Solar Comfort Radiant Barrier Study Report

Sacramento Municipal Utility District

SMUD™

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About the Customer Advanced Technologies Program…

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems, daylighting and a variety of other technologies.

For more program information, please visit:
https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

1. Executive Summary

ADM Associates was contracted by SMUD to perform a study of split system and packaged heat pumps in an office building to determine if the new Solar Comfort radiant barrier would yield measurable HVAC cooling energy savings along with increased occupant comfort. The study involved power monitoring of two heat pump HVAC units which served three offices where the radiant barriers were installed on south facing windows. The monitoring period took place from June through October of 2014.

The results for this study support the claims that the Solar Comfort radiant barriers reduce HVAC cooling energy usage and increase occupant comfort. The combined total cooling energy savings is 345 kWh per year, or 23.6% of the cooling energy for the two systems. The total window area covered by the radiant barrier was 378 square feet. The two systems have a combined cooling capacity of seven tons. Based on the amount of shades installed, an average of 0.9 kWh/year per square foot of shade installed can be saved in cooling energy for this installation.

Office occupants were surveyed to determine their level of satisfaction and comfort with the Solar Comfort radiant barriers. They stated they felt cooler in the summer when the shades were down and that the shades reduced the brightness and glare in the office space. They also liked that the shades provided additional privacy in the office.

2. Project Description

2.1 Background

An office building near Sacramento installed new Solar Comfort SC400 radiant barrier screens for windows in south facing first floor private offices. The screens were installed to increase occupant comfort during hot summer days.

ADM Associates was contracted to perform a study to determine if the new Solar Comfort radiant barrier would yield measurable HVAC cooling energy savings along with the increased occupant comfort.

ADM installed power monitoring equipment on heat pump units associated with offices with new Solar Comfort SC400 radiant barriers. One specific heat pump unit (HP5, 3 tons) serves one specific corner office with three south facing and two west facing windows which are covered for a total shaded area of 169 square feet. Another heat pump (HP9, 4 tons) serves two offices with south facing windows; one office has two windows and the other office has four windows for a total of 208.5 square feet of shaded area.

The Solar Comfort SC400 is a perforated film, comprised of four laminated layers; a base, an aluminized coating, a non-energy absorbing pigment, and a tinted Polyester/Nylon. It has a solar heat gain of 0.29 (71% of energy reflected) and visible light transmittance of 38%[1]. In this application, the perforated film is rolled and mounted above the windows on the inside. For this study the shades were designed to roll up and down similar to a rolled window blind. This allowed the operation of the shades to provide control periods when the shades were not covering the windows. The normal installation of the radiant barrier is permanent fixed to a window. Traditional horizontal window blinds are still affixed to the windows to allow occupants to adjust the amount of light into the office and to close at night time for privacy. This study included the unregulated occupant adjustment of these blinds.

Additional occupancy, light intensity, and space temperature monitoring occurred in offices 1, 2, and 3. Data was collected during the summer cooling season from June through October, 2014.

[1] See website http://solarcomfort.ca/downloads for performance characteristics and Appendix C for product line card technical information.

2.2 Assessment Objectives

The goal of this study was to quantify measureable cooling energy savings due to the installation of Solar Comfort radiant barriers acting as additional window shading. This assessment included monitoring the energy consumption of specific office HVAC systems and interior office space conditions during the summer.

2.3 Methodology

The monitored data are aggregated and analyzed to compare dates with the shades up and dates with the shades down. Monitoring took place between June 2014 and October 2014. During that time, the shades were rolled up or down on a weekly or bi-weekly occurrence with nine changes over the course of the period. The total period of days with shades down is 92 and the total period of days with shades up is 42. For detailed information on monitoring equipment used, please reference Appendix A.

HVAC energy consumption was collected in 5 minute intervals, but through analysis, the daily cumulative energy consumption provided the best correlation. Daily heat pump energy use was regressed with the average outside air temperature during working hours and day of the year from the summer solstice. The average daily outside air temperature was calculated only during the HVAC operating hours of 8:00 a.m. and 6:00 p.m. Weather data for the monitoring period were collected from the McClellan AFB station which is close proximity to the test site. Regression of HVAC energy use with indoor monitored temperature, occupancy logger data, operation of the room lights, and solar radiation were tested, but correlation was low compared to the outside ambient temperature and day of the year. A multi-variant regression using outside temperature and modified Julian day based on the summer solstice provided the best fit. Additional details are provided in Appendix B. Weekend days were not included in the analysis since the HVAC units were typically turned off based on the thermostat programmed schedule.

Additional lighting savings attributed to the use of the radiant barriers were tested. The hypothesis was that occupants may leave the blinds open and lights off due to the use of the new radiant barriers. Lighting logger data were reviewed and normalized based on occupancy sensor logger data and no significant differences were found in the operation of the lights.

Typical Meteorological Year 3 (TMY3) data for Sacramento Executive Airport were used to build an annual savings estimate for this specific radiant barrier installation for a typical year. Regression statistics determined from actual monitoring period were used to determine the energy used with the shades in place for all hours versus the energy used without the shades. Sacramento TMY3 outdoor ambient temperature was calculated for the HVAC usage period of 8:00 a.m. to 6:00 p.m. each day.

3. Results

3.1 Energy Monitoring Results

The HVAC energy monitoring period took place between June 2014 and October 2014. During this time the radiant barriers were placed in the full up (no effect) or in the full down (effective) position for alternating week periods. The operation of the shades was confirmed by the data collected from the light intensity loggers placed in each office. Based upon the monitoring data and analysis, energy savings of twenty and twenty-nine percent were realized for HP9 and HP5 respectively. This equates to a total savings of 345 kWh per year for the 378 square feet of covered window area. Based on the amount of shades installed, an average of 0.9 kWh/year per square foot of shade installed can be saved in cooling energy for in this installation.

HVAC daily energy use was regressed with the average outdoor ambient temperature between the hours of 8:00 a.m. and 6:00 p.m. and periods of shades up and shades down were compared to determine the effective energy savings from the radiant barriers as shown in Figure 1 and 2. The linear trend lines on the charts only represent the fit with outdoor temperature.

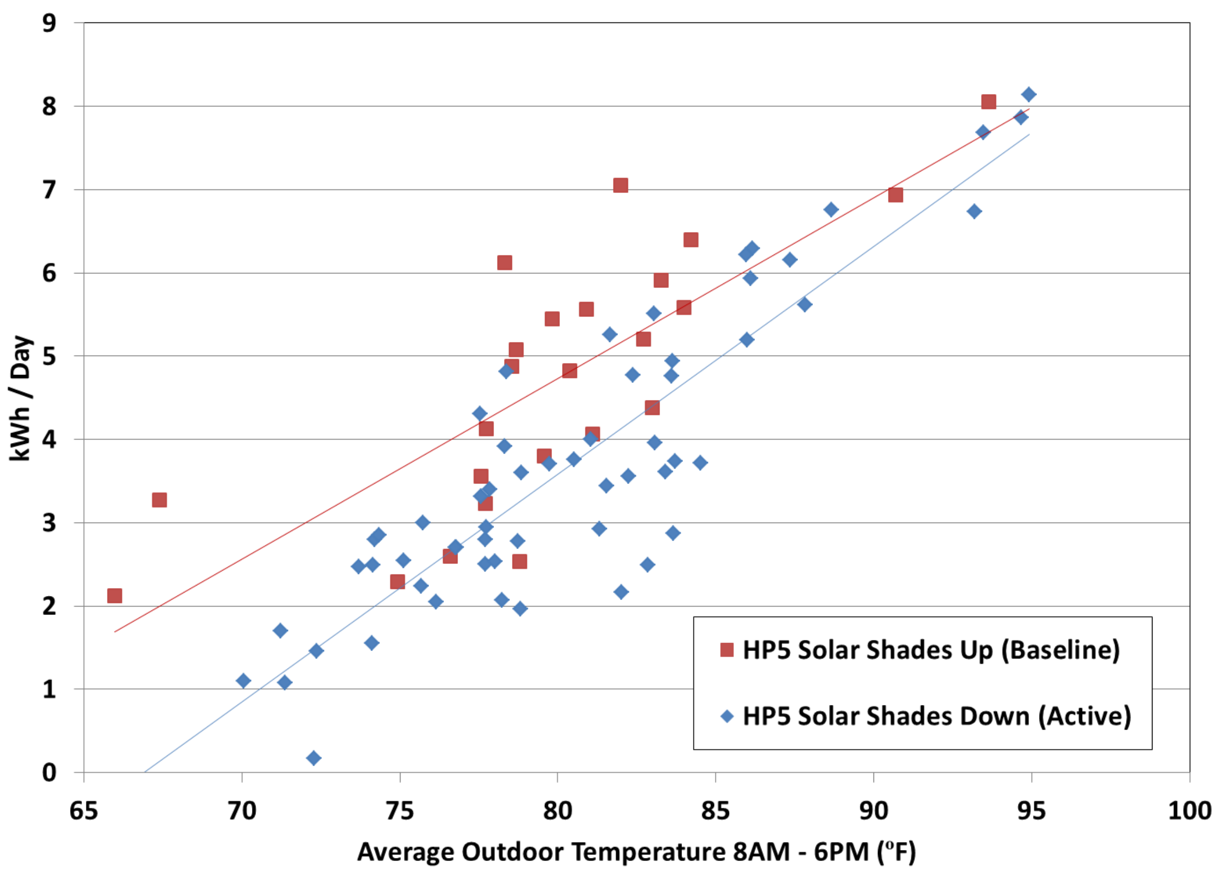


Figure 1: Corner Office Served by Heat Pump 5 on Days with Solar Shades Up vs. Shades Down

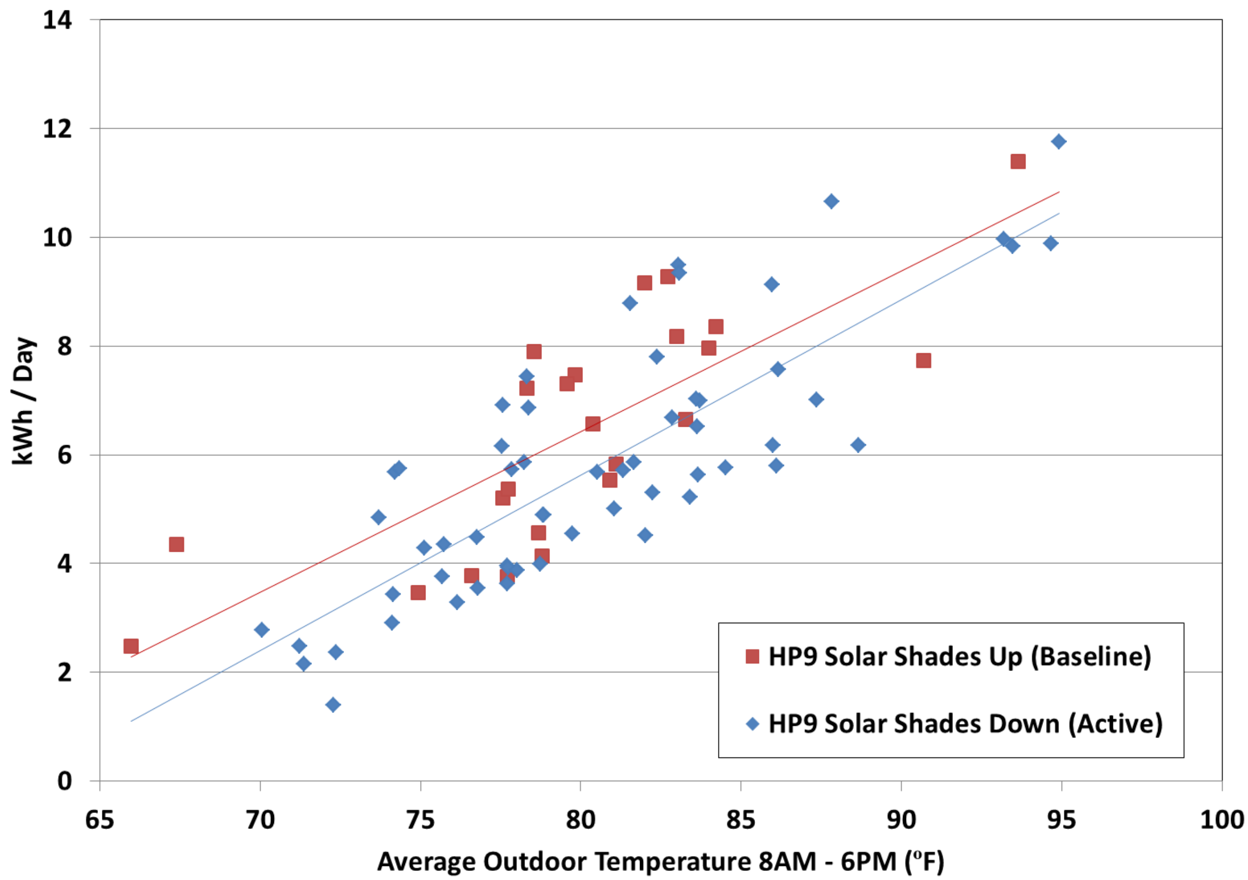


Figure 2: Daily Heat Pump Operation for Two Adjacent Offices with Solar Shades Up vs. Shades Down

Annual HVAC energy savings were projected for this project based on Sacramento TMY3 weather data and the multi-variant regression coefficients. The charts in Figure 3 and 4 show HVAC energy used when the shades are up versus shades down for a typical meteorological year for each heat pump.

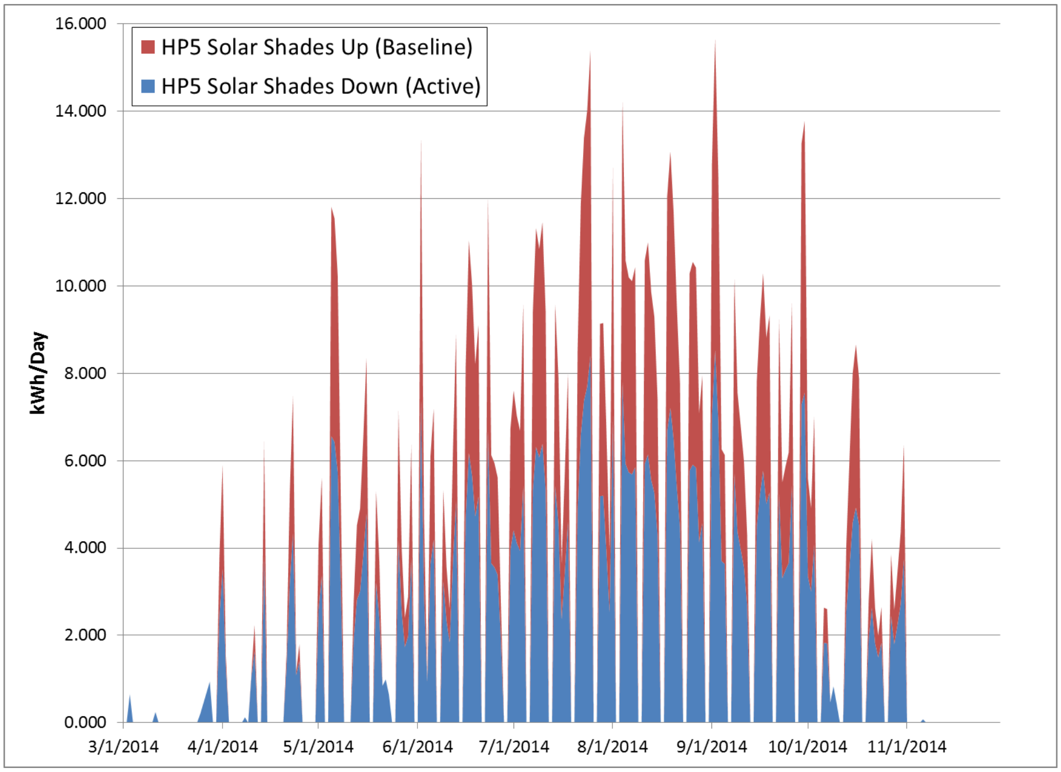


Figure 3: Projected HP5 Annual Energy Use

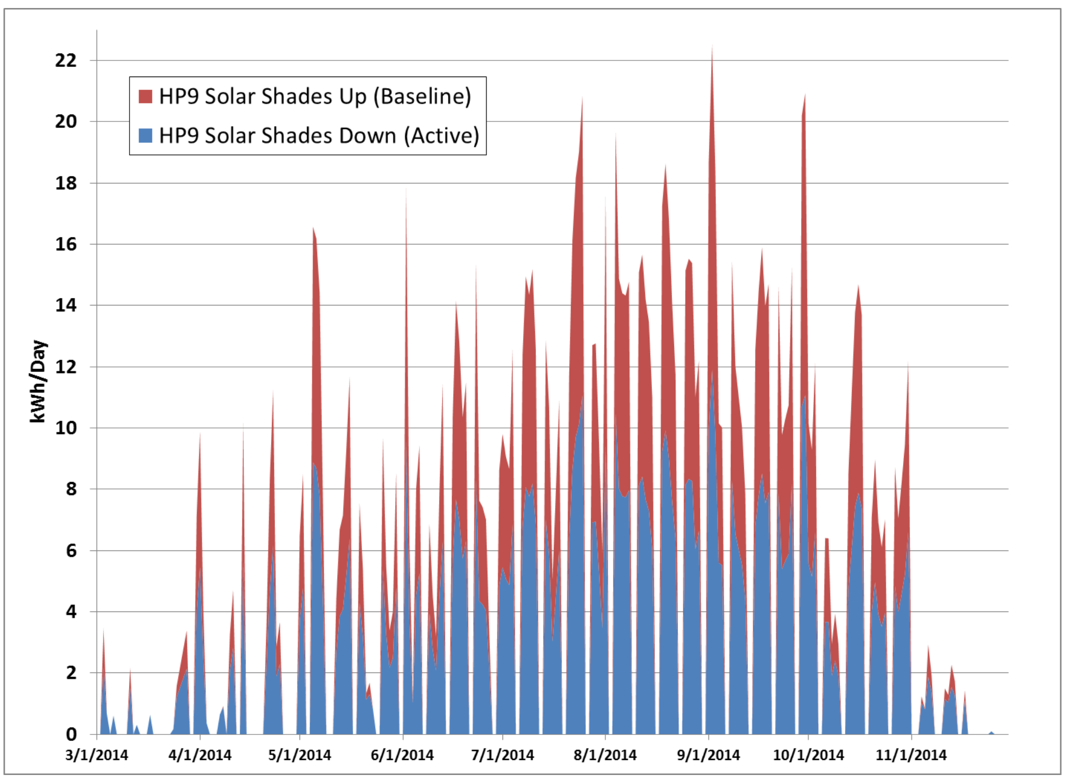


Figure 4: Projected HP9 Annual Energy Use

Total annual energy use for HP5 and HP9 with and without the radiant barrier is shown in Figure 5.

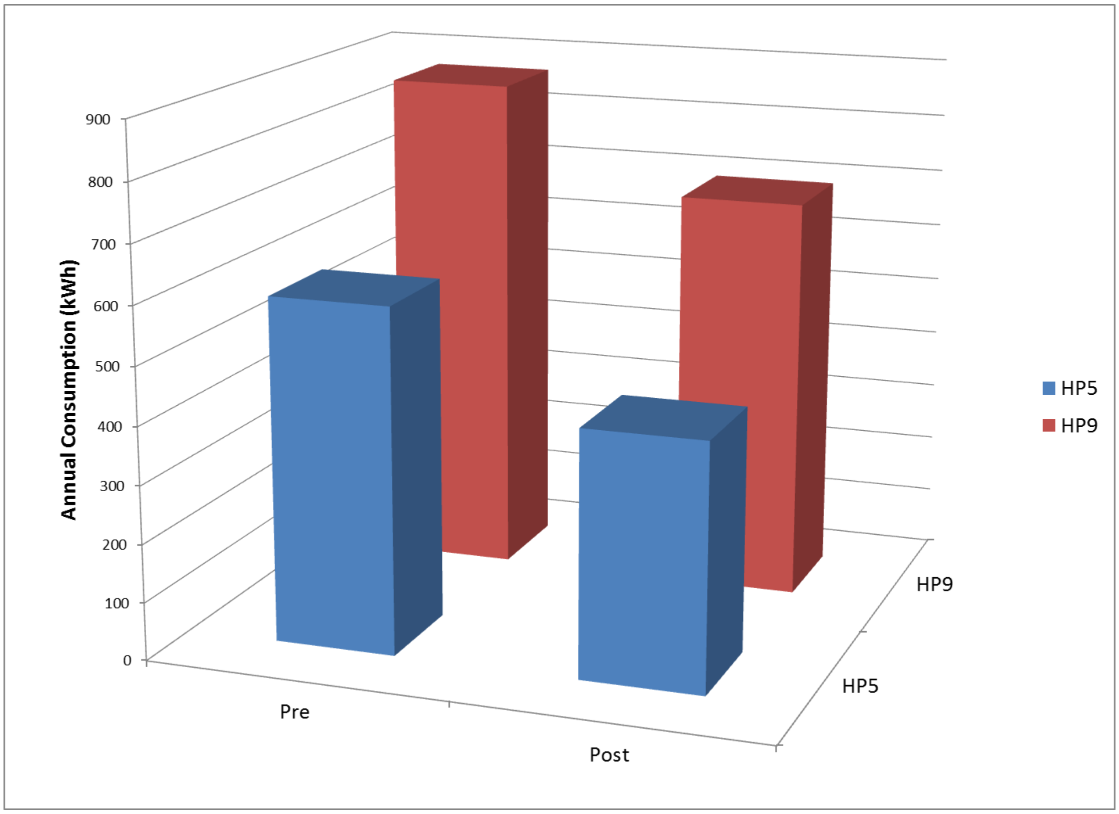


Figure 5: Annual Energy Use Comparison

4. Discussion

The results of the study provide a 20-29% savings realization in HVAC cooling energy for the 1st floor offices with south facing windows. The data analysis shows the most correlation between the daily energy consumption of the HVAC equipment and the average outdoor ambient temperature during operation (8:00 a.m. – 6:00 p.m.). The study supports the claim that the Solar Comfort radiant barriers save energy by limiting the amount of heat transfer through building windows.

For this study, the solar radiation measured at a weather station in the region did not have a statistically meaningful effect on the power consumption. However, the amount of savings based on the ambient air temperature could be seen to change based on the changing solar angle of the seasons. A modified Julian Day (with day 1 being the summer solstice) was constructed to compare energy savings per day. It appears the energy savings per day is reduced faster over the increasing Julian day compared to the average temperature for the same period. This would support the idea that some of the savings for the solar shades is due to reduced solar radiation from the shades and not just attributed to heat flow based on temperature. This may be a small component of the total savings and cannot be separated in the estimation of the total annual cooling energy savings.

Potential improvements for this study would include measurement of solar radiation through the window with and without the Solar Comfort radiant barrier on a typical sunny day. This would confirm if the existing windows and blinds are already effectively reducing the amount of solar radiation entering the space which would require additional mechanical cooling. This can also aide in attributing an additional component of solar radiation savings to the annual energy savings.

An extension of the study to continue through the winter months could determine if the radiant barriers conserve heating costs. Since heat is provided by the heat pumps which are currently being monitored and the lighting logger monitoring did not improve the statistics of the results, the study could be conducted with limited additional effort.

Occupant comfort was improved with the installation of the Solar Comfort radiant barriers. Occupants were surveyed and the general consensus was they felt cooler when the shades were drawn and more comfortable. Other benefits of the shades were that they provided more privacy from people outside the office during the daytime and the shades reduced the amount of glare in the offices.

5. Conclusion

The results of the study support a 20-29% HVAC cooling energy savings by using the Solar Comfort radiant barriers. The estimated cooling savings in this application in Sacramento is 0.9 kWh/yr-ft^2 of window shade. The savings are claimed based on the monitored HVAC power consumption correlated to the outside ambient air temperature and day of year compared with the shades active (down) or not (up). Additional occupant comfort improvements can also be attributed to the use of the Solar Comfort radiant barriers.

6. Appendix A

Monitoring Instrumentation

A 16-channel Enernet K-20 power recorder was installed in an electrical room to monitor the power for two heat pump compressor/outdoor fan units. The K-20 can monitor electric energy, analog signals and digital pulses. This multi-channel meter recorder was used to monitor true rms kW power of electric loads. The K-20 recorder contained a 2400 baud modem which was connected to an unused phone line in the building. Data were collected by remote dial-up every few days. Hourly weather data were downloaded from a local weather station covering the duration of the monitoring period.

Stand-alone Onset HOBO® data loggers were installed in each of the three private offices to lights, occupancy and temperature. The lighting in each of the three offices was monitored by placing a HOBO® UX90-002 light On/Off logger inside a ceiling fixture in each office. The occupancy of the room was monitored in each of the three offices using a HOBO® UX90-005 occupancy logger placed on the frame of the recessed ceiling lighting fixture looking down upon the office space. The temperature and light level in each of the offices was also recorded by a HOBO® UA-002-64 pendant logger placed either next to the thermostat or on a bookshelf.

Monitoring Equipment Accuracies

The K-20 logger accuracy for a power measurement is ±0.5% from 1 to 100% of full scale. Current transformer accuracy is ± 0.5% from 1% to 100% of full scale. Split-core current transducers with 50 Amp primary ratings were used to monitor the heat pump load.

HOBO® loggers from Onset Computer Corp. were used. These are small battery operated loggers with clock accuracies of ±1 minute per month. HOBO® UX90-002 lighting loggers have a button to calibrate to the current light level conditions and have an operating range of -4 ºF to 158 ºF and from 0% to 95% RH. These loggers hold up to 84,650 transition records. HOBO® UX90-005M occupancy data loggers have occupancy sensors with a range of 16 feet and a 47º field of view. The logger has an operating range of -4 ºF to 140 ºF and from 15% to 85% RH. These loggers hold up to 346,795 measurements. HOBO® UA-002-64 loggers have a light level operating range from 0 to 320,000 lux and a temperature measurement range of -4 ºF to 158 ºF. They have a temperature accuracy of ±0.95 ºF. Light sensor is designed for relative light level measurements. These loggers hold up to 28,000 measurements.

7. Appendix B

Multi-Variant Regression Results

The following table shows equation coefficients and the regression fit results for the two heat pumps and both shade conditions.

Parameter	HP5, Shades Down	HP5 Shades Up	HP9, Shades Down	HP9 Shades Up
Intercept Coefficient, kWh/day	-19.33	-16.43	-24.38	-25.19
Solstice Day Coefficient, kWh/day	0.00647	0.01568	0.02662	0.03303
Average OD Temp Coefficient, kWh/day	0.28189	0.25572	0.35661	0.37676
Multiple R	0.903	0.843	0.920	0.908
R Square	0.816	0.710	0.847	0.824
Adjusted R Square	0.809	0.682	0.841	0.808
Standard Error	0.780	0.906	0.913	0.964
Observations	58	24	58	24

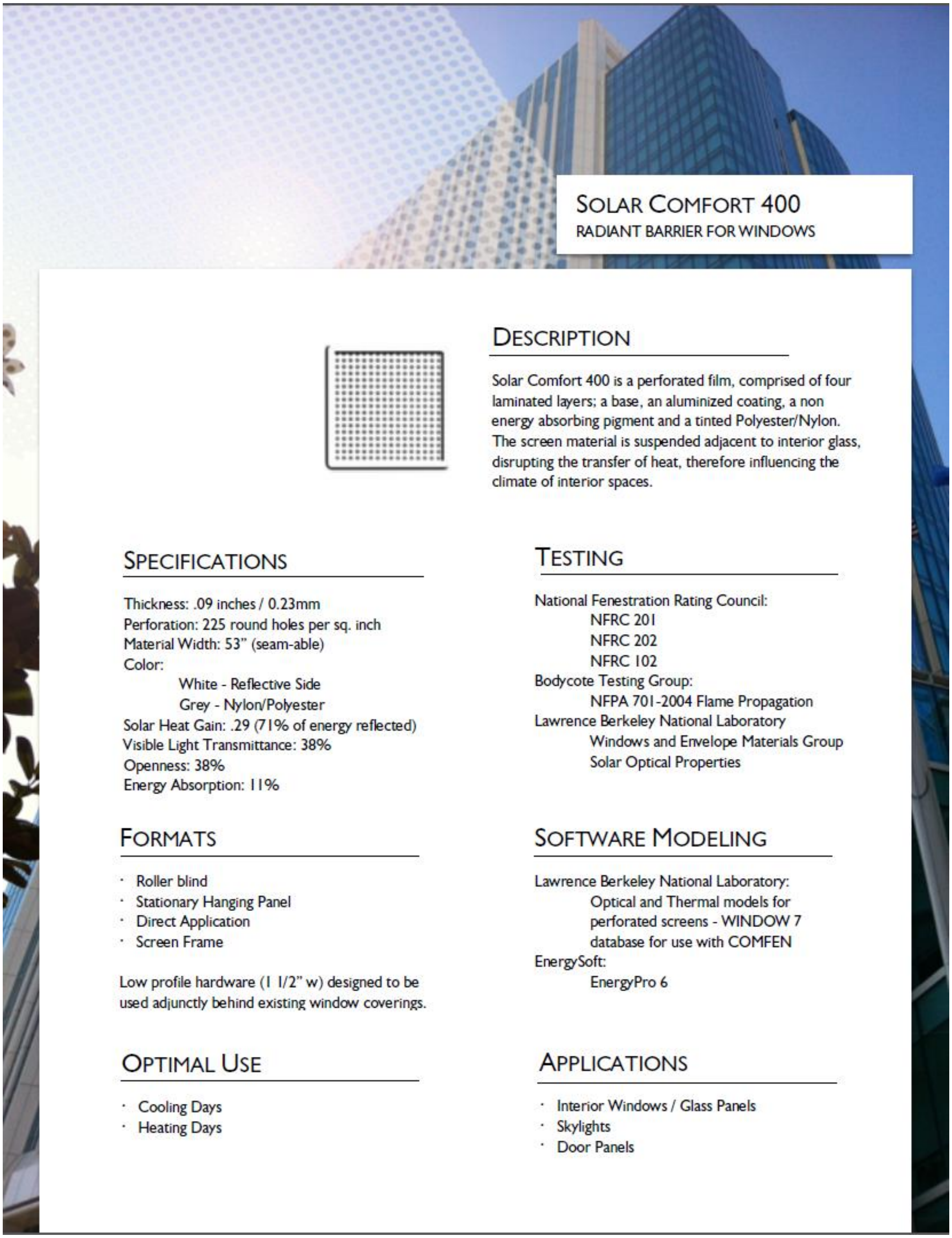
Savings

The following table shows annual energy use and savings by Heat Pump.

Parameter	HP5	HP9
Annual Heat Pump Energy Use, Shades Up, kWh	593.6	869.3
Annual Heat Pump Energy Use, Shades Down, kWh	422.8	694.6
Annual Heat Pump Energy Savings, kWh	170.8	174.6
Percent Savings,%	29%	20%

8. Appendix C

Radiant Barrier Line Card



SOLAR COMFORT 400
RADIANT BARRIER FOR WINDOWS

DESCRIPTION

Solar Comfort 400 is a perforated film, comprised of four laminated layers; a base, an aluminized coating, a non energy absorbing pigment and a tinted Polyester/Nylon. The screen material is suspended adjacent to interior glass, disrupting the transfer of heat, therefore influencing the climate of interior spaces.

SPECIFICATIONS

Thickness: .09 inches / 0.23mm
Perforation: 225 round holes per sq. inch
Material Width: 53" (seam-able)
Color:
White - Reflective Side
Grey - Nylon/Polyester
Solar Heat Gain: .29 (71% of energy reflected)
Visible Light Transmittance: 38%
Openness: 38%
Energy Absorption: 11%

TESTING

National Fenestration Rating Council:
NFRC 201
NFRC 202
NFRC 102
Bodycote Testing Group:
NFPA 701-2004 Flame Propagation
Lawrence Berkeley National Laboratory
Windows and Envelope Materials Group
Solar Optical Properties

FORMATS

- Roller blind
- Stationary Hanging Panel
- Direct Application
- Screen Frame

Low profile hardware (1 1/2" w) designed to be used adjunctly behind existing window coverings.

SOFTWARE MODELING

Lawrence Berkeley National Laboratory:
Optical and Thermal models for perforated screens - WINDOW 7 database for use with COMFEN
EnergySoft:
EnergyPro 6

OPTIMAL USE

- Cooling Days
- Heating Days

APPLICATIONS

- Interior Windows / Glass Panels
- Skylights
- Door Panels