Testing the Energy Performance of Wood Windows in Cold Climates

A Report to
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EXECUTIVE SUMMARY

During rehabilitation of historic buildings, the question of how to treat the windows is inevitably raised. The desire to retain the historic character of the windows and the actual historic material of which the windows are made is seen as competing with the desire to improve energy performance and decrease long term window maintenance costs. Replacement of window sash, the use of windows inserted inside existing jambs or whole window replacement is often advocated in the name of energy efficiency, long term maintenance cost reduction, ease of operation, and better assurance of window longevity. Other approaches to improve the energy efficiency of historic windows retain all or part of the existing sash and balance system and typically include exterior triple-track storm window rehabilitation or replacement. Some building renovations only include storm window repair or replacement and prime window maintenance. To date there is little data quantifying the impact on annual heating costs of these varied upgrade options or comparing estimated first year energy savings to installed costs. This study was undertaken to test the assumption that historic windows can be retained and upgraded to approach the thermal efficiency of replacement sash or window inserts.

While upgrades often improved other aspects of windows, including ease of operation, reduction of lead hazard, and occupant comfort, only energy impacts were included in this study. In order to assess energy improvements due to window upgrades, it was necessary to establish first year heating energy costs associated with windows before and after upgrades. Energy costs resulting from thermal losses associated with a window are due to both infiltrative and non-infiltrative losses.

Infiltrative thermal losses through a window arise from air moving around the sash and jamb as well as through any cracks or gaps associated with the window. Thermal losses also occur due to radiation through the glazing, conduction through the window materials, and convection of the air layer next to the window materials. These latter three methods of heat loss (conduction, convection, and radiation) are considered to be non-infiltrative thermal losses and were modeled using WINDOW 4.1, a computer program simulating fenestration thermal performance.

Infiltrative thermal losses were investigated by field testing 151 windows during 1995 and 1996, primarily in northern and central Vermont. Leakage characteristics of these windows were estimated by fan pressurization. Of these 151 windows, 64 were in original condition and 87 were of various upgrades. A percentage of infiltrative exterior air was estimated during field tests based on temperature differences in the test zone during fan pressurization. Exterior air leakage was summed with sash leakage to estimate a whole window total infiltrative thermal loss rate due to infiltration. Total window leakage rates were correlated with heating season infiltration rates by using a computational model established for estimating whole building infiltration rates. Results for the 64 original windows were used to model typical, tight, and loose original condition windows. Estimated annual energy costs of these assumed windows were used to estimate first year energy cost savings for the various upgrade types.

The significance of exterior air infiltration to the total heat load of a window was observed throughout the study. Thermal loss due to exterior air infiltration can cause the thermal performance of a tight window to approach that of a loose window. The importance of reducing exterior air infiltration during any renovation was noted. Interior storm windows effectively reduced exterior air infiltration as well as reducing sash air infiltration. Exterior storm windows in good condition showed significant reductions in sash infiltration when in the closed position.

One issue in assessing energy performance of windows fitted with storms was if the storm was in the closed position during the heating season, a factor which can change the energy performance significantly. This study did not attempt to quantify how many storms were likely to be open or closed. Therefore, the assumed loose window with no storm allowed comparison of upgrades with storm windows open as well as with windows not fitted storm windows.

First year energy savings for window upgrades and estimated annual energy costs of the assumed windows were based on a typical Vermont climate (7744 degree days). Neither cooling cost savings nor changes in solar heat gain due to window improvements were addressed.

Results of testing and analysis were expressed in a number of ways including:

- effective leakage area (ELA), which may be loosely described as the size of a single orifice with similar air flow characteristics as the sum of the cracks of the window tested;
- sash air leakage rate at 0.30 inches of water pressure differential across the window, expressed in standard cubic feet per minute pre linear foot of crack, a standard value given in specifications for new windows, representing a useful point of comparison; and
- first year estimated heating cost savings compared to the three baseline original condition windows described above.

Costs of window upgrades were investigated primarily by interviewing developers of affordable housing in Vermont. Material, installation and mark-up costs are included for the window upgrades studied. Costs for upgrades were considered above those which would be required for routine window maintenance (paint, putty, caulk, and sash balance maintenance). Routine maintenance costs were considered a baseline for any building rehabilitation apart from energy upgrades. Costs for upgrades field tested ranged from a low of $75 to a high of $500. The lower cost option included sealing the top sash, installing bronze V-strip weatherstripping and sash locks, and retaining the existing prime and storm windows. If lead abatement was required for an original sash, an additional cost of $125 was added to the upgrade cost. The larger upgrade cost was for a wood window insert with double-pane insulating glass.

The findings of the study indicated the wide range of window upgrade options and installed costs resulted in annual heating cost savings that were similar. Within several types of window upgrades tested, there were examples where inappropriate application of an upgrade or an incomplete installation resulted in below average energy performance. However, when installed carefully, virtually all the options studied produced savings in a similar range.

Estimated first year energy savings per window due to field tested upgrades ranged from zero to a high of $3.60 as compared to an assumed typical window and were slightly lower when compared to an assumed tight window. Estimated savings compared to an assumed loose window ranged from $12.40 to $16.60 per window. Estimated savings increased when windows with low-e glazing were modeled using WINDOW 4.1. It should be noted that estimated first year savings as shown should be viewed solely as relative savings when compared to other upgrades within the context of the study and not actual savings realized.

The variability in estimated first year energy savings for all window upgrades was small. A comparison of estimated energy savings per upgrade to costs for upgrade materials and installation revealed energy savings were two orders of magnitude lower than renovative costs. Based on the range of estimated first year energy savings of window upgrades generated by the study as compared to an assumed typical window and those costs associated with upgrade purchase and installation, replacing a window solely due to energy considerations did not appear to be worthwhile. Estimated first year savings of upgrades when compared to an assumed loose window are significantly greater, reflecting the importance of the original window condition in determining first year energy savings. Life-cycle costs of window upgrades were not included as a part of this study and may have a bearing on the decision making process.

As a result of the similarity in savings between upgrade types and the small savings indicated when existing windows were similar in performance to a typical or tight window, the decision to rehabilitate or replace a window generally should be made on the basis of considerations other than energy cost savings. It should be noted that this decision is not clear cut. Some upgrades that retain the original sash make major sash modifications while some replacement upgrades mimic historic windows effectively. There is a continuum between replacing and rehabilitating windows where the developer must find a solution appropriate to the particular context while considering non-energy issues such as maintenance, ease of operation, historic character, and lead abatement.

The population served by the housing is another important variable in an upgrade decision. Tenant populations in rental housing have no financial incentive to close storm windows or may be unable to operate them. In such cases, the value of estimated first year savings of an upgrade may be higher than expected if double-glazing is used in the prime window.

Once the decision to upgrade or replace an existing window is made, it is important to select a strategy that not only meets the needs of the building occupants and owners but also utilizes techniques that achieve the highest levels of energy savings and occupant comfort justified by the financial constraints and financing mechanisms of the building rehabilitation project. In general:

- Window upgrades using existing sash can achieve performance indistinguishable from replacement sash but economics of the upgrade depend on the leakiness of the original window.
- If the existing window is loose, it can often be cost-effective to address this leakage, including air leakage between the window and rough opening as well as between an exterior storm window and trim. If the window is already in typical or tight condition, an upgrade is unlikely to be cost-effective regardless of the cost-benefit test used.
- If the windows have single glass, it is worthwhile considering installing a second layer, including the options of storm windows, replacement insulated glass units, energy panels and use of low-emissivity glass (low-E).

While it is tempting to compare first year energy savings to the total installed costs of a window upgrade, it should be noted that some window upgrades may be done for reasons other than energy savings. Therefore, a strict comparison of energy costs to total installed costs may not be appropriate in all cases. In addition, the time frame over which savings may be calculated can vary significantly. Developers of affordable housing, which often includes rehabilitation of historic structures, are often concerned with establishing "perpetually affordable" housing which includes decreased long-term maintenance and energy costs.

Within the decision-making process for deciding to replace or renovate an existing window, energy considerations should not be the primary criteria, but should also not be ignored. The resulting window rehabilitation strategy should result in the most comfort and appropriate degree of energy savings.

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