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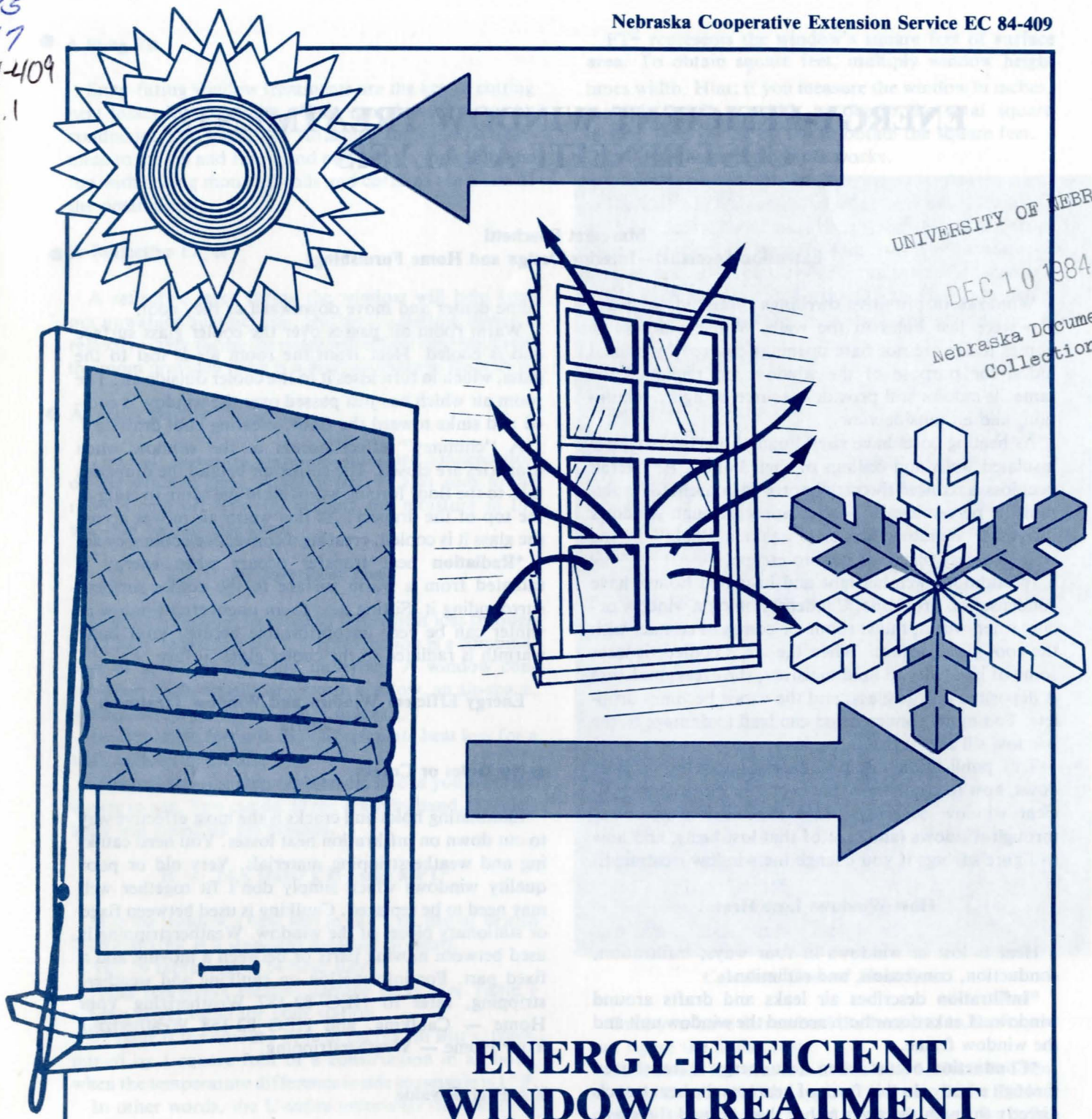

ENERGY-EFFICIENT WINDOW TREATMENT

Cost Benefit Analysis

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ENERGY-EFFICIENT WINDOW TREATMENTS: COST-BENEFIT ANALYSIS

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Windows in primitive dwellings thousands of years ago were just holes in the walls. While windows in homes today are not bare openings covered by animal hides, the purpose of the window has remained the same. Windows still provide a source of light, ventilation, and an outside view.

As heating costs have risen, many homeowners have insulated walls and ceilings of their homes. As overall heat loss is reduced through improved household insulation the percentage of heat escaping through windows increases. Windows are once again a "hole" in the wall—an easy place for heat to escape.

In addition, weathertight and insulated homes have condensation problems. Condensation on a window occurs when warm, moist room air comes in contact with the cool glass surface. When the air is cooled, it loses some of its ability to hold moisture, the excess moisture is deposited on the glass, and the vapor becomes droplets. Too much condensation can lead to damage to the window sill and surrounding areas.

This publication discusses how heat is lost at windows, how to counteract that heat loss with energy efficient window coverings, how to calculate heat loss through windows (and cost of that lost heat), and how to figure savings if you change the window treatment.

How Windows Lose Heat

Heat is lost at windows in four ways; infiltration, conduction, convection, and radiation.

***Infiltration** describes air leaks and drafts around windows. Leaks occur both around the window unit and the window frame.

***Conduction** occurs when heat energy is transferred through a body. In this form of heat loss the heat travels directly through the glass rather than around the glass, as in infiltration.

Glass provides very little resistance to heat lost by conduction. Another way to explain this is that glass is a poor insulator but an excellent conductor of heat. The greater the temperature difference between the inside and outside of the house, the greater the rate of heat loss through conduction.

***Convective** air currents are created when gases (air) expand and move upward as they are warmed or become denser and move downward as they cool.

Warm room air passes over the cooler glass surface and is cooled. Heat from the room air is lost to the glass, which in turn loses it to the cooler outside air. The room air which has just passed over the window is cooled and sinks toward the floor, creating cool drafts.

A "chimney" effect occurs at the window when draperies are closed. The cooler air behind the draperies falls to the floor forcing warm air in the room to enter at the top of the drapery. As this warm air moves across the glass it is cooled, creating a convective cooling cycle.

***Radiation** heat transfer occurs when energy is radiated from a warm surface to the colder surfaces surrounding it. Sitting next to an uncovered window in winter can be very uncomfortable because your body warmth is radiated to the cooler glass surface.

Energy Efficient Window and Window Treatment Criteria

● No Holes or Cracks

Eliminating holes and cracks is the most effective way to cut down on infiltration heat losses. You need caulking and weatherstripping materials. Very old or poor quality windows which simply don't fit together well may need to be replaced. Caulking is used between fixed or stationary pieces of the window. Weatherstripping is used between moving parts or between a moving and a fixed part. For information on caulking and weatherstripping, refer to HEG 82-157 Weatherizing Your Home — Caulking, and HEG 82-158 Weatherizing Your Home — Weatherstripping.

● A High R-value

Raising the R-value of the window and window treatment will reduce conduction heat losses. R-value is a measure of the material's resistance to heat flow. The higher the R-value, the better the insulation.

Adding layers of glass or plastic is one possibility. Other ideas for increasing the R-value of the total window with insulating window treatments are in EC 80-2052, Managing Window Treatments for Energy Efficiency.

- **A Snug Fit**

Snug-fitting window treatments are the key to cutting heat losses by convection. They can also cut losses by conduction and radiation. Attaching the window treatment to the sill and frame and providing a snug fit to the top with ceiling mounted rods and cornices are a few of the possibilities.

- **A Reflective Layer**

A reflective layer facing the window will help keep out unwanted summer sun. During the heating season a reflective layer facing the room will reflect heat back into the room provided there is a dead air space in front of it.

- **A Vapor Barrier**

This cuts down on undesired moisture condensation on the window glass. A vapor barrier also adds to the room's comfort level by keeping the moisture in the air—not on the cool glass.

Calculate Heat Loss

Use the following formula to figure heat loss through any given "construction." A construction is a combination of layers of different materials. A window construction might consist of a storm window, an air-space, a window, an air-space, and a drapery.

It is the same formula used to calculate heat loss for a wall, ceiling, or floor.

If you follow the step-by-step directions you will find it easy to use. You can do all the math by hand. A calculator will speed up the process.

$$H = 24 \times HDD \times U\text{-value} \times FT^2$$

H is the window's heat loss in Btu's (A Btu or British Thermal Unit is a standard measure of heat).

The 24 represents a 24-hour day.

HDD represents Heating Degree Days (See Table 1 for the HDD value for your station.

U-value is the amount of heat energy, in Btu's, transmitted by 1 square foot of a construction in an hour, when the temperature difference inside to outside is 1 ° F.

In other words, the U-value represents the ability of the construction to let heat pass through. The smaller the U-value the lower the heat loss.

To get the U-value add all R-values for typical window materials found in Table 2. After you have added the R-values, divide them into 1. This gives the U-value. The mathematical formula for U-value looks like this:

$$\text{U-value} = \frac{1}{(R_1 + R_2 + R_3 \ldots)}$$

FT^2 represents the window's square feet of surface area. To obtain square feet, multiply window height times width. Hint: if you measure the window in inches, multiply height x width to obtain the total square inches. Then divide by 144 to obtain the square feet.

Let's see how the formula works.

EXAMPLE: A family in Broken Bow, Nebraska, wants to know how much energy they are losing from their living room picture window. The window is doublepane glass with 1/4-inch air space between the glass. The window is presently covered with loose draperies. The window measures 48 x 60 inches.

HDD = 6740

U-value =

$$\frac{1}{R_1 + R_2} = \frac{1}{\underset{\text{double pane}}{1.50} + \underset{\text{conventional drapery}}{.20}} = \frac{1}{1.70} = .5882$$

U-value = **.5882**

$$FT^2 = \frac{48 \times 60 \text{ inches}}{144 \text{ inches}} = 20$$

FT^2 = 20

Putting these values into the heat loss formula:

H = 24 x HDD x U value x FT^2

H = 24 x 6740 x .5882 x 20

H = 1,902,945

The family is losing 1,902,945 Btu's of energy out their living room window each year.

Calculate Cost of Heat Loss

Once you have determined the heat loss in Btu's, you can figure the dollar cost.

First divide the heat loss in Btu's by 1,000,000. Then, look up the cost for the type of fuel you use in Table 3 or use your own local costs if available. Take the dollar value in the right-hand column and multiply it by the number of million Btu's used. This will give you the dollar cost of heating the window for one year. This is the mathematical equation:

$$\$ = \frac{H}{1{,}000{,}000} \times \text{Cost for 1 million Btu's usable heat}$$

Table 1. Annual heating degree days for Nebraska stations. (1 HDD = 1° F difference between inside and outside temperatures for a 24-hour period).

Station	Annual	Station	Annual	Station	Annual
Ainsworth	6726	Falls City	5475	Mullen	6546
Albion	6796	Fort Robinson	7025	Norfolk	6981
Alliance	6946	Franklin	5732	North Loup	6545
Alma	5753	Fremont	6117	North Platte	6743
Arthur	6902	Geneva	6084	Oakdale	6920
Ashland	6197	Genoa	6320	Ogallala	6446
Atkinson	6825	Gordon	7306	Omaha Eppley	6049
Auburn	5636	Gothenburg	6139	Omaha North	6601
Beatrice	5819	Grand Island	6420	O'Neill	6960
Beaver City	5647	Halsey	6684	Osceola	6317
Benkelman	5766	Harrison	7766	Oshkosh	6501
Big Springs	6368	Hartington	6827	Osmond	6903
Blair	6437	Hastings	6070	Pawnee City	5426
Box Butte	7269	Hayes Center	6284	Purdum	6657
Bridgeport	6434	Hay Springs	7189	Ravenna	6261
Broken Bow	6740	Hebron	6010	Red Cloud	5859
Burwell	7042	Holdrege	5926	Saint Paul	6359
Butte	6886	Imperial	6122	Scottsbluff	6774
Cambridge	5893	Kearney	6467	Seward	6063
Central City	6197	Kimball	6723	Sidney	6564
Chadron	7031	Kingsley	6169	Stanton	6677
Clarkson	6582	Lexington	6309	Stapleton	6650
Clay Center	5998	Lincoln	6218	Syracuse	5961
Columbus	6297	Lodgepole	6233	Tecumseh	5890
Crescent L	6811	Loup City	6541	Tekamah	6330
Crete	5922	Madison	6586	Valentine	7300
Culbertson	6102	Madrid	6179	Wakefield	6860
Curtis	6115	McCook	5714	Walthill	6843
David City	6261	Merriman	6955	Weeping Water	6056
Ewing	6919	Minden	6002	West Point	6602
Fairbury	5986	Mitchell	6907	York	6082
Fairmont	6086				

Source: Path to Passive, Nebraska Energy Office, 1982.

EXAMPLE: The family in Broken Bow is losing 1,902,945 Btu's each year out the living room window. They want to know how much it costs them in dollars for this lost heat. They have been heating their home with propane gas for about five years.

$$\$ = \frac{1{,}902{,}945}{1{,}000{,}000} \times 9.73$$

$$\$ = 18.52$$

It costs about $18.52 each year for heat lost through the living room window.

The Difference with an Energy-Efficient Window Treatment

To determine how much difference a more energy-efficient window treatment would make, you simply re-figure the heat loss and fuel cost again, using the R-values for the particular window treatment you are considering. Add to the window treatment R-value the basic R-values for your window glass, storm window, and any air spaces.

Then determine how much you can save by subtracting the cost of your desired window treatment from the cost of your present window heat loss.

EXAMPLE: The same Broken Bow family wants to improve the window's energy-efficiency. They want to use an insulated Roman shade, but first they want to know if that will save money. They want a shade with a medium of bulk, so they are planning to use two layers of fiber-fill for insulation.

$$H = 24 \times HDD \times U\ value \times FT^2$$

(Note: The only value that changes this time is the U-value for the window and window treatment.)

$$U\ value = \frac{1}{1.50 + .9 + 3.12} = \frac{1}{5.52} = .1811$$

double-pane + air space + fiberfill batting

Putting this U-value into the heat lost equation:

$$H = 24 \times 6740 \times .1811 \times 20$$

$$H = 585{,}895$$

The window would only lose 585,895 Btu's each year with Roman shade. Cost of the heat loss with the shade is figured in the same way as figuring the loss with the drapery:

$$\$ = \frac{585{,}895}{1{,}000{,}000} \times 9.73$$

$$\$ = 5.70$$

The cost to heat the family's living room window with an insulated Roman shade is about $5.70 each year.

Subtracting this cost from the original heating cost will show how much money each year would be saved with the addition of the insulated Roman shade.

$18.52 original heating cost
- 5.70 heating cost with Roman shade
$12.82 saved each year by adding the insulated Roman shade.

Calculate Payback Period

Saving money with insulating window treatments is important. It is also important that the cost to install the window treatment is paid back within a reasonable time.

What is a "reasonable time" for one family might be two years, for another five.

The length of the payback period also depends on how much the window treatment costs in the first place. If two windows of exactly the same size are located in a home, the homeowner might choose two different window treatments, especially if the windows were in different rooms. One treatment might cost twice as much

Table 2. Approximate R-values for selected materials.

Material	R-value*
Single pane glass[1]	.90
Double pane glass[1]	
1/4-inch air space	1.50
1/2-inch air space	2.00
Triple pane glass[1]	
1/4-inch air space	2.55
1/2-inch air space	3.22
Storm windows[1]	
1 pane plus air space	2.00
Air space[1]	
3/4-inch to 4 inches deep	.90
Drapery	
Conventional (not insulated; not sealed)	.20
Two-layer system (drapery & lining on separate tracks)	1.94
Quilted[5] - Window Blankets	
5/8-inch fiberfill, 2 layers fabric	1.94
Roller-shade[2]	
Conventional	.18
Side tracks	.96
Venetian blinds[2]	.20
Interior shutter[2]	
3/4-inch polystyrene core between 1/8-inch Plywood panels	4.90
Fiberfill batting[3]	
5/8-inch thick per layer	
1 layer	1.56
2 layers	3.12
3 layers	4.68
Fiberglass batts[4]	
1-inch thick	3.20
Rigid foam insulation board[4]	
1-inch thick	
polyurethane	6.10
polystyrene (beadboard)	3.40
polystyrene (styrofoam)	3.80

[1]ASHARE Handbook of Fundamentals, 1977.

[2]U.S. Dept. of Energy. A Comparison of Products for Reducing Heat Loss Through Windows, 1981.

[3]Wisconsin Energy Extension Service. What About Windows? 1978.

[4]Agnet HOUSE program.

[5]Manufacturer's Test Data

*Values are from a variety of sources and must be used with caution. Existing window conditions (installation factors, air leakage characteristics, product variations) will alter calculations of installed product performance.

Table 3. Cost of fuel.[1]

	Cost/unit	Furnace efficiency[2]	Btu/unit[3]	$Cost/million Btu's usable heat
Electric	7.63¢/kWh[4]	100%	3413	$22.36
Natural Gas	70¢/100 cu.ft.	75%	101,600/100 cu.ft.	9.19
	,,	95%	,,	7.25
Propane	84.2¢/gal.	75%	91,000/gal	12.34
	,,	95%	,,	9.73
Oil, #2	$1.09/gal.	65%	134,700/gal	12.09
	,,	75%	,,	10.48

[1]Costs established by Department of Energy, March 19, 1984. To use your own fuel costs use this equation for determining $ cost/million Btu's:

$$\frac{\text{(cost/unit) x (1,000,000)}}{\text{(BTU/unit x (\% efficiency)}}$$

[2]Furnace efficiencies vary with age and maintenance practices. Newer units have higher rates of efficiency than older units. Well maintained units will also have higher efficiency;. Rates in table are for comparison of older to newer units.

[3]Btu Stands for British Thermal Unit

[4]kWh Stands for killowatt hour

Table 4. Estimated materials and costs for a 20-square foot insulated Roman shade.

Material	Amount	Unit Cost (1984)
Face fabric (Chintz)	3 yds.	$2.50-4.50/yd.
Lining fabric	3 yds.	1.99/yd.
Polyester fiberfill (2 layers)	40 sq. ft.	.14/sq.ft.
Plastic sheeting	20 sq. ft.	.10/sq. ft.
Cord	9.5-10 yds.	.15/yd.
Plastic rings	24	.04 each
Slat rod	60" length	.13/ft.
Mounting board	1" x 2" x 60"	.11/ft.
Awning cleat	one	1.69

as the other. If both saved the same amount of heat each year, it would still take twice as long to pay back the costs of installing the more expensive window treatment.

It is important to note that the same window treatment won't be appropriate for every home or every room in the home. Variety adds spice to life! What is best for you may not be the choice that someone else would make.

The formula for calculating simple payback period is:

$$\textbf{PB} = \frac{\textbf{dollar cost of window treatment}}{\textbf{cost of heat saved each year}}$$

EXAMPLE: The Broken Bow family wants to know how long it will take them to save enough money on their heating bill to pay back the cost of putting in the insulating Roman shade.

To figure cost of the shade materials see Table 4. (Note: See HEG 80-111 How to Make a Roman Shade for explanation of materials).

For a 20-square foot shade the following materials costs are estimated.

$ 5.60 fiberfill batting
2.00 plastic sheeting
6.00 lining fabric
7.50 face fabric
5.26 cord, cleat, rings, board for mounting, slat rod
$26.36 Total cost for shade and installation

Take the total cost and divide by the yearly savings to get the payback:

$$PB = \frac{26.36}{12.82}$$

$$PB = 2.05$$

The payback for this particular Roman shade is about two years.

Remember that payback is always figured on the basis of current costs for fuel and price paid for the window treatment. If fuel costs rise, the payback period will be shorter.

Equations

1. Heat loss: $H = 24 \times HDD \times U\text{-value} \times FT^2$

2. Cost/million BTU's usable heat:

$$\frac{(\text{cost/unit}) \times (1{,}000{,}000)}{(\text{Btu/unit}) \times (\%\ \text{efficiency})}$$

3. Cost of heat loss:

$$\$ = \frac{H}{1{,}000{,}000} \times \frac{\text{cost/million Btu's}}{\text{available heat}}$$

4. Payback:

$$PB = \frac{\text{dollar cost of window treatment}}{\text{cost of heat saved each year}}$$

Adapted from FS776 Energy-Efficient Window Treatments, South Dakota State University, Cooperative Extension Service, 1983 with help from Rich Pierce, Ag Engineering Department, UNL.

Table 3. Cost of Fuel.[1]

	Cost/unit	Furnace efficiency
Electric	[illegible]	100%
Natural Gas	79¢/100 cu. ft.	[illegible]
	[illegible]	95%
Propane	$4.20/gal.	75%
	[illegible]	95%
Oil, #2	$1.39/gal.	80%
	[illegible]	75%

[1] Data examined in September at Portage, Walton Dr. [illegible]

[2] Furnace efficiency varies with age and other factors [illegible] will also have higher efficiency. Table is taken just for comparison [illegible]

[3] [illegible] Thermal Units.

[4] [illegible] kilowatt hour.

Table 4. Estimated materials and costs for a 29-square foot insulated Roman shade.

Material	Amount	Unit Cost (1986)
Face fabric (Chintz)	3 yds.	$7.50-8.50/yd.
Lining fabric	3 yds.	1.49/yd.
Polyester Fiberfill (1 layer)	40 sq. ft.	.14/sq. ft.
Fusible interfacing	20 sq. ft.	.10/sq. ft.
Cord	9.5-10 yds.	.15/yd.
Fiberglass rings	24	.04 each
Top rod	60" length	12.00
Mounting board	1" x 2" x 60"	11.00
Average shade	one	1.69

as the other. If both saved the same amount of heat each year, it would still take twice as long to pay back the costs of installing the more expensive window treatment.