

Energy Efficiency and Historic Buildings

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Introduction

This article is intended to provide the reader with some basic information about energy efficiency and historic buildings so that logical and smart choices can be made regarding decisions that combine the two.

Prefatory to considering energy efficiency and historic buildings, bear in mind the following:

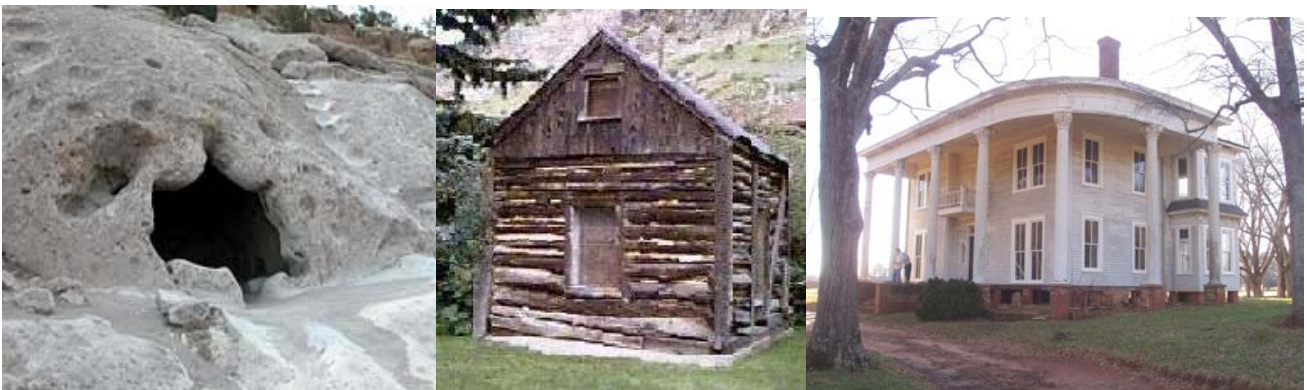
1. Where does energy efficiency rank for you as a priority in building use and function?
2. Do you understand how your home or building deals with energy?
3. Do you keep track of your home or building energy usage and costs?
4. Have you have had an energy audit?
5. What can you afford to spend to have an energy efficient home?
6. Do you think you need new windows?

Establishing the Paradigm

To start our discussion of energy efficiency, we need to establish, define, and understand what is actually being dealt with.

The basic concept here, then, is that buildings are used to shelter us from “the elements,” mainly rain, temperature, and other manifestations of the weather. Our expectations are that they provide comfortable warmth in winter, comfortable coolness in summer, and both at a reasonable cost.

To this end, our shelters have evolved from simple use of natural sheltering features (such as caves), to minimal built comfort (like log cabins), to moderate built comfort in sync with the local environment (such as houses and buildings in the south with high ceilings, sleeping porches, and tall windows strategically located to take advantage of cross-breezes), to buildings designed for excellent comfort in all seasons using advanced climate control that is a fundamental intent of most new construction.



While this seems to put energy efficiency into a simple enough context, everyone has probably had some experience with the complications of achieving such environmental comfort.

So let's look at some of the complications.

Building Systems and Definitions

As we have made advances in controlling our interior environment to counter the exterior environment, our relatively simple systems have become complex ones. Yet we are still dealing with two principal challenges.

First, we have exterior environmental encroachment, which involves Nature's need to equalize everything, or to put it another way "Nature abhors a vacuum." This balancing act is a dynamic one, one that is constant and continuous. We recognize its effects, cold air rushing in when the door's opened in the winter, water evaporation on a hot day, but maybe do not exactly understand why it happens and how it relates to energy efficiency.

Second are the inherent weaknesses in our building systems. These essentially boil down to the need to have openings in our buildings and, also, by the very nature of the way they are put together, creation of air leakage points.

Now, in this context, building systems are:

- The Building Structure: roof, walls, windows and doors – this is considered the building "envelope"
- The Mechanical System: consisting of furnace, air conditioner, ductwork, and
- Energy Users (which are in addition to the mechanical system): including water heater, dish washer, clothes washer, dryer, refrigerator, lighting, and other appliances

Before we look at how we meet these challenges, a review of some terms that crop up in specifications, advertising, and other discussions of energy efficiency is appropriate, like:

- **R-Values and U-values.** These are scientific calculations that measure thermal resistance (R) and thermal conductance (U), or in simpler terms, how slowly or quickly heat flows through a material. These values are related, in that they are the inverse of each other ($U=1/R$). They show up on labels for insulation and windows, but the important things to remember are the larger the R-Value or the lower the U-value the better the insulating capability.
- **Conduction, convection, and radiation.** These are the different ways of heat (energy) transference. Conduction is through solid objects, convection is by air movement, and radiation is heat transfer from a surface to the surrounding air without a transfer medium.

Notice that these terms closely parallel the two challenges mentioned.

Other terms that can appear include:

- **Vapor Diffusion.** This is the movement of moisture in the vapor state through a material because of vapor pressure and temperature differences. Moisture moves from areas of greater to lesser concentration and from warm to cool sides of materials. The measurement of moisture movement is by units of permeability, also known as "perms." Any material with a perm rating of less than 1.0 is a Vapor Diffusion Retarder (aka Vapor Barriers).
- **Climate Zones.** These have been established for the United States by the National Oceanic and Atmospheric Administration (NOAA) and are regions with relatively homogenous climates based on 30-year averages for heating degree-days (HDD) and cooling degree-days (CDD) calculations. Georgia falls in Climate Zones 4 (northern) and 5 (southern).

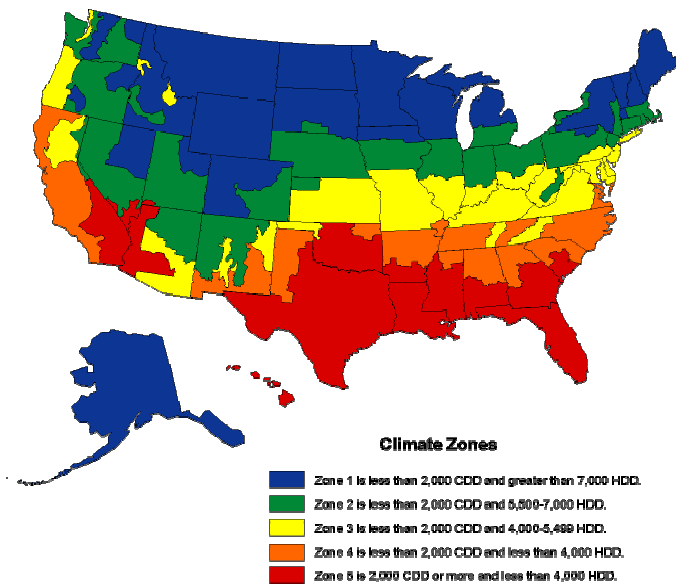
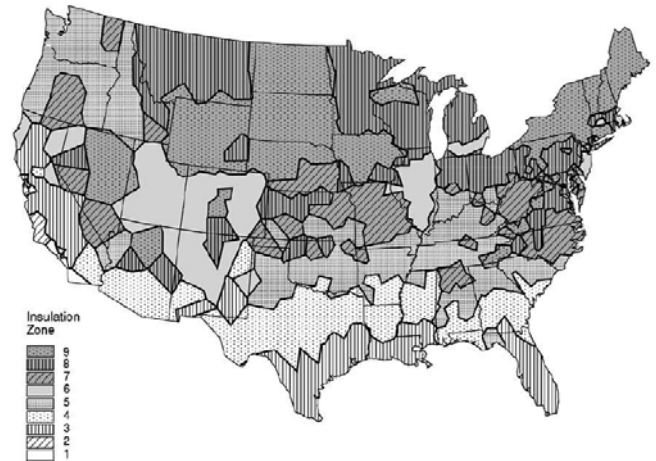


Figure 2. Insulation Zones for use with Recommendations in Table 4. (For Hawaii, Puerto Rico, and Virgin Islands, your Insulation Zone is 1.)



- **Insulation Zones.** The U.S. is also divided into Insulation Zones, which, in Georgia at least, roughly parallel the Climate Zones. Insulation Zones are used for design purposes to determine recommended insulation levels. Georgia falls for the most part in Insulation Zones 4 (southern) and 5 (northern).

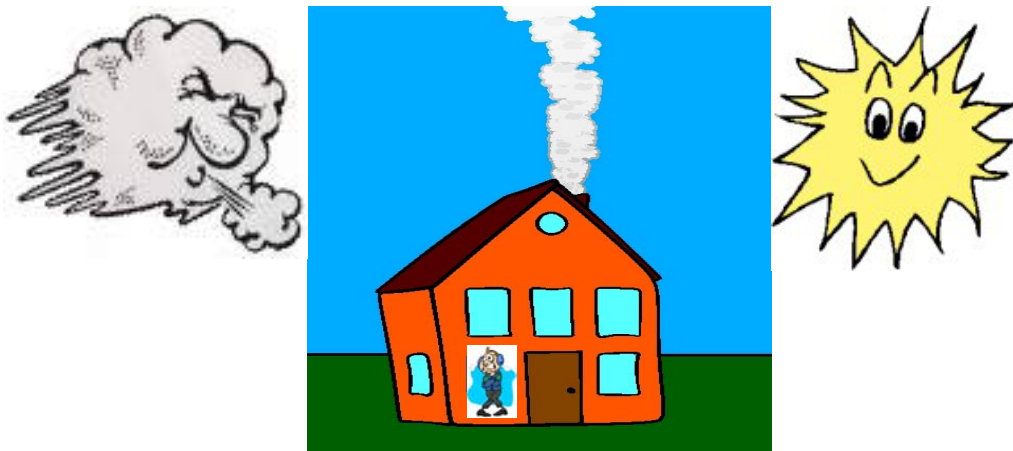
Note that climate zones and insulation zones provide important basic guidance for design purposes and characterize our environmental adversary. However, be aware that the various places you find this information use the data to define the zones somewhat differently. So depending on where you look, be it the internet, code books, or other sources, the maps and zone designations are probably going to vary. Nonetheless, the basic information is pretty consistent.

With the help of these definitions, we need to bring our discussion into some sort of understandable perspective.

Approaches to Energy Efficiency Improvements

On one hand we have a building, its systems, and the desire to be energy efficient and comfortable at a reasonable cost. On the other hand we have Mother Nature knocking at the door.

What to do, what to do?



The first thing to do is know what you're working with and where you want to get. In other words, you need to understand your local climate, its recommended design efficiencies, and make an assessment of your building systems, which also includes understanding your individual energy costs.

Understanding your local climate and design efficiencies is relatively easy - - you look at maps and tables. Probably the most useful are the Insulation Zone Map and tables of Insulation Groups, which are available on the U.S. Department of Energy website.

Table 5: Recommended Total R-values for Existing Houses(a)

Insulation Group	Attic	Floor over unconditioned space	Wall cavity	Crawl space wall(b)	Basement wall	Add insulated sheathing to an uninsulated wall(c)	Add insulated sheathing to an insulated wall(c)
E1	19	11	0	11	11	5	0
E2	30	11	11	11	11	5	0
E3	38	11	11	19	11	5	0
E4	38	19	11	19	11	5	0
E5	38	25	11	19	11	5	5
E6	49	25	11	25	11-13	5	5

(a) R-values have units of $R = \frac{ft^2 \cdot h \cdot Btu}{Btu}$. This table, when used with Tables 3 and 4, provides recommended total R-values for existing houses and was produced using the ZIP-Code computer program. The recommendations are based on an analysis of cost-effectiveness, using average local energy prices, regional average insulation costs, equipment efficiencies, climate factors, and energy savings for both the heating and cooling seasons.

(b) Use only if floor is uninsulated and the crawlspace is unventilated - see the discussion about unventilated crawlspaces.

(c) Recommendation assumes that the exterior siding was removed for other purposes, i.e., does not include any consideration of the cost of removing and replacing the exterior siding. The R-values shown here represent 1 inch of foam sheathing. Foam sheathing with R-values up to R-7 could be used.

The tables provide recommended levels of insulation for various parts of your house. For instance, southern Georgia falls in Insulation Zone 4. If you have gas heat, this puts you in Insulation Group E-3. The recommended amounts of insulation for this group include:

- R-38 for Attics, which equals about 13"
- R-11 for floors over unconditioned space and for walls, which equals about 3½"

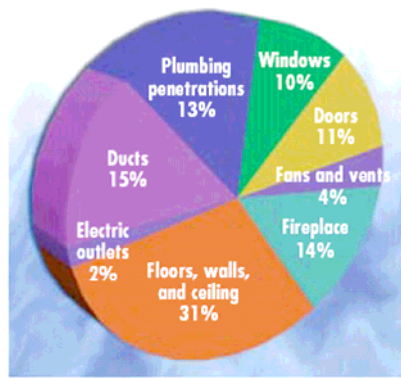
An alternate source for similar information is the International Energy Conservation Code (be aware it will look different than the DOE maps and tables).

These numbers give you a baseline for comparison when you assess your building systems.

But besides looking at how much or little insulation you have, you need to look at and evaluate other things, too. In no particular order, you should inspect the building envelope for leakage points, which includes around windows, doors, fireplaces, and pipe and wire penetrations; check floors, walls, and attics for insulation levels; check your furnace and air-conditioning unit to determine if they are approaching an age where they might need replacement; check your ductwork for joint seals and insulation; finally, check your major appliances, including water heater, to determine if they are getting to the point of replacement.

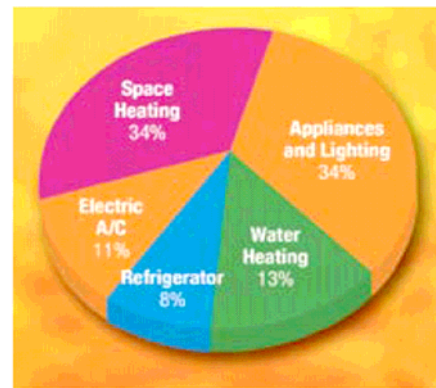
Concurrent with the building systems assessment, you also need to look at past energy costs and usage, since without this information, you really can't quantify any improvements. Of these two numbers, the one for usage will likely be more useful as an indicator of improved efficiency.

With this information in hand, it's time to look at a couple of other government provided charts. These charts identify how we typically use and lose energy. Combined, they tell us where money is best spent to make improvements. Also factored into these prioritization decisions should be the ease with which something can be accomplished.



How Does the Air Escape?

Air infiltrates into and out of your home through every hole, nook, and cranny. About one-third of this air infiltrates through openings in your ceilings, walls, and floors.



How We Use Energy in Our Homes

Heating accounts for the biggest chunk of a typical utility bill.

Source: 2005 Buildings Energy Data Book, Table 4.2.1., 2003 energy cost data.

So how would this work? Maybe something like this (indulgence is requested for taking and manipulating numbers out of context):

If the building systems assessment reveals that wall penetrations aren't sealed, openings aren't caulked and weather-sealed (windows will be addressed a little later), and ductwork isn't properly sealed and insulated, then it makes good sense to take care of these things first. Air leakage from these areas accounts for almost half of the infiltration total and the single worst culprit is ductwork, accounting for 15%. Sealing and insulating ductwork, caulking plumbing and other penetrations could eliminate more than a quarter of the air leakage. And, relatively speaking, doing so is easy and inexpensive, as typically everything is readily accessible, and the quantity of the materials small and reasonable cheap.

To get a sense of what this means relative to energy efficiency, if, using the energy use chart, 34% of energy used is for space heating and 11% for cooling, and you assume the reason you're using that energy is, in great part, to replace conditioned air lost due to leakage, then eliminating more than 25% of the leaks should reduce total energy usage by about 12% ($.34 + .11 = .45 \times .28 = .126$).

While more expensive because of the amount of material you'd need, adding insulation to recommended levels is also cost effective, especially if added to attic spaces and floors over unconditioned spaces. In such a scenario, since the chart combines floors, walls, and ceiling leakage (31%), let's say floors and ceiling account for about half of that – 16% – doing so should reduce energy usage another 7% ($.45 \times .16 = .072$).

In this hypothetical example, over 19% energy savings could be achieved by doing things relatively easy that wouldn't have a major disruption factor on building use. Obviously, real-world results will vary.

Now consider some big-ticket items. If the furnace and air-conditioning unit are old and need to be replaced, doing so with ones, for instance, 15% more efficient, should translate into energy savings of about another 7% ($.45 \times .15 = .0675$). Applying the same 15% more efficient figure to a new refrigerator gains you 1% and to a new water heater about 2%.

Again, while these numbers are hypothetical, there is a recognizable trend here. That is, doing some less expensive, relatively easy, and low physical impact work results in greater energy savings, while more expensive equipment replacement work, while making sense if replacement is necessary, actually has a lower energy savings return of investment or one that takes longer to recoup expenditures.

Which brings us to windows.

Somehow old windows have become the poster-child for energy inefficiency, while new windows are touted as the miracle cure - - "cut your energy bills up to 25%!" However, such numbers don't appear to stand up under closer examination. If, using DOE figures, windows account for 10% of energy loss (air leakage), stopping all of that loss only calculates into energy savings of just under 5% ($.45 \times .10 = .045$). Additionally, this best-case scenario is unlikely in that a typical single-glazed wood window should have a U-value of about .98, which converting to R-value is about 1. A comparable double-glazed window with a low-e treatment has a U-value of about .34 or R-3. Logic would indicate the values available aren't great enough to achieve such a remarkable improvement in overall energy usage.

The point here is that windows are, by their very nature, not very energy efficient. However, they also provide a multitude of functions; among them are light, ventilation (sometimes) and stylistic character. Light and ventilation come at a cost to energy efficiency that we all seem willing to pay. And, from casual observation and judging from the selection of windows used in new construction, it appears that the costs of style are readily accepted, too.

From a preservationist perspective, old windows are very significant to the stylistic character of old buildings; in fact, they go further, because they also help define their physical historic character. As such, retaining old windows as part of a rehabilitation renovation or maintenance project really is a reasonable and desirable expectation. And, old windows don't need to be replaced for the sake of energy efficiency. Some independent studies indicate that adding a storm window to single-glazed windows will provide similar efficiencies as new double-glazed windows.

But this isn't to say you should keep the old windows in their current condition, which in many cases probably is pretty sad. It's kind of ironic that old windows have proven durability because they've withstood neglect, little or no maintenance for years and years, yet can often be repaired to function as they did originally and continue to last indefinitely, with a little care.

The reasons for this are that the material these windows are made from generally is of a higher quality than what is readily available and typically used today, and their assembly techniques make them quite repairable. Of course, that doesn't mean that working on old windows is necessarily cheap, but, then again, neither are replacement windows.

But you might be thinking about maintenance and its associated costs. The answer to that is twofold.

First, maintenance is a good thing. Stuff lasts longer if you take care of it. And, if you are doing regular maintenance, you get to know your building and systems pretty well and have a greater chance of catching problems when they're small and easily taken care of. Windows that are candidates for replacement probably got that way because they were neglected. If they had been taken care of regularly, their maintenance costs should have been relatively low. The alternative to maintenance is a big window project, either repair or replacement - - both expensive. And, actually, what are your choices? Repair a window that may last as long or longer than it already has (60-80-100 years?) or put new ones in that tout low or no maintenance and a warranty that ends at 20-years.

Second, if something isn't designed for maintenance, by default it's designed for replacement. Which in the long run costs more?

So, while it makes sense to replace a window that has deteriorated to the point that it can't be repaired, replacing repairable windows doesn't appear quite as logical when you factor in these considerations.

While windows have been the main point of this retention versus replacement discussion, the same basic concepts apply to other historic features as well. Some energy efficiency improvement projects can be done with little or no impact on historic features and materials, like adding attic insulation; others could constitute a historically detrimental impact, like removing plaster to insulate walls.

There are other cautionary notes relative to energy efficiency improvements for historic buildings. Energy efficiency improvements could also have unintended consequences, which for the most part generally involve moisture-related problems, including mold, rot, condensation, and peeling paint. When sealing and insulating and otherwise making a building snug and tight, you might also be creating situations where moisture is being trapped and will lead to these problems.

How could this happen?

One circumstance could be installing a “vapor barrier” incorrectly. The general rule of thumb is to put a Vapor Diffusion Retarder on the warm side of the building envelope. But, you might be thinking, “the warm side varies, in winter it’s the inside, in summer, it’s the outside.” Well, what’s really recommended is based on what Climate Zone you’re in and more specifically its number of Heating Degree Days. For Georgia, generally, in the northern half of the state, the Vapor Diffusion Retarder should be put on the interior side, while in the southern portion of the state one shouldn’t be used.

Another situation could be the inadvertent use of a paint, which because of its perm rating, acts as a Vapor Diffusion Retarder. If you’re having paint peeling problems, that could be a reason why your paint is not sticking.

Other moisture problems might have to be dealt with by adding exhaust vents in bathrooms and kitchens and/or by installing a dehumidifier.

Conclusion

Improving the energy efficiency of historic buildings can be a beneficial objective. Doing so makes the buildings more desirable and agreeable as places in which to live and work, allowing for their continued use, which also helps stabilize communities and neighborhoods. Often these improvements can be accomplished economically and with minimal physical impact on the historic fabric of the buildings. However, the means by which the improvements are made and the level of improvement expected should be carefully considered so that the historic character of the buildings is not compromised and so that money will be spent for those improvements which will provide the best results.

To plan an energy efficiency improvement project, remember to:

- Recognize your building as an assembly of systems – framing, including wall/ceiling/roof finishes; mechanical system, including furnace, A/C, and ductwork; and energy users, including water heater, appliances, and lighting.
- Identify weaknesses in the systems and where they might be failing or need improvement. Understand that changes in one system may impact the others, e.g., sealing the house up too tight may result in conditions where existing ventilation and humidity control are no longer adequate, resulting in mold growth and other moisture-related problems.
- Fix or improve the easy and less expensive stuff first.
- Avoid treatments that require wholesale removal or loss of historic material or finishes.

A good source for energy efficiency guidance can be found at: www.eere.energy.gov/buildings/info

Acknowledgments

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The Historic Preservation Division's mission is "to promote the preservation and use of historic places for a better Georgia."

HPD works in partnership with federal and state agencies, local governments, preservation organizations, community groups and individuals to achieve a greater appreciation and use of historic resources in the context of everyday life. Working at the state level, the Historic Preservation Division helps bring together national, regional and local interests to support community and economic development throughout Georgia. Georgia's state preservation program encourages regional and local planning, neighborhood conservation, downtown revitalization, economic development, heritage tourism and archaeological site protection.