There is tremendous value in the historic windows that exist in our buildings. They lend character and authenticity to a building, their durability is unsurpassed by any modern window, and maintaining them is a sustainable practice when so much of building construction is an environmental nightmare. (NEWRA 2010) Maintaining and restoring historic windows along with other building materials is our responsibility. We owe it to the people who built the buildings and to the people who will use them after we are gone. We also owe it to our environment to reuse building materials rather than procuring new materials, which is detrimental in two ways: Manufacturing of new building materials depletes our natural resources and creates waste. Most replaced windows end up in landfills (Wolff 2007) and the newly manufactured materials require processing, transportation, and installation. Depending on the new material this environmental impact could be minimal, or it could be devastating.

Authenticity

Retaining and celebrating authenticity is one key element of an exemplary preservation program. No one should take lightly the option of discarding authentic historic materials without fully evaluating the consequences. Once authentic material is lost, it is lost forever. (Sedovic and Gotthelf 2005) The authentic material that makes up our historic buildings gives our neighborhoods, and cities truthfulness of origin. These artifacts are a powerful reminder of where we came from and "an expression of period technology and design". (James 1996). When historic windows are replaced, authenticity is lost forever. Original windows were usually carefully matched to the building in terms of scale, weight and layout. (Bock 1998) Replacement windows do not fit a building as well as the original windows. Even what might seem like small changes in window elements can be noticeable and have a detrimental effect on the character of a building. (Sedovic and Gotthelf 2005) Replacement windows chosen for historic buildings are likely chosen from a small selection of "historic reproductions". Hundreds of window variations have been distilled to ten or maybe twenty, so homes with new windows look uniform and sterile. (Sedovic and Gotthelf 2005) Additionally, replacement windows are smaller than the originals because the whole window assembly is made to fit inside of the original jamb. Due to this reduction in window size, 15% or more visible daylight is blocked from the interior, which causes a need for more electric light indoors and is explicitly not consistent with a sustainable approach. (Sedovic and Gotthelf 2005)

Antique glass, first growth lumber, and high quality craftsmanship are major contributosr to the authenticity of a window. Antique glass has a beauty in it's color and texture variations as well as telling a story about the time when it was manufactured. (NEWRA 2010) Modern glass offers an uninteresting reflection. Particularly since the true divided light sash is no longer commonly used, the reflection from a single sheet of glass functions as an advertisement for replacement windows. First growth lumber combined with traditional joinery is the reason that many historic windows have survived this long. This exceptional durability is intrinsic to the concept of 'Authentic Architecture'.

Sustainability

Sustainability and historic preservation are a natural marriage. (Sedovic and Gotthelf 2005) The 'greenest' building is a building that has already been built. This holds true for windows as well. The most sustainable choice is utilizing the embodied energy intrinsic in our historic windows rather than using our limited resources to procure raw materials, manufacture, ship, and install replacement windows; and remove and dispose of historic windows. When evaluated from this perspective, replacing windows consumes a whole lot of energy. (NEWRA 2010)

Sustainability is defined as the ability to endure. It takes into account more than just the cost of heating or cooling a building. (Sedovic and Gotthelf 2005) Like preserving whole buildings, restoring historic windows is a solid step forward into the realm of sustainability. (Sedovic and Gotthelf 2005) Upgrading or preserving historic windows, unlike installing replacement windows, is a sustainable practice. Salvaging historic materials such as wood sash, obviates the need to harvest live trees (Sedovic and Gotthelf 2005), and reusing historic glass minimizes the need for the manufacture of new glass, which is a very energy intensive process.

Embodied energy is defined as the energy that has already been expended in creating and installing an existing building material. It includes the energy required to extract raw materials, and manufacture, transport and install building products. Production of new windows consumes approximately 2.3 million BTU's annually. (Wolff 2007) This does not include the energy required for extraction of the raw materials or for their installation or shipping. Preserving historic windows not only conserves embodied energy, it also eliminates the need to spend energy on replacement windows. Aluminum and vinyl – the materials used in many replacement windows – and new glass itself possess levels of embodied energy that are among the highest of most building materials. (Sedovic and Gotthelf 2005)

Green principles include more than just energy efficiency. When evaluating historic windows, we should consider the environmental and financial consequences of the window's entire life cycle. (Wolff 2007) The approach suggested as the first alternative to replacement windows among green-building advocates is maintenance and retrofit components such as weather stripping.

(Sedovic and Gotthelf 2005) A window with these improvements can meet and even exceed the efficiency of replacement units. (Smith 1978)

In addition to the energy savings from avoiding new materials and eliminating excess waste, preservation work is nearly twice as labor intensive than new construction, which benefits local economies. (Sedovic and Gotthelf 2005) More dollars spent go to people in the community than to materials. Repairs and restoration work are done by local craftspeople paying local taxes. They use a minimum of materials and resources and a maximum of labor. (NEWRA 2010) This type of spending has the beneficial effect of producing stronger, more dynamic local economies. (Sedovic and Gotthelf 2005) If more building owners choose to maintain and repair their historic building components, the practice would become more readily available and less expensive for the common homeowner and the cycle would continue. The forecast has to be for more repairs than replacements in the future. (Yagid 2010)

Durability

A hallmark of sustainability is long-term performance, (Sedovic and Gotthelf 2005) and many historic windows have been in use for more than a hundred years. (Wolff 2007) These windows were designed to be readily disassembled which allows selective restoration or upgrades of individual components as needed. (Sedovic and Gotthelf 2005) However, the components of historic windows rarely wear out. Even with years of neglect, a wood frame double hung window can last a hundred years. Windows that have been maintained properly can last hundreds of years, (NEWRA 2010) while new windows are estimated to have a useful life ranging from two to twenty years. (Wolff 2007)

Two of the reasons that historic windows are so strong and durable are the traditional joinery and the first growth wood. The true mortise and tenon construction of historic windows is extremely durable and no amount of staples, finger joints or heat welds can match the performance. (Sedovic and Gotthelf 2005) Unfertilized, early growth wood is denser and more weather resistant that the wood available today. (NEWRA 2010) This combination of traditional joinery and first growth wood creates a window that performs with greater stability than a modern window. Minimizing dimensional changes, holding a paint coating longer, and securing mechanical fasteners tightly are all benefits of stability that contribute to the long life of the window. (Sedovic and Gotthelf 2005)

Window Description

The wood frame double hung window is the window most frequently found in historic residences today. Vertically sliding sash have been in use in Europe since the mid 1600's. (Louw 1983) This coincides with the colonization of North

America, so many of the oldest buildings in the US utilize vertically sliding sash windows for light and ventilation. Toward the end of the 17th century in Europe, a system of weights and pulleys for counterbalancing was introduced which allowed a heavy sash to be moved easily to any position along its course of travel and eliminated the need for sash pins or other propping devices. (Louw 1983) This type of hung sash window appeared in the US around 1750 and was in widespread use until the 1930's when mass produced metal windows became more common. (Bock 1998)

The double hung window consists of two or more sash, which slide vertically past one another within the window jamb. The sash are made up of vertical members called stiles and horizontal members called rails. The top rail of the bottom sash and the bottom rail of the top sash are called 'meeting rails' because when the sash are in their closed position, these two rails meet tightly to prevent air leakage. Wooden members, known as muntins, divide the sash into regular segments corresponding with the size of the available or desired glass and hold the individual panes of glass in place. Glazing compound, along with glazing points are used to secure the pane to the muntins and to fill any gaps creating an airtight seal.

The configuration of a hung sash window is identified by "number of panes in upper sash" / "number of panes in lower sash". For instance, the window in the example on page 5 is a 4/4 double hung window. Initially, the panes of glass were very small, but as glass making became more mechanized, the panes grew larger until after the civil war, when 2/2 or even 2/1 was possible. This configuration wasn't fashionable for long and windows soon returned to smaller panes. (Bock 1998)

The sash are held apart by the parting beads on each side and are held inside the jamb with stops on both the interior and exterior side of the window. The counterweight system attaches to each sash using a sash cord or chain. If sash weights with a pulley are present, the sash cord is threaded over the pulley and attaches to a heavy weight in the sash pocket, which is concealed by the interior casing. Refer to the illustration below for a visual explanation of the major components of a double hung window.

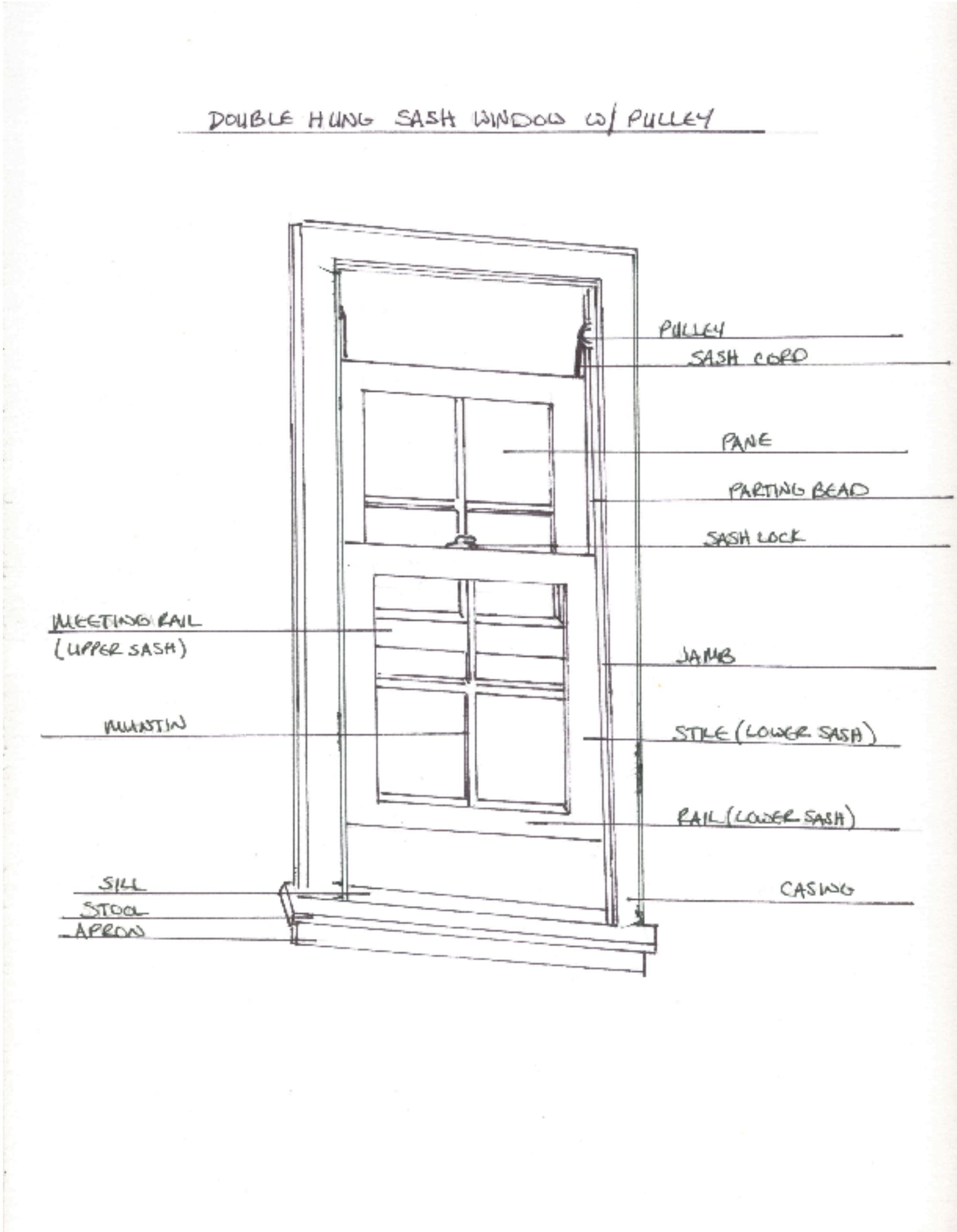

Figure 1 Typical Double-Hung Window

Window Manufacturer's Claims

When historic windows are replaced, it is generally a result of window manufacturer's advertising campaigns offering replacement windows that will save you hundreds of dollars annually in heating and cooling costs. Many preservationists and building owners continue to believe this advertising, which claims that the first order of business is to replace old windows. However, in the context of authenticity and sustainability it is well worth reconsidering this approach. (Sedovic and Gotthelf 2005)

The purported savings from installing replacement windows vary by manufacturer, but range from 15% to a nearly 50% reduction in heating and cooling costs. (Yagid 2010) However, two separate studies found the fraction of window leakage to be approximately 20% of whole house leakage. (James 1996) If this is true, a savings of 50% of heating and cooling costs would be impossible.

Most of the heat or cooling loss in a building is attributed to air infiltration around window rough openings and doors. This infiltration around window openings is not necessarily remedied by installing new windows. In fact it is often made worse depending on the quality of the installation and the material of the new window. The rigid structure of a replacement window doesn't move and shift over time with the movement of the building; causing gaps to open up around the window openings. This results in more air infiltration than with the original wood windows. (NEWRA 2010)

There is actually little data to support the idea that replacement windows save any amount of energy in typical homes. (Yagid 2010) The data supplied by window manufacturers is typically the result of computer modeling software (James 1996) and a random sampling of the window models tested in accredited laboratories to ensure compliance. (James 1996) In a study of window leakage rates in the Minneapolis / St. Paul area, 60% of the windows tested exceeded the manufacturer's performance specifications. (James 1996) It's likely that the reason for this is that the performance data is highly dependent on the quality of the installation (James 1996); so, if poorly installed, replacement windows start out leaky.

Consumers want guaranteed performance and a label that gives them that satisfaction. (Yagid 2010) Whether or not the old windows outperform new ones, new ones make people feel secure and green. The U-values on these labels are often misleadingly quoted as the value for the entire window unit, when in fact it is the value through the center of the glass, not that of the sash nor the average of the entire unit. (Sedovic and Gotthelf 2005) Also, when window manufacturers compare their data to the performance of the original windows, they often use data for a single pane aluminum window, which is an inappropriate analogy. Metal-framed windows are rarely the subjects of preservation efforts. (Sedovic and Gotthelf 2005)

Another argument made by window manufacturers is that new windows are "maintenance free". This may be true that the window is maintenance free, but they neglect to mention that it's because the materials degrade and are difficult or impossible to recycle or conserve "When the material degrades, it then becomes necessary to replace the replacement". (Sedovic and Gotthelf 2005)

Data

Any window, whether it is two months old or two hundred years old causes heat loss. (Roos 2008) All windows are a poor thermal barrier and often a source of air infiltration. (Smith 1978) Only 25% of heat loss through a loose fitting, non-weatherstripped window is attributable to air infiltration, and a window typical of new construction is estimated to have 12% of it's thermal losses attributable to air infiltration. (James 1996) This leaves a large amount of heat loss due to radiant heat loss through the glass.

The energy efficiency of modern windows is expressed in three values, R-value, U-value and SHGC. The R-value indicates how resistant the material is to heat flow. (Rupar 2009) A material with a higher R-value is more resistant to heat flow than a material with a lower R-value. U factor typically measures the thermal transmittance of the entire window, but can also refer to one portion of the window such as one sash or one pane. It's the amount of heat a one-foot square section of window would lose per hour for every one degree Fahrenheit temperature differential between the interior and exterior surfaces of the window. (James 1996) A lower number means it will be better at keeping the hot air on the side of the window where you want it. (Rupar 2009) The SHGE, solar heat gain coefficient measures how effectively a window blocks heat coming from the sun, the lower the better. (Rupar 2009) For the purposes of this paper, U-value will be the data most commonly discussed and SHGC will not be discussed at all as it is generally not a consideration in the northeast.

A study by Glasgow Caledonian University for Historic Scotland measured U-values for traditional wood windows with various traditional and modern retrofits as compared to replacement windows. The windows tested in the retrofitting experiment were professionally draft proofed before beginning experiments to minimize air infiltration. A sampling of the data from the experiment that is most applicable to preservation efforts can be seen in Table 1.

Table 1.

	Reduction in Heat Loss	**U-value (W/m^2K)**	**Temperature of Interior Room Facing Surface °F**
Center of Glazing	-	5.4	54
Heavy Curtains	14%	3.2	68
Shutters	51%	2.2	66
Insulated Shutters	60%	1.6	70
Modern Roller Blind	22%	3.0	70
Modern Roller Blind with Low Emissivity Plastic Film	45%	2.2	68
Victorian Roller Blind	28%	3.2	64
Thermal Honeycomb Blind	36%	2.4	70
Victorian Blind & Shutters	58%	1.8	66
Victorian Blind, Shutters & Curtains	62%	1.6	70
Storm Windows	63%	1.7	66
Storm Windows & Curtains	66%	1.3	72
Storm Windows & Insulated Shutters	77%	1.0	70
Storm Windows & Shutters	75%	1.1	68
Double Glazing	55%	1.9	64

The most effective traditional retrofit solution was shutters, showing a 51% reduction in heat loss. Insulating the panels of the shutters produced a significant improvement of 60% and a U value equivalent to low emissivity double-glazing. (Baker 2008) All of the traditional retrofits resulted in some reduction in heat loss, and interior and exterior retrofits could be combined for even lower U values.

In a collaborative effort, the Vermont Energy Investment Corporation, the University of Vermont's Department of Civil and Environmental Engineering, and the US Army cold Regions Research and Engineering Laboratory set out to test the value in wood-window repair. (Yagid 2010) The purpose of the study was to determine the energy savings, in terms of cost, seen as a result of window upgrades. Table 2 shows a selection of the data from this study, which was most relevant to common preservation efforts.

Table 2.

Window Upgrade Description	Annual Heating Cost Per Window	Tight Window	Typical Window	Loose Window
Tight Window w/Storm	$14.38			
Typical Window w/Storm	$15.91			
Loose Window w/out Storm	$28.93			
V-strip weather-stripping around lower sash, top sash painted in place, existing triple track storm windows caulked in place	$13.77	$0.60	$2.10	$15.20
Reglazed and painted with new aluminum triple track storm, caulked to trim	$13.40	$1.00	$2.50	$15.50
Interior plexiglass storm window held by magnetic strips	$13.00	$1.40	$2.90	$16.00
Replacement sash with storm window	$14.20	$0.20	$1.70	$14.70
Replacement sash with double-glazed insulating glass	$13.65	$0.70	$2.30	$15.30
Replacement window inserts with low-e double glazed insulating glass	$8.95	$5.40	$7.00	$20.00

Values in this table are in 1996 dollars and are relative to each other only in the context of the study and are not absolute values.

Presuming that a homeowner replaces a very loose fitting window without a storm, it would take a number of years before they saw any real savings after accounting for the cost of the window. The likelihood is that most people buying replacement windows are replacing typical windows in which case the payback time would be much longer. Engineer Keith Haberern, Chairman of the Collingswood, NJ, Historic Districts Commission estimates that the payback time needed to recover the financial investment in a new window is 41.5 years. Generously assuming a useful life of 20 years, new windows are not in use nearly long enough for homeowners to recover their cost. (Wolff 2007)

The issue of energy savings is often used to justify replacement over restoration, but how valid is this argument? (Sedovic and Gotthelf 2005) The data show that it is not worthwhile to base upgrade decisions solely or even primarily on energy considerations. Other non-energy considerations should play a greater role in deciding whether to upgrade or replace existing windows. Energy performance should be included as part of the decision making process however, all of the costs of window upgrades should also be considered, including maintenance costs over time. (James 1996) Replacing an historic window does not necessarily result in greater energy savings than upgrading that same window. (James 1996)

Traditional Retrofits

Windows are important, otherwise the people who lived in these homes when they were new wouldn't have bothered. Instead they found ways to remedy the inherently leaky nature of any opening in a wall. To minimize the heat gain or loss from windows, historic buildings often utilize interior or exterior shutters, interior venetian blinds, shades, curtains and drapes or exterior awnings. (Smith 1978) Many historic buildings also incorporate wood-frame storm sash that must be removed and installed seasonally.

Adding storm windows greatly improves poor thermal characteristics. (Smith 1978) In general, properly installed new storm windows in combination with existing single glazed windows may achieve U-values comparable to modern insulating glass and reduce air infiltration while lowering maintenance costs and extending the life of the window. (James 1996)

Adding exterior storm windows should be seen as a viable alternative to replacing historic windows and it is the recommended approach in preservation retrofitting. (Smith 1978) Existing aluminum triple track or fixed panel aluminum storm windows reduce sash leakage by 45% on average, and new aluminum triple track storm windows decreased sash leakage by 75% on average when the frame was caulked to the exterior trim. (James 1996) Exterior storm windows provide the additional benefit of lowering window maintenance costs as well as prolonging window life by preventing accumulations of moisture. (Smith 1978) If moisture were trapped between the windows, the condensation would form on the inexpensive aluminum window without damaging the wood frame window. (Wolff 2007) Aluminum 'triple-track' storm windows aren't the most visually appealing option, but they are the least expensive and most widely available option for storm windows. Using single lite storm sash may reduce the negative visual effect of exterior storm windows. (James 1996) Traditional wood frame storm / screen sash are usually more attractive than aluminum storm windows, but require more maintenance and need to be installed and removed with the seasons. (Wolff 2007)

Interior storm windows significantly reduced both sash leakage and exterior air leakage, averaging reductions of approximately 95% and 80% respectively. (James 1996) Interior storm windows can be as simple as rigid plastic sheets attached directly to the historic sash. (Smith 1978) Other interior storms can be purchased or fabricated that will open and close so they don't have to be removed with the change of seasons. They increase energy efficiency, but don't protect the window from the elements, and can trap moisture between the windows allowing condensation to form on the wood frame window. (Wolff 2007) However, they do not obscure the exterior look of the building and with vent holes and a sealed fit, condensation problems can be minimized. (James 1996)

Significant reductions in infiltration may also be accomplished by routine maintenance of an existing window while improving its ability to endure. Routine maintenance includes removing the glass, applying back putty, reinserting the glass, repointing and reglazing. Excess paint should be removed and any necessary sash or frame repairs done along with the installation of good quality weatherstripping. Repainting the sash, frame, and glazing will help provide a good seal against the elements. (James 1996)

The intent of weather stripping a window is to reduce the amount of air infiltrating through the sash / jamb junctions and the meeting rails. Infiltrative losses were reduced from 37% to 17% of total house infiltrative losses when metal rib-type weather-stripping was installed around the windows. This corresponded to an approximate 24% reduction in building energy costs. (James 1996) Given the small investment required for weatherstripping, this reduction in energy costs is a tremendous return.

Conclusion

The advantages of window renovation versus window replacement in an historic building include saving the authenticity and historic value of the window as well as the interior / exterior appearance of the building. For these reasons, it is advantageous to investigate methods of rehabilitation in an historic building. It has been shown that effective window rehabilitation can be accomplished at a lower cost than replacement windows while still resulting in significant energy savings. (James 1996)

Embracing a more encompassing definition of sustainability teaches us that the answer is not as simplistic as window manufacturers would have us believe. (Sedovic and Gotthelf 2005) Any savings in energy costs that new windows provide are canceled by the cost of building the new window and disposing of the embodied energy that were wrapped up in the existing window.

“We can’t build our way out of the global warming crisis. We have to conserve out way out. That means we have to make better, wiser use of what we have already built.” Richard Moe, President of the National Trust for Historic Preservation (NEWRA 2010)

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