Windows: Energy Efficiency Facts and Myths

Shanon Peterson Wasielewski

Purpose and Methodology

My decision to do this project was prompted by my belief in the important of retaining historic windows and my second-hand knowledge that replacing them in the name of energy efficiency was not sound, especially in warmer climates. The problem was that while I could say make that statement I didn't really understand how to back it up. As I started, I realized just how little I knew about energy efficiency, heat flow, etc. Over the course of the semester, I've conducted a great deal of research about energy efficiency, window rehabilitation, window replacement, etc. I've spoken with various energy-related professionals and worked with various computer programs designed to measure the efficiency of various windows. In general, the only time I ran across the advice to replace windows was in literature from the industry. Most articles and books on energy efficiency in general did not recommend wholesale replacement of windows as a cost effective option. It's intriguing that the replacement window has seemingly had such huge success in shifting public opinion. I spoke recently to a recently hired Energy Advisor at my local electricity provider. I asked him about energy audits. He informed me that he didn't do audits per se, but he would visit with people at their homes about how to conserve energy. "If I went to a house with single-pane historic windows, the first thing I'd say is to think about replacing them." I questioned if that would really be the first bit of advice and he answered affirmatively. I challenged him with the fact that replacing the windows would be costly and, in this climate, might only save a homeowner $30/yr. "Yes, but triple pane windows are most efficient." How else do you explain this gut reaction by an energy professional than to attribute it to the successful marketing by the window industry?

As I see it, the purpose of this project is to inform both historic homeowners and small contractors about wood windows: not only their architectural significance but also their ability to be retained and rehabilitated. It is to educate them about how and why it is more cost effective to repair windows than to replace them. With this purpose in mind, the document is not written in a technical way, but rather in layman's terms for use by the general public. All the technical information about windows and energy efficiency one could ever want is out there somewhere. What is lacking, both for preservationists as a way to "make their case" and for homeowners concerned with the bottom line, is information in plain English. That's what I hope to provide.

Windows: Energy Efficiency
Facts and Myths

The replacement window industry says that single-pane wood windows cannot be energy efficient and must be replaced. The local historic district design guidelines say that historic windows must be retained, seemingly without regard to energy efficiency. The homeowner is caught in the middle without the facts. The truth is that windows (old or new) are never highly energy efficient when compared with other materials. Will triple-glazed, Low-e, argon gas-filled replacement windows decrease heat loss to a level below that which is allowed by a historic window? Chances are that it will. The big question, though, is whether the decrease will result in a cost savings that makes replacing the windows cost effective. In general, the answer is no. This paper will elaborate on this point.

We'll start with a general discussion of heat flow and of home energy as well as energy audits and identifying areas of energy loss. This will be followed by a discussion of windows: value, design, materials, costs, life expectancy, etc. To conclude, we'll look at energy cost calculations of various window types and compare those costs or savings over its lifetime with the initial cost of the window.

Heat Flow and Energy Loss

The basic issue behind understanding energy efficiency is heat flow: the transfer of heat energy from one place to another. It's important to understand and remember that heat always flows from warm area to cool ones. In your home in winter, heat does not just disappear it leaves. The opposite occurs in the summer; the heat flows inside and forces your air conditioner to cool it as well. The level of winter heat loss and summer heat gain, along with efficiency of appliances, etc., plays a dominant role in determining energy costs. Weatherization efforts decrease heat flow. In a typical one-story house, 25-28% of heat loss occurs through the ceiling or roof, 22-25% is lost through the walls, 15-22% is attributable to the windows, 14-15% of heat loss occurs by air infiltration and 5-10% is lost through the floors.[1] This is important to understand. While windows are often blamed for heat loss, they account for approximately 1/5 of the heat loss.

It's also important to learn how heat flows: conduction, convection and radiation. Conduction is the transfer from one molecule to the next. Convection is the transfer of heat by the movement of liquids or gases. Commonly, this is referred to as air infiltration or "drafts." Finally, radiation is the transfer of heat through open space by electromagnetic waves. The heat radiates in a straight line from a source to a cooler area. Radiation is the least significant method of energy loss in a home. Convection is a larger consideration. It is the leakage of outdoor air into the home such as the cold draft the sometimes blows under the door in winter, for example. According to Doug Rye, 35% of the average heating and cooling load is due to air infiltration alone. Windows of any kind account for some level of air infiltration, but there are many other culprits. Air infiltration comes from cracks throughout the house, around electrical outlets,

---

[1] Lewis Vaughn, *Chilton's Guide to Home Energy Saving* (Radnor, Pennsylvania: Chilton Book Company, 1982), 3.

through recessed can lighting and through the fireplace. In addition to these areas and others, the biggest offender in the southern United States is ductwork leakage.[2]

A house loses most of its heat by conduction. As mentioned above, conduction is the transfer of heat from one molecule to the next. Conducted heat travels like a spill soaking into a paper towel: it spreads. The rate of conduction depends on the type of material. If you place a metal rod near a fire, you will quickly feel the heat at the other end. This is because the rate of conduction is high (resistance is low). Adversely, if a wood rod were placed near the fire, it would take much longer to feel the heat at the other end due to woods lower rate of conduction. Conduction is also the reason that a tile floor will feel colder to a bare foot than the bathroom rug will. Tile is a faster conductor, so the heat from the foot transfers to the tile much more quickly. The cold sensation felt by the skin is due to the heat loss.

Conduction is best discussed by using R-values and U-values. A material's resistance to heat flow is its R-value. The R-value is a ranking of resistance and has no unit of measure. The U-value, which is the inverse of the R-value, is the measure of the rate of heat transmission through a material. Specifically, the U-value is the amount of heat transmitted per hour through a square foot of material when there is a one-degree temperature difference between the air on each side. U-values are expressed in Btu (British thermal unit), a standard heat measurement defined as the amount of heat required to heat a pound of water one degree. These definitions both use degrees Fahrenheit. For example, a single glass window might have an R-value of .88-1, while a typical wall with moderate insulation might have an R-value in the 16-19 range. To determine the R-value of a unit, wall for example, with more than one material, you simply add up the R-values of all the materials present.

In order to really understand what is happening in terms of energy loss in a house, a home energy inspection or energy audit must be done. Several books and websites exist with instructions and formulas for do-it-yourself energy inspections. To do this, one would follow a number of steps to locate air leaks, check for insulation, inspect heating and cooling equipment and examine lighting.[3] Obvious air leaks can be expected from windows that rattle or where daylight can be seen through cracks and around frames. Many air leaks can be sealed by caulking or weather stripping. According to Doug Rye, in a typical house all of the air infiltration alone adds up to the equivalent of having two doors standing open all the time.[4] Energy efficient appliances are of particular importance as well as efficient light bulbs. A typical household light bulb gives off 90% heat and only 10% light. Better light bulbs conserve energy.

It is also an option to have a professional energy audit. This will likely include both a walk-through similar to the one discussed above and a blower door test to determine the air infiltration rate. It is important for a professional to become involved before making significant changes in the air pressure, especially if gas appliances are involved. If the wrong place is fixed or it's all

---

[2] Doug Rye, "Doug Rye Energy Tips II: Seal Your Windows, Doors and Ducts, and Save Yourself Some Really Big Bucks" Videotape.
[3] U.S. Department of Energy, "Home Energy Audits" (Energy Efficiency and Renewable Energy Website. http://www.eere.energy.gov/consumerinfo/refbriefs/ea2.html), Accessed 20 March 2004.
[4] Rye video.

sealed up too well, carbon monoxide poisoning could result. In addition, some breathability is a beneficial way to reduce the risk of mold and other moisture related problems.

Understanding Windows

Why all this concern over windows in the first place? "Some have compared the windows of a building to the eyes of a person's face. Clearly, the windows on traditional buildings are an important aspect of their architectural character. The size and proportion of the openings, the material that they are made from and their finishing details are all important in maintaining a building's character."[5] Several features make windows significant, such as pattern and size of openings, proportions, configuration of panes, profiles, etc. Replacement windows often alter some or all of these window features. When making decisions about windows in historic buildings, it important to understand what makes a window significant. "Windows should be considered significant to a building if they: 1) are original, 2) reflect the original design intent for the building, 3) reflect period or regional styles or building practices, 4) reflect changes to the building resulting from major periods or events, or 5) are examples of exceptional craftsmanship or design."[6]

Except in the case of fixed or picture windows, windows are meant to open and provide natural ventilation. In general, windows open in two ways: on hinges (casement, awning, hopper) or sliding (horizontal sliders or double and single hung). The principles discussed here relate to any type of operating system, but in general, the discussion will focus on double hung windows. New windows can be made of a number of different materials and types of glass.

Many historic homes have retained wood frame, single pane, double hung windows. These windows are constructed of old-growth wood, which is much more durable, both with greater strength and life, than new wood. In many cases, these windows have been in service for a hundred years or more, which demonstrates their durability--especially, when one considers that most historic window deterioration occurs from lack of maintenance and could be prevented. Historic wood windows have a proven track record.[7] Additionally, many historic homes were designed to be naturally energy efficient because they were not centrally heated and cooled. The placement of the house and windows, the size of the overhangs, the planting of trees, the thickness of walls, the design of the windows and many other aspects were strategically chosen to maximize energy efficiency naturally.

Replacements windows come in a variety of materials and types. Frames are available in aluminum, vinyl, wood or wood clad in aluminum or vinyl. Aluminum is the cheapest option, but because aluminum has a low R-value, it conducts heat and is not as efficient as the other options. Vinyl windows are more expensive than aluminum and provide a higher level of efficiency. Wood frames clad in another material are most expensive but generally will last

---

[5] Ministry of Culture, "Dave's Top Five Reasons to Conserve Historic Wood Windows" (Toronto, Ontario: Ministry of Citizenship, Culture and Recreation, 2002), 1.

[6] John H. Myers, "Preservation Briefs: 9 The Repair of Historic Wooden Windows" (Washington, D.C.: Technical Preservation Services, U.S. Department of Interior, 1981), 2.

[7] New Jersey Department of Environmental Protection Division of Parks and Forestry Historic Preservation Office, "Saving Wood Windows," http://www.state.nj.us/dep/hpo/4sustain/windowsave.pdf), Accessed 15 April 2004, 2.

longer than vinyl or aluminum. However, they are susceptible to moisture problems from moisture trapped behind the cladding material. Framing material is not the only choice. One also must wade through the glazing options: single, double and triple panes; low-e heat resistant coating, reflective glass, argon gas-filled, vapor sealed, etc. Layers of glass and special coating are offered as a way to increase energy efficiency.

Replacement window costs and installation vary widely from very inexpensive windows at around $150-400 all the way up to $750-1000 per window. On a replacement window discussion board, several consumers cited quotes from reputable replacement window companies for $1000/window or more. Homeowners can learn to rehabilitate existing windows or they can hire a contractor to do the rehabilitation. Rehabilitation of existing windows by a contractor will cost anywhere from $100-400, depending on the level of deterioration and number of divisions in the sash (more labor-intensive). Materials for rehabilitation alone will cost a maximum of $50, so the most cost-effective way to rehabilitate a window, of course, is for the homeowner to do it himself. A custom-milled wood window can cost anywhere from $400-1200 depending on the design and level of detail. Cost is not the only consideration. Closely related to cost is life expectancy and/or warranty coverage. While there is the perception out there that replacement windows require no maintenance and will last a lifetime, it's not the case. Replacement windows can leak and rot as any window can.

"Durability in new wood windows has decreased as new growth timber…is being used in construction. Vinyl and PVC materials break down and discolor in ultraviolet light…In addition to the frame and sash, many other components of replacement windows deteriorate relatively quickly. The seal around double glazing can fail within six to ten years resulting in condensation between the panes and necessitating replacement."[8] Additionally, many of the seals holding the glass in place have a life expectancy of ten years or less.

The ability to complete repairs is another consideration. Historic wood windows can be repaired and maintained with relative ease by repairing or replacing only deteriorated parts because the technology is familiar and has not changed for over a hundred years. Because the replacement window designs change, often times it is difficult to find replacement parts for damaged windows. The general understanding is that replacement windows will last anywhere from six to fifteen years.

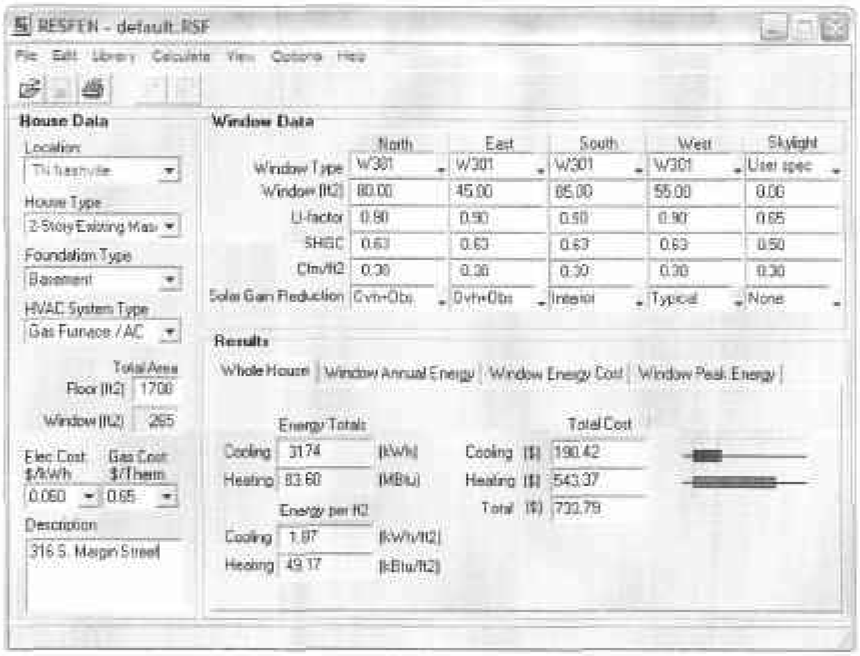
So why do people think about replacing windows at all? While there are times when the level of deterioration is such that a quality wood replacement window is warranted, many times windows are replaced in the name of energy efficiency. As previously stated, windows are never going to be good insulators. A historic wood window might have an R-value of around 1. A replacement window with all the bells and whistles might provide an R-value approaching 3, but most replacement windows will have an R-value in the 2 range. When one considers that maybe 20% of heat loss is attributable to windows, even if the R-value is doubled, that only decreases the heat loss by 10%. The bottom line, then, is whether the related cost savings associated with the decrease in heat loss is enough to justify the sizable expenditure (as well as the loss of historic significance and architectural character) of replacement windows.

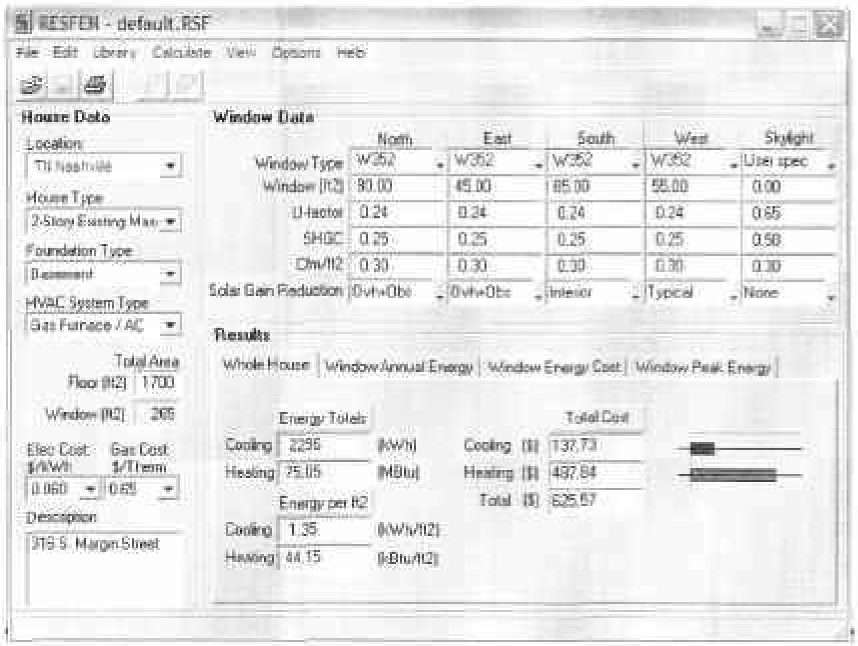
[8] Ibid.

Before we move on to discuss the costs/benefits of original window and replacement windows, other weatherization options must be outlined and considered. The most typical forms of weatherization of historic windows are weather stripping and adding secondary glazing or storm windows. Weather stripping is an extremely inexpensive alternative relative to the other options and can be done relatively quickly. Storm windows, by adding a second layer of glazing and by trapping the insulating air in between can increase the R-value to about 2. Storms windows can be installed in the winter months to lessen heat loss and be removed in the warmer months to allow use of the double hung windows' natural ventilation. In general, storm windows are much more affordable than replacement windows. The Office of Energy Efficiency and Renewable Energy also suggests several options such as installation of blinds, curtains, awnings or shutters and planting trees to shade windows to keep heat away from the house.

Cost/Benefit Analysis

So how do we determine the energy savings associated with replacement windows? Several methods and computer programs have been developed. After exploring a few of the options and discussing them with professional, I've decided to use RESFEN 3.1. The program was developed "for calculating the heating and cooling energy use of windows in residential buildings." This is the best methodology my research has uncovered for assessing the effectiveness of replacement windows in various settings and climates. Climate, location of windows, level of shading, size of windows and many other factors will influence the level of heat flow through the windows. This program takes these factors into consideration. First, we'll examine a historic, 2-story brick house in Nashville, Tennessee. The energy cost associated with single pane windows is $733.79. Replacing the windows with wood or vinyl frame, triple-pane, low-e, argon gas-filled windows results in an associated energy cost of $625.57. This is a difference of about $108 per year. Assuming this house has 20 windows and replacement windows can be installed for $400 a window, the cost of replacement is $8000. In this scenario, it would take about 70 years to make up the cost of the replacement windows in energy savings…well beyond the life expectancy or warranty period of a new replacement window. It is important to keep in mind that this is an *extremely* low estimate for the purchase and installation of replacement windows. The quality of these windows would be fairly low. In all likelihood, the replacement of 20 windows would cost in the $15,000 to $20,000 range.





In the same home, a restoration contractor or the homeowner could rehabilitate the 20 windows. Assuming a price range of $100-400 for the contractor, as mentioned above, the rehabilitation would cost, at a maximum, $8,000. Mostly likely, it could be done for $4,000-6,000 by a contractor and much less than that ($500-1000) by the homeowner. Rehabilitated wood windows that are properly maintained will generally last another 50 to 100 years.[9] The energy

---

[9] Ibid.; New York Landmarks Conservancy, *Repairing Old and Historic Windows*, (New York: John Wiley & Sons, Inc., 1992).

costs analysis is for a home in Nashville, Tennessee. Some have argued that in colder climates replacement of windows is more cost effective. However, a recent study in Vermont found that window replacement for energy reasons is not usually the most cost effective approach in cold climates.[10]

Conclusion

Historic windows are significant architectural features of a building and should be retained and preserved whenever possible. The good part about this is that saving them makes economic sense as well. Historic wood windows (or high quality new wood windows when necessary) are more durable (longer life expectancy) than replacement windows made of other materials. When properly repaired and maintained, a rehabilitated window can last for another fifty to one hundred years. Weatherization techniques such as weather stripping and caulking reduce air infiltration and storm windows provide secondary glazing and added insulation. Finally, historic wood windows are easily repaired. All in all, rehabilitation of existing windows is more cost effective than replacement of those windows. As Bob Yapp says, "preservation doesn't cost, it pays!"

---

[10] Brad James, Andrew Shapiro, Steve Flanders, David Hemenway, *Testing the Energy Performance of Wood Windows in Cold Climates: A Report to the State of Vermont Division for Historic Preservation Agency of Commerce and Community Development.* (National Center for Preservation Technology and Training, 1996).

Bibliography

Bell, Malcolm, Robert Lowe, Peter Roberts. *Energy Efficiency in Housing.* Brookfield: Avebury, 1996.

Corbett, John M. "A Last Look at Historic Wood Windows." *The Restoration Trades Catalog.* www.restorationtrades.com/articles/windowrestoration.shtml. Accessed 4 April 2004.

"Cost of Replacement Windows." Online Discussion Board. http://ths.gardenweb.com/forums/load/remodel/msg1017544213511.html. Accessed multiple times March-April 2004.

Economic Commission for Europe. *Energy Efficient Design: A Guide to Energy Efficiency and Solar Applications in Building Design.* New York: United Nations, 1991.

Energy-Efficient Housing. Connecticut: Taunton Press, 1993.

First Replacement Windows. "Window Replacement Comparisons on Vinyl, Aluminum, Wood and Clad." http://www.1st-replacement-windows.com/window-replacement-comparisons.htm. Accessed 30 April 2004.

Fisher, Charles E. and Hugh Miller, editors. "Wooden Windows." *Caring for Your Historic House.* New York: Harry N. Abrams, Inc., 1998.

Halacy, Dan. *Home Energy.* Emmaus, PA: Rodale Press, 1984.

Hull, Brent. *Historic Millwork: A Guide to Restoring and Re-creating Doors, Windows and Moldings of the Late Nineteenth Through Mid-Twentieth Centuries.* New Jersey: John Wiley & Sons, Inc., 2003.

James, Brad, Andrew Shapiro, Steve Flanders, David Hemenway. *Testing the Energy Performance of Wood Windows in Cold Climates: A Report to the State of Vermont Division for Historic Preservation Agency of Commerce and Community Development.* National Center for Preservation Technology and Training, 1996.

Lawrence Berkeley Laboratory, Windows and Daylighting Group. *WINDOW 4.1 PC Program for Analyzing the Thermal Performance of Fenestration Products.* Berkeley, California: 1994.

Ministry of Culture. "Dave's Top Five Reasons to Conserve Historic Wood Windows." Toronto, Ontario: Ministry of Citizenship, Culture and Recreation, 2002.

Mitchell, Robin, Joe Huang, Dariush Arasteh, Robert Sullivan. *RESFEN 3.1 for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings*. University of California: Lawrence Berkeley National Laboratory, 1999.

Myers, John H. "Preservation Briefs: 9 The Repair of Historic Wooden Windows." Washington, D.C.: Technical Preservation Services, U.S. Department of Interior, 1981.

New Jersey Department of Environmental Protection Division of Parks and Forestry Historic Preservation Office. "Saving Wood Windows." http://www.state.nj.us/dep/hpo/4sustain/windowsave.pdf. Accessed 15 April 2004.

New York Landmarks Conservancy. *Repairing Old and Historic Windows*. New York: John Wiley & Sons, Inc., 1992.

Rye, Doug. "Doug Rye Energy Tips II: Seal Your Windows, Doors and Ducts, and Save Yourself Some Really Big Bucks." Videotape.

Shapiro, Andrew and Brad James. "Creating Windows of Energy-Saving Opportunity." *Home Energy Magazine Online*. September/October 1997.

Smith, Baird M. "Preservation Briefs: 3 Conserving Energy in Historic Buildings." Washington, D.C.: Technical Preservation Services, U.S. Department of Interior, 1978.

U.S. Department of Energy. "Energy-Efficient Windows." Energy Efficiency and Renewable Energy Website. http://www.eere.energy.gov/erec/factsheets/eewindows.html. Accessed 20 March 2004.

U.S. Department of Energy. "Home Energy Audits." Energy Efficiency and Renewable Energy Website. http://www.eere.energy.gov/consumerinfo/refbriefs/ea2.html. Accessed 20 March 2004.

Vaughn, Lewis. *Chilton's Guide to Home Energy Savings*. Radnor, Pennsylvania: Chilton Book Company, 1982.