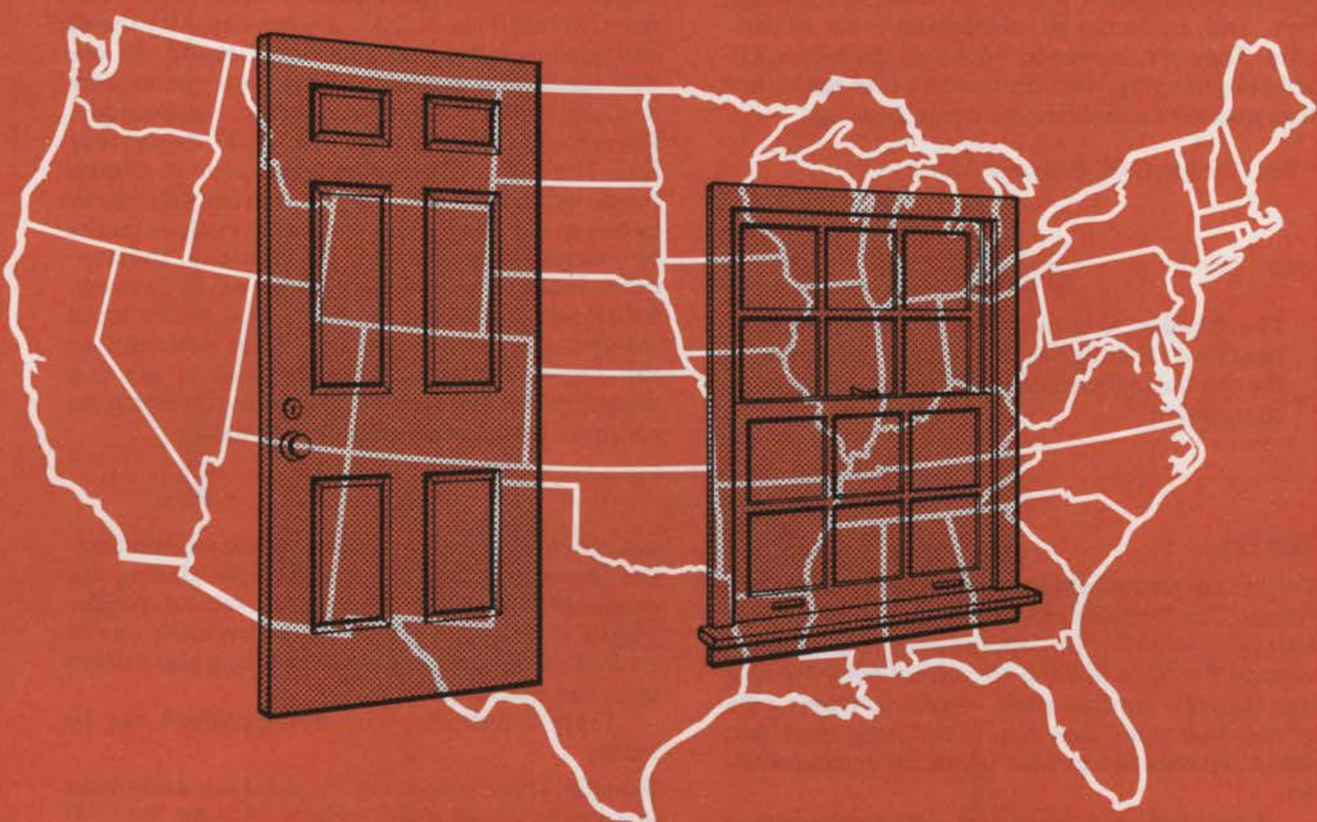
University of Illinois at Urbana-Champaign
Small Homes Council-Building Research Council

COUNCIL NOTES



A1.61 SAVINGS
by Insulating Doors and Windows

Savings by Insulating Doors and Windows A1.61 Volume 4 Number 3 Winter, 1980 Twenty five Cents

This publication provides data for estimating the energy that can be saved by the insulation of doors and windows.

The tables give estimates of the amount of natural gas that must be purchased and consumed to offset the heat loss from doors and windows with varying treatments.

Fuel requirements are expressed in terms of natural gas because most of the homes in the United States are heated with gas. Simple conversion factors are provided on page 7 for changing therms of natural gas to gallons of fuel oil or LP gas or to kilowatt-hours of electricity. The tables are adjusted to account for the efficiency* with which the different fuels can be utilized.

The figures in the tables are estimates, since weather conditions, quality of building construction, and, in particular, living habits are so variable. They are, however, based on the best available engineering data for making fuel consumption and cost estimates for home heating.

* See Circular G3.5, *Fuels and Burners*.

R-Value

The R-value is a measure of resistance to heat flow; the higher the R-value the better the insulating properties of the material or component.

Degree-Days

The degree-day is a convenient measure for estimating the heating demand for a building. For any given day, the number of degree-days for that day is given by the difference between 65°F and the mean daily temperature (average of minimum and maximum values). The daily values are added to provide monthly and seasonal totals.

USE OF TABLES

To use these tables: **Determine the degree-days for your locality.**

Pages 4 and 5 of this circular show a degree-day map (in intervals of 1,000 degree-days) for the 48 contiguous states and southern Canada. To use this simplified method, locate your community and the nearest degree-day lines. For example, Cleveland, Ohio, is near the 6,000 degree-day line. The degree-day values correspond to column headings in each table. If you live about midway between two lines, then average the values for the two degree-day columns. For instance, Indianapolis, Indiana, would use average values between 5,000 and 6,000 degree-days. Any more exact interpolation is not realistic. After determining the degree-day value for your locality, use this value for all subsequent calculations, ignoring the columns for all other degree-day values.

DOORS

Doors contribute substantially to the heat loss of a house. The R-values of a door may be higher than that for a window, but oftentimes the infiltration around the door is more important than the heat loss through the door itself. Weatherstripping the prime door is the first step in reducing heat loss, and a separate storm door is usually recommended.

A vestibule is an extremely effective means of reducing entry losses. Sliding glass doors can be extremely large energy users except when located on the south wall. In cold climates, double glazing and the use of doors with tight fit to reduce infiltration of outdoor air are recommended. Doors with factory-sealed triple glazing are available. In severe climates, a second single-glazed sliding glass door can be installed on the outside of the prime unit, or a sliding glass storm door can be added.

Table 1 indicates the savings which can be made.

Example. Three storm doors are added to outside doors in a house located about midway between the 8,000 and 9,000 degree-day zones.

Fuel Requirement before and after change.

1. **Before:** Consider case (2), door with weatherstripping. Use the average of 78 and 88, or 83 therms for each door.
2. **After:** Consider case (3), and use the average of 54 and 61 or 57 therms for each door.
3. **Therms Savings:** 83 − 57 = 26 therms for each door.
4. **Adjustment for Number:** 26 × 3 = 78 therms per season for three doors.

Note that the savings would be much larger if the original doors were not provided with effective weatherstripping. It is apparent that weatherstripping is a high priority measure in any retrofit program.

An insulated metal door by itself is almost as effective as a wood door plus storm door.

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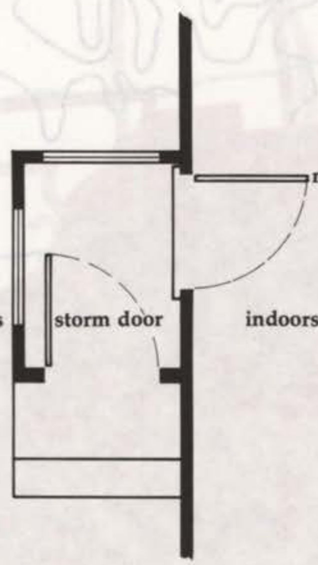
TABLE 1. OUTSIDE DOORS

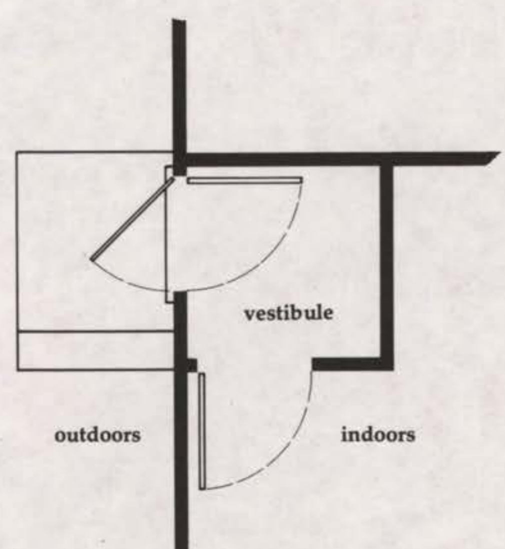
(therms of natural gas burned per season to replace heat lost through one 20 sq. ft. door)

Type of door	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
1. Single door	30	46	63	80	98	115	132	149	167
2. Single door, tight fit	18	27	37	47	58	68	78	88	98
3. Storm door added	12	18	25	33	40	47	54	61	69
4. Metal door	13	21	29	37	45	54	62	70	79
5. Vestibule (see sketches below)	4	6	8	10	13	15	17	20	22
Sliding Glass Doors (therms of natural gas burned per season to replace heat lost through 2 doors totalling 40 sq. ft.)									
6. Single glazing, average fit	39	60	83	105	128	150	172	196	218
7. Double glazing, average fit	25	40	56	71	87	103	118	135	151
8. Double glazing, tight fit	18	29	41	52	64	76	89	101	113
9. Double glazing, storm door	15	25	36	46	57	67	78	89	100
10. Triple glazing, storm door	10	17	24	30	37	44	51	58	66

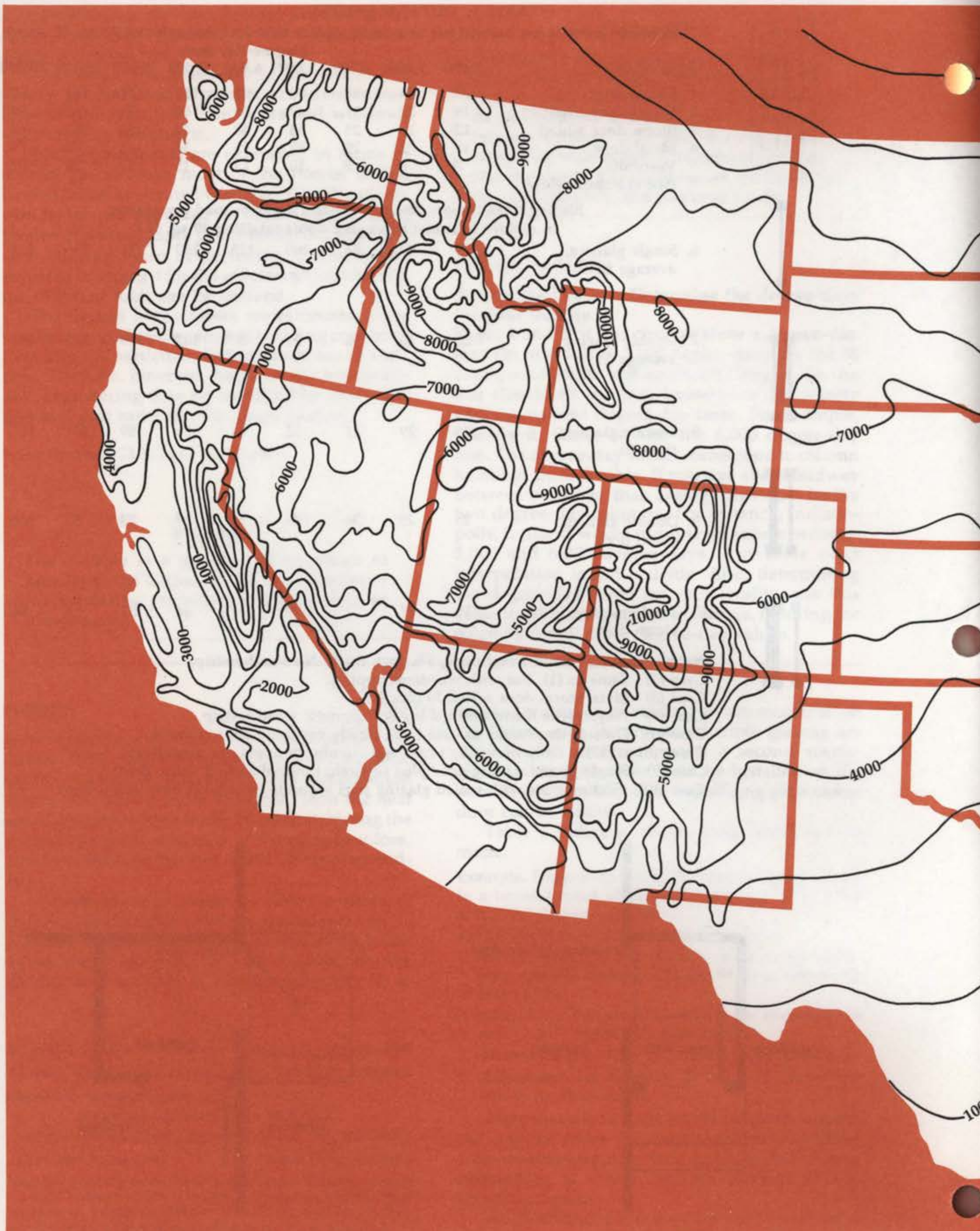
Notes: Case (1) Solid wood door, 1¾ inch thick. No weatherstrip.
Case (2) Same as (1), but with weatherstripping.
Case (3) Metal storm door added to case (2).
Case (4) Polystyrene foam, thermal break, magnetic weatherstrip.
Case (5) Outside door same as case (2). Outside vestibule door is metal.
Cases (6) to (10). Only thermally improved aluminum doors are considered.
Case (9) Single glazed sliding door plus separate external sliding storm door.
Case (10) Sliding door with sealed glazing plus separate external sliding storm door.



Enclosed porch



Enclosed vestibule with outside door and storm door.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HEATING DEGREE-DAYS
65°F. base
Redrawn from The National Atlas of the United States of America, 1970

WINDOWS

The R-value for windows vary widely, so that a single R-value could not be selected for each type of glazing. The R-value depends upon:

- the air space between the panes of glass (the smaller air spaces have lower R-values than do spaces greater than ¾-inch).
- the presence of thermal barriers or "thermal improvements." (These are insulating plastic connectors that reduce the heat conduction of metal frames.)
- the width of metal or wood frames that enclose the glass. (Since wood has a higher R-value than glass, the wider the wood frame, the smaller the glass area, and the higher the overall R-value for the window.)

The R-value (or the U-value, which is 1/R) of the entire window can be obtained from the manufacturer's catalog. This value should be one determined from actual tests rather than from theoretical calculations.

Note that it is possible for a triple-glazed window (R-1.70) to show an R-value less than that of a well-constructed, double-glazed window (R-1.79). The difference is presumably due to the differences in the air spaces between the panes.

In the tables that follow, the various combinations of window glazings are defined as follows:

- A **single-glazed window** has just one thickness of glass.
- **Double-glazing** has two glass sheets with one air space, either in the form of a **sealed, insulating glass** unit or a single-glazed window **with storm sash**.
- **Triple-glazing** refers to either a factory-sealed insulating unit consisting of three panes of glass enclosing two air spaces, or a sealed insulating glass unit plus a separate single pane.
- **Quadruple-glazing** refers to the ultimate in glazing protection, consisting of sealed glass units in both the prime window and storm sash.

Energy calculations are based on windows of good quality and workmanship. In the case of aluminum windows, for example, the data in the tables include only those for "thermally improved" windows. Within each class of windows, wide variations in R-values were found in available windows. Be sure, therefore, to obtain manufacturer's **certified test values**.

Annual Energy Savings

To estimate **annual energy savings** due to improvement of windows:

1. Determine annual fuel requirement for the **original** windows from Tables 3 and 4.
2. Determine annual fuel requirement for **improved** windows.
3. The difference between 1. and 2. is the **annual fuel savings** (in therms of natural gas).
4. Adjust for the actual area of the windows. (Determine total area of windows, divide by 10, and multiply by the value from step 3.)
5. To convert to other fuels, and to determine the **return on investment,** see pages 7 and 8.

Example. Seven windows in a house in the 6,000 degree-day zone have a total area of 72 square feet. All seven windows, which now have single glazing, are to be fitted with storm sash.

Fuel Requirement before and after change.

1. **Before:** 28 therms for 10 square feet of single glazing. (See 6,000 degree-days.)
2. **After:** 12 therms for 10 square feet of double glazing. (Also 6,000 degree-days.)
3. **Therm Savings:** 28 − 12 = 16 therms for 10 square feet, or
4. **Adjustment for Area:** 16 × 7.2 = 115 therms for 72 square feet.

In addition to saving energy and money, improved glazing makes the room more comfortable by reducing drafts and providing warmer glass surfaces. When a storm sash is used in addition to the prime sash, it allows less infiltration around the sash and reduces the transmission of outside noise. The warmer glass surface also allows higher humidity without condensation on windows. Estimated glass temperatures are given in Table 2.

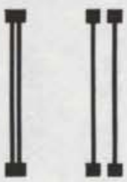
The use of triple glazing should be seriously considered in both old and new homes, especially in cold climates (5,000 degree-days or more) or regions of high energy costs. In existing houses, the installation of the third layer of glass or plastic can be either on the inside, outside, or in between the existing window and storm sash.

TABLE 2
INSIDE GLASS SURFACE TEMPERATURES
(for 0°F outdoor and 70°F indoor temperatures)

Single glazing	16°F to 23°F
Double glazing	
sealed glass unit	38°F to 43°F
prime + storm	43°F to 49°F
Triple glazing	
sealed triple unit	42°F to 52°F
prime (sealed double) + storm	50°F to 53°F
Quadruple glazing	
prime (sealed double) + storm (sealed double)	54°F to 56°F

TABLE 3. MOVABLE SASH

(therms of natural gas burned per season to replace heat lost through 10 square feet of glass area)



Glazing type	R-value	U-value	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Single Glazing	*0.89	1.12	8	13	18	23	28	32	37	42	47
	**1.01	0.99	8	12	16	21	25	29	34	38	43
Double Glazing											
Insulated glass	1.47	0.68	5	8	11	14	17	21	24	27	31
	1.79	0.56	4	7	10	12	15	18	21	24	27
Prime + storm	1.79	0.56	3	6	8	10	12	15	17	19	22
	2.22	0.45	3	5	7	9	11	13	15	17	19
Triple Glazing											
Insulated glass	1.70	0.59	3	6	9	11	14	17	20	23	26
	2.70	0.37	3	5	7	9	11	13	15	17	20
Prime (insulated	2.33	0.43	2	4	6	7	9	11	13	15	17
+ storm)	2.78	0.36	2	3	5	6	8	10	11	13	15
Quadruple Glazing											
Insulated prime +	3.01	0.33	1	2	4	5	7	8	9	11	12
insulated storm	3.41	0.29	1	2	4	5	6	7	8	10	11

* Mean of thermally improved aluminum windows (AAMA tests).

** Calculated values for wood windows based upon ASHRAE *Fundamentals*, 1977, p. 22-24.

Savings for Other Fuels

Use the preceding tables to determine savings in therms of natural gas.

Oil. Multiply the savings in therms by 0.7 to get savings in terms of gallons of fuel oil per season. These estimates are based on a well-maintained and properly operating oil burner both **before** and **after** the change in insulation.

LP Gas. Multiply the saving in therms by 1.08 to determine the savings in gallons of LP gas.

Electrical Resistance Heating. Multiply savings by 20.5 to get savings in kilowatt-hours of electricity. This is based upon resistance heating, either baseboard or ceiling cable located in the room. For an electric furnace, multiply by 21.5.

Electric Air-to-Air Heat Pump. If operating data for seasonal operation is available locally, your power supplier may help you determine the multiplier for your locality. If such data are not available, use the multiplier given below.

Zones 2,000 to 3,000 - Use multiplier of 12.
Zones 4,000 to 5,000 - Use multiplier of 15.
Zones 6,000 to 7,000 - Use multiplier of 17.
Zones 8,000 to 10,000 - Use multiplier of 18.

Dollar Savings

To determine the dollar value of the annual energy savings, multiply the therms of gas, gallons of oil or LP gas, or kilowatt-hours of electricity saved by the unit price of the fuel. Natural gas is normally priced by the therm, LP gas and oil by the gallon, and electricity by the kilowatt-hour. Your local supplier can provide current prices.

TABLE 4. FIXED SASH

(therms of natural gas burned per season to replace heat lost through 10 square feet of glass area)

Glazing type	R-value	U-value	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Single Glazing	*0.89	1.12	7	10	14	17	21	25	29	32	36
	**1.01	0.99	6	9	12	15	19	22	25	29	32
Double Glazing											
Insulated glass	1.47	0.68	3	5	7	9	12	14	16	18	21
	1.79	0.56	3	4	6	8	10	11	13	15	17
Prime + storm	1.79	0.56	3	4	6	8	10	11	13	15	17
	2.22	0.45	2	3	5	6	8	9	11	12	14
Triple Glazing											
Insulated glass	1.70	0.59	2	4	6	7	9	11	13	14	16
	2.70	0.37	1	2	3	5	6	7	8	9	10
Prime (insulated	2.33	0.43	2	3	4	5	7	8	9	11	12
+ storm)	2.78	0.36	1	2	3	4	6	7	8	9	10
Quadruple Glazing											
Insulated prime +	3.01	0.33	1	2	3	4	5	5	6	7	8
insulated storm	3.41	0.29	1	1	2	3	4	4	5	6	7

* Mean of thermally improved aluminum windows (AAMA tests).
** Calculated values for wood windows based upon ASHRAE *Fundamentals*, 1977, p. 22-24.

Return on Investment

Get an estimate of the cost of the improvements you wish to make, such as storm windows. Determine the annual dollar savings, as above. Divide the total cost of the improvements into the annual dollar savings, and multiply by 100 to get percent return on investment.

Example. Storm windows which cost $325 to install will save $62.50 in fuel each year. The return on investment is $62.50/$325 × 100 = 19.2%.

Basis for Calculations

The following assumptions were made in the calculation procedure used in this circular: A degree-day base of 65°F; an indoor-air temperature of 70°F; R-values and U-values for materials as published in ASHRAE tables; for natural gas, furnace and boiler efficiency of 70%; for fuel oil, calorific value of 140,000 Btu per gallon and efficiency of 70%; for electrical resistance heating, thermal value of 3412 Btu per kWh and efficiency of 100%; for electrical heat pump heating, performance as indicated; infiltration, based on crackage method, is included in the heat loss for doors and windows; R-value for ceiling-roof combination is based on an R of 3 (R-value of ceiling alone) and temperature difference taken from indoor to outdoor air; slab floor design heat loss data from Small Homes Council data; and, finally, the modification in the "24" of the basic equation as in *Estimating Energy Requirements for Residential Heating*, by Warren S. Harris and Calvin H. Fitch, ASHRAE Journal, October, 1965.