.1645	120.746	61.862	82.553	110.366	63.734	74.11025
8/7/02	2495.546	71.009	85.628	60.968	87.574	133.55	56.804	87.27575	135.986	56.822	85.50125	112.916	67.172	83.05475	104.474	68.57	76.1355
8/8/02	2513.629	71.99475	88.82	56.876	84.75325	135.266	46.46	83.58725	133.352	46.502	82.5725	113.384	58.802	80.7125	104.834	61.328	75.22825
8/9/02	2328.488	74.782	88.232	61.658	87.293	134.27	54.614	86.42475	132.32	54.254	85.224	113.096	64.568	83.202	104.678	66.65	77.111
8/10/02	2311.495	75.34175	90.368	62.408	88.45975	136.442	53.84	87.75375	134.666	53.684	84.96375	113.882	62.834	82.6025	105.116	64.652	75.62825
8/11/02	2293.311	71.419	84.362	62.69	85.58625	130.16	57.14	85.03725	128.348	57.254	83.9675	110.792	66.398	81.87125	102.362	68.342	75.92975
8/12/02	2277.34	70.8055	82.046	63.44	83.88667	127.184	58.082	83.69975	126.176	57.92	82.543	108.656	64.13	80.46875	100.682	65.63	74.1765
8/13/02		68.58188	80.954	61.724	82.652	126.62	57.266	82.172	124.67	57.32	82.08825	107.708	66.176	80.287	99.764	67.916	75.2525
8/14/02		68.93575	78.812	60.272	82.58	124.004	54.446	82.0395	122.114	54.434	82.008	106.694	65.18	80.231	98.978	66.992	75.84225
8/15/02		69.7605	79.748	62.3	83.584	124.208	56.678	83.13575	122.78	56.846	81.022	106.172	65.144	78.739	98.288	66.602	73.0915
8/16/02		69.67225	79.556	63.71	83.96825	123.392	63.788	83.53775	121.658	63.662	80.262	105.914	65.426	77.636	97.832	65.444	70.57725
8/17/02		69.16175	78.206	64.544	82.339	121.952	65.114	81.95125	120.206	64.952	80.04275	104.786	67.16	77.882	97.202	67.49	71.8305
8/18/02		65.5645	73.712	62.384	74.54575	113.99	63.23	74.299	112.394	63.122	74.957	93.794	67.022	73.8515	88.082	67.622	70.83575
8/19/02		66.0405	74.606	61.07	77.607	115.94	61.322	77.0645	113.684	61.352	76.4125	97.916	65.45	75.39775	91.832	65.9	71.478
8/20/02		68.9315	76.982	63.566	83.13325	122.648	64.778	82.75475	120.62	64.568	82.02575	105.788	69.11	79.7325	97.19	69.794	74.29025
8/21/02		69.67025	78.398	64.238	84.549	118.52	63.53	84.00925	117.098	63.458	82.5105	105.884	67.724	79.9075	97.298	68.486	73.31725
8/22/02		69.86	80.96	60.656	84.12675	123.074	55.988	83.48775	121.874	55.676	82.142	107.786	66.23	79.5685	98.786	67.172	72.98975
8/23/02		69.58974	86.588	58.136	82.50748	128.9	50.126	81.85087	127.442	50.042	80.74139	109.04	60.398	78.58478	100.04	62.918	73.63348

Appendix B: SDG&E Schedule A

SCHEDULE A

GENERAL SERVICE

APPLICABILITY

Applicable to general service including lighting, appliances, heating, and power, or any combination thereof, and to three-phase residential service, including common use. This schedule is not applicable for single-phase service to residential customers otherwise eligible for service under Schedule DR. This schedule is applicable for single-phase service for separately metered residential common use areas, provided that such common use facilities serve residential customers residing in detached homes located on separate premises. This schedule is not applicable to any customer whose Maximum Monthly Demand equals, exceeds, or is expected to equal or exceed 20 kW for 12 consecutive months. When demand metering is not available, the monthly consumption cannot equal or exceed 12,000 kWh per month for 12 consecutive months. This schedule is the utility's standard tariff for commercial customers with a demand less than 20 kW.

Non-profit group living facilities taking service under this schedule may be eligible for a 20% California Alternate Rates for Energy (CARE) discount on their bill, if such facilities qualify to receive service under the terms and conditions of Schedule E-LI.

Agricultural Employee Housing Facilities, as defined in Schedule E-LI, may qualify for a 20% CARE discount on the bill if all eligibility criteria set forth in Form 142-4032 is met.

TERRITORY

Within the entire territory served by the utility.

RATES

Description	Transm	Distr	PPP	ND	FTA	Restruc	CTC	RMR	UDC Total
Basic Service Fee ($/mo)		8.24							**8.24**
Energy Charge ($/kWh)									
Secondary – Summer	.00671	.04341	.00368	.00065	.01306	.00084	.00857	.00412	**.08104**
Primary – Summer	.00671	.03917	.00368	.00065	.01306	.00084	.00830	.00412	**.07653**
Secondary - Winter	.00671	.03472	.00368	.00065	.01306	.00084	.00857	.00412	**.07235**
Primary - Winter	.00671	.03133	.00368	.00065	.01306	.00084	.00830	.00412	**.06869**

Notes: Transmission Energy charges include the Transmission Revenue Balancing Account Adjustment (TRBAA) of ($.0007) per kWh, the Transmission Access Charge Balancing Account Adjustment (TACBAA) of $.00007 per kWh and a Supplemental Surcharge (SS) of $.00007 per kWh. Restructuring Implementation Rate is comprised of rates for Internally Managed Costs (IMC) and Externally Managed Costs (EMC). I

Minimum Charge
The minimum charge shall be the Basic Service Fee.

Rate Components
The Utility Distribution Company Total Rates (UDC Total) shown above are comprised of the following components (if applicable): (1) Transmission (Trans) Charges, (2) Distribution (Distr) Charges, (3) Public Purpose Program (PPP) Charges, (4) Nuclear Decommissioning (ND) Charge, (5) Trust Transfer Amount (TTA), sometimes referred to as Fixed Transition Amount (FTA), (6) Restructuring Implementation Rate (Restruc) which is the sum of the rates for Internally Managed Costs and Externally Managed Costs (7) Ongoing Competition Transition Charges (CTC), and (8) Reliability Must Run Generation Rates (RMR).

Utility Distribution Company (UDC) Total Rate shown above excludes any applicable commodity charges associated with Schedule EECC.

(Continued)

SCHEDULE A

Sheet 2

GENERAL SERVICE

RATES (Continued)

Fixed Transition Amount Adjustment
For residential and small commercial customers as defined in Rule 1 – Definitions, and as described in Public Utilities Code Section 331(h), the rates shown above will be adjusted in accordance with the rates set forth in Schedule FTA.

D

Time Periods
Summer: May 1 to September 30
Winter: October 1 to April 30

Franchise Fee Differential
Franchise fee differential of 1.9% will be applied to the monthly billings calculated under this schedule for all customers within the corporate limits of the City of San Diego. Such franchise fee differential shall be so indicated and added as a separate item to bills rendered to such customers.

SPECIAL CONDITIONS

1. Definitions: The Definitions of terms used in this schedule are found either herein or in Rule 1.

2. Voltage: Service under this schedule normally will be supplied at a standard available Voltage in accordance with Rule 2.

3. Voltage Regulators: Voltage Regulators, if required by the customer, shall be furnished, installed, owned, and maintained by the customer.

4. Reconnection Charge: In the event that a customer terminates service under this schedule and re-initiates service under this or any other schedule at the same location within 12 months, there will be a Reconnection Charge equal to the minimum charge which would have been billed had the customer not terminated service.

5. Service to X-ray and Electronic Equipment. Service under this schedule will be supplied to X-ray or Electronic Equipment, provided the apparatus is served from transformer capacity required to serve other general service load. In case the customer requests the utility to install excess transformer capacity to serve X-ray or electronic load, the customer charge will be increased by $1.00 per kVa of transformer capacity requested.

(Continued)

SPECIAL CONDITIONS (Continued)

6. Parallel Generation Limitation. This schedule is not applicable to standby, auxiliary service, or service operated in parallel with a customer's generating plant, except as specified in Rule 1 under the definition of Parallel Generation Limitation.

7. Compliance with Applicability Provisions. For customers who are demand metered, applicability will be measured by the "20 kW for twelve consecutive months" provision. Applicability will be measured by the "12,000 kWh for twelve consecutive months" provision when demand metering is not available.

8. Net Energy. Net Energy is energy generated by the generation facility and fed back into the utility's system, minus energy supplied by the utility. If the energy supplied to the utility is less than the energy purchased from the utility then the rates specified in the Rates section of this schedule shall be applied to the positive balance owed to the utility. D

9. Net Energy Billing. This provision is available on a first-come, first-served basis to a small commercial customer of this utility that owns and operates a solar or wind electric generating facility, or a hybrid system of both, with a capacity of not more than ten (10) kilowatts that is located on the customer's premises, is interconnected and operates in parallel with the electric grid, and is intended primarily to offset part or all of the customer's own electrical requirements. This provision shall be available until the time that the total rated generating capacity used by the eligible customer-generators equals one-tenth of 1 percent of the utility's aggregate customer peak demand. T

   The annualized net energy metering calculation shall be made by measuring the difference between the electricity supplied to the eligible customer-generator and the electricity generated by the eligible customer-generator and fed back to the electric grid over a 12-month period. In the event the energy generated exceeds the energy consumed during the 12-month period, no payment will be made for the excess energy delivered to the utility's grid. If the utility is the customer's Electric Service Provider, this condition may be modified where the customer has a signed contract to sell any portion of the customer generated energy to the utility.

   The eligible customer-generator shall be billed, at the end of each 12-month period following the date of the utility's final interconnection of their system, and on the anniversary date thereafter, for electricity used during that period. The utility shall determine if the eligible customer-generator was a net consumer or a net producer of electricity during that time period. L

   If the utility is the customer's Electric Service Provider, the utility shall provide net electricity consumption information on each regular bill to every eligible customer-generator. The consumption information shall contain the current monetary balance owed to the utility for net electricity delivered/consumed since the last 12-month period ended. The utility shall, upon customer-generator's request, permit the customer to pay monthly for net energy delivered/consumed. L

(Continued)

SCHEDULE A

GENERAL SERVICE

SPECIAL CONDITIONS (Continued)

10. Billing: A customer's bill is first calculated according to the total rates and conditions listed above. The following adjustments are made depending on the option applicable to the customer:

   a. **UDC Bundled Service Customers** receive supply and delivery services solely from SDG&E. The customer's bill is based on the Total Rates set forth above. The EECC component is determined by multiplying the EECC price for this schedule during the last month by the customer's total usage.

   b. **Direct Access Customers** purchase energy from an energy service provider (ESP) and continue to receive delivery services from SDG&E. The bill for a Direct Access Customer will be calculated as if it were a UDC Bundled Service Customer, then crediting the bill by the amount of the EECC component, as determined for a UDC Bundled Customer.

   c. **Virtual Direct Access Customers** receive supply and delivery services solely from SDG&E. A customer taking Virtual Direct Access service must have a real-time meter installed at its premises to record hourly usage, since EECC change hourly. The bill for a Virtual Direct Access Customer will be calculated as if it were a UDC Bundled Service Customer, then crediting the bill by the amount of the EECC component, as determined for a UDC Bundled Customer, then adding the hourly EECC component, which is determined by multiplying the hourly energy used in the billing period by the hourly cost of energy.

   Nothing in this service schedule prohibits a marketer or broker from negotiating with customers the method by which their customer will pay the CTC charge.

11. Other Applicable Tariffs: Rules 21, 23 and Schedule E-Depart apply to customers with generators. N