



Effect of Solar Radiation Control on Energy Costs

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This section presents an interactive tool to assist commercial building owners and/or operators in estimating the maximum effect of solar radiation control on energy needs for a building under a low-slope roof. The following locations were used and their climates go from cooling-dominated to heating-dominated: Phoenix, Arizona; Miami, Florida; Tampa, Florida; Dallas/Fort Worth, Texas; Knoxville, Tennessee; Boulder, Colorado; Minneapolis, Minnesota and Anchorage, Alaska. The low-slope roofs had light weight decks and insulation levels of R-4.8, R-12.6, R-25.2 and R-31.5 h-ft²·°F/Btu (R-0.9, R-2.2, R-4.4 and R-5.5 m²·K/W). The interactive estimating tool does not apply to high slope roofs with a ventilated attic space between the roof deck and the attic floor. Solar insulation is slightly different than it is for a horizontal roof. More importantly, the ventilated attic space affects the conditions for heat transfer through the attic insulation. For information on the [effect of radiation control for high slope roofs by use of radiant barriers](#) inside attics. For the results of recent measurements of whole house cooling energy use in Florida with various high slope roofs on identical houses see an article on the Florida Solar Energy Center web site. The interactive estimating tool for low slope roofs allows for simple plenum spaces above drop ceilings. Include the small thermal resistance that they add in the thermal resistance of the roof assembly. Simple plenum spaces can include well-insulated supply and return air ducts for the building conditioning system. More complicated situations are not allowed because interactions between the duct system and the plenum air are not included. The basic assumption of the estimating tool is that the heat flow through the roof deck directly affects the load on the building conditioning system.

To devise the estimating tool, seven combinations of solar spectrum reflectance R and infrared emittance E were modeled. They corresponded to measured values after two years in a [comprehensive study of the thermal performance of twenty-four different coatings](#) and four uncoated specimens. The combinations RxxEyy, where xx is the percentage solar reflectance and yy is the percentage infrared emittance, were R70E90 and R48E82, for the highest and lowest reflectance white latex coatings, respectively; R50E52 and R26E68, for the highest and lowest reflectance aluminum coatings, respectively; R33E90 for an aluminized asphalt emulsion,



R64E11 for an aluminum capsheet; and R05E90 for an uncoated roof membrane. Cooling load per unit area of the roof on the building cooling equipment was defined as the annual sum of heat flow through the roof deck when outside air temperature exceeded 75°F (24°C). Heating load per unit area of the roof on the building heating equipment was defined as the annual sum of heat flow through the roof deck when outside air temperature was below 60°F (16°C). Inside air temperature below the roofs was held at 72.5°F (22.5°C) and no thermostat setup or setback was modeled. Judging from results with a warehouse in an annual energy use estimate for the whole building, including severe thermostat setup and setback during unoccupied hours, the loads used for the estimating tool show the maximum amount of energy savings from radiation control on roofs of buildings with small internal loads. Inside air temperatures $\pm 5^\circ\text{F}$ ($\pm 3^\circ\text{C}$) different from 72.5°F (22.5°C) are allowed because the estimating tool does calculations for a roof with radiation control relative to one without radiation control. As long as the inside air temperature is the same with and without radiation control, the estimates with the tool are valid. This includes effects of different thermostat set points during the heating and cooling seasons. In the estimating tool, polynomials are used to fit the results from the roof-only model. This permits the user to input parameters of interest that are not exactly the values used in the model. The cooling loads are fit as a function of solar reflectance and infrared emittance of the roof surface, roof thermal resistance, and cooling degree days and average daily solar irradiation for the location. The heating loads are fit as a function of solar reflectance and infrared emittance of the roof surface, roof thermal resistance, and heating degree days for the location. Assuming a constant price for electricity and a constant efficiency of the air conditioning equipment, cooling savings are calculated relative to the cost to cool a building with an uncoated roof. The difference between the cooling load for the uncoated roof and the roof with radiation control is multiplied by average cost per kWh of electricity and divided by the average coefficient of performance of the air conditioner. Assuming a constant price for natural gas or other heating fuel, including a separate heating season price if electricity is used for both heating and cooling, and a constant efficiency of the heating equipment, heating savings are calculated relative to the cost to heat a building with an uncoated roof. The difference between the heating load for the uncoated roof and the roof with radiation control is multiplied by average cost per Therm of natural gas or other fuel and divided by the average efficiency of the heating system. A negative difference means there is a heating penalty with radiation control. The sum of cooling savings and heating savings gives the net savings in U.S.\$/ft² of roof area per year. For U.S.\$/m², multiply U.S.\$/ft² by 10.76. After estimating annual energy cost savings for the proposed implementation of radiation control, the

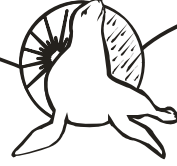


tool allows another estimate. If the user selects the option, the thermal resistance of the roof without radiation control is increased relative to the thermal resistance chosen for the roof with radiation control. A rapidly converging iteration scheme produces the R-value of a roof without radiation control that has the same annual energy cost for heating and cooling as the candidate roof with radiation control. The total R-value of the new roof without radiation control may be difficult to achieve if there is no space available to add conventional insulation. Local roofing contractors should be consulted for cost estimates to do this task. For a typical cooling coefficient of performance and typical furnace efficiency along with year 2000 average commercial electricity cost and year 1999 average commercial natural gas cost, Table 1 shows results from the estimating tool as a function of location and roof thermal resistance. Table 1. **Example net savings in annual energy costs per square foot of coated low-slope roof and R-value for an uncoated roof with same annual energy costs as a coated low-slope roof for \$0.0745/KWh of electricity with air conditioner COP=2.5 and \$0.533/Therm of natural gas with furnace efficiency=0.85. RxxEyy means solar reflectance of xx% and infrared emittance of yy%.** The roof with an uncoated surface has R05E90. The R70E90 surface is the best white latex coating, the R50E52 surface is the best aluminum coating, and the R64E11 surface is an aluminum capsheet. These RxxEyy values were obtained after two years of weathering in the study on Reflective Roofing Systems.

	Net Savings (\$/ft ²) vs. R05E90			R _{uncoated} for Same Savings		
	R70E90	R50E52	R64E11	R70E90	R50E52	R64E11
Miami						
R-5 h-ft ² ·°F/Btu	\$0.166	\$0.077	\$0.074	R-13	R-8	R-8
R-13 h-ft ² ·°F/Btu	\$0.070	\$0.032	\$0.029	R-32	R-17	R-16
R-25 h-ft ² ·°F/Btu	\$0.038	\$0.017	\$0.016	R-35	R-32	R-32
R-32 h-ft ² ·°F/Btu	\$0.030	\$0.013	\$0.012	R-36	R-34	R-34
Knoxville						
R-5 h-ft ² ·°F/Btu	\$0.067	\$0.047	\$0.062	R-7	R-7	R-7
R-13 h-ft ² ·°F/Btu	\$0.028	\$0.018	\$0.024	R-16	R-15	R-16
R-25 h-ft ² ·°F/Btu	\$0.016	\$0.010	\$0.013	R-32	R-31	R-32
R-32 h-ft ² ·°F/Btu	\$0.012	\$0.008	\$0.010	R-34	R-34	R-34
Minneapolis						
R-5 h-ft ² ·°F/Btu	\$0.015	\$0.022	\$0.037	R-5	R-6	R-6
R-13 h-ft ² ·°F/Btu	\$0.006	\$0.008	\$0.013	R-14	R-14	R-14
R-25 h-ft ² ·°F/Btu	\$0.004	\$0.004	\$0.007	R-25	R-28	R-29
R-32 h-ft ² ·°F/Btu	\$0.002	\$0.003	\$0.005	R-32	R-33	R-33

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Surface	R _{solar} (%)	E _{infrared} (%)
Highest R white latex coating	70	90
Average R white latex coating	56	90
Lowest R white latex coating	48	82
Highest R aluminum coating	50	52
Average R aluminum coating	39	56
Lowest R aluminum coating	26	68
Aluminized asphalt emulsion	33	90
Aluminum metal capsheet	64	11
Uncoated asphaltic surface	05	90

There are 235 different locations built into the pull-down lists in the estimating tool. They come from the TMY2 set of typical meteorological year climatic data for the United States, Pacific Islands and Puerto Rico. Annual heating degree days based on 65°F (HDD65), annual cooling degree days based on 65°F (CDD65), and average daily solar irradiation in Btu/ft² (QSavg) are entered automatically for each location when it is selected in the estimating tool. When you use the tool, if you do not find a location near yours, you will be able to view the data for all 235 locations in order to find one with weather similar to yours.

Once the location has been chosen and the reflective roof's insulation level and candidate reflective surface %R and %E have been entered, economic factors are needed. Required inputs are the price of electricity for cooling (in U.S.\$ per kilowatt-hour), annual average coefficient of performance of the air conditioning system, choice of heating by electricity or by combustion, price of electricity for heating (in U.S.\$ per kilowatt-hour) or price of heating fuel if not electricity (in U.S.\$ per Therm) and seasonal average efficiency of the heating equipment (as a fraction). A Therm is 100,000 Btu of heating value. For natural gas with a heating value of 1,000 Btu/ft³ this is equivalent to 0.100 MCF; for heating oil with heating value of 140,000 Btu/gallon, this is equivalent to 0.71 gallon. For example, natural gas at \$6.50 per MCF costs \$0.65 per Therm. Heating oil at \$1.25 per gallon costs \$0.89 per Therm. Prices obtained from your local energy supplier are recommended.