ENERGY RETROFITTING

HISTORIC

DOUBLE HUNG WINDOWS

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RON ZMYSLO has been involved in the building industry for over 33 years beginning at age 15. His background includes careers in construction estimating, project management, building design and contracting. Ron has been employed by both large and small general contracting firms in Northwest Indiana and Southwest Lower Michigan. In addition he has completed a 10 year apprenticeship under Architect Everette Jewel A.I.A. in South Bend, Indiana. His experience includes residential, commercial, industrial and institutional design and constructing as well as historic preservation. Prior to his current position with Historic Landmarks Foundation of Indiana as the Director of Restoration Services, he owned and operated a design and build firm "Creative Residential Designs" specializing in new home construction and remodeling and renovation. Additionally he has relocated and renovated scores of vintage and historic properties in Northwestern Indiana. Ron is a member of the Association of Preservation Technology International (APTI) and the Preservation Trades Network (PTN). Currently he is President of the newly formed Ohio Valley Chapter of APTI a regional chapter encompassing the states of Indiana, Ohio, Northern Kentucky and Southeastern Illinois. Over time Ron has sat on all three sides of the construction relationship: as the designer, the builder and as the owner bringing to the table his unique perspective.

ENERGY RETROFITTING HISTORIC DOUBLEHUNG WINDOWS
OUTLINE

I. PERFORMANCE DATA

A. Home Energy Magazine *What Should I Do About My Windows?* Mattinson, DePaola, Arasteh

B. U. S. Department of Energy *A comparison of Products for Reducing Heat Loss through Windows*

II. ENERGY ISSUES

A. Infiltration/exfiltration

1. Weather-stripping

B. Thermal Resistance

2. Glazing options

C. Balancing systems

III. THE SYSTEM

A. Weather-stripping system

B. Glazing

C. Storm windows

IV. COST COMPARISON

and the information we've generated from applying the prototype tool to a retrofit project in a cold climate.

Our decision tree will help users to answer basic performance and energy-related questions, such as these:
- What is the existing system, and how well does it perform?
- How is the proposed system expected to perform?
- Will there be significant energy
savings?
- Will comfort, condensation, fading, and noise problems be improved?

Answers to these questions, tempered by the budget and personal preferences of the homeowner, can help to take guesswork out of decision making. As with any other home improvement project, nonenergy-related consideratio example, how long the owner intends to keep the home and what effect the changes will have on the property valu arise that are wildcards beyond the scope of our evaluation.
Answering the first question, on the performance of the existing windows, is often difficult, because information o and SHGC values of older windows is scanty. To overcome this obstacle, we used WINDOW, an NFRC simulation available free from Lawrence Berkeley National Laboratory (LBNL), to calculate U-factor and SHGC values for so existing windows and various retrofit scenarios (see Table 1). The effects of infiltration were bounded using stand for tight, average, and leaky installed windows. Homeowners, builders, or product vendors should be able to use t values and plug them into RESFEN—a software program that produces annual energy simulations for homes in m of the United States—to make reasonable energy performance calculations and develop dollar savings estimates f strategies that they are exploring. RESFEN is easy to use and is also available free from LBNL.

Table 1. Tested Performance Values for Several Window Retrofit Scenarios

Case	Product	U-factor	SHGC	Notes	Inside surface glass temp. at 0°F outside
1	Single-pane wood	0.98	0.64	Unimproved single-pane	16
2	Single-pane + exterior storm (existing DePaola)	0.49	0.56	Single-pane clear glass, storm added	44
3	Single-pane + low-e storm	0.38	0.48	Hard coat low-e on storm	51
4	Single-pane + interior film	0.50	0.57	Typical DIY interior storm	44
5	Single-pane + storm + film	0.32	0.51	Add exterior + interior storm glazing	53
6	Double-pane + cellular shade	0.24	0.24	Mfg. data (not tested by us), values are with shade closed	Not available
7	Double-pane wood/vinyl clear glass	0.50	0.58	Wood or vinyl double-pane, no low-e	45
8 high	Double-pane wood/vinyl low solar low-e argon	0.40	0.54	Wood or vinyl double-pane with high solar gain low-e glass + argon	55
8 low	Double-pane wood/vinyl low solar low-e argon	0.34	0.34	Wood or vinyl double-pane with low solar gain low-e glass + argon fill	57
9	Double-pane wood + exterior storm	0.32	0.47	Wood double-pane + clear single-pane exterior storm	54
10	Double-pane wood low-e + storm	0.29	0.41	Wood low-e + clear exterior storm	58

* Note: Values for cases 7–10 are typical for similar products; ask suppliers if NFRC values are available.

Replacing Windows in Wisconsin

Table 2. Annual Window-Only Heating and Cooling Costs in Madison, Wisconsin

Case	Option (All have wood prime window)	Infiltration	Annual Cost	Description
1A	Single-pane	0.3 CFM	$356	Best-case, very tight-fitting, single-pane wood windows
1B	Single-pane	1.0 CFM	$389	Tight single-pane wood windows
1C	Single-pane	2.0 CFM	$437	Loose, leaky single-pane wood windows
2A	Single-pane +storm	0.3 CFM	$176	Tight single-pane wood windows with storm windows
2B	Single-pane +storm (existing DePaola)	1 CFM	$211	Loose fitting single-pane wood windows with storms
2C	Single-pane +storm	2 CFM	$257	Single-pane wood with storm—large air leaks
3A	Single-pane + low-e storm	0.3 CFM	$138	Existing single-pane + low-e storm; low air leakage
3B	Single-pane + low-e storm	1 CFM	$170	Add low-e storm, moderately tight
4A	Single-pane + interior storm	0.3 CFM	$180	Add interior DIY storm —very tight fitting
4B	Single-pane + interior storm	1 CFM	$214	Add interior storm—moderately tight
5A	Single-pane + exterior storm + interior storm	0.3 CFM	$104	Add both interior and exterior storm —low leakage
5B	Single-pane + exterior storm + interior storm	1 CFM	$135	Add interior + exterior storm —moderate air leaks
6	Single-pane + cellular shade	NA	NA	Not available—Results depend on whether blind is open or closed
7	Double-pane clear	0.3 CFM	$178	New double-pane wood or vinyl window
8A	Double-pane hard low-e	0.3 CFM	$137	New double-pane wood or vinyl with high solar gain low-e
8B	Double-pane low solar low-e	0.3 CFM	$137	New double-pane wood or vinyl with low solar gain low-e
9A	Double-pane, clear glass + exterior storm	0.3 CFM	$109	New Double-pane wood + exterior storm (tight)
9B	Double-pane, clear glass + exterior storm	1 CFM	$141	Existing Double-pane clear wood + exterior storm (moderate leak)
10	Double-pane low-e + exterior clear storm	0.3 CFM	$100	High solar low-e (Note: Double-pane clear window/low-e storm performance is similar.)

Note: This table accounts for heat loss and gain through windows only.

Evaluating the Choices by the Numbers

Any of the retrofits described above may be appropriate, depending on the condition of the existing windows, hea aesthetic considerations, budget constraints, and product availability. While many window retrofits will be made of whether they save energy ("I just can't stand these old windows for another winter"), economic comparisons ar

U.S. Department of Energy

A Comparison of Products for Reducing Heat Loss through Windows

Many products similar or identical to those described in the tables on pages 4.5,6, and 7 are offered under different product names by different distributors. Since the array of available products is expanding rapidly, it is difficult to keep abreast of all newly offered products. Manufacturers are encouraged to send information on their products to: Energy Efficient Windows Program, Lawrence Berkeley Laboratory, B90-3111, Berkeley, CA 94720.

Product descriptions, performance claims, and data are reproduced from information supplied by the manufacturers. No claims are made concerning the validity, accuracy, or completeness of any product descriptions. Owing to the number of manufacturers of these products, only a representative sample could be included. Absence of any product, trade name, or manufacturer should not be construed to reflect unfavorably on that trade name or manufacturer, and the mention of certain company names or brand-name products is not intended as a recommendation of them over other companies or similar products on the market. Before purchasing or ordering any materials, the reader should follow sound practice and contact the manufacturer directly (or appropriate distributors and retailers) for complete information regarding a proposed application. Inclusion in this document does not constitute an endorsement by the Lawrence Berkeley Laboratory, the University of California, or the U.S. Department of Energy.

A primary goal of the Department of Energy (DOE) is the development and commercialization of new building design strategies, products, and technologies to improve the design, construction, and operation of energy efficient buildings. Lawrence Berkeley National Laboratory is providing technical assistance to the Buildings Division, Conservation and Solar Energy, DOE, by managing its energy efficient windows program.

The table presented in this brochure is taken from the Energy Efficient Windows Program publication **Windows,** which is available free of charge to individuals or firms involved in any aspect of the development, manufacture, and use of energy efficient windows, components, and accessories. To be added to the mailing list, write to the program address given below. **Windows** seeks to accelerate exchange of information by (a) bringing together inventors and manufacturers, (b) bringing new products and research results to the attention of architects and engineers, and (c) bringing grass-roots communications to the attention of those in the complex structure of federal, state, and local energy programs. DOE believes that a single contact between individuals or firms resulting from information contained in the publication may have considerably greater impact in advancing the commercialization of a new window product than would a substantial direct R&D investment by DOE. The intent of **Windows** is not to advertise products but rather to inform readers about them and to provide sources of further information.

DISCLAIMER

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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.

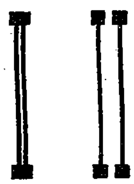
In addition to saving energy and money, improved glazing makes the room more comfortable by reducing drafts and providing warmer glass surfaces. When a storm sash is used in addition to the prime sash, it allows less infiltration around the sash and reduces the transmission of outside noise. The warmer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

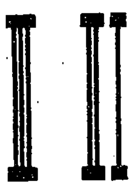
The use of triple glazing should be seriously considered in both old and new homes, especially in cold climates (5,000 degree-days or more) or regions of high energy costs. In existing houses, the installation of the third layer of glass or plastic can be either on the inside, outside, or in between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

The sash are held in the frame by the stops and parting beads which form a channel in which the sash slide up and down. The window frame is held in the wall by the interior and exterior casings which are nailed to the frame along their inner edges and to the wall along their outer edges.
As I survey and assess the conditions of windows I sketch sections of the jamb, header and sill with measurements and notes on materials. These sketches are important planning tools -- as important as the pry bars and scrapers used later on. They help me understand how the window is constructed and how it should operate.