The Thesis committee for Serena Gigliola Bolliger

Certifies that this is the approved version of the following thesis:

Harmony in Marriage: integrating sustainable solutions into historic house museums without interfering with the historic fabric.

APPROVED BY

SUPERVISING COMMITTEE:

Supervisor: ______________________________

Steven A. Moore

Co-Supervisor: ______________________________

Michael Holleran

Harmony in Marriage: integrating sustainable solutions into historic house museums without interfering with the historic fabric.

by

Serena Gigliola Bolliger B.A.; M.A.; M.S.H.P.

Thesis

Presented to the Faculty of the Graduate School

of the University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Sustainable Design

The University of Texas at Austin

May 2014

Harmony in Marriage: integrating sustainable solutions into historic house museums without interfering with the historic fabric.

by

Serena Gigliola Bolliger, MSSD

The University of Texas at Austin, 2014

SUPERVISORS: Steven A. Moore and Michael Holleran

Historic buildings live a double life between climate-adapted largely-passive structures and draughty, poorly-maintained ones. Preservation professionals argue that preserving these structures is more resource effective than constructing new buildings, and that pre-electricity structures were built to take advantage of climate and geography, using passive technologies to perform efficiently. Modern technologies have also been adopted- electrical lights, air conditioning, fire alarms - as a natural progression of inhabitation. Yet in historic house museums, there is still the promise of historic representation, one unmarred by 'inauthentic' additions. If modern and past technological changes have been accepted and integrated, how is the historic house museum not a 'living building culture'? And if house museums are indeed a living building culture, why not allow a more flexible representation of our historic properties if they are interpreted with integrity and honesty?

The EPA estimates that buildings represent 65% of the U.S. electricity use, and predictions estimate 80% of the 2030 building stock exists today. If we truly plan to reduce our energy consumption, we must confront the reality that existing buildings are a significant contributor to our output. If, as curators, it is our hope for historic buildings to represent preservation, then we must admit that in preserving the past for the future, we must begin by preserving our future.

This thesis analyses the opportunities and risks for historic house museums to respect their historic interpretation but adapt to changing conditions. Examples of energy efficiency strategies both historic and current, will be examined in historic structures, illustrating that caretakers of historic buildings are making value judgments about the future of their property, in terms of environmental, fiscal and historical sustainability.

This thesis includes the analysis of a case study historic house museum in Austin, Texas, the French Legation Museum, which is used as a base model for estimating energy efficiency gains from the adoption of some low-energy technologies. Calculations based on this information indicate which integrations and additions could offer the greatest return on investment for this historic building to operate as or more efficiently than a modern code construction without visible or egregious alteration to the historic fabric.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

In 2011 the United States signed, but did not ratify, the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The World Bank calculated that the United States (U.S.) used 6,793 kilograms (kgs) of oil per capita in 2012, down from 7,032 in 2011. As a point of comparison, the United Kingdom was estimated to have expended 3,043 kgs of oil per capita in 2012. Similarly in 2011 the U.S. was estimated to have spent 13,246 kWh per capita versus the United Kingdom's 5,516 kWh per capita.[1] The American Recovery and Reinvestment Act of 2009 provided, in its more than $80 billion budget, $5 billion to weatherize low income homes to reduce their energy consumption, $4.5 billion to make federal buildings more energy efficient and $11 billion to encourage smarter use of energy within homes.

The Environmental Protection Agency (EPA) estimates that buildings account for 36% of the U.S. total energy use, 65% of electricity use and 30% of raw materials use.[2] The Institute for Building Efficiency estimates that 50% of the 2050 building stock has already been built.[3] Thus even if every building constructed from this day forth were net-zero, we would only solve half of our building-based energy consumption.[4] LEED New Constructions have been acclaimed as the solution to our building problem, however they only partly outperform code buildings, and studies have revealed that some LEED buildings perform at the equivalent level of

---

[1] "Energy Use (kg of oil equivalent per capita)," The World Bank, Data, International Energy Agency Statistics, accessed December 10, 2013. http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE?order=wbapi_data_value_2012+wbapi_data_value+wbapi_data_value-last&sort=desc
[2] "EPA Green Buildings," Environmental Protection Agency, last updated September 10, 2013, accessed October 1, 2013. http://www.epa.gov/oaintrnt/projects/
[3] "Why focus on existing buildings?" Institute for Building Efficiency, accessed October 1, 2013. http://www.institutebe.com/Existing-Building-Retrofits/Why-Focus-On-Existing-Buildings.aspx
[4] "Case Studies," Living Building Challenge, accessed October 1, 2013. http://living-future.org/casestudies

code buildings when audited after commissioning.[5] Zero-Energy buildings are gaining traction, although their development for mass consumption is only in the beginning stages, and there are only 14 Living Building Challenge certified structures in the U.S. Focusing on new construction will not solve our current and future energy problem. We must start by reworking and repairing the designs and fundamentals that already pervade our constructed fabric.

Carl Elefante's quotation "The greenest building is one which is already built" has been adopted by historic preservation proponents as the trademark expression for the sustainable preservation movement. The statement represents a variety of arguments, most notably the appreciation for embodied energy in existing buildings, and the belief that historic buildings have often been built with great structural integrity and a construction method that innately provides a certain energy independence. The latter argument is falling into contention as structures built to rely on electricity, HVAC, and materials manufactures in foreign climates, are celebrating their 50th birthdays, thus making them eligible for consideration of inclusion on the National Register of Historic Places.

The National Register of Historic Places which was authorized under the National Historic Preservation Act of 1966 lists criteria for nominated historic properties as follows:

> **Criteria for Evaluation** The quality of significance in American history, architecture, archeology, engineering, and culture is present in districts, sites, buildings, structures, and objects that possess

---

[5] Nadav Malin "Lies, damn Lies and… Another look at LEED energy efficiency" *Building Green*, September 2, 2008. http://www2.buildinggreen.com/blogs/lies-damn-lies-and-another-look-leed-energy-efficiency

> integrity of location, design, setting, materials, workmanship, feeling, and association, and:
> **A.** That are associated with events that have made a significant contribution to the broad patterns of our history; or
> **B.** That are associated with the lives of persons significant in our past; or
> **C.** That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
> **D.** That have yielded or may be likely to yield, information important in prehistory or history.

Structures with particular merit are recognized as having "character defining features" which are defined by the National Park Service as follows.

> "those architectural materials and features that are important in defining the building's historic character and which must be retained in order to preserve that character…The character of a historic building may be defined by the form and detailing of exterior materials, such as masonry, wood, and metal; exterior features, such as roofs, porches, and windows; interior materials, such as plaster and paint; and interior features, such as moldings and stairways, room configuration and spatial relationships, as well as structural and mechanical systems."[6]

In most situations, the interior of the building is not protected in the same manner as the exterior facades visible to the public.[7] Interiors provide more flexibility than exterior changes which affect original features, giving building owners greater opportunity to suit the interior of the building to their need while fulfilling the expectations of the Secretary of the Interior.

---

[6] "Rehabilitation: The Approach," National Park Service, accessed October 1, 2013. http://www.nps.gov/hps/TPS/standguide/rehab/rehab_approach.htm

[7] "while preserving the exterior of homes in historic districts is commonplace, most states do not include interiors in their preservation-enabling legislation." Robert W. Mallard, "Avoiding the "Disneyland Façade": The Reach of Architectural Controls Exercised by Historic Districts Over Internal Features of Structures." Widener L. Symp. J. Vol. 8 Issue 2. 2002. p.323-324.

For the purposes of this thesis, a historic property, structure or building refers to any structure either 50 or more years old. I refer generally to structures which are on the National Register and abide by the Secretary of the Interior's Standards for Historic Preservation, however I do include historic commercial properties whose caretakers have chosen not to conform strictly to the Standards when they illustrate particularly interesting examples of historic architecture having been integrated with modern low-energy technologies.

Aaron Lubeck states that "The culture and art of old houses is unmatched by new houses."[8] Buildings constructed before the widespread use of electricity are widely recognized as having been built to demand as little energy as possible outside of that already provided by the natural climate. Thermal mass, solar heating, seasonal shading, targeted tree planting, are only a few among many strategies employed to live comfortably all year round in a seasonal climate. Traditional Cypriot houses feature an elongated design, with large windows on the north side, encouraging high velocity airflow in summer, and small windows and a veranda on the south side to reduce the incidence of solar radiation. Sod roofs, or birch bark roofs are used in Scandinavian climates both to insulate and to apply pressure on the log construction of the home, making it more draught-proof. The Alhambra features a spectacular example of passive cooling via evaporation, employing ponds to cool during the day and release solar heat at night. People relied only on techniques such as wood and coal burning stoves, transhumance (animals living alongside humans to share heat energy,) and cultural traditions, for example sleeping outside in summer, to supplement the energy properties of their homes. Without heating and cooling or electrical light, structures had to be made to take full advantage of

[8] Lubeck, Aaron. *Green Restorations : Sustainable Building and Historic Homes*. New York: New Society Publishers, 2010. p.19

their climate, local resources and traditional building knowledge. The burden of long distance materials transportation also required builders to use local materials. Thus a pre-electricity building would theoretically have been constructed in an ideal location, taking advantage of shelter and exposure as required by the climate, with low impact materials sourced within a few hundred miles. Sarah Brophy, author of *The Green Museum,* explains that "Sustainable practices are old concepts…catching water in rain barrels and cisterns, using reading and work lamps instead of overhead lights, capitalizing on the natural terrain and solar orientation for siting buildings, getting by with less, reusing what we could."[9] Here Sarah Brophy uses 'sustainable' as a catchall phrase to refer to practices which are more energy efficient, less water intensive or less toxic to humans and habitats. However 'sustainability' was most specifically defined by the Brundtland Commission in 1987 as a system by which the needs of the present could be met without compromising the ability of future generations to meet their own needs. For products and technologies, technically this would refer to objects with no carbon emissions and a net-zero impact lifecycle. It has also gained a more colloquial definition referring to items which embody one or more of : energy efficient, water efficient, non-toxic, ethically sourced, fairly traded, and socially equanimous among other traits. The term also incorporates a dimension of 'social' equity, which is largely excluded in the priorities and vocabulary of historic preservation. I will refer to sustainability as a social, environmental and financial concept, however I do not want to imply that many of the technologies here are 'sustainable' in terms of their manufacturing, production or end-of-life.

The introduction of electricity into homes provided residents with the option to abandon their naturally lit east-facing breakfast rooms in which to read their

[9] Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham, Altamira Press. 2008. p. 113

newspapers, it made north-facing homes feasible in bitter climates where opening up the north side meant allowing cold infiltration, because it could be combated by mechanical heating. The removal of the need to keep the elements at bay with thick walls and air pocket insulation allowed more lightweight material use, whose experimental and nascent use meant a lack of understanding of how it would perform in the moment and long term. Preservation is now facing these issues- debating the intended longevity of experimental and modern structures and the best method of preserving or replacing failing materials and buildings.

The value of the ageing materials in historic buildings is not to be scoffed at, from either a direct or indirect economic aspect. Embodied Energy, or Emergy[10], is a growing concern in new 'green' building, however it has long been considered one of the strong sustainable aspects of historic architecture. Mike Jackson, chief architect with the Illinois Historic Preservation Agency calculates that a 'green' building will really start saving energy after 40 years, after it has paid off the energy debt of its construction.[11] However the analysis of embodied energy in a historic structure goes beyond the current moment and investigates the value of the energy that has already been put into the building and the payback the building is receiving on the initial investment. If new construction is being considered on an existing site, it will take into account not only the new construction and the amount of time it would take to start 'saving energy', but the loss of the energy and resources that had been put into the existing building, and asks how long it would take a 'green' building to work off the energy consumption of not only the new building, but the existing building that was lost for it.

---

[10] M. Lenzen "Primary Energy and Greenhouse Gases embodied in Australian Final Consumption: an Input-Output Analysis" Energy Policy, Vol 26, Issue 6, May 1998, Pp. 495-506.
[11] Wayne Curtis, *A Cautionary Tale,* Preservation Magazine, National Trust for Historic Preservation, January/February 2008. http://www.preservationnation.org/magazine/2008/january-february/cautionary-tale.html#.Uo-mCmTEq38

However seemingly complex and specialized maintenance for unique elements of historic buildings has deterred curators from prompt care of these valuable assets, and deferred maintenance can cause minor damages to become serious faults, which can appear to be inherent building flaws rather than adopted defect. Reasons for neglect are various but range from inconvenience to a lack of funding or expertise. Allen Powell II reports in *The Advocate* about homeowners struggling with city government over desired changes to historic properties "Often homes were being neglected because property owners couldn't get permission from the city's Historic District Advisory Committee to make certain types of renovations or to demolish the structures"[12] Active negligence in Chicago has caused an Underground Railroad historic home to crumble, with neighbours reporting that "[the homeowner] is aware of the condition of the home but has other things to take care of."[13] Municipal ordinances and the mention of the Secretary of the Interior's Standards for Rehabilitation of Historic Properties can intimidate building owners who then believe the restrictions on their properties prevent them from implementing routine maintenance, or require strict adherence to unexpected code requirements.[14]

This gap in the knowledge field and subsequent maintenance deferral leads to leaky envelopes, failing windows, and sometimes eventual structural failure. For the purposes of this paper, properties suffering from structural failure are not of concern, since they are generally no longer in use and have (hopefully) had their energy supplies cut. The structures that will be the topic of this paper are those

---

[12] Allen Powell II, Gretna struggles with rules to prevent neglect of historic properties, *The Advocate,* February 21, 2013. http://theadvocate.com/news/5218758-123/gretna-struggles-with-rules-to

[13] Carolyn Starks, "Neglect Leaves Its Mark On Historic House," *Chicago Tribune*, November 29, 1999. http://articles.chicagotribune.com/1999-11-29/news/9911290126_1_historic-places-national-register-19th-century-house

[14] Ken Bernstein, "Top Ten Myths About Historic Preservation," *Los Angeles Conservancy*, accessed December 12, 2013. http://www.preservation.lacity.org/files/Top%20Ten%20Myths.pdf

historic homes that the Sustainability Institute estimates are 20% less efficient than average existing homes, 50% less efficient than the standard new home and 65% less efficient than an EnergyStar home.[15] To narrow the field further, I will examine some of the 35,000 buildings that the National Trust for Historic Preservation estimates are maintained as historic house museums.

I have chosen this particular subset because of my background and expertise in museum administration, in addition to the interesting and specific challenges posited by historic house museums. Historic house museums consider their building to be part of their collection. Their mission is focused around stewardship, and the American Association of Museums Code of Ethics states "This stewardship of collections entails the highest public trust and carries with it the presumption of rightful ownership, permanence, care, documentation, accessibility and responsible disposal."[16] As such, the care of their building or structure is of essential importance to the adherence to their mission. At the same time, they are open to the public and adhere to certain health and safety standards, alongside comfort expectations from their patrons. In addition to historic tours, house museums often host weddings, conferences, celebrations and similar events to boost revenue and to connect with the community. These require the installation of HVAC systems, lighting, and mechanical and electrical equipment that is not original to the house but are deemed a necessary investment for the survival of the home.

---

[15] Benjamin Leigh and Sarah Welniak, "Energy Efficiency in Historic Buildings," The Sustainability Institute, May 2010, accessed January 27, 2014. shpo.sc.gov/events/Documents/EnergyEfficHyPres.ppt

[16] "Code of Ethics for Museums," American Alliance of Museums, Adopted 1991, Amended 2000, accessed January 27, 2014. http://www.aam-us.org/resources/ethics-standards-and-best-practices/code-of-ethics

Thus historic house museums have the energy use of a public building, and the demands of clients and patrons, with the restrictions placed upon maintaining the integrity of their historic structure. Curators are faced with the ethical quandary of how to change and upgrade a building for a modern audience without interfering with the 'authenticity' of what they have promised to protect. The idea of 'authenticity' is mired in complex connotations for historic house museums whose staff labour to present an accurate representation of a historic moment and often create more of an ambience than a precise portrayal. Information lacunae, lack of financing, lost furniture, and destroyed original materials all contribute to the struggle that historic house museums face in establishing their image. However the idea of 'authenticity' remains, an intangible, out-of-reach concept which has no professional definition. Enacting maintenance and trying to maintain historic integrity can already offer difficulties- latex caulk, non-lead based paint, modern replacement window panes- so in the face of 'authenticity', the idea of upgrades and energy efficiency improvements can be a hard, if not impossible, pill to swallow.

However it is becoming increasingly apparent that preservation is becoming entertwined with environmental sustainability in more ways than merely representing saved embodied energy. Carol Enseki, president of the Brooklyn Children's Museum, member of the AAM board and also on the Accreditation Visiting Committee, says "I can see future AAM accreditation criteria dealing with sustainability. A good aspect of planning is how to improve energy efficiency, which of course frees up dollars to go towards programs and services."[17] In 2014, the California Association of Museums' Foresight Committee published the *Foresight Research Report: Environment and Resource Sustainability in Museums*.

---

[17] Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham, Altamira Press. 2008. p.51

One of its projected statements for 2015 was that “museums [will] gather together and make a commitment to sustainability by re-working vision and mission statements to include a section on sustainability in exhibits, programs, collections and building infrastructure.”[18] Once environmental sustainability is incorporated into museum missions, institutions will no longer have to fear that decisions they make in regards to energy efficiency and sustainable work practice will be considered frivolous spending of important operation monies.

Thus far, integration of low energy technologies into historic house museums has ranged from reawakening those strategies that were already inbuilt, to introducing modern high efficiency systems to boost performance. Given the push toward satisfying customer need, the venerated importance of maintaining a certain collections environment, and the desire to conform to health and safety codes, these modern systems have been adopted either de facto (lighting, fire monitoring, alarm systems) or with explanatory interpretation on the part of the staff. This indicates that these historic properties, despite advertising themselves as representing a moment in time, actually embody a changing, living building culture: one which exemplifies both a historic building tradition, and an adapting modern one. This understanding opens a wide array of opportunities for historic museums seeking to engage audiences with a more dynamic and sustainable interpretation of architecture and the life lived in and around it. This is a building culture that represents more than an ossified moment in time, it would be the new living history. Howard Davis refers to ‘building culture’ as “the coordinated system of knowledge, rules, and procedures that is shared by people who participate in the

[18] “Foresight Research Report: Environment and Resource Sustainability” in Museums California Association of Museums Foresight Committee, March 2014, accessed March 27, 2014. http://futureofmuseums.blogspot.com/2014/03/towards-green-future-environment-and.html

building activity and that determines the form buildings and cities take."[19] Here I use 'building culture' more broadly to refer to a set of values and systems that are embodied in the construction and inhabitation tendencies of a population. I believe a building culture carries its own vocabulary and can be quite strictly defined, or flow fluidly into building cultures which are in proximity either in time or place. It can refer to the vernacular style of a single community or the ethos of a cross-dimensional generation.

Gwendolen Raley, Museum and Heritage Tourism Director for the Indiana Landmarks Indianapolis, has witnessed the wane in popularity and viability of historic house museums, and she proposed the following to the American Association for State and Local History (AASLH) Historic House Affinity Group Committee. "Museum professionals have been grappling for well over a decade with the question of how to make once-vibrant—and now deliquescing—HHMs (Historic House Museums) more relevant to their communities and sustainable for the future… Overwhelmingly, museum professionals have collectively come to the same conclusion: HHMs must change to adapt to the evolving world around them, but there is no one size fits all solution that can be employed in all cases." [20] It follows that this solution will be different for every institution, however sustainability, in any or all of the economic, social or environmental iterations, has become an agenda that cannot be ignored.

---

[19] Davis, Howard. The Culture of Building. Oxford: Oxford University Press, USA, 2000. p. 3 http://UTXA.eblib.com/patron/FullRecord.aspx?p=693995 (accessed April 23, 2014)

[20] Gwendolen Raley, *"Making Changes: Beyond Rethinking the Historic House Museum,"* AASLH Historic House Affinity Group Committee, March 2014, accessed March 29, 2014. http://www.mynewsletterbuilder.com/email/newsletter/1411406096

The movement towards less energy intensive operations is welcome news to many hard working staff members at institutions around the country. A number of these homes and buildings have already decided to integrate sustainable technologies into their building operations. From smaller measures such as insulation, radiant barrier, and small duct high velocity central air to geothermal, wind, and solar, historic house museum curators are bringing their buildings into the modern time while respecting the antiquity of the structure. For example, the Teackle Mansion in Princess Anne, MD, has had great success in installing a sizeable geothermal system in its basement, which has been a great boon to its financial situation. Even the White House, which many people do not realize is a historic house museum, is outfitted with solar panels and state of the art climate control. What follows will include an investigation into the sustainable measures that have been used, successfully and unsuccessfully, in historic house museums both in the U.S. and further afield.

We cannot begin to understand the energy efficiency improvement needs required by a particular building until we understand its existing structure, performance and usage reports. Thus the importance of an energy audit cannot be overstated. Audits reveal air infiltration, damp, insulation failure, and identify where these can be improved to reap great benefits for indoor comfort and energy performance. The intimate appreciation for the complexity and singularity of a building's construction, performance, weaknesses and strengths is particularly important for historic structures, whose design is often unique, and whose value can be based on the integrity of the structure and the survival of its character defining features. Applying a one-size-fits-all solution to these structures would result in money wasted on ineffective strategies and not invested in crucial upgrades.

This research has been conducted in order to identify through the analysis of an existing historic house museum case study, the opportunities and limitations available for the building to reach expected interior climate conditions while using a comparable amount of energy as a current house of the same size.

Chapter 2 will outline the methodology of the paper and plan of each chapter. In Chapter 3 I will conduct a study of historic energy efficiency technologies, used in a variety of historic buildings. In the fourth chapter I will review sustainable technologies that have been implemented in historic house museums and historic museums to create a list of strategies that have been used successfully by curators and building owners. In Chapter 5 I will investigate a case study, the French Legation Museum in Austin, Texas. I will examine the property, and its construction, opportunities, and needs in order to identify which strategies might be most appropriate for this particular historic museum property. The final chapter will conclude the thesis, suggesting further study opportunities and potential for implementation in other historic house museums.

Definitions

Secretary of the Interior's Standards: The Secretary of the Interior is responsible for establishing standards for advising federal agencies on the preservation of historic properties listed in or eligible for listing in the National Regjster of Historic Places. In partial fulfillment, the agency developed a guide for building work undertaken on historic properties. There are separate standards for Preservation, Rehabilitation, Restoration and Reconstruction. According to the Secretary of the Interior: "The Standards for Rehabilitation (codified in 36 CFR 67) comprise that section of the overall treatment standards and address the most prevalent treatment. "Rehabilitation" is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values.""[21] I will refer to these as 'Standards.' However I do not presume that these are permanent standards, they exist based on a current understanding of preservation and the needs of the historic stock. As our appreciation evolves, and our understanding of our building fabric adapts, the standards of care that we expect will change to fit current ideals.

<u>Energy Efficient and Low-Energy:</u> Since I will be discussing largely discussing electricity and energy use, I will refer to energy efficiency measures, and low-energy strategies, in reference to the expectation that these methods perform, or cause a building to perform, more efficiently than standard construction systems estimated by the U.S. Energy Information Administration as being the norm from 2000-2009.

<u>Strategy and Technology:</u> "Technology…is knowledge as well as artifacts."[22] MacKenzie and Wajcman include 'practices' in their dissection of the development and meaning of 'technology,' however I will avoid the study of practices in order to focus my thesis. A study of energy efficient practices in historic house museums would be a thesis in itself and a study of each staff member's philosophical and political opinions on energy efficiency. In this thesis I will use the word 'strategy' to separate the idea of technological knowledge from the idea of artifact, represented by the word 'technology.'

---

[21] Anne Grimmer, Jo Ellen Hensley, Liz Petrella, Audrey Tepper, "The Secretary of the Interior's Standards for Rehabilitation and Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings," U.S. Department of the Interior, National Park Service, Technical Preservation Services. 2011. http://www.nps.gov/tps/standards/rehabilitation/sustainability-guidelines.pdf Accessed December 10, 2013.

[22] MacKenzie, D. and Wajcman., Judy, Ed. (1999). *The Social Shaping of Technology*. Philadelphia, Open University Press. P.7

I refer to a 'technology' as any mechanical solution to a problem, however old or simple- from operable windows to daylighting sensors that lower blinds- as I wish to ensure that the idea of 'technology' is not accidentally wrapped in the shroud of modernity. A 'strategy' includes non-object applications, for example building orientation, landscaping, in addition to 'technologies' such as solar panels and UV film.

Renovation, Rehabilitation and Retrofit: I will be using renovation/retrofit/rehabilitation interchangeably where I am not referring specifically to the Secretary of the Interior's Standards. Renovation refers to a less strict adaptation of an existing building, as outlined in the Standards.

Preservation: I will use 'preservation' broadly to refer to the field and ethos of preservation. I will specify where I refer to the definition of 'preservation' as outlined by the Standards.

Chapter 2: Methodology

Many years ago I realized how strongly our opinions, our teachings, coloured our view of the world. Groat and Wang would suggest that I believe a radical form of constructivism, tending on relativism, that "a virtually infinite number of realities can be presumed. Knowledge can only temporarily or provisionally established, and is soon to be reinterpreted."[23] I understand that there are many stakeholders in any situation, all of whom have a valid perspective which should be respected. In terms of buildings and rehabilitation, there are owners, curators, architects, contractors, engineers, neighbours, city officials, all of whom have a particular expertise and an opinion which is worthwhile. Taking all of these approaches into account is paramount in developing an integrated management plan for the historic structure in question. I believe my background has made me privy to the priorities and concerns of many of the groups I work with, since I often find myself to be one of them- a preservationist, environmentalist, museum worker, homeowner, contractor. I am obviously missing many social understandings, however I believe that the internal struggle I have undergone to appreciate the importance of the historic fabric as a frustrated homeowner trying to install a kitchen in their historic home, or as preservationist trying to argue that CFLs just are not appropriate for a historic space, particularly not one with wooden collections, has helped me walk a mile in someone else's shoes. Or work boots. I also believe that I also am partly pragmatic, I agree with Cheryl Misak's interpretation of Charles Sanders Pierce that pragmatists are not searching for a definition of truth, but how a concept applies to our practice in everyday life.[24] I believe that our thoughts can be used to shape the

---

[23] Groat, Linda N.; Wang, David. *Architectural Research Methods*. Hoboken: Wiley, 2013. http://UTXA.eblib.com/patron/FullRecord.aspx?p=1166322 Accessed February 19, 2014.
[24] Pihlstrom, Sami. "Cheryl Misak, ed.: New Pragmatists." *Philosophy in Review* 28.5 (2008): 355+. *Academic OneFile*. Web. 19 Feb. 2014.

world, and that understanding their relative use in context leads to practical solutions.

In Chapter 3 I investigate interpretation of historic house museums as a living example of knowledge as described in critical theory. Guba and Lincoln state that "Knowledge does not accumulate in an absolute sense; rather, it grows and changes through a dialectical process of historical revision that continuously erodes ignorance and misapprehensions and enlarges more informed insights." [25] This philosophy is one which historic house museums embody and yet eschew in favour of a positivist nature of knowledge which leaves their claims to 'authenticity' in the gray area of the black and white construction they have created for historic interpretation.

Goal

I am trying to produce a framework by which curators of all sorts can begin to grasp the process of understanding their own building, in order to then consider the best strategies for improving building performance and maintenance. I define 'curator' as any caretaker of a historic property and/or collection. In becoming the steward for a cultural treasure, this person has taken upon himself or herself the responsibility for its well-being, and should make decisions with the integrity of the property at heart. This may be the building owner, the director of an institution, the facilities staff, the caretaker, the exhibits curator, even the federal agency in charge of making a decision about a historic federal building in its care. These guidelines should appeal to both preservationists and sustainable designers, without requiring either to compromise their principles. This system, although substantially unique to each structure, should be replicable to some degree.

---

[25] Guba, Egon and Yvonne Lincoln, "Competing Paradigms in Qualitative Research," in *Handbook of Qualitative Research* (Thousand Oaks, CA: Sage, 1994)

General Structure of Framework/Test

The process would involve (1) an analysis of the current building structure both (a) stylistically and (b) in terms of typical energy use; (2) period energy efficiency features would be researched, both in use in the building and in literature; (3) the analysis of a working database of sustainable strategies used in museums and historic buildings; (4) calculations in regards to the current energy performance of the building compared to the current standard building construction as reported by the census data for the U.S. Energy Information Administration (EIA) and the building's projected efficiency improvements given the addition of appropriate technologies. (5) Conclusions will be drawn as to the opportunities and limitations identified in the process, and the likely results and possible implementation in the structure.

Building Analysis

The Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings encourage the use of building analysis, including whole building audits, blower door tests, infrared thermography, energy modeling and daylight modeling, to begin the study necessary to design an appropriate weatherization and rehabilitation plan.

An adage that is often used in business "You cannot manage what you do not measure" applies here in terms of encouraging both an understanding of a building, and of comparable energy use before a strategy can be developed. One cannot reach the moon without knowing how far away it is.

> "Before implementing any energy conservation measures to enhance the sustainability of a historic building, the existing energy-efficient characteristics of the building should be assessed. Buildings are more

than their individual components. The design, materials, type of construction, size, shape, site orientation, surrounding landscape and climate all play a role in how buildings perform. Historic building construction methods and materials often maximized natural sources of heating, lighting and ventilation to respond to local climatic conditions. The key to a successful rehabilitation project is to identify and understand any lost original and existing energy-efficient aspects of the historic building, as well as to identify and understand its character-defining features to ensure they are preserved."

The Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings [26]

1. Energy Auditing

An energy audit involves an investigation and analysis of the energy performance of a building, including building envelope tightness, leaking seals, insulation weakness and system failure. An audit can take many forms, and can be completed in several steps,

◊ Preliminary analysis can follow a site visit, but is generally based on climate data and energy use tracking, from 12-36 months of bill monitoring to identify cycles in energy use and building performance.

◊ An on-site evaluation may consist of a blower door test to test air changes per hour, infrared thermography to reveal envelope issues such as leakages and faulty insulation, duct leakage diagnosis, combustion appliance inspection, smoke puffer test, building air flow loss calculations, a domestic hot water inspection, and PerFluorocarbon Tracer Gas (PFT) air infiltration

[26] Anne Grimmer, Jo Ellen Hensley, Liz Petrella, Audrey Tepper, "The Secretary of the Interior's Standards for Rehabilitation and Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings," U.S. Department of the Interior, National Park Service, Technical Preservation Services. 2011. http://www.nps.gov/tps/standards/rehabilitation/sustainability-guidelines.pdf Accessed December 10, 2013.p.1

measurement technique tests long term infiltration problems, although it is not used as often as the blower door test.

The Bryant Homestead, a 1799 National Historic Landmark in Massachusetts, completed an energy audit that revealed that warm air leakage by convection was turning the building into a heat sieve. Infrared thermography revealed that the vent stack ran vertically through the building and was drawing heat straight outside. Sealing the vent stack and all the contributing plumbing pipes, was the beginning of valuable improvements for the home's performance, followed by attic insulation and caulk around doors and windows. Replacing cracked lead-filled window putty with acrylic putty stopped heat from seeping out of the structurally strong historic windows.[27]

2. Energy Modeling

Groat and Wang identify a model as a "system that simulates the reality being studied." A model can be presented in any of a variety of incarnations- physical, theoretical or virtual. In architecture physical models are often built to give clients a feeling of scale and a tangible feel for the operation of the project. Virtual models can be used to test stresses, climate conditions and occupancy situations. For example, models may be used to test fire safety measures planned for the building, such as evacuation routes for the maximum occupancy. These programs can be used to create a virtual simulation of a building, system or condition which can be manipulated to project possible outcomes of design decisions. However Groat and Wang stress that simulations teach us patterns of behavior or projections of possible

[27] Jane Roy Brown, "Let It Snow!," *Special Places Magazine*, The Trustees of Reservations, Winter 2011-2012. http://www.thetrustees.org/what-we-care-about/climate-change/let-it-snow.html Accessed January 15, 2014.

behavior, rather than predicting future behavior.[28] The University of California Santa Barbara Engineering Department identifies the following popular whole building simulation tools. In North America; EnergyPlus, eQuest, EE4, Ecotect, EnergyPro, Trace, Modelica, Trnsys. In Europe, popular systems include IES virtual environment, DesignBuilder, ESP-r, and IDA ICE.[29]

Architects John H. Cluver and Brad Randall in an article for the Association of Preservation Technology explain "In addition, practical and objective analysis tools are needed in the process, and that is the benefit of including energy modeling and life-cycle costing in assessing potential changes. These calculation tools can help all of those involved in a project to understand which solutions truly offer energy and operating cost savings."[30] Energy modeling is less intrusive than an energy audit, an intensive process which requires a building to be closed to the public for some hours. However the programs themselves are fairly limited- one can only model the iterations which have been created and input into the system by the software developers. Historic buildings have unique and unexpected construction, quite the opposite of the uniformity that is being designed and tested in most modeling programs. Unless a preservation expert develops a software program specifically for historic buildings, it is unlikely that a modeling program could easily accurately depict a historic structure.[31] A recent study in the Building

---

[28] Groat, Linda N.; Wang, David. *Architectural Research Methods*. Hoboken: Wiley, 2013. p. 360 http://UTXA.eblib.com/patron/FullRecord.aspx?p=1166322 Accessed February 19, 2014.
[29] Bryan Eisenhower, "Introduction to Building Energy Modeling," Institute for Energy Efficiency, Center for Energy Efficient Design, UC Santa Barbara Engineering School. Fall 2012. engineering.ucsb.edu/~bryane/BEM/Files/Week1.pdf Accessed March 29, 2014.
[30] John Cluver and Brad Randall, "Saving Energy in Historic Buildings: Balancing Efficiency and Value," Association for Preservation Technology Bulletin*: Journal of Preservation Technology*. Volume 41:1, 2010. http://www.apti.org/clientuploads/pdf/Cluver-Randall-41-1.pdf Accessed May 2013.
[31] For foundation information consider the following resource. "What is Energy Modeling and Building Simulation," Energy Models http://energy-models.com/what-is-energy-modeling-building-simulation

Research & Information journal revealed "Available evidence suggests that technology-focused modelling of home energy use tends to overestimate actual energy consumption, with average modelled consumption across house groups often 20–50% higher than observed averages"[32] Indicating that manual calculations and estimated based on actual data might be more reliable than modeled data. My original thesis design included a virtual model of a case study in EnergyPlus and subsequent models of variations of the case study with additions of historic and modern low energy technologies. However the program, and many of its fellows, were found to lack the flexibility required to reflect the unique assembly of historic structures, with options representing only the standard construction for which the software was designed.

3. Energy Monitoring

There are many ways in which curators can choose to analyse their building performance. Opportunities for properties seeking to understand their usage include:

- ◊ Installing meters and submeters to give a real time reflection of energy use.
- ◊ Tracking utility bills for 12-36 months.
- ◊ Installing plugload monitors.
- ◊ Installing real-time energy consumption trackers.

This can be very useful when seeking to identify the source of a large volume of usage. The Smithsonian National Zoo installed submetering for their water supply and immediately realized that there was a severe leak in one of the tanks which had been increasing their water use. However their water use was already so vast

[32] Aaron Ingle, Mithra Moezzi, Loren Lutzenhiser, Richard Diamond, "Better home energy audit modelling: incorporating inhabitant behaviours," Building Research & Information, February 28, 2014. http://www.tandfonline.com/doi/abs/10.1080/09613218.2014.890776#.U0xF1eZdVKg

that the loss was not noticed. Submetering their installations allowed them to identify a large and unnecessary burden on their resources. There are some state of the art systems that can track use and present it in an engaging and visual way. Siemens has chosen Lucid to interpret its data, an eye catching interactive dashboard which engages staff and visitors alike.

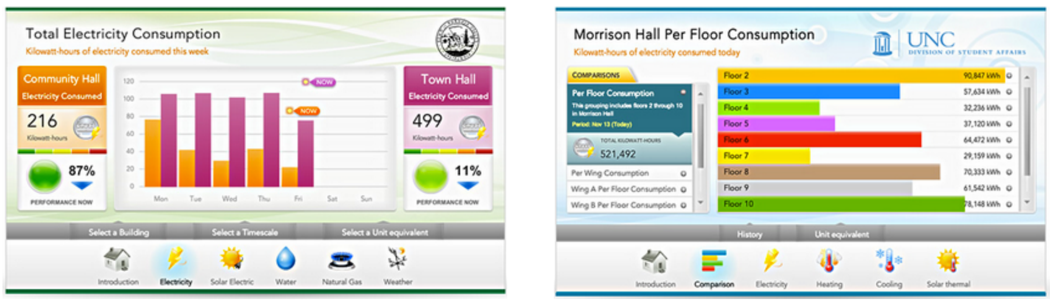


Figure 2.1. Courtesy of the Lucid Design Group[33]

Tracking energy bills from month to month and annually can help property managers understand their use internally, and in comparison with use locally and nationally. Watching use grow by tracking bills can help indicate that maintenance is in order, or that a system is coming to the end of its useful life. Another benefit is that it is free, and often easily accessible, even for property managers who are not owners, or who do not always have access to the structure in order to perform an audit or money for an energy model.

Benchmarking

A reference point, or database of reference points is necessary to understand building performance in context. Results of energy monitoring mean little if one does not know how other buildings of similar size, construction, and climate are

[33] "Building Dashboard," Lucid Design Group, accessed March 10, 2014. http://luciddesigngroup.com/buildingdashboard/kiosk.html

performing or are expected to perform. Researching the performance of buildings in the area, their electricity and gas use per square foot, is a simple place to start. The U.S. Energy Information Administration regularly releases energy consumption statistics for the nation, and includes consumption for houses by decade of construction, although thus far it only reaches the 1940s.

Table 2.1 The U.S. Energy Information Administration Summary of Household Site Consumption and Expenditures in the South Region

Table CE1.4 Summary Household Site Consumption and Expenditures in South Region (2009)									
		Site Energy Consumption				Energy Expenditures			
	Total Housing Units (mill)	Total (quad BTU)	Per house-hold (mill BTU)	Per house-hold member (mill BTU)	Per Sq Ft (thou BTU)	Total (bill $)	Per house-hold ($)	Per house-hold member ($)	Per Sq Ft ($)
Total South	42.1	3.220	76.5	30	41	85.75	2,038	798	1.09
Before 1940	2.4	0.237	97.9	39.6	47.8	5.42	2,243	907	1.10
1940-49	1.6	0.122	78.6	38.8	51.1	3.06	1,966	720	1.28
1950-59	3.6	0.271	75.7	32.9	46.6	6.95	1,944	844	1.20
1960-69	4.4	0.344	78.3	33.8	45.8	8.68	1,979	854	1.16
1970-79	6.5	0.448	68.7	28.1	42.8	12.32	1.890	773	1.18
1980-89	7.5	0.513	68.6	26.8	42.4	14.73	1.972	770	1.22
1990-2000	8.0	0.616	77.5	29.7	37.4	17.13	2,154	825	1.04
2000-09	8.2	0.670	81.7	29.2	35.5	17.46	2,129	761	0.92

Table 2.1 Courtesy of the U.S. Energy Information Administration[34]

The Northwest Energy Efficiency Alliance (NEAA) is in the latter phases of a study in 'Deep Energy Savings in Existing Buildings.' It has begun with an analysis of

[34] "Consumption and Expenditures Table CE1.4, 2009 RECS Survey Data," Residential Energy Consumption Services, U.S. Energy Information Administration. Released December 14, 2012. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary

historic commercial buildings identified by the New Buildings Institute (NBI) which have met or exceeded a 30% improvement on energy performance of a comparable building. The savings were either 'measured' by metered data or bills, or 'estimated' through modeling of the data. However common comparison is complicated because the baselines used for comparison varied from project to project, based on age of the building, program requirements and location. Benchmarks included ASHRAE 90.1 1999, ASHRAE 90.1 2004, CA Title 24, CBECS, and ASHRAE 90.1 2007.[35] Such problems also exist for new buildings which have to contend with emerging baselines and unverified energy efficiency programs. Divergent operations also require different standards for energy use. The Dell Children's Hospital in Austin, Texas, opened in 2007 and was one of the first LEED Platinum hospitals in the country. As a new facility, it cannot benchmark its performance against previous energy use, and as a specialized facility it cannot compare itself to other institutions to estimate its rank in comparison. Isolation units, emergency rooms, long term care, surgery space, all these units use varying amount of energy, and an average would not reflect a fair benchmark for other institutions which may run more or less energy intensive operations. Therefore even with the best intentions, benchmarking can be misleading, and triangulation of data is important for verifying performance across platforms.

Period Technologies

Many historic buildings are recognized as having inherently low-energy properties. In some instances these continue to function as they were designed- deep eaves and porches preventing solar gain for example- and in some instances, their functionality has been lost- where windows have been painted shut, and

[35] "NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

ventilation is entirely mechanical. Reawakening existing low-energy features that have been left dormant is key in maximizing a building's potential. I will identify historic house museums which have been lauded for maximizing their use of existing historic low-energy technologies and propose how these might be used in other homes built in a similar style, period and location. I do not suggest that Victorian homes in Boston should consider adobe walls to increase their thermal mass, but that late 19th century homes whose immediate (in time and place) neighbours had operable awnings, which had gained popularity in the years after the Civil War, might consider adopting awnings to fend off the summer heat. In historic house museums, this adoption could be incorporated into a good interpretation plan, to highlight the building's architecture, and the institution's commitment to environmental sustainability.

Historic house museums represent their structures as a static moment in time, yet it has been observed that architecture represents quite the opposite. Stewart Brand, in his study of *How Buildings Learn* details "the term 'architecture' always means 'unchanging deep structure.' It is an illusion. New usages persistently retire or reshape buildings… From the first drawings to the final demolition, buildings are shaped and reshaped by changing cultural currents, changing real-estate value and changing usage."[36] In the way they continue to operate, historic house museums represent a building culture rather than a built instance, and were they to take ownership of this aspect of their identity, a multitude of interpretation doors would open.

[36] Stewart Brand, *How Buildings Learn: What Happens After They're Built*, Penguin, October 1, 1995. p. 2

Modern Energy Efficiency Technologies

I have chosen to research current, state-of-the-art strategies that have already been implemented in historic house museums, historic museums and historic buildings in order to ensure that I am studying tactics which have been vetted by curators, both of museums and historic structures. Stewards of these buildings are highly trained caretakers, and operate largely under codes of ethics such as the American Alliance of Museums' (AAM) and the International Council of Museums (ICOM) "Code of Ethics for Museums" treating their buildings as part of their invaluable collections. The staff in many historic buildings, in consultation with architects, engineers, and caretakers of other historic properties, have adopted a wide variety of strategies uniquely selected to complement their construction and performance. These are mentioned in news articles and press releases but never collected in an inventory for access by properties seeking a comprehensive view of tried and tested techniques. As successful strategies are identified, I will provide information on performance and energy savings for each technique.

A Note On Collections Care

Historic house museums often come with the distinguished complication of containing historic collections of various materials, ages, and conditions which demand a delicate balance of the elements to secure their future. Given the priority that museums have in terms of stewardship of their collections, the protection of these oft-fragile collections must be a primary consideration when investigating energy efficiency measures within the home's walls.

American conservation standards for historic collections have undergone significant changes over the past century. In a bid to entertain standards similar to those already used in Europe, the Boston Museum of Fine Arts adopted parameters of a 50-60 degree temperature and at least 50% humidity in 1905. These standards evolved over the next seventy years, as curators managed humidity and temperature levels and monitored the results. By 1956 temperature was described as "purely a function of visitor comfort"[37] with no relation to collections conditions, while humidity control was seen as the key to artifact preservation. In 1962 Richard Buck declared Harold Plenderleith's 63F (Fahrenheit) temperature requirement to be too onerous for caretakers, and suggested a 68F temperature goal. As studies developed, it became apparent that some materials were more resilient than others, and that specialized conditions could be created for different collections in order to reduce the burden of the energy intensive conditions expected for more vulnerable objects. The Smithsonian and the Canadian Conservation Institute implemented studies in the 1980s and 1990s, which, coupled with information set out during the 1992 New Orleans Charter for Joint Preservation of Historic Structure and Artifacts, the Smithsonian adopted a broader range of temperature and humidity ranges. Some experts still believe there is not enough viable data to adopt this behavior, since research does reveal that the chemical stability of certain collections does increase as temperatures and humidity drops. However ASHRAE began to outline standards for museums, archives, galleries and libraries in 1999 and continued to develop them in subsequent versions. In 2010 The American Institute for Conservation of Historic and Artistic Works (AIC) revisited the guidelines through the lens of *Dialogues for the New Century: Discussions on the Conservation of Cultural Heritage in a Changing World.* Collections management procedures and loan standards are constantly re-evaluated, and for some years the feasibility of their energy intensity has been part of the discussion.

[37] "Environmental Guidelines," American Institute for Conservation of Historic & Artistic Works Collaborative Knowledge Base Wiki, http://www.conservation-wiki.com/wiki/Environmental_Guidelines Accessed December 12, 2013.

These issues are not only being discussed in North America, but in the European theater in which the standards originated. The British National Archives developed a new environmental standard published by the British Standards Institute in 2012 (PAS 198:2012,) which focused on the four most severe agents of deterioration for collections- relative humidity, temperature, pollution and light. PAS 198:2012[38] also promotes best practice energy-efficient approach to collection management, encouraging stewards to identify collections needs before installing large mechanical systems, and to allow slow temperature and humidity changes throughout the year to mirror natural climate fluctuations and conserve energy while avoiding rapid and extreme condition changes. Energy conservation is being integrated into collections management language, and is being recognized as a valid consideration in preservation conversations.

When integrating energy efficiency measures into spaces with collections, stewards have had to learn to balance energy goals with priorities for collections management. As with many incipient methods, new strategies caused trial and error. Error however, when dealing with invaluable and one-of-a-kind objects, is abhorrent, and thus sustainable practice became a villain in the museum field.[39] However as conversations between professionals and academics have developed, common ground both theoretical and physical has been found which has allowed mutual goals and compromise. A language of sustainable collections management has slowly emerged- non toxic, low energy, and respectful of the cultural value of the artifact. I will not discuss non-toxic collections care, since I am focusing on energy efficiency. However I do remember a moment many years ago while working at a museum when I was asked to prepare the example artifacts for an

---

[38] "Environmental Standard for Cultural Collections," The National Archives, accessed December 10, 2014. http://www.nationalarchives.gov.uk/about/environmental-standard.htm

[39] Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham, Altamira Press. 2008.

upcoming school visit. These artifacts, in this case metal arrowheads, were routinely handed around for children to look at up close. When pulling them out of the box, the curator offhandedly warned me not to touch them because historic museum practice had used arsenic as a preserving coat. It dawned on me that while I was being told to handle the objects with gloves, the same courtesy was not being given to the hordes of school children who came in regularly to touch the artifacts. At this moment I wondered whether non-toxic preservation methods might be a useful consideration.

Modern construction museums have more flexibility when implementing energy efficiency measures. Microclimates, for example, are an option for modern museums whose collections have specific and different climate needs in order to save energy in the larger museum space, these are particularly valid for museums with sporadic attendance, which might benefit from carbon dioxide or heat monitors in ventilation systems. However the risks of these strategies even in modern buildings should not be overlooked. One topic at the 2007 conference on Museum Microclimates in Copenhagen details the risks of accidental microclimate development in museum spaces when ventilation systems are not appropriate for the size or configuration of the museum space in which they have been installed. Localised condensation can occur when HVAC zones interact poorly, therefore the layout of sensors, and supply and return systems are important considerations.[40]

Some house museums have made conscious decisions not to include their collections in their historic space. Lincoln's Cottage maintains its exhibits in its

---

[40] Editors Padfield, Tim and Borchersen, Karen. "Museum Microclimates: Contributions to the Copenhagen conference." 19-23 November 2007. National Musuem of Denmark. http://natmus.dk/fileadmin/user_upload/natmus/bevaringsafdelingen/billeder/far/Museum_Microclimate/Proceedings/musmic150.pdf

visitor center, which has freed up the staff to think separately of collections conservation, and building conservation and performance. Drayton Hall is considered a seminal example of Georgian-Palladian architecture and maintains no collections within its walls beside the walls themselves, which allows the staff to operate the museum's environment in tandem with the local climate.

However this is not the case for many museums that have to manage their property and an interior collection. The institutions need to contend with the protection of a historic site, the interpretation of the property, visitor experience and the conservation of valuable and unique physical collections. Decisions made for the integrity of a museum's collections are paramount to the future of cultural and historic objects on display and in storage. In the case of Villa Finale, the curators were faced with the debate of historic authenticity of the setting versus the protection of their collections, while needing to keep in mind the comfort and interest of their visitors.

> "Sunlight is a beautiful and necessary element. However, it can wreak havoc in a historic house, in fact, in anybody's house. Villa Finale is no exception. Ultraviolet rays are the single largest cause of fading and material degradation in any setting, home or elsewhere. In years past, when Mr. Mathis lived at Villa Finale, he very often kept the interior shutters closed in order to protect his collections, carpets and furniture from light. But now, for visitor comfort and the stunning appearance of the museum rooms, the staff decided to leave the shutters open for tours -a decision that necessitated installing ultraviolet light blocking film."[41]

[41] Meg Nowack, "Enlightening! UV Blocking Window Films at Villa Finale," Villa Finale Museum Preservation Blog, March 30, 2011, accessed December 15, 2013. http://villafinale.wordpress.com/2011/03/30/enlightening-uv-blocking-window-films-at-villa-finale/

The museum researched highest performance UV film and consulted fellow institutions and professional organisations about experience installing and removing film in order to ensure that the process was reversible and non-damaging to historic surfaces. Due diligence was exercised in making a decision about the treatment, with the wellbeing of the museum building and its collections at the forefront of the decision.

Drayton Hall staff undertook a similar debate. Their building is not climate controlled, therefore the staff has chosen to store furniture elsewhere until a climate controlled interpretive center has been built to accommodate it. The institution placed higher priority on maintaining industry standards than maintaining the collections in the environment in which they would originally have been kept. In 2003, the director explained the museum's decision to install roller blinds instead of UV film.

> "We investigated various UV films and concluded that there are no films that can be safely applied to historic glass and can be easily removed when it is time to replace the film (typically 10-15 years). We opted, instead, for film attached to spring-loaded roller shades. It was a painful decision, as the roller shades are not invisible and do cause a small amount of damage for the mounting hardware. The trade-off, however, is that the rollers are easy to replace without tools and without further damage to the historic fabric. Now, about 9 months after installation, we are happy with our decision -- our visitors hardly notice the film, and we actually use our experience to explain to our visitors what measures are necessary to preserve historic fabric in a historic building."[42]

In the decade since that decision, UV film has vastly improved, thus explaining why Villa Finale was willing to integrate this technology into their conservation

[42] Wade Lawrence, "Re: UV Window Film?" Museum-L Archives, February 26, 2003, accessed January 14, 2014.http://home.ease.lsoft.com/scripts/wa-HOME.exe?A2=ind0302D&L=museum-l&F=&S=&P=58516

plan. The decision made at Drayton Hall however, although also made with a preservation focus, has not been without consequences. An *Environmental Monitoring and Conservation Study of Drayton Hall in Charleston, South Carolina*[43] analysed paint deterioration and hypothesized a possible link between the removal of mid nineteenth-century interior blinds in the 1970s as a possible source for UV-related decay of the interior finish. Another conclusion involved the lack of an active environmental-control system, which allows quick swings in humidity and temperature. Both of these identifications suggested that solutions would need to be strategies not original to the building. Therefore actual effective preservation of the fabric of the building will require either the active use of period technologies (such as shutters and drapes) and modern technologies (such as UV film and mechanical climate control), or constant maintenance as it would have been implemented by the original residents, repainting and replastering to keep up with deterioration. Either solution presents the building in a more dynamic and active light than we have previously shed on a structure associated with an unmoving moment.

In addition to temperature and humidity stabilization, a key conclusion to the study was the importance of constant monitoring of the collections environment. As stated throughout this thesis, data is crucial. This is not only in terms of identifying and tracking energy expenditure, but for proper maintenance and care of collections, and reacting in a timely manner to conditions surrounding collections that may be conducive to deterioration. Knowledge of how much energy is being used, and what conditions that energy is creating, is paramount to properly

[43] Michael Mills and George Fore, "Environmental Monitoring and Conservation Study of Drayton Hall in Charleston, South Carolina," *Association for Preservation Technology Bulletin*, Vol. 31, No. 2/3 (2000) pp. 63-70. http://eprints.sparaochbevara.se/473/1/environmental_monitoring_and_conservation_study.pdf Accessed January 14, 2014.

managing the property in your trust, whether that is a building or a painting within its walls.

Structure of This Framework

Since this investigation system is individualized to each structure, I have chosen a case study, the French Legation Museum, in Austin, Texas, upon which to apply this framework. This will illustrate only one of many possible iterations of the guidelines. I will analyse the architectural styles represented by the historic home, and the styles that were present and prevalent in Austin when the house was constructed in 1831. I have done extensive research into the technologies that were used in this time and place to improve pre-electricity building performance in the hot, humid climate. Simultaneously I have created a working list of some of the technologies that have been used, to varying success, in museums and historic homes throughout the world, which I will use as a foundation for considering feasible options for inclusion in the French Legation Museum's operations.
I will be using data on the building's current and historic energy use, its interior temperature and humidity, its size and occupancy, and its climate conditions to understand how it is using its energy, and how it might reduce its energy use with techniques suited to its construction. Conclusions will be drawn about how efficiently the building can produce specific interior climate conditions, and whether it can perform at a similar level to a code compliant modern building of the same size, use and climate.

"Human comfort" is an oft debated term, which has seen many variations over the years. In order to use a consistent and measurable baseline, I will be using the temperature and humidity standards preferred by the staff of the French Legation Museum itself, although other institutions can access ASHRAE 55 guidelines for human comfort which project certain variables onto the psychrometric chart to identify the movement in temperature and humidity that we are willing to tolerate inside a public building. I had originally hoped to also compare modern comfort standards with past comfort standards, however pre-electricity there were few quick-fix solutions for extremely intolerable climate events, so to some extent people had no say in their comfort range, although references to climate situations unfavourable for work- in particular farming and outdoor work- are available in diaries and almanacs, implying that there was a limit in temperature for human activity. Despite the key position that air conditioning quickly took as a representation of middle class affluence, air conditioning was initially developed not for comfort, but for industrial processing.[44] In his 2001 publication *The Invention of Comfort: Sensibilities and Design in Early Modern Britain and Early America,* John E. Crowley discusses the concept of human physical comfort and its development over time "Historical changes in the technology of elementary comforts depended on the existence of a fashion conscious public that was made aware of the *dis*comfort of what had been previously considered functionally adequate."[45] Thus today, when comfort has a high premium, and is encouraged and enforced by building, health and sanitation standards, comfort conditions are especially integral to building performance. This indicates a trend in modern building culture which became apparent through subsequent testing of energy modeling software designed for the current building standard.

I had planned to use computer software to model the French Legation Museum. Yet after extensive efforts, I discovered that the limitations of the modeling programs I

[44] Cooper, G. (1998). *Air-Conditioning America: Engineers and the Controlled Environment, 1900-1960*. Baltimore, Johns Hopkins University Press.

[45] John E. Crowley, *The Invention of Comfort: Sensibilities and Design in Early Modern Britain and Early America*. Baltimore: Johns Hopkins University Press, 2001 p.292 http://muse.jhu.edu/journals/tech/summary/v043/43.4berger.html Accessed April 1, 2013.

was testing were too restrictive to result in comprehensive and useful data. After researching the most highly reviewed modeling systems, I tested multiple methods for modeling and attempted to create a model which I could manipulate to reflect the period and historic strategies I have researched. However historic structures are unique, and software programs are developed for uniformity and to reflect modern building culture. In order to be modeled, each item needs to be itemized in the software program as an option, which with the multitude of dimensions, materials, and treatments in historic buildings would take a lifetime and particular professional expertise, which has not been applied to building modeling as of yet. Basic, reliable models can certainly be produced, however the extent of their flexibility is limited.

If architects who use these modeling programs are limited to the options inbuilt by software engineers, now who is the 'designer' in this case? The software engineer is using a set of modern construction standards to create a limited universe from which the architect can pick and choose only a selection of the options provided. The architect can no longer design without limit or impunity, but starts to design within the parameters of a hegemonic building system. Opportunities are now framed by tools de rigueur and the systems imposed by other disciplines. If design tools are co-constructed with the current building system then they will continue to reiterate their reality, without allowing space or capability to develop another.

The research I have collected is by no means complete, nor is it static, the volume of information will quickly grow over time as more institutions welcome modern design into their halls. I will be transferring my research into the archives of the Sustainable Operations Toolkit operated jointly by the American Alliance of Museums PIC Green and the National Children's Museum in order to allow this knowledge base to grow as the field expands. In the meantime, I will use the list of structures that I have researched as a foundation collection of options for historic buildings. This list includes some of the many historic structure whose curators have chosen to implement energy efficiency measures, whose information can be used as a springboard for consideration or as the beginning of a plan for future development.

The above methodology illustrates the process by which I will identify historic and modern technologies that are being used in historic buildings in order to evidence the argument that historic buildings can indeed exist and perform harmoniously and efficiently. Then I will use these examples of precedent to develop a customized plan for the French Legation Museum case study. The chapter that follows is an analysis of historic museums and historic commercial structures whose caretakers have either reawakened existing historic strategies or adopted non-original but time appropriate historic features in order to increase the low-energy performance of their building.

Chapter 3: Historic Energy Performance Technologies

Historic building curators are no strangers to low-energy strategies that take advantage of a climate's more forgiving characteristics. Architect Richard Rogers expounds on the benefits of thermal mass in the National Building Museum "The oldest masonry buildings work much better, really. They mediate between inside and outside, cool off at night, and then keep the cool inside during the day."[46] Thermal mass is only one of many techniques employed to keep buildings livable. Some of these technologies are very visible, verandas and porches are identifiable character defining features on many hot-climate homes, providing shading during the day and screened sleeping areas at night. These shading devices- awnings, shutters, blinds and curtains- depending on the season and their use, can control interior light and temperature conditions by affecting how much direct and diffuse solar radiation and daylighting enters the building. Strategically placed windows take advantage of cross breezes in hot, humid climates, or prevent heat escape on northern facades in cold climates. Raised bungalows in swamp climates allow ventilation below the floor, and when electricity finally arrived, ceiling fans provided the air-flow that had been lacking. In cold climates saltbox roofs shed the heavy snow that tried to accumulate on their surfaces, and sod roofs (which would now be considered 'green roofs') provided thick, reliable insulation.

The Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings, as previously quoted, agree that "Historic building construction methods and materials often maximized natural sources of heating, lighting and ventilation to respond to local climatic conditions.

---

[46] Rogers, R. "On sustainability and how it's changing the face of modernism." Gissen, D (Ed.). 2002. *Big and Green: Toward Sustainable Architecture in the 21st Century*. New York: Princeton Architectural Press, p. 172.

The key to a successful rehabilitation project is to identify and understand any lost original and existing energy-efficient aspects of the historic building, as well as to identify and understand its character-defining features to ensure they are preserved."[47]

When considering energy performance therefore, including existing aspects is key to engaging both the history of the place and maximizing its potential before moving on to modern technologies which might jar with the historic atmosphere. In a historic house museum, the atmosphere is an extremely valuable asset, which should be analysed carefully before being interrupted or distorted. Incorporating any addition, even one necessary for daily operation, is a hard conundrum, which curators have been considering for decades- adding electric lighting, HVAC, accessible entrances and ramps, and the like. Yet an option that is rarely considered is that of introducing features from the period in order to reach a certain building performance goal because of the sense of fabricated 'authenticity.'

The Secretary of the Interior's Standards for Rehabilitation warn against creating a false sense of history:

> 3) Each property shall be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or architectural elements from other buildings, shall not be undertaken.
>
> 9) New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The

[47] Anne Grimmer, Jo Ellen Hensley, Liz Petrella, Audrey Tepper, "The Secretary of the Interior's Standards for Rehabilitation and Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings," U.S. Department of the Interior, National Park Service, Technical Preservation Services. 2011. P. 1 Accessed December 10, 2013.
http://www.nps.gov/tps/standards/rehabilitation/sustainability-guidelines.pdf

> new work shall be differentiated from the old and shall be compatible with the massing,
> size, scale, and architectural features to protect the historic integrity of the property and its environment. [48]

However I think it may be possible to create a higher performance building while using historic technologies that would have been available to the original owner (or the owner during the period of significance.) Decisions in this vein are often made in historic buildings- the Sagrada Familia by Gaudi is an ongoing 'historic' project whose aesthetic is currently being built according to an 1882 design but with modern methods. Does this make its historic architectural status any less "authentic"? Westminster Cathedral has never been completed, its interior lies bare. If the church were finished according to the historic ornamentation of its period of construction, would that be considered an inappropriate reconstruction of history? I believe that an argument can be made for retaining the historic atmosphere of a property by minimizing the introduction of modern technologies and maximizing the opportunity for historic atmosphere and interpretation. Interpretation in museums is a crucial way for the institution to engage its public, and a good interpretive plan could use this historic technology upgrade in weaving its story just as easily as it could make excuses for modern technologies that are visible to the public. Showcasing contemporaneous historic technologies could be a fresh interpretive tactic for an education team, and explaining their benefit to the performance of the building could be used to educate the public and to reaffirm the institution's commitment to sustainable practice.

Many building curators and museum professionals might consider my investigation into opportunities for the installation of non-original period features as

---

[48] Standards for Rehabilitation, National Park Service, accessed October 12, 2013. http://www.nps.gov/hps/tps/standguide/rehab/rehab_standards.htm

controversial given the strict standards outlined by the Secretary of the Interior. However historic buildings are valued for a variety of reasons, indeed within the criteria for listing a property on the National Register of Historic Places, only one out of four reasons is architectural. The three remaining criteria include A. associated with significant events, B. associated with significant persons, and D. likely to yield important information in history or prehistory. None of these are strictly architectural or prescriptive about appearance. For structures that are not preserved for their stylistic representation, I believe that thoughtful and subtle integration of modern or historic features, particularly when properly interpreted, can be of little offence. There will always be dissent over this topic, and it may never be accepted as a practice, however I thought it a valid exercise to identify the information.

At the Experts Roundtable on Sustainable Climate Strategies in Spain in 2007, Michael C. Henry urged fellow preservation professionals to consider a more flexible approach when considering the climate management of their properties. His recommendations included adjusting and broadening performance criteria, and while he validated the concern for accuracy of representation, he illustrated examples of existing and accepted aesthetic changes which had been adopted for what is now considered standard performance of a building. "Window and door screens may be historically anachronistic for certain interpretive periods, but they may be needed to reduce insect, avian, and pest entry through open windows."[49]

[49] Michael C. Henry, "The Heritage Building Envelope as a Passive and Active Climate Moderator: Opportunities and Issues in Reducing Dependency on Air Conditioning," Experts Roundtable on Sustainable Climate Strategies, The Getty Conservation Institute, 2007. http://www.getty.edu/conservation/our_projects/science/climate/paper_henry.pdf Accessed April 1, 2014.

I believe that given professional opinions such as that of Michael C. Henry, and urging by advocates worried about the increasing irrelevance of historic house museums, such as Gwendolyn Raley speaking to the AASLH Historic House Affinity Group Committee, the argument for re-interpreting the house museum has already been made. Museums are beginning to reconsider the representation of themselves and their building culture as more dynamic than they have been in years past. Museums began with the integration of modern technologies such as light fixtures, HVAC, fire alarms and the like, which begins to suggest that there could be a more fluid interpretation of their building culture to include non-original features in a ethical and honest manner. In doing so, there may be the opportunity to create a living building culture that represents more than an ossified moment in time. While some house museums have chosen to eschew modern technologies to provide a more realistic example of interior conditions in their historic space, integrating modern technology is a widely accepted practice in historic houses that have prioritized a controlled interior climate for the conservation of their collections (see: A Note on Collections Care in Chapter 2 for more information.) Yet there is no consideration of bringing in historic technologies that were available at the time to represent more of the historic moment and less of the staid mold represented by the building combined with the traces of current construction expectations.

Stewart Brand investigates semantics and its effect on our understanding of buildings and architecture in his publication on *How Buildings Learn*. "The word 'building' contains a double reality. It means both 'the action of the word BUILD' and 'this which is built'- both verb and noun, both action and the result. Whereas 'architecture' may strive to be permanent, a 'building' is always building and rebuilding. The idea is crystalline, the fact fluid. Could the idea be revised to match the fact?"[50] In this interpretation, preservation of a historic house museum would represent a historical moment rather than an isolated historical execution.

In terms of professional codes of ethics for museums, these offer a broad expectation of obligation to a museum's collections, not a restrictive or punitive demand. The American Alliance of Museums (AAM) "Code of Ethics for Museums (*Collections)"* outlines that "The distinctive character of museum ethics derives from the ownership, care and use of objects, specimens, and living collections representing the world's natural and cultural common wealth. This stewardship of collections entails the highest public trust "[51]

Having examined the American Alliance of Museums (AAM), and the International Council of Museums (ICOM) museum association codes of ethics, there appear to be no professional ethical ramifications. The Secretary of the Interior's Standards are clear about their recommendations, however they are recommendations, which are designed for a universal mold. The Guidelines for Sustainability begin to examine opportunities for both historic and modern sustainable technology, so it is possible that flexible conditions might be acceptable. In its Preservation Brief on *Improving Energy Efficiency in Historic Buildings*[52] the National Park Service 'highly recommends' upgrades and retrofits that require 'minimal alteration' including: reduce air leakage, adding attic insulation, installing storm windows, insulating

---

[50] Stewart Brand, *How Buildings Learn: What Happens After They're Built*, Penguin, October 1, 1995. p. 2

[51] "Code of Ethics for Museums," American Alliance of Museums, adopted 1991, amended 2000, accessed January 27, 2014. http://www.aam-us.org/resources/ethics-standards-and-best-practices/code-of-ethics

[52] Jo Ellen Hensley and Antonio Aguilar, "Improving Energy Efficiency in Historic Buildings," National Park Service, Technical Preservation Services, Preservation Brief #3, December 2011. http://www.nps.gov/tps/how-to-preserve/briefs/3-improve-energy-efficiency.htm Accessed December 4, 2013.

basements and crawlspaces, ducts and pipes, weather striping doors and add storm doors, and adding awnings and shading devices where appropriate.

In another National Park Service Preservation Brief, Chad Randl states "Where no awning currently exists, and there is no evidence of a past one, it may still be possible to add an awning to a historic building without altering distinctive features, damaging historic fabric or changing the building's historic character."[53] Preservation is more dynamic than it is given credit for, and it is constantly re-evaluating its practice, so even for sheer research sake, all approaches should be considered. I consider this avenue less like false historic representation and more like representing a dynamic history that doesn't have a voice and is not represented. A new concept in 'living history' space, this would represent the true life of a homeowner in the period, keeping up with the Joneses, following trends, nesting, and revamping their homes.

Critical theory posits that knowledge is power, and, as previously stated, "Knowledge does not accumulate in an absolute sense; rather, it grows and changes through a dialectical process of historical revision that continuously erodes ignorance and misapprehensions and enlarges more informed insights."[54] Interpretation of a historic space- including tours, education, signage- all contribute to a greater visitor experience, and a more informed patron.

A flaw in the house museum knowledge value system is that some knowledge is prized more highly, and for each building only one vocabulary is considered

---

[53] Chad Randl, "The Use of Awnings on Historic Buildings, Repair, Replacement and New Design," National Park Service, Technical Preservation Services, Preservation Brief #44, April 2005. http://www.nps.gov/tps/how-to-preserve/briefs/44-awnings.htm Accessed December 10, 2013.
[54] Guba, Egon and Yvonne Lincoln, *Competing Paradigms in Qualitative Research*, Handbook of Qualitative Research, Thousand Oaks, CA: Sage, 1994.

appropriate, and that is the vocabulary that was present on the building when it was built. It does not include the vocabulary of the surrounding buildings, those in its vicinity not only physically, but in time, and style, or the vocabulary that it has developed throughout its story. House museums present one page of a story, whereas critical theory states that one cannot understand the story if it is not told in its entirety.

Where claims and expectations of 'authenticity' become contentious, I restate that authenticity as a concept that has no professional definition in museum governing code. Joseph Pine and James Gilmore, authors of *Authenticity: What Consumers Really Want* presented about 'authenticity' in museums at the American Alliance of Museums (then American Association of Museums) conference in 2007. An excerpt of the article written for the Museum News magazine in advance of their presentation is as follows:

> "museums must confront these two standards for all of their artifacts, edifices and encounters:
> (A) Is it true to itself?
> (B) Is it what it says it is?
> To be perceived as authentic on the second dimension, understand everything you represent your museum to be- considering your assigned names, expressed statements, established places, declared motivations and displayed appearances- and then ensure that there is no disconnect between what you say you are and what people actually experience in your museum. Recognise that the easiest way to be perceived as phony here is to advertise things you are not."[55]

Here the authors remind curators that museum interpretation should seen less as an 'accurate portrayal of a moment' and more as an accurate portrayal of what you have assembled from the building's evolution. Too often house museums borrow

[55] Joseph Pine and James Gilmore, *Authenticity: What Consumers Really Want,* presented at the American Alliance of Museums, 2007, accessed March 23, 2014. http://www.strategichorizons.com/documents/MuseumNews-May07-Museums&Authenticity.pdf

‘likely’ furniture from unoriginal sources because original pieces were sold and lost, and gloss over (no pun intended) the wall colours that are not strictly historic in a bid to promise their visitors that their experience is ‘authentic.’ However would it not be more historically honest and educational to use what is actually present to interpret not only the historical moment, but the story that the property has lived in order to arrive at this present moment in time? Here, the idea of authenticity by creating a false history is debunked. House museum staff struggle to peel back layers of, what is in fact, history, to reach the ‘real’ history that they are attempting to present. However in doing so they are removing layers of knowledge and creating a false sense of the present. The argument they make, that house museum operates as a historic building, is erroneous, since it, as part of a greater building culture, also operates as a current structure, as part of the modern architectural landscape.

A detailed description of some historic properties that are actively implementing period energy efficiency technologies and strategies can be found in Appendix A.

This chapter reviewed the conscious preservation decision to either reawaken existing strategies and technologies in a historic property, or adopt previously existing technologies that had been lost through time. Such actions have set a precedent for building caretakers who may have considered similar treatments but been hesitant to implement them either from a preservation stand point or a concern about return on investment.

The following chapter will examine historic sites whose caretakers have chosen to integrate modern low energy technologies into their historic properties, and the energy savings that have been, and could be realized.

Table 3.1 List of Historic Properties featuring Historic Strategies, full description and spotlight information available in Appendix 1.

List of Historic Properties featuring Historic Energy Performance Strategies		
Historic House Museums	**Year Built**	**Detailed Strategy Description**
Drayton Hall	1742	Spotlight: Shading and thermal barriers for windows
Bryant Homestead	1799	
Gibson Mill	1800	
Haas-Lilienthal House	1720	Spotlight: Natural Ventilation
Museums		
National Building Museum	1893	
Commercial Historic Buildings		
The Copper Kettle	1934	Spotlight: Awnings
Beardmore Building	1922	
The Christman Building	1928	
200 Market Building	1940	
Joseph Vance Building	1910	Spotlight: Storm windows

Chapter 4: Modern Energy Performance Technologies

This chapter examines modern energy efficiency technologies that have been adopted for use in museums and historic buildings. As previously discussed, the curators of many historic buildings are not unfamiliar with low-energy techniques. With the identification that our preservation of the historic fabric should reflect a preservation of the modern and future world, the staff of some historic structures- from homes to commercial buildings to museums- have opted to integrate current sustainable design into their frames.

Using existing examples as a foundation for research adds a layer of reliability for building caretakers who might be concerned about compromising the 'authenticity' of their structure. In welcoming a new technology into their space, curators have analysed their building's needs and made difficult and technically specific decisions about the care of their structure. This decision is particularly resonant where museum curators have been involved, since it reflects a qualitative decision about the future of their collections and institution, made with an obligation as stewards of their collections, and with the strength of professional codes of ethics behind their decisions. Therefore I have included technologies implemented in historic house museums, museums, historic buildings, and commercial historic buildings, which in some cases are complete renovations of the interior.

Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings

My main point of professional reference for the appropriate nature of a treatment has emerged from a close study of the Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic

Buildings. These guidelines outline clearly which treatments are, or are not, recommended by the Department of the Interior and the National Park Service. The key element to abiding by the guidelines is effecting as little harm as possible to the historic fabric, maintaining character defining features, and not creating a false sense of history. In that vein I have recounted examples of museums and historic buildings that have pursued retrofits in the spirit of the standard. There are some commercial historic buildings whose renovation has included techniques that are not recommended, however these buildings may have been pursuing ‘renovation’ rather than ‘preservation’ or ‘rehabilitation’ on the scale of retrofit efforts. In either case, there is no universal answer for all buildings- one technique may be appropriate in one building, and inappropriate in another, and therefore if a strategy is ‘recommended’ by the Standards and there is an example of its adoption by a historic house museum, or historic museum, it may not indicate that it would be appropriate for every application. The large crawl space and attic of the Truman White House allowed the curators to install a high velocity small-duct system for their HVAC. With customized features, this new system was virtually undetectable, and the entire house renovation still boasts that 85% of its historic fabric remains intact. This might not be possible in a concrete multi-storey building with shared walls where stonework would have to be punctured, destroyed or moved in order to insert a new system. Each decision is individual to a project and dependent on the situation and conditions of the historic structure. Where poor conditions require the replacement of a floor, or windows, a low-energy solution may present itself to be a convenient fit both for the building and for the Standards, where elsewhere, in better conditions, the retrofit would be considered degrading to the historic material.

Windows, for example, are a highly contentious asset in historic properties. The general belief maintains that windows are where most energy is lost, and that replacing old windows is key to beginning any energy efficiency project. Some historic property owners believe that they have little flexibility when it comes to the maintenance and treatments that can be applied to historic windows. Yet while windows are considered crucial considerations in the character defining nature of many building facades, their rehabilitation is not entirely hindered. The Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings outline plenty of options in a range of more or less aggressive tactics. Caulking and weatherstripping are encouraged to make existing windows more weathertight, and historic windows can be retrofit with high performance glazing (where it cannot be repaired) or UV film if the historic character can me maintained. Compatible storm windows are recommended, and where windows are missing or cannot be repaired, there is an opportunity to install compatible energy efficient replacement windows where they match the appearance, size and profile of the deteriorated historic windows. Where a treatment would not affect the appearance of the building, curtain walls can be thermally retrofit, and low-e glass panes can be introduced to reduce solar gain, or film can be used to allow daylighting where historically dark panes did not admit light.

This is only one instance where the Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings offer a variety of options for a customized restoration of a home. Solar arrays, wind power, green and cool roofs are among many of the options discussed in the Standards. They also refer to site features and water management, not to mention daylighting, insulating and HVAC. Using the Standards will ensure that work is done with the best intentions and most successful implementation.

As with any changes, there can be some complications that arise with the introduction of new strategies in an enclosed and vulnerable space. On introducing a new air conditioning unit to Roosevelt's 1932 Little White House the building operators noticed that humidity problems were developing, particularly in the artifact storage areas. Given the importance of the artifacts, the building operators had to quickly understand the performance of the building, the affect of the new air conditioning unit, and the best way to manage the interior environment.[56] Therein lie the following important facts: that new, large and/or expensive mechanical systems may not be an immediate fix-it for an interior environment; that systems need to be tailored to the space in which they are installed; and that there may be unforeseen consequences that accompany energy retrofits. However careful monitoring, and a deep understanding of the space and the collections needs will ensure that the correct solution is applied and that the optimal conditions are created.

Proviso

Developments in this field are constantly arising, therefore this list will not be accurate for very long, nor do I claim that it is complete. However in order to ensure that this list becomes part of a system that is accessible and usable, I will be inputting all of this information into the Sustainable Operations Toolkit developed by the sustainable practice interest group of the American Alliance of Museums. This is an online wiki project which the developers hope will become the

[56] "Historic Museum Is Certified Green." *EcoBuildingPulse*. Accessed March 6, 2014. http://www.ecobuildingpulse.com/energy-efficiency/hindsight-is-2020.aspx

repository for all information on procedures and technologies for sustainable practice currently used in museums.

Table 4.1, full description and spotlight information available in Appendix 1.

List of Historic Properties featuring Modern Energy Performance Strategies		
Historic House Museums	**Year Built**	**Detailed Strategy Description**
Truman White House	1890	Spotlight: HVAC
Villa Finale	1876	Spotlight: UV film
Mark Twain House	1874	Spotlight: Occupancy Sensors
Hooper Strait Lighthouse	1879	Spotlight: Lighting
Westport Town Farm	1720	Spotlight: Insulation
Bryant Homestead	1799	
Bullitt Farmouse	1830	
Teackle Mansion	1802-1819	Spotlight: Geothermal
Museums		
Field Museum of Natural History	1893	
Brooklyn Children's Museum	1899	
Children's Museum of South Dakota	1936	
British Museum	1753	
Montclair Art Museum	1914	
Phipps Conservatory	1893	
Boston Children's Museum	c. 19^{th} C.	

Table 4.1 (continued)

Adirondack Museum	**1957**	
Historic Buildings		
Empire State Building	1929	
Trinity Church	1872	
Federal Historic Buildings		
Hipolito Garcia Courthouse	1937	
Department of the Interior	1936	
Commercial Historic Buildings		
Doty and Miller Office	1934	Spotlight: Photovoltaic panels
Alliance Center	1908	
Beardmore Building	1922	
The Christman Building		
Northern Plains Resource Council	1940	
The Lovejoy Building	1910	
200 Market Building	1973	
Mercy Corps	1892	
Joseph Vance Building	1929	
Harris Center for Conservation Education	1913	

The table that follows, Table 4.2 is a visual representation of the energy efficiency choices made by building caretakers- both original caretakers and current ones, to aid in the performance of the building. Here the information is displayed by building type, in Appendix 2 the same information is displayed according to climate type in order to more easily track strategies that are preferred in particular climates.

Table 4.2 shows that high performance lighting and occupancy sensors are consistent selections across building categories, suggesting that lighting is seen as a low-hanging-fruit energy gain. Insulation improvements and PV arrays are also adopted across categories, indicating that staff are choosing both traditional, unobtrusive strategies, and modern, publicly-viewable strategies to reduce energy consumption. However in terms of traditional, publicly-viewable strategies such as shutters, these are used largely by historic house museums, possibly because with the smaller scale of these buildings, the operation of the shutters is not too onerous for the staff. Daylighting and natural ventilation appear to be favourites for staff in historic commercial buildings, which may be explained a) by the need for occupant comfort and a pleasant work environment in commercial spaces; and b) by the value that curators of historic house museums place on the preservation of their collections, which studies have indicated are put at risk by ultraviolet rays and temperature and humidity fluctuations. Historic commercial buildings run primarily as businesses have been the main adopters of monitoring, and retrocommissioning, suggesting that these businesses are most concerned with ensuring that their buildings perform to provide the greatest amount of savings. However the reality of this bottom line is no less true in the other building types, it just appears to be less highly prioritized.

In Appendix B, the most notable pattern is the large proliferation of humid continental properties, which I attribute to local interest in both historic preservation and energy efficiency, leading to a strong combination of the two. Given the development of the United States (East to West, from humid continental away to other climates) it follows that there might be more opportunity for historic preservation in the humid continental climate. In this climate, as in the humid subtropical climate where solar heat gain combined with humidity makes indoor temperatures unpleasant, there is less interest in daylighting and natural ventilation. In oceanic climates, solar gain avoidance strategies such as verandas, awnings and shutters are completely missing, however the strategies that are most favoured in the semi-arid and oceanic climates are modern performance technologies, while interestingly this mirrors an equal lack of interest in the humid subtropical sphere. High performance lighting. monitoring and retrocommissioning are universally appreciated across climates, as are photovoltaic arrays, however it is interesting to note how many arrays are in the northern humid continental climates, rather than in the humid subtropical or semi arid climates.

This chapter illustrates how modern energy performance technologies are currently being used in historic buildings across the country and beyond. In the Appendix I have outlined 30 buildings: 8 historic house museums, 8 museums housed in historic buildings, 2 publicly accessible historic buildings, 2 federal historic buildings, and 10 commercial historic buildings. The locations are scattered, from England to New England, and strategies are various, however they are all part of a growing, changing, living, historic building culture which exemplifies a successful use of modern energy performance technology in a historic fabric.

The next chapter will set the scene for the historic house museum, the French Legation Museum, that will be used as a hypothetical case study in applying these strategies where appropriate.

Table 4.2 Historic Properties Exhibiting Energy Efficiency Strategies, by type

Institution	Climate	Veranda / Porch	Trellis	Awning	Shutters
Historic House Museums					
Bryant Homestead	Humid Continental				■
Bullitt Farmhouse	Humid Continental				
Drayton Hall	Humid Subtropical				■
Gibson Mill	Oceanic				
Haas-Lilienthal House	Pacific Coastal	■			
Hooper Strait Lighthouse	Humid Subtropical				
Mark Twain House	Humid Continental	■			
Teackle Mansion	Humid Subtropical				
Truman White House	Tropical Savannah	■			■
Villa Finale	Humid Subtropical	■			
Westport Town Farm	Humid Continental				
Historic Museums					
Adirondack Museum	Humid Continental				
Boston Children's Museum	Humid Continental				
British Museum	Temperate Oceanic				
Brooklyn Children's Museum	Humid Continental				
Children's Museum of South Dakota	Continental				
Montclair Art Museum	Temperate Oceanic				
National Building Museum	Humid Subtropical				
Phipps Conservatory	Humid Continental			■	
The Field Museum	Humid Continental				
Historic Buildings					
Empire State Building	Humid Continental				
Trinity Church	Humid Continental				
Federal Buildings					
Department of Interior, HQ	Humid Subtropical				
Hipolito Courthouse	Humid Subtropical				
Historic Commercial Buildings					
200 Market Building	Oceanic				
Alliance Center	Semi Arid/ Sub Humid Continental				
Beardmore Building	Semi Arid/ Sub Humid Continental				
Christman Building	Humid Continental				
Doty and Miller	Humid Continental				
Harris Center for Conservation Education	Humid Continental				
Joseph Vance Building	Oceanic				
Lovejoy Building LLC	Oceanic				
Mercy Corps	Oceanic				
Northern Plains Resource Council	Semi Arid		■	■	
The Copper Kettle	Humid Continental			■	

Table 4.2 (continued)

	Blinds	Caulking	Operable windows	Windows revealed	Storm Windows	Day-lighting	Natural venti lation	Water Turbine	High Velocity HVAC	Heat Recovery HVAC
B		■	■							
B										
D	■		■							
G								■		
H			■							
H										
M									■	
T										
T									■	
V										
W										■
A										
B										
B						■				■
B										
C									■	
M										
N			■							
P										
T										
E										
T										
D					■	■			■	
H					■	■				■
2	■									
A	■									
B						■	■		■	
C						■				
D										
H	■		■			■				
J	■		■			■	■			
L	■					■				
M										
N						■				
C										

Table 4.2 (continued)

	Variable Air Volume Handlers	Heat Pump	Low-E Glazing	UV film	High Performance Lighting	Occupancy sensors	DCV	Photo-sensors	Direct Digital Controls	Insulation
B										■
B		■								■
D										
G										
H										
H					■					
M					■	■				
T										
T										
V				■						
W										■
A										
B			■		■		■			
B						■				
B						■	■			
C					■					
M										
N										
P										
T										
E	■		■				■	■		■
T										
D					■				■	
H										
2	■					■				■
A				■		■		■	■	
B		■	■		■		■			
C			■		■	■			■	■
D										
H	■	■	■		■			■		
J					■	■				
L			■		■		■	■	■	■
M										
N			■		■		■	■		■

Table 4.2 (continued)

	Radiant Barrier	Weather-St ripping	Geo thermal	Central Chiller	Earth Tubes	Environ-mental Education	PV Array	Monitor-ing	Retrocom-missioning
B		■							
B									
D								■	
G							■		
H									
H									
M							■		■
T			■						
T									
V									
W									
A							■		
B									
B							■		
B			■				■		
C									
M									■
N									
P					■			■	
T				■					
E	■							■	
T			■						
D				■					
H				■			■		
2									
							■	■	■
A							■	■	■
							■	■	
B							■	■	
C									■
D							■		
							■	■	■
H							■	■	■
J		■						■	■
L							■		
M									
N							■		■

Chapter 5: Case Study

a : French Legation Museum

Figure 5.1 French Legation Museum

Architectural Styles and Period Technologies

Today the French Legation Museum is identified as Louisiana Bayou Style, or Creole style, one influenced by native tropical climate and French colonial imported style. Local architecture in Austin in the 1830s featured Tonkawa huts and Spanish Mission structures, later also displaying signs of the so-called Anglo-American style. The 1934 Historic American Building Survey written history states “It is improbable that there was an Architect for these additions, and the name of the Builder is unknown."[57] The house may have boasted a local architect however the name of the designer has been lost, thus it is not possible to tell whether the architect was an expert bayou architecture connoisseur, or a local architect who blended the demands of his client into the final structure.

Louisiana's French Creole Architecture Multiple Property Nomination identifies that "Creole architectural tradition is ultimately the produce of several different nationalities and influences amalgamated into a uniquely American architectural type in the West Indies, the Gulf Coast, and the Mississippi Valley." [58]
It lists the most important features as:

1) wide verandas with roofs supported by light wood columns
2) a broad, stretching roofline
3) an above-grade construction to increase below-building ventilation
4) heavy timber construction combined with a brick and/or mud infill.
5) French doors
6) wraparound mantels
7) geometric design with opportunity for addition and expansion

Creole designers were highly aware of the intricacies of the tropical climate, such as the need for natural ventilation, separation from humidity in the ground and air, shading from direct sun, and design for spaces semi-open to nature- sun rooms and screened porches.

---

[57] "French Legation to Republic of Texas, Seventh & San Marcos Streets, Austin, Travis County, TX, 33-C1." *HABS/HAER/HALS Collection at the Library of Congress, Prints & Photographs Division*. February 15, 1934.
[58] "Louisiana Architecture 1945-1965: The Past as Inspiration," Louisiana Department of Culture Recreation and Tourism, accessed October20, 2013. http://www.crt.state.la.us/Assets/OCD/hp/nationalregister/historic_contexts/historicismfinal.pdf

French and French Colonial

Virginia and Lee McAlester[59] have reported that French colonial architecture in North America was largely concentrated along waterways in mission complexes and military outposts. These single storey structures had narrow openings and paired shutters on windows and French doors. The windows were originally casement often adapted to function as double hung sash windows. Steeply pitched roofs shed water quickly, and wide porches were probably developed to suit the tropical conditions of the West Indies. Narrow gabled dormers provided attic light in some roofs. Paired French doors had transom lights or fanlights above, and the shutters opened outwards. Greek Revival or Adam door surrounds were added in later incarnations of the style. Windows were glazed with small single glass panels with vertical board shutters with horizontal battens.

Tonkawa

" In aboriginal days the Tonkawas lived in short, squat tepees covered with buffalo hides. As the buffalo became scarce, brush arbors, resembling the tepee in structure but covered with brush branches and grass, replaced the buffalo-skin tepee. Still later, these structures were replaced with simple flat-topped huts covered with brush."[60]

Spanish Mission or Spanish Colonial

Originating around 1600, this type of architecture persisted until 1850 and 1900 in some communities, by which time it was Mission Revival. Usually single storied, thick masonry rubble or adobe walls were covered in protective stucco. The two

---

[59] Virginia McAlester and Lee McAlester, A Field Guide to American Houses. Knopf, New York, 1984.

[60] Jeffrey D. Carlisle, "TONKAWA INDIANS," *Handbook of Texas Online,* Published by the Texas State Historical Association, uploaded on June 15, 2010, accessed October 15, 2013. http://www.tshaonline.org/handbook/online/articles/bmt68

main subtypes feature either a pitched roof or a flat roof with a parapet. The pitched roofs were generally constructed from thatch and wood framing, tiled or tar covered. The flat roofs consisted of large horizontal timbers supporting a heavy roof of earth or mortar. While the types appear with some regularity throughout areas of Mission architecture, there does not appear to be a climatic reason for the implementation of each style, since the heavy earthen roof would work best in hot dry climates and yet is not used exclusively or universally in these conditions. Usually constructed in fairly desolate outposts, initial Spanish colonial architecture was simple and practical. As more colonial powers entered the continent, the mission style was influenced by the wealth and building traditions of Anglo immigrants who added ornaments that veered towards Greek Revival- decorative wood detail, double sash windows, and shingled roofs. Thus developed a quasi Anglo-Spanish-Green revival home, as it was coined by Virginia and Lee McAlester.[61] These thick masonry structures have a famed longevity, able to withstand decades, sometimes centuries of abandonment, while adobe structures are irretrievable after roughly 20 years of neglect given their need for constant maintenance and repair.

Low Energy Performance Strategies

Louisiana's French Creole [Climate Humid subtropical]

- ◊ Verandas for shading
- ◊ Crawl space for ventilation
- ◊ Natural ventilation
- ◊ Separation of the home from humidity in the ground and in the air
- ◊ Shading from direct sun

[61] Virginia McAlester and Lee McAlester, A Field Guide to American Houses. Knopf, New York, 1984.

- ◊ Spaces partly open-air such as sun rooms and screened porches etc.

<u>French Colonial</u>

- ◊ Shutters to prevent heat gain in summer and to control heat loss in winter
- ◊ Casement windows converted to double hung
- ◊ Wide porches to provide shading
- ◊ Transom lights for daylighting without exposure to bright direct sunlight
- ◊ Gabled dormers for light in attic

<u>Tonkawa</u>

- ◊ Light material to allow ventilation and to prevent heat gain.

<u>Spanish Mission or Spanish Colonial</u>

- ◊ Thick masonry or adobe walls to take advantage of thermal mass in the harsh desert climate. In this situation, the strategy would be inappropriate for the Austin climate, since pairing a humid climate with high mass walls would reap poor results. Night temperatures do not drop low enough to either need the warming effect of the day's radiant heat, or restore the walls to a cool temperature in time for the morning.

History

In the 1400s the area now known as Austin, Texas, was the Comancheria, inhabited by Comanches who had expanded into the land displacing the many tribes, largely Apaches, who had lived on the land. By 1600, the same area was then identified as the northern part of the Spanish Empire.

In 1810, Mexico declared independence therefore making Tejas part of Mexico. Conflict with Native Americans caused stagnant growth and development in the area, so the Mexican government made attractive offers to settlers in order to 'people' Tejas. Moses Austin had planned to bring 300 families to Mexico from Virginia but he died before he could finish his work. His son, Stephen F Austin, reluctantly took up the banner and completed his father's promise.

Jean Pierre Isidore Alphonse Dubois was the secretary to the French Legation in Washington D.C. and was then charged with representing the interest of the King of France to the Republic of Texas. He was expected to maintain a residence in Austin and arrived in 1839 to a tiny settlement, which at the time boasted about 800 people, living in log cabins. The tallest building in the 'town' was a 2 storey hotel, which Dubois was resigned to patronizing until he completed his own home which it is said was design to show the uncultured people of Austin true 'civilization.'

After only a few years' ownership of, and sporadic presence in the home, Dubois sold it to a French catholic priest who had caretakers maintain the home. M Baker stayed 6 mos. The Robertson family moved in and attempted to open a school in the public rooms. The school failed but the family flourished, expanding from one child to eleven. Miss Lily, the last remaining Robertson daughter always lived in home, hoping to preserve it as the 'French Embassy.' The State of Texas bought the home and preserved it to the Dubois time period. The house was opened as a museum in the 1950s as representation of a moment in the history of the State.

Construction

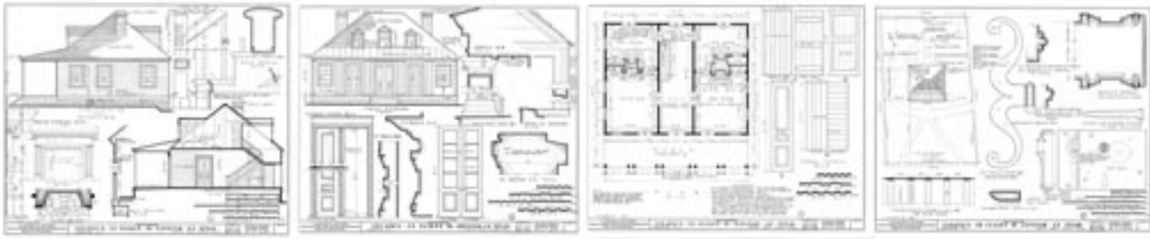


Fig 5.2 1932 HABS Drawings

Construction on the home began in 1840 and was completed in 1841. The house is made of milled bastrop pine, a break from the typical local log cabin and it is the oldest milled wood building in Austin. The pier and beam foundation sits on concrete piers which were added in 1951. Since Dubois was unmarried, he had little need for extensive rooms, and commissioned a basic floor plan of 4 rooms, two for private life and two for public life. A second storey was included, but was never finished or inhabited. A cellar has been partly dug into the hard rock below the house, and may have been meant for a wine cellar. A Historic American Building Survey (HABS) authored in 1934 itemised the home's construction, indicating thus-far additions and material dimensions.

The south facing white-painted building has an open portico on the southern façade. A photograph ca. 1900 shows a trellis affixed to the columns on the South and wrapping around to the East side providing further shade for the windows and a frame for plants to grow, which in hot climates can have an evaporative cooling effect. The hipped roof consists of wood shingles over a standing tin seam roof. The exterior cladding is clapboard siding, and the interior is a canvas layer. "Saligny had not sealed the house, but had purchased canvas, such as was used by the

Spaniards to make gates for irrigation ditches in Texas, stretched it from joist to joist and painted it."[62]

The HABS account states that by 1934 "All windows originally casement windows with shutters, have been replaced with inside screens, double hung windows and shutters of no architectural value."[63] The windows all have single pane glass, with no weatherstripping. The shutters on the East side are missing for restoration, but all other openings have dark painted shutters.

"All flooring in rooms and hall are 1"x6" T+G flooring, all ceilings in rooms and hall are 1"x12" with 1x4 battens and at walls with ⅝ x ¾ panel mould. Hall walls are 1x1/4 shiplap painted. The walls of the parlor and other room are now covered in canvas and painted muslin. All casings, base mantels, doors and stairways are yellow pine. The porch ceiling is 1x10 boards with 3/4x 1 ½ half round battens over joints and 1x3 at walls and porch columns to cover the ends of the battens."[64] There are three interior fireplaces, an untraditional inclusion for a cooling intensive climate, but popular in French design. One might consider this an example of the mal appropriation of one climate and culture's technology for another, less appropriate one.

No running water was installed in the home, a free standing kitchen was constructed to avoid exposing the home to fire risk, and rightly so, since the

[62] [Mrs Barcalay (Margaret) Megarity, "Authenticated Research on French Legation," May 1, 1957, p. 3 Texas State Archives.] Volz & Associates consider the veracity of this information to be in question
[63] "French Legation to Republic of Texas, Seventh & San Marcos Streets, Austin, Travis County, TX, 33-C1." *HABS/HAER/HALS Collection at the Library of Congress, Prints & Photographs Division*. February 15, 1934.
[64] "French Legation to Republic of Texas, Seventh & San Marcos Streets, Austin, Travis County, TX, 33-C1." *HABS/HAER/HALS Collection at the Library of Congress, Prints & Photographs Division*. February 15, 1934.

kitchen burned to the ground in 1880. Recent archaeology discovered the kitchen footprint and a reconstruction was developed for interpretation purposes, although it is an approximation of the likely structure. The new kitchen is in the 'Creole' style and is air conditioned. Robertson attached a kitchen and bathroom to the building, however they were removed by the State of Texas to restore 'authenticity' to the structure.

In 1953 and 1954, extensive maintenance and repair requests were made for the home as it was prepared to be opened as a museum. Volz and Associates, Inc collected this information when they produced a historic structures report for the home in 1997.[65]

1953 Electricity rewired, carpentry repairs begun.

Thresholds and exterior doors to be made watertight.

Canvas to be removed, and shiplap drawn as tight as possible.

Canvas and paper to be replaced (was not done)

All floors to be carpeted.

1954 Outside blinds installed

House wired 'inconspicuously'

Replacement of glass.

"Seal open spaced in roof and waterproof entire house"

1962 Furnace recomissioned and metal ductwork moved to improve heating and cooling.

A Lennox compressor and cooling coil on existing furnace.

[65] "Historic Structures Report for the French Legation Museum Main House," Volz & Associates, Inc, August 20, 1997.

Throughout the 1950s and 1960s there was rewiring throughout, including the installation of sconces, ceiling lights and ceiling fans.

Although Dubois did furnish it, the current contents of the home either belonged to the Robertson family or are donated period pieces, with the exception of two original pieces. However the home is interpreted largely to the Dubois period, with the history of the Robertsons included in the tour.

Notable mentions of architectural features in historic correspondence:[66]

> c.1902 "Darkly painted blinds cover the windows" AHC photo
>
> c. 1915 Molding or additional framing edge the window opening. No screen doors yet.
>
> 1917 Samuel Gideon states "The walls of the front rooms were covered with brown burlap and the back rooms with white canvas. Former plain batten shutters are replaced by outside blinds."
>
> 1920 Screen doors have been installed (photograph)
>
> 1940s Wallpaper installed
>
> 1951 Roof replaced, shingles saved and salvaged for sale as souvenirs.

This chapter has begun to illustrate the information one might collect when beginning to consider energy performance options for a historic house museum. From extant strategies, and lost or adopted strategies, to relevant and harmonious tactics, analyzing all available opportunities is key to maximizing your potential.

---

[66] "Historic Structures Report for the French Legation Museum Main House," Volz & Associates, Inc, August 20, 1997.

The next chapter will take an in depth look at potential strategies for improving energy efficiency, and how to apply these estimates to historic data information for an actual building. The case study, the French Legation Museum, will undergo a thorough investigation into its energy performance potential.

Chapter 5: Case Study

b : French Legation Museum Audit and Analysis

Figure 5.3 French Legation Museum Model Image

This chapter will include a detailed analysis of the French Legation Museum's electricity use, an estimation of how much electricity use can be contributed to different sources, and which strategies can offer reduction in electricity use.

Electricity Use

The Energy Information Administration regularly surveys the nation for data including energy consumption information.[67] It collects data on residential home size, date of construction, tenancy, and applies electricity use information in order to draw rough conclusions about national electricity use. This allows potential patterns to be analysed in order to begin to identify opportunities for highest return on investment for energy efficiency efforts.

[67] "Consumption and Expenditures Table CE1.4, 2009 RECS Survey Data," Residential Energy Consumption Services, U.S. Energy Information Administration. Released December 14, 2012. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary

The following chart represents average electricity use for the case study museum, construction pre-1940, current standard construction 2000-2009, residences with the same square footage as the case study museum, and residences with one resident, which was the closest estimate to a building maintained for no residents.

Table 5.1 National Residential Annual Electricity Use, U.S. EIA

Residential Annual Electricity Use (KWH) (for year 2009)	
French Legation Museum	17,484
U.S. EIA Pre 1940 Construction	13,323
U.S. EIA 2000-2009 Construction	15,819
U.S. EIA 1000-1499 sq ft Home	13,207
U.S. EIA 1 Occupant	10,026

The French Legation Museum electricity bills for August 2012 through July 2013 were procured in order to create an electricity use baseline both to understand the use in the context of other, similar structures, and to have a benchmark against which to calculate energy savings.

Table 5.2 French Legation Museum Electricity Use (year 2012-3)

French Legation Museum Electricity Use (KWH) (for year 2012-3)	
August	3251
September	2283
October	941
November	872
December	1310
January	943
February	741
March	899
April	812
May	1382
June	1947
July	2103
Total	17,484
Average	1457

The U.S. EIA estimates electricity use at 65.8% of total energy use. The electricity breakdown goes towards: air conditioning, appliances, lighting and operation. The Museum does not have the average amount of appliances in a residential home: no refrigerator or computers, or televisions, the entire electricity load goes towards lighting, a sump pump and air conditioning.

According to a recent Preservation Needs Assessment,[68] the current interior conditions have been recorded as ranging from 67-71.5 degrees Fahrenheit, and from 32-62% humidity. The Museum staff aim to maintain the 1,350 square foot

[68] Jenna Cooper and Katherine Isham, "French Legation Museum Preservation Needs Assessment," March 25, 2013

building[69] at 70 F throughout the year. Therefore I will aim to ensure that my calculations provide the same performance with less consumption. The goal would be to reach the average use of a 1,000-1,499 square foot home, as estimated by the U.S. EIA. This would represent a 24% reduction in annual energy use, or 4277 less kWH used per year. However the calculations that follow are all estimates, based on national or local averages, they should be considered a guide, not an expectation. Results will vary based on building, construction, climate, and human intervention and occupancy.

Sources of Electricity Use in French Legation Museum

Since there are no regular household appliances in the museum, the electricity use can be attributed to the machines that operate within its walls. Once these energy users have been identified, the remainder of the electricity can be attributed to heating and cooling loads. However we must estimate the amount of time each of these appliances is used. Lights are turned on for tours, which occur Tuesday through Sunday at 1.15, 2pm, 3pm and 4pm. Tours last approximately 40 minutes, 30 of which are in the home with the lights turned on. Two hours per day, 6 days per week, not including holidays, of which there are 10, according to the federal government. This comes out to roughly 604 hours per year. There are roughly 10 special event days per year where the lights remain on from 1pm-5pm, which adds 40 hours to the total, bringing it to 644 hours per year. This does not include weddings or private events.

[69] Note: I have not included the cellar or attic in square footage calculations since I do not consider these to be livable space, nor were they used as livable space during the active inhabitation of the home. The HABS report indicates that the cellar was filled in and used as a closet, and the historical record indicates that the attic was never lived in.

Table 5.3 French Legation Museum Non Cooling Load Electricity Use

French Legation Museum Non Cooling Load Electricity Use				
Lighting		**Electricity Use (KW)**	**Estimated Use**	**Total Use Annually KWh**
Incandescent	21 bulbs	0.60 Kilowatt	644 hours	386.4
CFL	6 bulbs	0.13 Kilowatt	644 hours	83.72
Appliances				
Sump Pump	1 Liberty 247 series	6.9 Kilowatts	70 hours	483
			Total	**953.12**

Lighting

Incandescent bulbs: 21 candelabra bulbs (Including 7 on each of two chandeliers)

CFL bulbs: 2 (Cellar) + 1 (Main floor) + 4 (Attic)

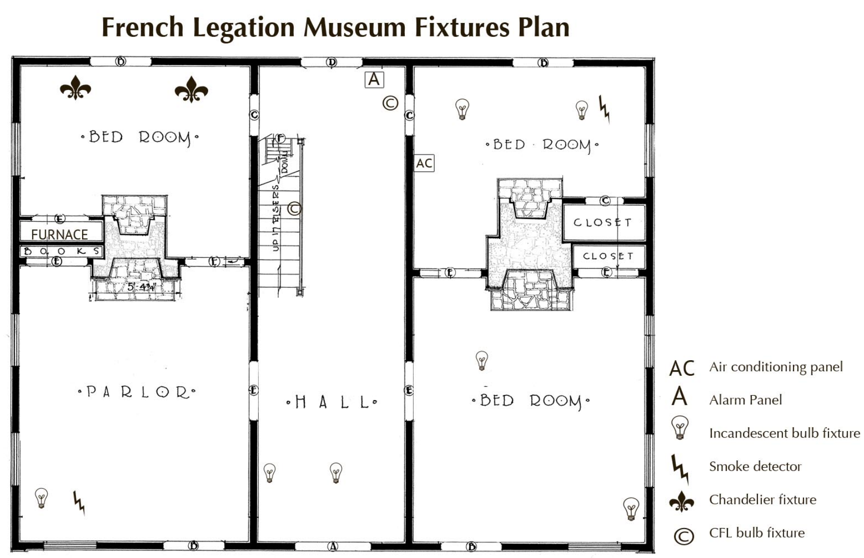


Figure 5.4 French Legation Museum Fixtures Plan

Appliances

Sump Pump: Liberty 247 series. 690 Watts (source: company enquiry.)

The furnace runs on natural gas, and therefore is not included in the electricity use.

The remainder can be attributed to air conditioning, including the air handler and air conditioning unit. 17,474 kwh (building annual total) - 953.12 kwh (lighting and appliances annual total) = 16,520.88 kwh

Space Guard High Efficiency Air Cleaner 2400

Lennox Dallas MN 14ACX-060-230-01 Air Conditioning Unit [5 ton capacity (060 code) SEER 14 rating.]

Heating and Cooling Load

In a Preservation Brief on *Improving Energy Efficiency*[70] the National Park Service quotes John Krigger and Chris Dorsi's Residential Energy Study for Existing Buildings that infiltration can account for 5-40% of a building's heating and cooling costs. The Department of Energy also states that infiltration can account for 40% of heating and cooling costs. These estimates do not illustrate the difference between heating and cooling loads, which averages the loads across seasons and skews the savings estimates. A study by the Lawrence Berkeley National Laboratory, performed an analysis of the components of residential heating and cooling loads across the United States, focusing on different climate areas and construction types.[71] This study estimated that the cooling load in "South Old Residential Buildings" is comprised of: 40% solar gain; 24% infiltration; 13% roof; 23% walls; 2% windows. It also includes a negative cooling load (as in a cooling gain) from the floors, through using the ground's constant temperature, however the French Legation Museum is raised, and in a hot humid climate, so I've decided not to include this estimate in my calculation. The study also includes a 'people' load, which in the French Legation Museum is sporadic, and an 'equipment' load, which largely does not exist in the building.

[70] Jo Ellen Hensley and Antonio Aguilar, *Improving Energy Efficiency in Historic Buildings*, National Park Service, Technical Preservation Services, Preservation Brief #3, December 2011. http://www.nps.gov/tps/how-to-preserve/briefs/3-improve-energy-efficiency.htm Accessed December 4, 2013.

[71] Joe Huang, James Hanford, and Fuqiang Yang, *Residential Heating and Cooling Loads Component Analysis* Building Technologies Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, University of California, November 1999. http://simulationresearch.lbl.gov/dirpubs/44636.pdf Accessed February 2, 2014.

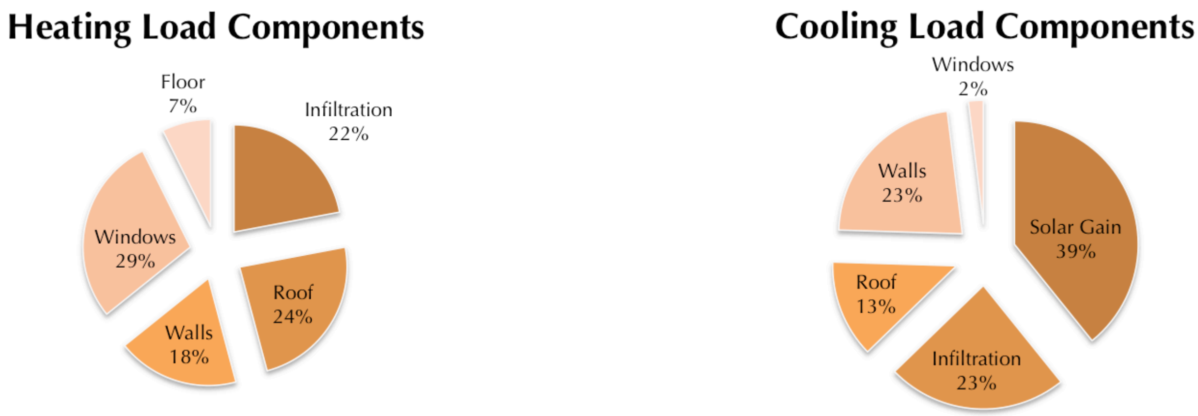


Fig 5.5 French Legation Museum Heating and Cooling Load Components

I will be using only the cooling load calculations, since heating is provided by a gas furnace. In using this study to identify the proportion of electricity use that goes to each cooling load, the distribution would be as follows.

Table 5.4 French Legation Museum Cooling Load Components

French Legation Museum Cooling Load Components		
Window Conduction	2%	330 KWH
Walls	21%	3,465 KWH
Roof	11%	1,815 KWH
Infiltration	23%	3,795 KWH
Solar Gain	39%	6,435 KWH
	Total	16,520 KWH

Considering Occupancy

Some museums need to incorporate occupancy loads into their projected energy use. Occupancy can affect energy use- from internal heat loads from a static or active occupancy, to traffic in and out of a building, opening doors and transferring energy. Occupancy is often overlooked during the auditing and analysis program, and energy efficiency failures are blamed on leaky buildings. However George Washington's Mount Vernon Mansion sees almost 3,000 visitors per day, over 300 per hour. In summer when visitation is highest, the doors remain open almost constantly, offsetting the building's performance because of occupant habits, for which the electric cooling system must work to balance. The French Legation Museum has a very controlled visitation system, regular tours only visit the building four times a day, six days a week, for about 25 minutes at a time. There are no offices or staff positions in the building, and the climate control is automated, so there is no human error to invalidate the function of the system. Obviously there is some small impact from attendance, but I assume it is negligible and evenly distributed.

Efficiency Studies

Having examined the Museum's electricity use, and the national statistics for electricity use, it is now possible to estimate electricity reduction potential based on strategies appropriate for the building.

Lighting

There are many kinds of bulbs are available on the market- ceramic halide, halogen, fluorescent, Edison, to name but a few, however in terms of energy efficiency, and the light options currently used in the French Legation Museum, an investigation of Light Emitting Diode (LED) is adequate. LED lighting is a relative newcomer to the scene, and therefore the past few years have seen various debates and studies released on its benefits, limitations and risks. Its alleged risks were advertised to the world when the Van Gogh Museum released a study claiming that LED lighting was speeding up the deterioration of chrome yellow pigment in their paintings (particularly dangerous for the 'Sunflowers' painting.) However this study has since been debunked, to the point that in 2013 Jim Druzik, Senior Scientist at the Getty Conservation Institute, and Dr. Michael Royer, a Light Engineer at the Pacific Northwest National Laboratory co-presented a talk entitled, "How safe is van Gogh's "Sunflowers" to LED lighting? Quite safe, actually!" The Smithsonian American Art Museum published a summary of their conference on "Gallery Illumination: LED Lighting in Today's Museums" in which they discussed the growing opportunities for LED lighting in museum environments, given monitoring by staff and thoughtful installation based on an understanding of the needs of the collections. [72]

---

[72] Summary of "Gallery Illumination: LED Lighting in Today's Museums" Smithsonian Art Museum, March 1, 2013. Accessed April 6, 2014. http://www.americanart.si.edu/conservation/program_docs/aic_summary.pdf

Table 5.5 Energy Use of Light Bulb by Lumen Output

Energy Use of Light Bulb by Lumen Output				
	Incandescent	Halogen	CFL	LED
800 Lumens	60 Watt	43 Watt	13 Watt	10 Watt
1100 Lumens	75 Watt	53 Watt	20 Watt	17 Watt
1600 Lumens	100 Watt	72 Watt	23 Watt	20 Watt
Rated Life	1 Year	1-3 Years	6-10 Years	15-20 Years

Courtesy of Champion Energy Services[73]

Some objections to LED lights include their incompatibility with certain fixtures, including some dimmers. However, rewiring the lighting system was suggested in the 2013 Preservation Needs Assessment, which would provide an opportunity to wire high efficiency compatible fixtures. If the building were rewired, it would give the staff opportunity to reconsider the current lighting system, which in some rooms includes non-original or period-appropriate standing lamps.

[73] *Watts Vs. Lumens- What's the difference* Oct 30, 2013 NRDC Staff Blog http://switchboard.nrdc.org/blogs/nhorowitz/fall_back_into_energy-saving_l.html Accessed: March 2, 2013.

Table 5.6 French Legation Museum Potential Savings: Lighting

French Legation Museum Potential Savings: Lighting				
Lighting	**Total items**[74]	**Electricity Use (KW)**	**Estimated Use**	**Total Use Annually KWH**
Current				
Incandescent	21 bulbs	0.60 KW	644 hours	386.4
CFL	6 bulbs	0.13 KW	644 hours	83.72
			Current total	**470.12**
Potential				
LED	27 bulbs	0.1 KW	644 hours	64.4
			Potential Savings	**405.72**

[74] Obviously the bulbs themselves are different types from fixture to fixture- candelabra, security, lamp- however the lumen output and use is the same.

Occupancy Sensors and Daylighting

Although very rewarding in some situations, given the regular and controlled visitation of the Museum, occupancy sensors would be a waste of money in this circumstance. As long as tour guides implement a strict policy of ensuring all lights are turned off when the house is vacated, an occupancy sensor could do little better. In Drayton Hall the human element of the passive cooling strategy was not successful- a working system for opening and closing windows and shutters throughout the day did not function as desired, and an automatic system may have been more successful. However this space is smaller than Drayton Hall with less requirements of the volunteer tour staff, since the interior collections are protected from the environment by closed windows and shutters. In addition to the concerns for UV light effect on interior historic collections, the heating dominated climate means that daylighting might create more heat load than it would save in electricity costs.

French Legation Museum Cooling Load Components

Table 5.7 French Legation Museum Cooling Load Components

	Cooling Load Components		
1	Window Conduction	2%	330 KWH
2	Walls	21%	3,465 KWH
3	Roof	11%	1,815 KWH
4	Infiltration	23%	3,795 KWH
5	Solar Gain	39%	6,435 KWH
		Total	16,520 KWH

1) Window Conduction: French Legation Museum Window Conduction Resultant Cooling Load = **330** KWH or 2% of cooling load.

The authors of the Lawrence Berkeley National Laboratory study remind us that window conduction actually represents "very little additional heat gain" (2%) although it does represent 29% of heat *loss* in winter. Paul Baker, at the Center for Research on Indoor Climate and Health at the Glasgow Caledonian University states that that conductive energy loss reduction for window systems is as follows.[75]

[75] Baker, Paul. *Thermal Performance of Traditional Windows*. Prepared for Historic Scotland's Technical Conservation Group. October 2008. http://www.historic-scotland.gov.uk/thermal-windows.pdf Accessed March 5, 2014

Table 5.8 French Legation Museum Potential Savings: Window Conduction

French Legation Museum Potential Savings: Window Conduction	**Percent Savings**	**Resultant total use in KWH**
Heavy curtains	14%	238.8
Shutters	51%	161.7
Shutters with insulation	60%	132
Modern roller blind	22%	257.4
Modern roller blind with affixed UV film	45%	181.5
Victorian blind	28%	237.6
Thermal honeycomb blind	36%	211.2
Victorian blind + Shutters	58%	138.6
Victorian blind + shutters + curtains	62%	125.4
Storm windows	63%	122.1
Storm windows + curtains	66%	112.2
Storm windows + insulated shutters	77%	75.9
Storm windows + shutters	75%	82.5

There are existent shutters on all but the East façade, where they have been removed for restoration. The windows on the attic do not have shutters. The shutters are painted dark green against the white siding, which may contribute to radiation. Since shutters are already on the building, one should assume that this saving has already been reaped. However it should be noted that according to the 1934 Historic American Building Survey, the original shutters had been replaced by 'shutters of no architectural value.' If they are not the original shutters, and restoration work already needs to be completed on the existing shutters, it may be an opportunity to consider custom shutters with inbuilt insulation, as investigated in the study by Paul Baker.

Given the rate of energy loss reduction through thermal shutters and heavy curtains, and the relatively small cooling load lost through the windows themselves, I see no reason to interfere with the historic appearance of the windows with blinds or shades. There are currently curtains on the windows, although they are not drawn. This may not be a severe problem for conduction in summer, but it could offer rewards when the heating load is under consideration, since for heating load, window conduction accounts for 29% of the energy losses.[76] Therefore I believe the installation of custom thermal shutters would reap the most reward with little to no effect on the historic aesthetic. That would offer a 60% saving on the electricity use, which is equivalent to 198 KWH saved.

2) Walls: French Legation Museum Wall Conduction Resultant Cooling Load = **3465** KWH or 21% of cooling load.

The historic walls leave little space for adding insulation. The original walls had canvas covering, and some is extant. There is little to no opportunity for adding any insulative barriers to the exterior conditions. However information on building material R-values is widely available, so it is possible to easily calculate the R-value of wall construction and the improvement with additional insulation where possible.[77] Take care to note thermal bridges, since they can invalidate the hard work of adding extra insulation.

---

[76] Baker, Paul. *Thermal Performance of Traditional Windows*. Prepared for Historic Scotland's Technical Conservation Group. October 2008. http://www.historic-scotland.gov.uk/thermal-windows.pdf Accessed March 5, 2014

[77] "Archtoolbox: the Architect's Technical Reference," for example, is a good resource.

3) Roof: French Legation Museum Roof Conduction Resultant Cooling Load = **1,815** KWH or 11% of cooling load.

Insulation

Given the fact that visitors do not see the second floor or enter the basement, insulation could easily be installed to severely improve the thermal performance of the building. Fiberglass batting and radiant barrier are reversible options which leave very little mess (compared say to loose fill insulation.)

R-Value is a measure of thermal resistance used in construction to indicate heat flux through an object. R-value is the inverse of U-value, 1/R. Therefore R-1 is also U-1. U- value is measured in W/m2/K, expressing the amount of heat transmitted across the material in watts, per meter squared, for each degree Celsius of temperature difference across the material (expressed in Kelvin.) R-30 to R-60 value insulation is required for roofs in Climate Zone 2 in Texas. There is currently no insulation in the attic or crawl space of the French Legation Museum. The shingles themselves offer roughly R-3 insulation, leaving between R-29 and R-59 to be added.

The Oak Ridge National Laboratory, in conjunction with the Lawrence Berkeley National Laboratory created a calculator for roof savings, which can be used to output information on heating and cooling loads reduced through radiant barrier and insulation installation. The calculator expressed a 1018 KWH saving on the building's cooling load, when the R-value was increased from R-3 (shingles) to R-38 (set value.) It also expressed a heating saving of 17 MBTUs.[78]

[78] "Residential Roof Savings Calculator Beta" Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory, accessed March 3, 2014. http://rsc.ornl.gov/rsc_main.htm?calc=res

Table 5.9 French Legation Museum Potential Energy Savings from Insulation Installation

French Legation Museum Potential Energy Savings from Insulation Installation			
	Energy loss attributed to missing insulation	**Percent reduction of loss from insulation**	**KWH savings**
R-38 roof insulation	1,815 KWH	45%	818

With the reduction in energy loss from the installation of R-38 insulation, the remaining energy loss through the roof can be estimated at 797 KWH.

Radiant Barrier

Studies by the Tennessee Valley Authority observed that in summer, radiant barrier added to an R-11 roof saved 34%, reducing heat flux from 2.38 BTU/hr-ft2 to 1.57 BTU/hr-ft2. For an R-30 roof the heat flux dropped from 1.06 BTU/hr-ft2 to 0.84 BTU/hr-ft2 with a saving of 20%.[79] In winter R-11 with radiant barrier offered a 6% saving from -2.42 to -2.28 BTU/hr-ft2 and R-30 also offered a 6% saving reducing heat flux from -0.96 to -0.90 BTU/hr-ft2.[80] Radiant barrier added to a 1,400 sq ft structure in Austin TX would save 809 KWH and 13 MBTUs for heating load.[81]

---

[79] Ambient temperature 81F, solar radiation 78 BTU/hr-ft2, wind speed 2.6mi/h, results will vary by location.

[80] Hall, James A. *Performance Testing of Radiant Barriers* Tennessee Valley Authority, Third Symposium on Improving Building Systems in Hot and Humid Climates, Arlington TX, November 1986. http://repository.tamu.edu/bitstream/handle/1969.1/6869/ESL-HH-86-11-10.pdf?sequence=3 Accessed March 17, 2014.

[81] "Residential Roof Savings Calculator Beta" Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory, accessed March 3, 2014. http://rsc.ornl.gov/rsc_main.htm?calc=res

4) Infiltration: French Legation Museum Infiltration Resultant Cooling Load = **3795** KWH or 23% of cooling load.

An illustration of the severity of energy loss through infiltration is as follows: a pair of 6' 8" exterior doors without weather-stripping, might have a gap of ¼" all along the edges where the doors meet. This ¼" opening adds up to a 20-square-inch opening to the outside.[82] This would be equivalent to the gap where the sashes meet on double hung windows. Typically this 20 square inch hole would allow over 40 cubic feet per minute (CFM) infiltration through the building.[83]

Infiltration can be calculated more accurately either with an energy audit, or with manual calculations for windows, doors and construction materials. The results of a blower door test, using the air change per hour (ACH) rate at 50 Pascals can be used to estimate average air infiltration during usual ventilation rates. Here I will use estimated average statistics from the Iowa Energy Center to identify the areas in which infiltration occurs to then calculate which measures are most suited to the French Legation Museum.

---

[82] Robert Grisso and Martha Walker, "Energy Series: What about Caulking and Weather-Stripping?" Virginia Cooperative Extension. July 2009, accessed March 15, 2014.. http://pubs.ext.vt.edu/2908/2908-9017/2908-9017_pdf.pdf

[83] "Caulking and Weather Stripping," Waste Reduction Partners, North Carolina Energy Office, March 2010, accessed April 1, 2014. http://wastereductionpartners.org/phocadownload/userupload/Resources/Energy_Saving_Fact_Sheet_Caulk_and_Weather_Strip.pdf

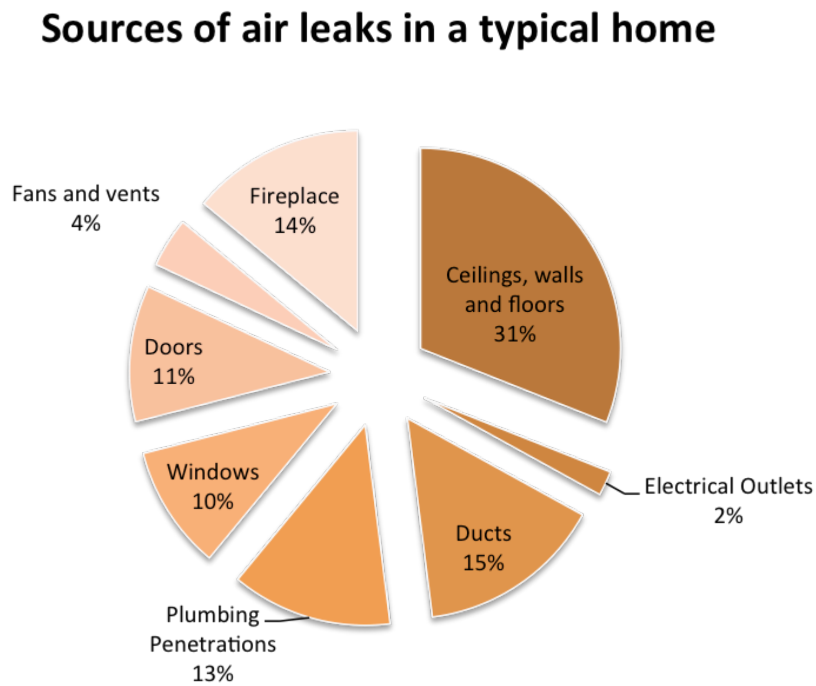


Fig 5.6 Sources of air leaks in a typical home, via Iowa Energy Center[84]

Table 5.10 French Legation Museum Infiltration Allotments

French Legation Museum Infiltration Allotments		Total: 3795 KWH
Ceilings, Walls, Floors	31%	1176.76 KWH
Electrical Outlets	2%	75.92 KWH
Ducts	15%	569.4 KWH
Plumbing Penetrations	13%	493.48 KWH
Windows	10%	379.6 KWH
Doors	11%	417.56 KWH
Fans and vents	4%	151.84 KWH
Fireplace	14%	531.44 KWH

[84] "Home Tightening, Insulation and Ventilation," Iowa Energy Center, Home Series 1. March 2012, accessed 4 March, 2014. http://www.iowaenergycenter.org/wp-content/uploads/2012/03/HomeSeries1.pdf

In Table 5.10 I divided the total amount of electricity lost via infiltration based on the average percentage identified by the Iowa Energy Center as sources of air leaks in order to allocate a measurable amount of electricity loss to each source. With this information I can calculate potential reduction in the loss and identify the highest return on investment for infiltration reduction efforts.

Caulking and Weathersealing

Caulking and window maintenance was included in the French Legation Museum's Preservation Needs Assessment from 2013. It is also a recommended practice in the Secretary of the Interior's Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings and was used very successfully in the Bryant Homestead.

Air Sealing Materials

Caulk: Seals gaps of less than ½ inch. Select grade (interior, exterior, high temperature) based on application.

Spray foam: Fills large cracks and small holdes. Can be messy. Do not use near flammable applications and do not use expanding types on windows and doors.

Backer rod: Closed cell foam or rope caulk. Press into crack or gap. Often used around windows and doors.

Housewrap: installed over exterior sheathing. Seal with housewrap tape or caulk to form airtight seal. Water resistant but not a vapour barrier.

Sheets goods: eg. Plywood, drywall. These create an air barrier and only leak at seams.

Weatherstripping: For moveable components such as windows and doors.

Mastic: Seals air handlers and duct connections.

Ceilings, Walls and Floors

In *Improving Energy Efficiency in Historic Buildings* Preservation Brief #3 details opportunities for air sealing in historic buildings to avoid the stack effect, which not only draws out conditioned air, but draws in moisture from the environment. Absolute air sealing in an existing house is a lofty goal. However in field tests, Owens Corning estimated that in a standard home sealant can reduce 70% of air infiltration, however this was for new construction. A Historic Scotland pilot project for the Scotstarvit Tower Cottage reduced its air leakage from 18 to 8 air changes per hour, a 56% reduction of its original infiltration rate.[85] Since this project was successfully completed on a historic property, I will use this as the benchmark for the French Legation Museum.

Ducts, Plumbing Penetrations and Vents

A study by David Jump and Mark Modera has stated that sealing and insulating ducts cut duct leakage by approximately 64%.[86] Plumbing penetrations, fans and vents can similarly be prevented from leaking by sealing with caulk or spray foam, depending on the application.

Electrical Outlets

The small amount of infiltration that filters through wall outlets can be virtually eliminated by sealing and gasketing electrical boxes.[87]

Fireplaces

---

[85] Jessica Snow, *Scotstarvit Tower Cottage, Cupar: Thermal Upgrades and Installation of Radiant Heating*, Historic Scotland Refurbishment Case Study 7. 2012, accessed April 2, 2014. http://www.historic-scotland.gov.uk/refurb-case-study-7.pdf

[86] Jump, D.A. and M.P. Modera. *Impacts of attic duct retrofits in Sacramento houses.* Lawrence Berkeley Laboratory,1994. Proceedings of ACEEE.

[87] "Air Infiltration and Energy Efficiency in Your Home," CertainTeed Home Institute, March 2000, accessed March 1, 2014. http://www.certainteed.com/resources/30-21-1225.pdf

In a 1990 study, the Energy Options Northwest discovered that even with a closed damper, the effective leakage area of the average fireplace was about 30 square inches.[88] Inflatable stoppers mold to the shape of the interior of the chimney to reduce losses almost entirely.

Windows and Doors

In a 2008 study, the Centre for Research on Indoor Climate & Health, Glasgow Caledonian University examined the thermal performance of traditional windows. The study examined various iterations of traditional weatherization of historic windows. This ranged from draught-proofing with caulk and weatherstripping to applying shutters and blinds to the window construction. The study revealed that whole window U-value was barely improved, however airtightness was improved 'considerably' reducing air loss by 86%.[89]

A report for the Center for Energy and Environmental Studies at Princeton University on the *Reduction of Air Infiltration Due to Window and Door Retrofits in an Older Home* studied the results of traditional metal weatherstripping installation on older windows, which offered a 14.7% reduction on infiltration.[90] Spring bronze, spring copper and zinc weatherstripping are popular retrofits on historic houses, having been used since the late 1800s as infiltration reduction measures. However their effectiveness is not as complete as that of high insulation weatherstripping such as foam or caulk. Since all of the windows and all but one of

---

[88] "Energy Loss," The DraftStopper, accessed April 1, 2014. http://www.draftstopper.ca/energyloss.htm?

[89] Paul Baker, "Thermal Performance of Traditional Windows," Centre for Research on Indoor Climate & Health, Glasgow Caledonian University, for the Technical Conservation Group, Historic Scotland, accessed March 6, 2014. http://www.historic-scotland.gov.uk/thermal-windows.pdf

[90] David Harrje, Ake Blomsterberg and Andrew Persily, "Reduction of Air Infiltration Due to Window and Door Retrofits in an Older Home," Center for Energy and Environmental Studies at Princeton University, May 1979, accessed February 12th, 2014. http://www.princeton.edu/pei/energy/publications/reports/No.-85.pdf

the doors in the French Legation Museum are rarely operated, I will suggest the plastic insulation over metal because it will not detract from the aesthetic but will render greater energy savings.

French Colonial buildings traditionally had casement windows, which were largely converted to double hung windows in the early 20th Century. The 1932 HABS drawings indicate that the original casement windows were replaced with sash windows. Therefore, the current sash windows, while they may now be considered a 'character defining feature' are probably not original. Casement windows have fewer seams than sash windows, less resultant infiltration, and are considered the most efficient window style on the market.

Table 5.11 Sash Types and Effective Open Area

Sash Type	**Effective Open Area**
Casement	90%
Awning	75%
Hopper	45%
Horizontal Shading	45%
Single-hung	45%
Double-hung	45%

Via U.S. Department of Energy[91]

In addition to reduced infiltration, were the Museum interested in returning to the casement style window of the original home, they could even consider higher performing glazing in the wood casement windows.

91 "Selecting Windows for Energy Efficiency," U.S. Department of Energy, January 1997, accessed Jan 15, 2014. http://windows.lbl.gov/pub/selectingwindows/window.pdf

Table 5.12 French Legation Museum Potential Energy Savings from Infiltration Prevention

French Legation Museum Potential Energy Savings from Infiltration Prevention			
	Initial infiltration Statistics	**Percent reduction of loss from air sealing**	**KWH savings**
Ceilings, Walls, Floors	1,176.76 KWH	56%	658.56 KWH
Electrical Outlets	75.92 KWH	100%	75.92 KWH
Ducts	569.4 KWH	64%	364.16 KWH
Plumbing Penetrations	493.48 KWH	64%	315.52 KWH
Windows	379.6 KWH	86%	325.5 KWH
Doors	417.56 KWH	86%	359.1 KWH
Fans and vents	151.84 KWH	64%	97.17 KWH
Fireplace	531.44 KWH	98%	520.8 KWH
		Total	**2,716.73 KWH**

Therefore from an initial estimate of 3,795 KWH expended on infiltration, we have identified a 2,716.73 KWH saving potential, which amounts to electricity consumption for infiltration standing at 1,078.27 KWH which is 28.4% of the current electricity use.

5) Solar Gain: French Legation Museum Solar Gain Resultant Cooling Load = **6,435** KWH or 39% of cooling load.

The opportunities for reducing solar gain are many, both inside and outside the house. Internally, windows can have treatments that block radiation from entering the room, such as curtains and blinds, the window itself can feature ultra violet blocking film to prevent radiation penetrating the windows. On the outside of a house, shutters, porches, and screens can help reduce insolation entering a building, and simultaneously maintaining opportunities for heat gain in winter.

There are mathematical calculations that can be performed to identify fairly accurate numbers on direct, diffuse and reflected solar insolation which would enter a window of a certain orientation, at a particular angle, however since I have information on the estimated amount of electricity that is used to mediate this solar gain, I will use this as my indication of the amount of solar heat gain collected by the French Legation Museum.

The French Legation Museum has 12 windows, four French doors and two solid wooden doors. The South side has a 9'4" deep porch on the south side, meaning that one wooden door, two French doors and two windows are shaded from direct insolation year round, it also has three gable windows in the roof which have neither shutters nor a shade. The West side has three windows with shutters. The North side has two shuttered French doors and an unshaded roof gable window. The East side has three unshuttered and unshaded windows.

I performed a climate simulation with Climate Consultant, a free computer program maintained by the UCLA Department of Architecture and Urban Design, which allows the user to simulate environmental conditions across the world. I applied the proportions of annual insolation averages for each direction for Texas in order to estimate the amount of solar gain from each façade.

Table 5.13 Annual Average of Daily Total Insolation on Vertical Surface

Annual Average of Daily Total Insolation on Vertical Surface		**Percent of Total**	**KWH solar gain**
South-facing	770 BTU	41%	2,638
North- facing	100BTU	5.5%	354
East- facing	400 BTU	21.5%	1,383
West- facing	600 BTU	32%	2,059

Therefore when I apply calculations to windows, I will apply them based on the percentage of impact that each façade has on the total solar gain. I am treating all windows and French doors as the same size surface for ease of calculation, since the French doors are wooden up to the trim rail.

Period Energy Performance Techniques

The following strategies have been identified as available in the structure's historically significant time period and location (in this case 1830 in Austin, Texas.)

Shading

Typical Louisiana French Creole buildings have verandas for shading and ventilation. The Museum has a south facing porch, but none on the other building facades, leaving them exposed to the hot morning and afternoon sun, particularly in summer. Adding a porch to the east and west façades would shade six windows, each of which has 21 square feet of glazing surface, leaving 126 square feet of glazed surface exposed to the sun. There is, however, no evidence that a west facing porch was ever considered- despite the use of French doors, none face the west side of the house, indicating that there was never meant to be a method of egress. There is historic evidence that the house had trellis attached to its south veranda, and that it ran along part of the west façade. A trellis with running plants would mimic some of the effect of an overhang, and the plants could supply an additional benefit of evaporative cooling. There are also four gable windows in the roof (three on the south side, one on the north,) mostly for aesthetic purposes, since the roof has never been used or inhabited, although they do have a negative effect, in exacerbating solar gain.

Fig 5.7 Trellis on French Legation Museum, c.1900 courtesy of the Austin History Center[92]

[92] Austin History Center PICA #17444 c. 1900

The Department of Energy has estimated that covering windows with an awning or overhang that allows no direct light can cut down on 77% of solar heat gain and 65% of gain on south facing windows.[93] However the east facing windows also receive insolation throughout the morning, which begins heating the house long before the hottest hours of the day have arrived. Therefore applying a similar treatment to both the east and west windows would most effectively shield the building from direct solar gain, and preserve the symmetry which was traditional in French cultural architecture.

The University of Minnesota Center for Sustainable Building Research, performed research on the impact of awnings on solar gain in buildings.[94] The calculations were based on the awning being deep enough to reject 100% of summer sun, but not so deep to reject the winter sun. However, since heating fuel use information was not available, winter calculations are not included in this study, and we will not use the heating MBTU figures included in the study results. Seven locations were tested in the research, Minneapolis, Boston, Seattle, Albuquerque, Phoenix, St. Louis and Sacramento in an effort to identify the difference in impact in hot and cold climates. I used the study of Phoenix, AZ against which to compare the Austin climate, since their peak temperatures and seasons are the most similar. The study revealed that awnings on windows with clear panes of glass with no low-e treatments provided an energy saving (in that building) of 5,905 KWH or a 21% energy saving on cooling energy. Awnings would be historically incorrect on the

---

[93] "Energy Efficient Window Treatments," Department of Energy. September 25, 2012, accessed March 10, 2014. http://www.energy.gov/energysaver/articles/energy-efficient-window-treatments
[94] "Awnings in Residential Buildings, The Impact on Energy Use and Peak Demand," John Carmody and Kerry Haglund, Center for Sustainable Building Research, University of Minnesota, Yu Joe Huang, Lawrence Berkeley National Laboratory, December 2006. http://www.kaplanawning.com/images/energystudy22007.pdf

roof gable windows, however an extended porch on the west and east sides, or a covered trellis, to mimic the lost historic trellis, would act in the same manner as an awning.

I will assume that porches or a covered trellis on every façade of the French Legation Museum would also reduce solar gain by 21%. However there is already a porch on the south side of the museum therefore that energy saving must be accounted for.

Table 5.14: Solar Gain on French Legation Museum Facades

Window	**Initial Gain per window in KWH**	**Reduction with porch**	**Resultant solar gain (each) KWH**	**Resultant solar gain (total) KWH**
South lower (4)	280	n/a	280	1,120
South upper (3)	506	n/a	506	1,518
West (3)	686	21%	542	1,626
North lower (2)	103	21%	81	162
North upper (1)	147	n/a	147	147
East (3)	461	21%	364	1,092
			Total	5,666

These measures would result in a reduction from 6,435 KWH to 5,666 KWH per annum.

Shutters

Currently there are shutters on the west, south and north windows, which keep out much (but not all) of the direct insolation, although they are painted dark green which absorbs more heat and will transfer it to the building. The shutters on the east façade are missing for repair and have been missing since the Preservation Needs Report was completed in 2013. There are no shutters on the roof gable windows.

The following image is a photo taken by a museum visitor showing the interior conditions of the home on a sunny day. What may not be immediately apparent, is that the shutters are closed, and in use, in this photo. This illustrates the amount of insolation that enters the home even when the current shutters are closed.

Fig. 5.8, French Legation Museum Interior, courtesy of Maureen Stevens[95]

[95] Maureen Stevens, *Check it out: The French Legation Museum,* Maureen Stevens Styling and Design blog. January 14, 2011. http://maureenstevens.com/2011/01/check-it-out-the-french-legation-museum/#.U0XtB61dVKg

The Preservation Needs Assessment highlighted the importance of repairing and reinstalling the shutters around the Museum. The shutters on the east side are currently missing for restoration, the rest have a 30% light blocking rate based on the slat size versus the spacing. If new insulating shutters were to be made for the Museum (according to the HABS drawings the current shutters are not original, and are in need of repair) as previously discussed in the section on energy loss through windows, even if the shutters only reflected 50% of insolation, to allow some daylighting of the interior, as is currently enjoyed, it would represent a improvement on current conditions.

However there are three unshuttered roof gable windows on the south façade, and one unshuttered gable window on the north façade, therefore to estimate the insolation on each surface properly I must separate the solar gain from each.
The south façade accounts for 2,638 KWH of the total solar gain. This solar gain is absorbed by three entirely uncovered windows, and four windows with shutters and a porch (the porch reduces insolation by 21%, and the shutters then reduce the resultant insolation by 30%.) Therefore the south gable windows account for 506 KWH solar gain each, while the shuttered porch windows account for 280 KWH solar gain each.

On the north side, there is also an unshaded window, meaning that the unshuttered window accounts for 146 KWH, while the shuttered windows account for 104.25 KWH each.

Adding shutters that reject 50% of insolation would reduce solar gain on each façade by the following amounts:

South: a) an improvement on the lower windows by 20% on the shutter performance, b) on the upper windows there would be a 50% reduction on insolation.

West: a) an improvement of 20% on the shutters

North: a) an improvement of 20% on the shutter performance, and b) an improvement of 50% on the insolation on the upper window.

East: a) an improvement of 50% on the insolation.

For windows with shutters, an improvement from 30% shading to 50% shading will be represented by an improvement of 29%.

Table 5.15: Solar Gain on French Legation Windows with Porch and Shutters

Window	Initial Gain per window in KWH	Reduction with porch in KWH	Reduction with shutters	Reduction with porch and shutters in KWH	Resultant solar gain (total) in KWH
South lower (4)	280	280	29%	199	795
South upper (3)	506	506	n/a	506	1,518
West (3)	686	542	29%	385	1,155
North lower (2)	103	81	29%	57.5	115
North upper (1)	147	147	n/a	147	147
East (3)	461	364	50%	182	546
				Total	**4,276**

The improvement and replacement of missing shutters could result in a reduction of energy costs to 4276 KWH annually.

Modern Energy Performance Techniques

UltraViolet Blocking Film is increasingly considered important in conservation of collections inside a building where insolation has caused deterioration of objects. This concern is included in French Legation Museum's Preservation Needs Assessment from 2013, where a call for protection of the interior collections was made.

Table 5.16: Solar Gain on French Legation Windows with UV film

Window	Initial Gain per window in KWH	Reduction with porch in KWH	Reduction with porch and shutters in KWH	Reduction with UV film in KWH	Resultant solar gain (total) in KWH
South lower (4)	280	280	199	99.5	398
South upper (3)	506	506	506	253	759
West (3)	686	542	385	192.5	577.5
North lower (2)	103	81	57.5	28.75	57.5
North upper (1)	147	147	147	73.5	73.5
East (3)	461	364	182	91	273
				Total	**2,138.5**

3M claims that its single pane clear UV film rejects 50% of solar energy. [96] If we were to apply UV film to all windows, including roof gable windows, the solar gain entering the windows might be reduced by up to half. Therefore the total savings from adding ultraviolet blocking film to all windows is roughly 2,138 KWH. The study on ultraviolet blocking film was most likely rendered with direct sunlight, therefore results might be different for a shaded surface.

I opted not to add interior treatments to the windows to reduce window conduction because studies revealed that the effect would not render as great a return as insulated shutters. I see no reason to add a modern technology to a historic aesthetic where it is not needed. However in the upper windows, white blinds could be added to only minimally change the aesthetic appearance from the exterior, in an interior space that is not visible to the public. The ducts for the HVAC system run through the attic, and their performance is affected by their environment. Maintaining the ducts that transport the air handler's cold air in a cooler environment than the attic that is currently completely exposed to solar insolation could improve their performance. Reducing the heat gain in the attic would also reduce the total gain in the building. A study by A. Laouadi for the Canadian Centre for Housing Technology estimates savings of 63% on conventional single pane windows, and 53% on high performance windows for interior reflective blinds.[97] Since I am applying this calculation to panes which have a hypothetical UV film application, I will use the statistic for high performance windows (high performance in terms of solar heat gain coefficient rather than

[96] "Prestige Series PR 70: Sun Control Window Films" 3M Multimedia, accessed February 4, 2014. http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuH8gc7nZxtUm8mBox_9evUqe17zHvTSevTSeSSSSSS--&fn=Prestige%20PR%2070%20Sample%2070-0709-01

[97] A. Laouadi, Guidelines for Effective Residential Solar Shading Devices, Canadian Center for Housing Technology, March 01, 2010. P.25 http://archive.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr300.pdf

conductivity.) An additional saving for adding interior reflective blinds to the gable windows on the south and north facades would result in a final amount of 34.5 KWH solar gain through the north façade gable window, and 357 KWH solar gain through the south side gable windows.

Table 5.17: French Legation Potential Energy Savings from Solar Gain Prevention

French Legation Museum Potential Energy Savings from Solar Gain Prevention			
	Energy Saved	**Accrued Savings**	**Final Energy Used in KWH**
Porch/Trellis	769	769	5,666
Shutters	1,390	2,159	4,276
UV film	2,138	4,297	2,138
Blinds	487	4,784	1,651

By adopting a porch or trellis around the house, insulated shutters, and UV film, the cooling load needed to balance solar gain would reduce from 6,435 MWH to 1,651 KWH, a saving of 74.34%.

Heating Ventilation Air Conditioning System Upgrade

Once these improvements have been applied, an HVAC upgrade (the need for which was included in Preservation Needs Assessment) might be in order. It is important to reduce demand before identifying the size of your unit, because an oversized unit will cycle on and off, which is less efficient than working longer at a low rate. [98]

The current system is a Lennox Dallas MN 14ACX-060-230-01 Air Conditioning Unit [5 ton capacity (060 code) SEER 14 rating.] A 5 ton capacity air conditioner is suggested for a 2400-3000 square foot home in the Austin climate zone.[99] However the conditioned square footage in the French Legation Museum is only 1400 square feet, which would require a 2.5 ton system. Say the museum chose not to seal off the attic, and to condition the space in order to improve the performance of the air conditioning ducts, the system would still not need to exceed 3 tons or 3.5 tons at most. The SEER ratings is 14, which is only one point above the legal minimum. In 2006 the SEER minimum rating for air conditioners was raised from 10 to 13. If the museum were to reduce its system to a 3.5 ton system at a higher SEER rating of only 16 (the most efficient systems have reached a SEER rating of 24.5) it would reduce its cost from 4.28 kw per hour to 2.71 kw per hour, using only 63% of its original load.[100] Given the efficiency upgrades applied to the historic house museum, by upgrading the HVAC system costs would drop by 37%. However before making any decisions about HVAC installation, a Manual J load calculation should be performed.

---

[98] "Central Air Conditioning," U.S Department of Energy, accessed April 4, 2014. http://energy.gov/energysaver/articles/central-air-conditioning
[99] "Air Conditioning Sizing Chart," AC Direct, accessed April 4, 2014. http://www.acdirect.com/systemsize.php
[100] "Cooling and Heating," Lee County Electric Cooperative, accessed April 4, 2014. https://www.lcec.net/energy-efficiency/green-energy-tips/cooling-and-heating.

Additional Energy Performance Strategies

Monitoring or submetering (also included in Preservation Needs Assessment) is key to moving forward. Currently the Museum does not have access to its bills, which are paid for by the State of Texas directly, since the Museum is a state property. The past bills on which the calculations were based were procured for me by the staff explicitly for the purpose of this paper. However, on a day-to-day basis, without any knowledge of monthly or even annual energy use, the staff have no benchmark from which to start or towards which to strive. Monitoring conditions and electricity consumption ensures that the proper conditions are met for collections, and allows staff to address any issues promptly. Studies have also shown that real-time energy data encourages reduced energy use. This phenomenon might be particularly valuable in the administrative offices where consumption can change and be changed.[101]

HVAC upgrade considerations might include a **geothermal heat pump** system, which might be very beneficial in a climate which has between 66-70 F degree groundwater temperatures year round and multiple 100+F degree months.[102] The Museum has extensive grounds, which, if dug vertically, could accommodate enough coils for the small size and demand of the building. Obviously one would generally not want to disturb a historic and potentially archaeological site. However the Museum staff has mentioned an upcoming archaeological effort to unearth information about some other structures they believe are on the property. Given the forthcoming excavation, I believe that geothermal might be an option for

---

[101] Sarah Darby, "The Effectiveness of Feedback on Energy Consumption," Environmental Change Institute, University of Oxford, April 2006, accessed April 4, 2014. http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf

[102] Gass,T. E., Geothermal Heat Pumps Geothermal Resources Council Bulletin 11(11), 3-8, 1982.

installation once the dig has been completed since the site will already be under construction.

Average Texas Surface Groundwater Temperatures, a subset of the U.S. map by Gasss, 1982.

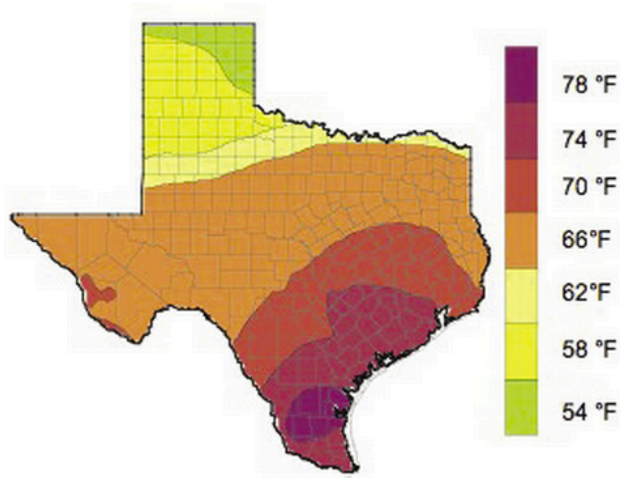


Fig 5.9 Texas Groundwater Map, courtesy of the State Energy Conservation Office[103]

The ClimateMaster calculator created an estimate based on the French Legation Museum conditions based on the Austin climate, with a design temperature of 28F in winter, and 100F in summer, 1,737 heating degree days, and an earth temperature of 72F, the 1400 square foot house could see a 29% savings on the output of the air handling unit. However after all air sealing, insulation and appliance upgrades were implemented, it identified 42% potential savings, since the air would be contained better, resulting in a lower output by the air handling unit.[104]

---

[103] "Geothermal Energy," State Energy Conservation Office, Texas, accessed March 10, 2014. http://www.seco.cpa.state.tx.us/publications/renewenergy/geothermalenergy.php
[104] "ClimateMaster Geothermal Savings Calculator," Climate Master, accessed March 4, 2014. http://www.climatemaster.com/residential/geothermal-savings-calculator/sc01.php

Results

Table 5.18 French Legation Museum Potential Energy Consumption Change

French Legation Museum Potential Energy Consumption Change			
	Initial Energy Consumption in KWH	**Predicted Energy Consumption in KWH**	**KWH Savings**
Lighting	470.12	64.4	405.72
Window Conduction	330	132	198
Walls	3,465	3,465	0
Roof	1,815	797	1,018
Infiltration	3,795	1,078.27	2,716.73
Solar Gain	6,435	1,651	4,784
HVAC upgrade	(after efficiency improvements) 1,651	1,045	606
		Total	**9,728.45**

The final tally for electricity consumption reduction for all measures (not including geothermal) is 9,728.45 KWH per year. From the original historic use of 17,484 KWH per year, this represents only 55.64% of the original use, meaning a 44.36% saving in electricity consumption. These numbers are very approximate, and only reflect a calculation based on averages and estimated numbers. Were these strategies all to be implemented, the electricity savings would not meet this quota precisely.

Conclusions

The French Legation Museum has a lot of potential for energy efficient incorporation, and its current position, being in need of preservation (according to the Preservation Needs Assessment) provides an opportunity to implement some of these changes while performing important preservation work on the building. Lighting upgrades, HVAC upgrades, all these things are important for the continued operation of the building, and also have been identified as opportunities for reducing energy consumption. Preservation of collections from UV exposure has also been identified as a priority, which can be resolved with UV film, which also cuts down on diffuse radiation and therefore solar gain.

The design of the house itself, with an empty attic and large crawl space offers great opportunities for insulation, as well as access to the entire house for improving ductwork for existing HVAC. If the building were operated without indoor climate management, I might suggest demi-shutters, which are an interesting and unusual concept. Slats in shutters already allow air flow, but open topped shutters might act even more effectively to allow the outflow of hot air, causing a small stack effect. However the collections in the building demand a more rigorous interior condition, so the point is moot.

An archaeological dig opens up the unexpected opportunity for geothermal heat exchange, which would severely reduce the heating load in the heat-dominated climate. However at times the geology in Texas can make plans for deep excavation complicated. Geological surveys can reveal feasibility for geothermal systems.

With this list in hand, the French Legation Museum can make more informed decisions about the returns on investment they will see by investing in some of these upgrades. However the most important steps towards improving energy use remain in understanding the building, monitoring its performance, and identifying how to use the style, spirit and construction of the house in order to combine cultural representation with environmental and financial concerns.

Chapter 6: Conclusions

The information I have collected is only a small sample of the efforts being implemented in historic sites across the nation (and abroad.) Some trials are experimental, some have been more successful than others, and all are colored by the unique construction of their property and its response to its climate and conditions. This information is also constantly growing and changing, and I can only hope that by beginning to collect this data, a comprehensive and accessible system can start to emerge to direct curators in the energy efficient maintenance of their historic properties and budgets. There is no record of how many historic properties have received a LEED certification, which the National Trust for Historic Preservation bemoaned recently, even though there is a new LEED Program for Neighborhood Development and Historic Preservation. Therefore a system needs to be created to act as a forum for and celebration of historic properties seeking energy efficiency.

Given the recent implementation of many of these strategies, the lack of communication on the subject, and the small field of study, information is still scarce and metrics are estimations. Much of the available information is generic, and designed for press release to the general public, rather than delving into the mechanics of a system. Therefore this structure is less of a system, and more like many individualized efforts toward the same goal. Within this arduous journey there are successes and failures, the failures of which may be increased because each institution must experience its own trial and error. The Provincetown Art Association and Museum, for example, meant to install a geothermal system until it failed due to the groundwater's high mineral content. "The lesson here is that buildings and system designs are location specific. Not every technology will work in every location."[105] Shared knowledge may be able to prevent this.

The Sustainable Operations Toolkit operated jointly by the American Alliance of Museums PIC Green and the National Children's Museum could become a valuable repository for caretakers in pursuit and in ownership of data as the field expands. LEED does not have a registry of its own, and sustainable practice goes far beyond the USGBC. A forum would allow properties to submit information on their projects and efforts of all sizes- uncertified, self-driven, and experimental- for feedback and support.

This would be valuable for the many institutions achieving truly great feats, and those considering them. I believe that my research begins to reveal that historic properties can perform to the same level as modern ones, a realization which will become ever more important as more buildings turn 50 and join the National Register of Historic Places. Historic commercial, federal and museum buildings are achieving this goal, and the Northwest Energy Efficiency Alliance and New Buildings Institute have a growing list of historic buildings that have blown past not only the ASHRAE benchmark, but the national average in performance.[106]

This performance is helping to redefine historic house museums as a contributing part of the building stock, most importantly in the eyes of historic property caretakers. The building culture that exists today has the longest lifespan of any

---

[105] Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham: Altamira Press, 2008. p. 103

[106] "NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014. http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

before it, it includes every standing structure, historic and modern, yet these have been compartmentalized into generational layers where interaction is seen as a betrayal of stylistic purity. However if building culture is seen as a system, a symbiotic process whereby modern buildings are inspired by past architecture, and historic structures are preserved and kept current with modern architecture, this opens a vast array of opportunities for continuing a long tradition of evolving building systems.

Historic house museum professionals are facing the reality that in order to flourish they need to improve their environmental, cultural and economic sustainability to appeal to today's audiences. Staff have begun to feel the pressure to be innovative and modern while preserving their collections and the integrity of their historic message. Accepting that a historic property is a living and evolving example of decades, if not centuries, of human culture, engineering, and art, opens doors, rather than closing them. Opportunities for education, interpretation and innovation arise when a building's history is seen as an asset, rather than a limiting factor.

Far more research is on the horizon. Tools necessary for curators to understand and fulfill building potential are missing- irradiation calculators, insolation statistics, infiltration measurements and impacts, geothermal heat pump potential for different climates, not to mention the ever changing discourse on collections care and the impact of energy efficiency measures on historic materials. Also missing is an appropriate energy modeling program with the flexibility to accept the particulars of historic construction, one made to welcome original design, not universalize it. One which accounts for natural ventilation, infiltration, loose boards which allow for shrinking and expanding with the weather, conduction of leaded windows, and draughts from air gaps in sash weight pockets, and all the peculiarities of the inimitable historic building.

Until then, there are still useful tools at everyone's disposal- the simplest being monitoring energy use and identifying its source. Awareness, knowledge and engagement are great assets and these can be applied in any situation. Understanding the performance and potential of your building helps you maximize your treatment of it and the return you gain from your investment in it. Knowing how to react to a condition allows you to make the most appropriate decision about conservation and preservation, in terms of your collection's state of health and your institution's financial and social wellbeing. Preservation is not only sustainable because of its reuse of materials with embodied energy, but because of its sparing and thoughtful use of thinning resources. Economically, environmentally and culturally, preservation's bottom line meets that of sustainable design in a harmonious and mutually beneficial marriage.

Appendix A: Energy Efficiency Strategies in Historic Buildings

Table A.1 Historic Properties featuring Energy Performance Strategies

List of Historic Properties featuring Energy Performance Strategies		
<u>Historic House Museums</u>	**Year Built**	**Detailed Strategy Description**
Drayton Hall	1793	Spotlight: Shading and thermal barriers for windows
Bryant Homestead	1799	
Gibson Mill	1800	
Haas-Lilienthal House	1720	Spotlight: Natural Ventilation
Truman White House	1890	Spotlight: HVAC
Villa Finale	1870	Spotlight: UV film
Mark Twain House	1874	Spotlight: Occupancy Sensors
Hooper Strait Lighthouse	1879	Spotlight: Lighting
Westport Town Farm	1720	Spotlight: Insulation
Bryant Homestead	1799	
Bullitt Farmouse	1830	
Teackle Mansion	1802-1819	Spotlight: Geothermal
<u>Museums</u>		
National Building Museum	1893	
Field Museum of Natural History	1893	
Brooklyn Children's Museum	1899	
Children's Museum of South Dakota	1936	
British Museum	1753	
Montclair Art Museum	1914	
Phipps Conservatory	1893	

Boston Children's Museum	c. 19th C.	
Adirondack Museum	1957	
Historic Buildings		
Empire State Building	1929	
Trinity Church	1872	
Federal Historic Buildings		
Hipolito Garcia Courthouse	1937	
Department of the Interior	1936	
Commercial Historic Buildings		
The Copper Kettle	1934	Spotlight: Awnings
Beardmore Building	1922	
200 Market Building	1940	
Joseph Vance Building	1910	Spotlight: Storm windows
Doty and Miller Office	1934	Spotlight: Photovoltaic panels
Alliance Center	1908	
The Christman Building	1928	
Northern Plains Resource Council	1940	
The Lovejoy Building	1910	
Mercy Corps	1892	
Harris Center for Conservation Education	1913	

Historic Energy Efficiency Strategies

Historic House Museums

Drayton Hall, 1742. Charleston, SC. [Climate: Humid subtropical] [collections housed outside of historic building]

The staff pursued a climate management system of opening and closing the shutters based on environmental data, but it was arduous to maintain and has been abandoned.

- ◊ Monitoring: a monitoring system combined with a real-time advisory system was temporarily used to alert staff to building needs: closed or open shutters and doors etc. Eventually abandoned.
- ◊ Windows: Blinds on windows to prevent UV infiltration.

Shading and Thermal Barriers for Windows

Dr Paul Baker, at the Center for Research on Indoor Climate and Health at the Glasgow Caledonian University produced a technical paper on the Thermal Performance of Traditional Windows for Historic Scotland's Technical Conservation Group.[107] Tests were applied to various window treatments to test both the infiltration and U-Value results for the assemblies. The historic window was provided by Historic Scotland and the laboratory applied conditions simulations to analyse the performance of each application. The following results for heat loss were revealed when the window was tested with: curtains, victorian blinds, modern roller blinds, duette honeycomb blinds, modern roller blinds + foil, shutters, blind + shutters, blinds+shutters+windows, insulated shutters, secondary

[107] Paul Baker, "Thermal Performance of Traditional Windows," prepared for Historic Scotland's Technical Conservation Group. October 2008, accessed March 5, 2014. http://www.historic-scotland.gov.uk/thermal-windows.pdf

glazing, secondary glazing+curtains, secondary glazing+shutters, secondary glazing + insulated shutters, and double glazing. The 'secondary glazing' consisted of a storm window fitted within the 'staff beads' of the sash window. The National Park Service includes storm windows as a recommended treatment for improving the energy efficiency of historic windows without replacing them or permanently damaging the historic aesthetic.

This graph represents a visual reflection of thermal strategies applied to single glazing in order to test the effect on heat conduction.

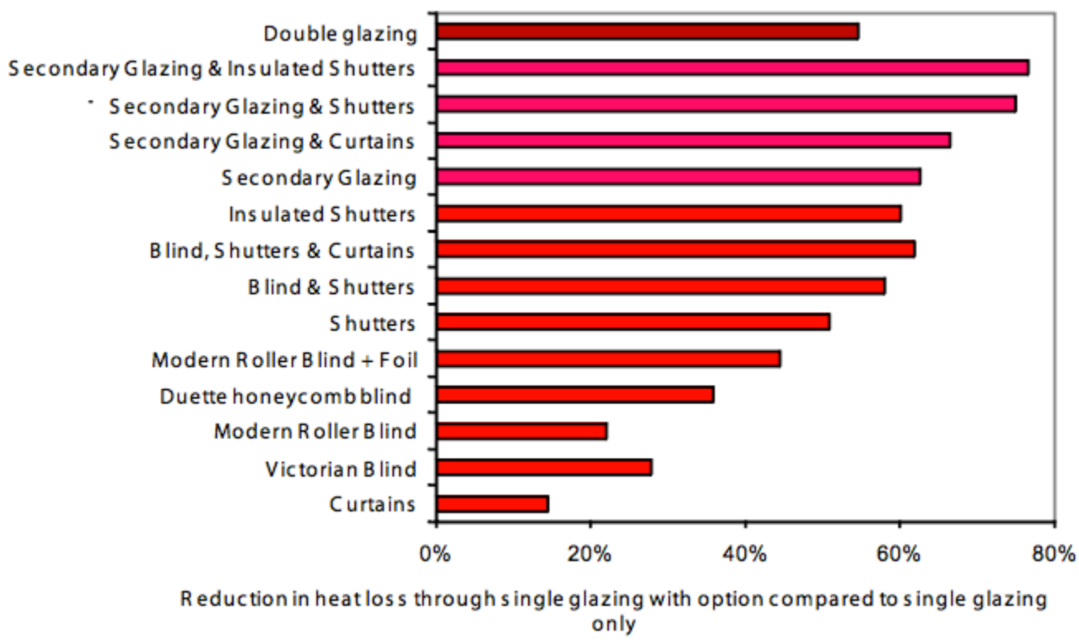


Figure A.1 Chart of thermal strategies on single glazing, via Historic Scotland[108]

The following figure illustrates the reduction in heat loss and the change in U-value offered by window treatments applied to single glazing.

[108] Paul Baker, "Thermal Performance of Traditional Windows," Prepared for Historic Scotland's Technical Conservation Group. October 2008, accessed March 5, 2014. http://www.historic-scotland.gov.uk/thermal-windows.pdf

Table 5: The effect of the various options on reduction in heat loss through single glazing, the estimated U-values and measured average surface temperatures

	Reduction in heat loss	U-value W/m^{2}K	Temperature of Interior (warm) room facing surface °C
Centre of glazing	-	5.4	12
Option 1. Heavy curtains fitted to rail on inside of insulated panel above window	14%	3.2	20
Option 2. Shutters	51%	2.2	19
Option 3. Modified shutters, with insulation inserted into panels and covered with 6mm plywood	60%	1.6	21
Option 4. Modern roller blind fitted at the top of the window case inner lining	22%	3.0	21
Option 5. Modern roller blind as option 4, with low emissivity plastic film fixed to the window facing side of the blind	45%	2.2	20
Option 6.Victorian blind fitted to the top of the recess formed by the window case pulley stiles at the side of the upper sash	28%	3.2	18
Option 7. A "thermal" Duette honeycomb blind manufactured by Hunter Douglas Europe b.v.	36%	2.4	21
Victorian Blind & Shutters	58%	1.8	19
Victorian Blind, Shutters & Curtains	62%	1.6	21
Secondary Glazing System	63%	1.7	19
Secondary Glazing & Curtains	66%	1.3	22
Secondary Glazing & Insulated Shutters	77%	1.0	21
Secondary Glazing & Shutters	75%	1.1	20
Double Glazing	55%	1.9	18

Fig A.2 Table of thermal strategies on single glazing, via Historic Scotland[109]

For more technical information, refer to: Hans Simmler, Bruno Binder, *Experimental and numerical determination of the total solar energy transmittance of glazing with venetian blind shading*, Building and Environment, Volume 43, Issue 2, Feb 2008.

[109] Paul Baker, "Thermal Performance of Traditional Windows," Prepared for Historic Scotland's Technical Conservation Group. October 2008. P. 14. Accessed March 5, 2014. http://www.historic-scotland.gov.uk/thermal-windows.pdf

Blinds

The Carbon Trust offers performance data for different varieties of modern blinds that can be used to reduce solar gain. Its performance study includes an analysis of privacy, glare, user adjustability and reflectivity, which could be useful for staff considering blinds for a building with multiple functions: adjustability and glare control for office spaces, and reflectivity in collections spaces.

System	Best for window types	% reflective total solar transmittance (south-facing)		% reflective daylight transmittance		Adjustability	Privacy	Glare control
		Summer	Winter	Diffuse	Back of room			
Clear double glazing, no shading	–	100	100	100	100	X	X	X
Overhang	S	55	84	61	72	1	X	2
Light shelf	S	51	78	52	90	1	X	2
External louvre						1*	3	2?
Shut	HSEW	4	4	3	3			
Open	HSEW	26	45	32	50			
Curtains	Any	50	49	6	6	3	3	3?
Venetian blind						3	3	3?
Shut	Any	57	58	3	3			
Open	Any	100	100	32	50			
Roller blind	Any	43	43	6	6	3	3	3?
Reflective roller blind	Any	34	33	4	4	3	2+	1*

Key:

Window types

N = north
S = south
E = east
W = west
H = horizontal

Adjustability

X = performance generally remains the same
1 = seasonal variation in performance
2 = some user adjustability
3 = completely adjustable
* = some types completely adjustable

Privacy

X = no improvement in privacy
1 = some improvement in privacy
2 = good privacy by day, not at night
3 = good privacy all the time
+ = opaque types give good privacy all the time

Glare control

X = no improvement in glare
1 = reduces sky glare but not reduce sun glare
2 = reduces sky glare and eliminates sun glare at certain times
3 = eliminates sky and sun glare
* = opaque types eliminate sky and sun glare
? = some types don't eliminate sun glare

Fig A.3 Effect of blinds on glazing, courtesy of the Carbon Trust[110]

[110] "How to implement solar shading," The Carbon Trust, accessed March 20, 2014. http://www.carbontrust.com/media/19525/ctl065-how-to-implement-solar-shading.pdf

Bryant Homestead, 1799.[111] Cummington, MA [Climate: Humid continental]
The curators of this National Historic Landmark effected an energy audit in order to identify the weakest points in the building's energy performance. Auditors designed a strategy to preserve the historic character of the building while weatherizing it to have a tighter seal.

- ◊ Windows: Most of the windows were structurally sound, but old, and cracked putty allowed heat emission. Staff removed the old window panes and used latex acrylic rather than the original linseed putty (which contains lead) to glaze the panes back into place. The restoration team also added new weather stripping on all the sashes and silicone strips for tighter seals at the muntin. This process is recommended by the Secretary of the Interior's Standards for Rehabilitation Guidelines for Sustainability.)

A pair of 6' 8" non-weatherstripped exterior might have a gap of ¼" along where the doors meet, which equals a 20-square-inch opening to the outside.[112] A similar gap where the sashes meet in two average-size double-hung windows would add up to the same 20 square inch hole. Under typical conditions, this gap would allow over 40 cfm into or out of the building.[113]

In a 2008 study, the Centre for Research on Indoor Climate & Health, Glasgow Caledonian University examined the thermal performance of traditional windows. The study examined various iterations of traditional weatherization of historic

---

[111] Jane Roy Brown, "Let It Snow!" *Special Places Magazine*, The Trustees of Reservations, Winter 2011-2012. Accessed January 15, 2014. http://www.thetrustees.org/what-we-care-about/climate-change/let-it-snow.html.
[112] Robert Grisso and Martha Walker, "Energy Series: What about Caulking and Weather-Stripping?" Virginia Cooperative Extension. July 2009, accessed March 15, 2014. http://pubs.ext.vt.edu/2908/2908-9017/2908-9017_pdf.pdf
[113]"Caulking and Weather Stripping," North Carolina Energy Office, March 2010, accessed March 15, 2014. http://wastereductionpartners.org/phocadownload/userupload/Resources/Energy_Saving_Fact_Sheet_Caulk_and_Weather_Strip.pdf

windows. This ranged from draught-proofing with caulk and weatherstripping to applying shutters and blinds to the window construction. The study revealed that whole window U-value was barely improved, however airtightness was improved 'considerably' reducing air loss by 86%.[114]

The National Park Service discusses the options for weatherstripping varieties of steel, aluminium, and wooden historic windows and doors. In the NPS Preservation Brief #13, *The Repair and Thermal Upgrading of Historic Steel Windows* Sharon Park walks through regular routine maintenance for steel windows, including cleaning, rust removal, priming, replacement of glazing compound, replacement of missing parts, cleaning and lubrication of hinges, repainting, and caulking. Preservation briefs for aluminium and wooden windows read similarly. The 'appropriate' weatherstripping options include spring metal, vinyl strips, foam tape, and sealant bead. Here a modern technology is recommended as a replacement for a defunct and decaying historic technology, suggesting that there is appropriate and harmonious integration of modern fabric into the recreation of a historic atmosphere for the purpose not only of energy efficiency, but the proper preservation of the historic fabric itself.

For more information, the following resources are a few of those available:

National Renewable Energy Lab document produced for the U.S. Department of Energy *Weatherize Your Home- Caulk and Weather Strip,* April 2001.
Preservation Brief 9: Repair of Historic Wood Windows
Preservation Brief 13: Repair and Thermal Upgrading of Historic Steel Windows
Preservation Tech Note: Windows No. 19: Repairing Steel Casement Windows

[114] Paul Baker, "Thermal Performance of Traditional Windows," Centre for Research on Indoor Climate & Health, Glasgow Caledonian University, for the Technical Conservation Group, Historic Scotland. http://www.historic-scotland.gov.uk/thermal-windows.pdf Accessed March 6, 2014.

Preservation Tech Note: Windows No. 22: Maintenance and Repair of Historic Aluminium Windows

Gibson Mill,1800. West Yorkshire, UK.[115] [Climate: Oceanic]
The mill ceased cotton production in the 1890s and was quickly converted into an entertainment complex, with a tea room, roller-skating rink and dance hall.

◊ Renewables: The trust revived the mill's 1927 water turbine to provide energy for the building. Two turbines, an original large turbine, and a smaller one hooked to the photovoltaic roof panels (for spring and summer lower water levels) provide the power and charge an 80 kilowatt storage battery for four days of backup.

Sarah Brophy, in *The Green Museum*, reminds curators that "it can all be interpreted to the public. So feel free to label, or interpret, a modern version of a historically energy efficient or sustainable practice to help your guests make the same connection between the wind turbine and the old windmill water pump, the gray water you use on your landscape and the dishpan water than was once dumped on the kitchen garden, and between your radiant heating and the technology of Roman baths."[116]

Haas-Lilienthal House, 1886. San Francisco, CA. [Climate: Pacific coastal]
The Haas-Lilienthal House is a role model for period-inspired energy efficiency. San Francisco Architectural Heritage set out to show that the corner stone of preservation- the historic house museum- could be relevant and modern. The 'remaking' of the house included physical improvements such as the restoration of

[115] Gibson Mill, Hardcastle Crags, Hedenbridge HebWeb, 2009, accessed February 19, 2014. http://www.hebdenbridge.co.uk/features/gibsonmill.html
[116] Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham, Altamira Press. 2008. p. 114

the windows and doors, and heating system upgrades, and administrative upgrades focused on the financial and cultural sustainability of the institution.

- ◊ Windows: Reactivate operable windows and operate in conjunction with ventilation goals.
- ◊ Ventilation: Properly use high ceilings and transoms above doors/windows for ventilation.
- ◊ HVAC: Utilize roofs and porches with wide roof overhangs to manage heating and cooling. Use interior pocket doors to compartmentalize spaces and control heating and cooling.

Natural Ventilation in Heritage Buildings

Michael Henry writes a compelling argument for and about heritage buildings that have passive climate control.[117] Henry examines the history of thermal comfort, the conditions expected for collections maintenance, and examples of heritage buildings whose staff maximize their building's passive and active climate moderation techniques. For a building whose operations offer the potential to take advantage of passive and active climate moderating strategies, Henry's work, particularly his analysis of successful case studies, and the concerns that emerged through the process, would be invaluable.

National Building Museum, 1887. Washington D.C. [Climate: humid subtropical]

- ◊ HVAC: Restored operability of windows, most notably those at the top of the main hall, which allows the hottest air to escape on summer days.

[117]Michael C. Henry, "The Heritage Building Envelope as a Passive and Active Climate Moderator: Opportunities and Issues in Reducing Dependency on Air-Conditioning," (contribution to the Experts' Roundtable on Sustainable Climate Management Strategies, Tenerife, Spain, April 2007). http://www.getty.edu/conservation/our_projects/science/climate/paper_henry.pdf

Historic Commercial Buildings

<u>The Copper Kettle</u>, 1916. Dubuque, IA. [Climate: Humid Continental]

◊ Shading: Restored copper awning on restaurant façade.

Awnings and overhangs provide a dual function- allowing sunlight to penetrate the building bringing heat and light in the winter months when solar radiation has a lower incidence, but blocking direct radiation in summer when rays have a higher angle of incidence and heat is an unwelcome condition.

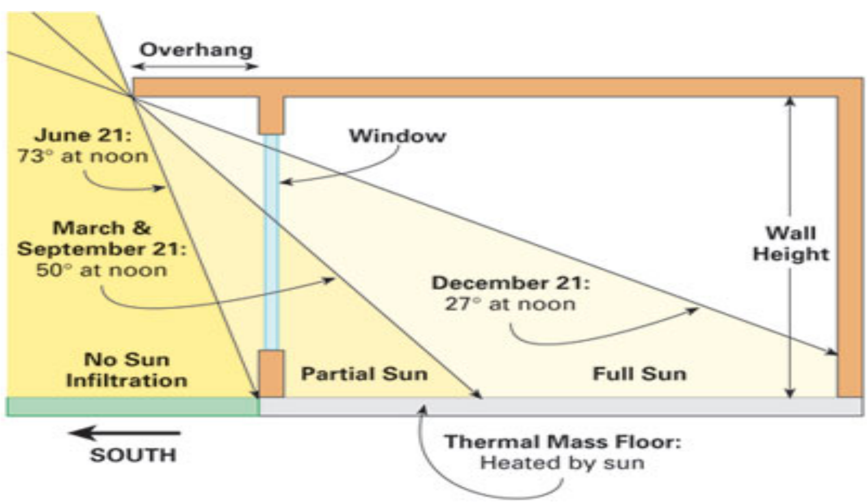


Fig A.4 Effect of overhang on solar gain, courtesy of Solar For Energy[118]

The University of Minnesota Center for Sustainable Building Research completed a study on awnings and their effects on solar heat gain and subsequent cooling energy saved for each façade of buildings in seven cities in various climates across the United States. The summary of the study is included below, but full results for each building are available through the study: John Carmody and Kerry Haglund, *Awnings in Residential Buildings, The Impact on Energy Use and Peak Demand,* Center for Sustainable Building Research, University of Minnesota, Yu Joe Huang,

[118] "Windows and Overhangs For Efficient Solar Home Design," Solar for Energy, accessed February 25, 2014. http://www.solar-for-energy.com/windows-and-overhangs.html

Lawrence Berkeley National Laboratory, December 2006.. As previously stated, National Park Service Preservation Brief, Chad Randl suggests that "Where no awning currently exists, and there is no evidence of a past one, it may still be possible to add an awning to a historic building without altering distinctive features, damaging historic fabric or changing the building's historic character."[119]

TABLE 1: SUMMARY OF AWNING IMPACTS IN SEVEN U.S. CITIES

CITY	EQUAL ORIENTATION		EAST ORIENTATION		SOUTH ORIENTATION		WEST ORIENTATION	
	Cooling Energy % Saved	Cooling Peak % Saved	Cooling Energy % Saved	Cooling Peak % Saved	Cooling Energy % Saved	Cooling Peak % Saved	Cooling Energy % Saved	Cooling Peak % Saved
Minneapolis	25-26%	9-10%	29-31%	22-23%	28-34%	5-22%	26-27%	25-32%
Boston	23-24%	17-22%	30-32%	28-37%	24-33%	22-36%	28-30%	33-40%
Seattle	60-70%	35-39%	51-69%	23%	71-80%	44-53%	69-72%	43-49%
Albuquerque	28-31%	11-17%	34-39%	12-27%	28-33%	9-19%	34-39%	35-43%
Phoenix	14-21%	9-13%	15-22%	4-6%	15-22%	3-11%	18-26%	20-31%
St.Louis	14-17%	11-16%	18-21%	13-23%	8-18%	17-30%	18-23%	20-33%
Sacramento	37-39%	15-21%	36-39%	9-13%	40-45%	10-26%	43-48%	30-39%

Fig A. 5 Impact of awning in seven U.S. cities, via the University of Minnesota Center for Sustainable Building Research[120]

Beardmore Building, Priest River, ID, 1922[121] [Climate: transitional zone between semi arid climate type and sub-humid dry-summer continental]

---

[119] Chad Randl, "The Use of Awnings on Historic Buildings, Repair, Replacement and New Design," National Park Service, Technical Preservation Services, Preservation Brief #44, April 2005. http://www.nps.gov/tps/how-to-preserve/briefs/44-awnings.htm Accessed December 10, 2013.

[120] John Carmody and Kerry Haglund, "Awnings in Residential Buildings, The Impact on Energy Use and Peak Demand," Center for Sustainable Building Research, University of Minnesota, Yu Joe Huang, Lawrence Berkeley National Laboratory, December 2006. http://www.kaplanawning.com/images/energystudy22007.pdf

[121] NEEA Study: Examples of Deep Energy Savings in Existing Buildings, prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February

◊ Windows: After many years spent covered up, the original skylights were refitted with new glazing to provide natural daylighting and ventilation.

The Christman Building, Lansing MI, 1928[122] [Climate: humid continental]

◊ Daylighting: Windows provide daylighting to 92% of occupied spaces building-wide, and outside views to 90% of the occupants.

200 Market Building, Portland OR, 1973[123] [Climate: Oceanic]

◊ Shading: translucent cloth shades on the perimeter single-pane windows

The Joseph Vance Building, Seattle, WA, 1929[124] [Climate: Oceanic]

◊ Windows: The team restored operability of the windows with new and refurbished hardware and weatherstripping, thereby allowing natural ventilation and improving performance without requiring the need for total glazing replacement. Window coverings were installed to improve occupant comfort.

◊ Daylighting: The 45-foot building width is the recommended width for passive design, and allows natural lighting and ventilation. Light shelves on the south and west exposures reflect sunlight to light-colored ceilings, reducing the need for overhead lights.

Storm windows

Storm windows were first manufactured in 1950, and today they vary in performance from shatter-reducing hurricane windows, to energy performance

---

20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

[122] Ibid.

[123] Ibid.

[124] Ibid.

low-e storm windows. A paper presented at the 2013 conference on Thermal Performance of the Exterior Envelopes of While Buildings, organized by the Oak Ridge National Laboratory (ORNL) provided an in depth *Field Evaluation of Low-E Storm Windows.* Six homes whose construction date ranged from 1930 to 1970 were tested for air infiltration before and after storm window installation. The results revealed that adding storm windows improved the airtightness of all six homes. Air infiltration rates were reduced between 231 and 335 CFM (393 and 570 M3/hr) when pressurizing the home to 50 Pascals. Although reduced infiltration is not a direct benefit of the second pane of glass, it appears to be a consistent and repeatable improvement in the homes' performance. From the six houses tested, the air infiltration reduction averaged from about 9 to 25 CFM50 (15 and 43 M3/hr) per window.[125]

[125] Craig Drumheller, Christian Kohler, Stefanie Minen, "Field Evaluation of Low-E Storm Windows," Oak Ridge National Laboratory, 2007, accessed March 1, 2014. http://web.ornl.gov/sci/buildings/2012/2007%20B10%20papers/022_Drumheller.pdf

Table 3. Before and After Airtightness Testing Results

House	Before Storm Windows CFM (M^3/hr) at 50 Pa	After Storm Windows CFM (M^3/hr) at 50 Pa	% Reduction
1	5,230 (8,891)	4,930 (8,381)	5.7%
2	4,759 (8,090)	4,459 (7,580)	6.3%
3	3,159 (5,370)	2,900 (4,930)	8.2%
4	4,930 (8,381)	4,595 (7,812)	6.8%
5	3,590 (6,103)	3,359 (5,710)	6.4%
6	3,850 (6,545)	3,520 (5,984)	8.6%

Table 4. Storm Window Energy Savings

	Percent Energy Savings	Reduced Therm Usage	Annual Savings (at $1.39/Therm)	Glass Area, ft^2 (m^2)	Therms Saved per ft^2 (m^2)
House 1* – low-e	27%	432	$600	132 (12.3)	3.27 (35.2)
House 2 – low-e	19%	353	$490	72 (6.7)	4.90 (52.7)
House 3 – Clear	8%	80	$111	107 (9.9)	0.75 (8.1)
House 4 – Clear	18%	228	$317	62 (5.8)	3.68 (39.6)
House 5 – low-e	23%	245	$341	58 (5.5)	4.23 (45.5)
House 6* – low-e	19%	105	$145	65 (6.0)	1.61 (17.3)

* Homes 1 and 6 did not have very high daily temperature to gas usage correlation coefficients requiring them to be removed from the final energy data analysis.

Fig A. 6 Airtightness testing on existing homes, via Oak Ridge National Laboratory[126]

APPENDIX A: HOUSE CHARACTERISTIC TABLE

House	Street Reference	Datalogger Type	# Stories	Heater Type	Year Built	Building Type	Conditioned ft^2 (m^2)	Window Area ft^2 (m^2)	Number of Windows	Before Airtightness cfm (m^3/hr)	After Airtightness cfm (m^3/h)
1	Whipple	Hobo Quadtemp Data Watcher	1	Hot Water Boiler	1930's	Bungalow	1625 (151)	132 (12.3)	33	5,230 (8,891)	4,930 (8,381)
2	Kedzie	Campbell Datalogger	1	Gas Furnace	1950	Bungalow	2250 (209)	72 (6.7)	12	4,759 (8,090)	4,459 (7,580)
3	Wabash	Campbell Datalogger	2	Gas Furnace	1935	Bungalow	1125 (105)	107 (9.9)	11	3,159 (5,370)	2,900 (4,930)
4	73rd	Campbell Datalogger	2	Gas Furnace	1925	Bungalow	1150 (107)	62 (5.8)	22	4,930 (8,381)	4,595 (7,812)
5	167th	Campbell Datalogger	1	Gas Furnace	1965	Ranch	2160 (201)	58 (5.5)	12	3,590 (6,103)	3,359 (5,710)
6	Perry	Hobo Quadtemp Data Watcher	1	Hot Water Boiler	1970	Bungalow	2500 (232)	65 (6.0)	24	3,850 (6,545)	3,520 (5,984)

Fig A. 7 Airtightness testing on existing homes, via Oak Ridge National Laboratory[127]

[126] Ibid
[127] Ibid

Modern Energy Efficiency Strategies

Historic House Museums

Truman White House, Key West, FL, 1890.[128] [Climate: tropical savannah climate] First built as officer's quarters for the submarine base naval station, this home gained notoriety when Truman began to use it as his winter holiday home in 1946. In 2009, the staff implemented a restoration project which included updating the HVAC system in order to properly preserve their interior collections and prevent humidity damage. "More than 85 percent of the historic fabric remains intact, so it was very important that we select the right HVAC system to protect the structure, our original furnishings and documentary collections. That's why we chose The Unico System of St. Louis," said Bob Wolz, executive director of Truman House.[129]

- ◊ HVAC: The house is divided in five zones with five air handlers and four chillers, completely self-contained air-to-water heat pump chillers that use chilled water circuit instead of refrigerant. This system allows individual chillers to work in a single area without the entire system running at full capacity. Unico's has circular outlets customized to complement the house interior, it was installed in the attic and 18 inch crawl space and is virtually undetectable. The Unico System is a small-duct, high-velocity central heating and air conditioning system which was installed in just one-third the space of more traditional HVAC ducting systems, and is quieter and less visible than many other systems.

---

[128] "The Truman White House Renovation," National Trust for Historic Preservation, accessed January 15, 2014. http://www.preservationnation.org/support-us/marketing--sponsorships/partners/unico/unico-truman-case-study.html#.Uwo6jEJdVKg
[129] Ibid.

HVAC upgrade and correct sizing

Upgrading HVAC systems is often seen as the golden goose of efficiency improvements. However a new system can be a waste if not properly installed and sized. Incorrect sizing (usually too large) will cause the system to cycle on and off constantly as the internal temperature reaches the desired temperature. This may seem more efficient because the system has periods where it is 'off', however it would be more efficient to have a smaller sized system that runs on less energy constantly. Failing to ensure ducts are properly insulated and sealed will cause unnecessary energy loss which will cause what appears to be a need for a larger HVAC system. Installing a vapour barrier, insulation, radiant barrier and sealing, caulking and weatherstripping will cut down on infiltration, conduction and radiation, and sizing your system after these efforts will lead to a far truer size.

The Seasonal Energy Efficiency Ration (SEER) rating indicates the operating cost of the unit. The reduction in kilowatt usage can be calculated using the table below by identifying the rating you would like to purchase and the correct size of the system. Lennox International Inc provides a calculator which is useful for calculating savings on an individual basis.[130]

[130] "Energy Savings Calculator," Lennox Residential, accessed April 4, 2014. http://www.lennox.com/resources/energycalculator.asp

Table A.2 SEER estimated air conditioning kilowatt demand (per hour)

SEER	**Estimated air conditioning kilowatt demand (for each hour of operation)**							
	1.5 TON	2 TON	2.5 TON	3 TON	3.5 TON	4 TON	4.5 TON	5 TON
10	1.80	2.40	3.00	3.60	4.20	4.80	5.40	6.00
11	1.64	2.18	2.73	3.27	3.82	4.36	4.91	5.46
12	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
13	1.38	1.85	2.30	2.77	3.23	3.69	4.15	4.60
14	1.29	1.71	2.14	2.57	3.00	3.43	3.85	4.28
15	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
16	1.11	1.51	1.91	2.31	2.71	3.11	3.51	3.82
17	1.02	1.42	1.82	2.22	2.62	3.02	3.42	3.42

Courtesy of LCEC[131]

[131] "Cooling and Heating," LCEC – Lee County Electric Cooperative, accessed April 6, 2014. https://www.lcec.net/energy-efficiency/green-energy-tips/cooling-and-heating.

Villa Finale, San Antonio, TX, 1876. [Climate: transitional humid subtropical]

The last home of locally renowned preservationist Walter Nold Mathis, this home has come to represent preservation in the King William National Historic District in San Antonio.

- ◊ Windows: 3m Prestige line ceramic-based UV film.

UltraViolet Blocking Film

UV film is applied directly to window panes and can be either tinted or clear. It acts as a barrier for infra-red radiation, reducing solar gain. However it has negligible insulating effect, and is not to be confused with clear plastic film which is applied over the entirety of historic windows in colder climates to create a second insulating barrier of air between the interior and the infiltration coming through the window.

3m describe their product, used at Villa Finale as the following: "Prestige Series window films use non-metallized, multi-layer optical film and nano-technology to reject up to 97% of the sun's infrared light and reject up to 60% of the heat coming through your windows. These films also reject up to 99.9% of damaging UV rays to reduce fading of your furnishings"[132]

[132] "Prestige Series," 3M, accessed February 7, 2014. http://solutions.3m.com/wps/portal/3M/en_US/Window_Film/Solutions/Markets-Products/Residential/Sun_Control_Window_Films/Prestige_Series/

Table A.3 Effect of 3M UV film on solar gain

Glass Type (All ¼)	Single Pane Clear	Single Pane Tinted	Double Pane Clear	Double Pane Tinted
Visible Light Transmitted	69%	42%	62%	37%
Total Solar Energy Rejected	50%	57%	44%	59%
Total Solar Energy Rejected — On 60° Angle	59%	63%	50%	62%
Infrared Rejected	97%	97%	97%	97%
Visible Light Reflected Int.	9%	7%	13%	12%
Visible Light Reflected Ext.	9%	6%	15%	8%
UV Rejected	99.9%	99.9%	99.9%	99.9%
Glare Reduction	22%	22%	22%	22%
Solar Heat Gain Coefficient	0.50	0.43	0.56	0.42
U Value	0.99	0.99	0.47	0.47
Luminous Efficacy	1.4	1.0	1.1	0.9

Technical Sheet Courtesy of 3M[133]

[133]"Prestige Series PR 70: Sun Control Window Films" 3M Multimedia, accessed February 4, 2014. http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuH8gc7nZxtUm8mBox_9evUqe17zHvTSevTSeSSSSSS--&fn=Prestige%20PR%2070%20Sample%2070-0709-01

Mark Twain House, Hartford, CT, 1874.[134] [Climate: humid continental]

A 33,000 square foot museum center was added to the 19 room Victorian mansion in 2003. In combination with the restoration, a sustainability initiative including resource conservation, environmental education and an energy management plan was developed. Using the EPA's Portfolio Manager tracking tool, they were able to benchmark their energy use and identify low or no cost measures for energy reduction.

- ◊ HVAC: upgraded HVAC appropriate for size and zones of building (future.)
- ◊ Lighting: LED in historic house and HID (high intensity discharge) lighting for outdoor spaces and parking (future.)
- ◊ Controls: Occupancy sensors throughout building.
- ◊ Recommissioning.
- ◊ Renewables: PV array (future.)

In September of 2009, the staff calculated a realized reduction of 138kBtu/sq ft since the beginning of the benchmarking period in January. They have demonstrated a reduction in weather normalized energy use of 24% more efficient than national average for entertainment facilities nationwide. [135] The Mark Twain House is an EnergyStar partner, one of the first museums in the country to achieve this standard.

---

[134] "EnergyStar Success Story: Mark Twain House & Museum," EnergyStar, accessed March 5, 2014. https://www.energystar.gov/ia/business/entertainment/Success_Story_MarkTwainHouse_Museum.pdf

[135] According to the The Energy Information Administration's Commercial Building Energy Consumption Survey (CBECS) 2003 the average energy intensity of an entertainment structure is 265 kbtu/sf/year."

Occupancy Sensors

The Lighting Research Center at the Rensselaer Polytechnic Institute and the EPA ENERGYSTAR program combined efforts to study the potential energy and cost savings for movement-based occupancy sensors. They identified opportunities for cost savings in break rooms, classrooms, conference rooms, private offices and bathrooms, during period of occupation and inoccupation with various time delays on the sensor shutoff.

> "People do not occupy spaces for a large percentage of time, and are not diligent about controlling the lighting in their spaces both during the workday, and after hours and weekends. This applies to both public spaces as well as personal spaces. The majority of this energy waste occurs during the weekdays, not during the weeknights or over the weekends. This pattern of energy waste is particularly suited to control by occupancy sensors, which not only prevent runaway operation after typical business hours, but also capture savings during the business day. "[136]

The results of the study were summarized as follows by the Lighting Controls Council of NEMA (National Electrical Manufacturers Association)[137]

Table A.4 Occupancy Sensor Energy Waste and Energy Savings table

Energy Waste and Energy Savings table for simulations			
Application	Energy waste	Energy savings using 5 min delay	Energy savings using 20 min delay
Break Room	39%	29%	17%
Classroom	63%	58%	52%
Conference Room	57%	50%	39%
Private Office	45%	38%	28%
Restroom	68%	60%	47%

---

[136] Bill VonNeida, Dorene Maniccia, Allan Tweed, "An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems," Lighting Research Center at the Rensselaer Polytechnic Institute and U.S. EPA, August 16, 2000. http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf

[137] "Demand Reduction and Energy Savings Using Occupancy Sensors" prepared by the Lighting Controls Council, National Electrical Manufacturers Association, updated October 24, 2001, accessed April 2, 2014. http://www.nema.org/Policy/Energy/Efficiency/Documents/demandreduction.pdf

Information courtesy of NEMA Lighting Controls Council

In addition to motion-controlled occupancy sensors, Demand Controlled Ventilation DCV through carbon dioxide monitoring and infra-red heat monitoring is an option for exhibit spaces with sporadic or seasonal visitation. Using carbon dioxide monitoring ensures good indoor air quality while reducing unnecessary conditioning of a space, allowing oxygen rich air to be cycled through the system continuously when carbon dioxide is not being produced by occupants.

Hooper Strait Lighthouse Chesapeake, VA, 1879 [Climate: humid subtropical]

- ◊ Lighting: Fresnel lens in lighthouse now runs on a 16 watt CFL.

Lighting

Lighting has advanced rapidly in the last decade, and now there are many options whose lighting is still being studied for its effect on human performance and the conservation of vulnerable collections. Since the technologies are still developing, some irritations have emerged with issues such as compatibility of dimmable ballast bulbs, the spectrum of colour and light, and lumens per watt. However conservation doubts in regards to the impact of new lighting on collections are still under debate, and should be taken into consideration. The Smithsonian American Art Museum published a summary of their conference on “Gallery Illumination: LED Lighting in Today’s Museums” in which they discussed the growing opportunities for LED lighting in museum environments, given monitoring by staff and thoughtful installation based on an understanding of the needs of the collections. [138]

Table A.5 Energy Use of Lightbulb by Lumen Output

Energy Use of Lightbulb by Lumen Output				
	Incandescent	Halogen	CFL	LED
800 Lumens	60 Watt	43 Watt	13 Watt	12 Watt
1100 Lumens	75 Watt	53 Watt	20 Watt	17 Watt
1600 Lumens	100 Watt	72 Watt	23 Watt	20 Watt
Rated Life	1 Year	1-3 Years	6-10 Years	15-20 Years

Courtesy of Champion Energy Services[139]

Bullitt Farmhouse, 1830.[140] Ashfield, MA. [Climate: Humid continental]

"The house has no furnace-no propane, no oil." Quigley, Director.

- ◊ Insulation: superinsulated in order to achieve an air conditioning system using as little fuel as possible.
- ◊ HVAC: the building's heat pump simply moves warm air around, and when it operates in optimal conditions, it can deliver up to 300% more heat energy than the electrical energy it consumes, a far cry from conventional methods.

[138] Summary of "Gallery Illumination: LED Lighting in Today's Museums" Smithsonian Art Museum, March 1, 2013. Accessed April 6, 2014. http://www.americanart.si.edu/conservation/program_docs/aic_summary.pdf

[139] "Watts Vs. Lumens- What's the difference" National Resources Defense Council Staff Blog, October 30, 2013, accessed March 2, 2014. http://switchboard.nrdc.org/blogs/nhorowitz/fall_back_into_energy-saving_l.html

[140] Jane Roy Brown, "These Walls Can Talk," *Special Places Magazine*, The Trustees of Reservations, Winter 2011-2012, accessed January 15, 2014. http://www.thetrustees.org/what-we-care-about/climate-change/archive/these-walls-can-talk.html

Westport Town Farm, 1720,[141] Westport, CT [Climate: humid continental]

- ◊ HVAC: energy-recovery ventilation system.
- ◊ Insulation: super-insulated attic.

Insulation and SuperInsulation

Insulation should be paired with air sealing to receive maximum benefits for reducing heating and cooling loads. Insulation reduces loss by conduction, increasing the thermal transmittance of a building by increasing the path of resistance between indoor and outdoor temperature differences.

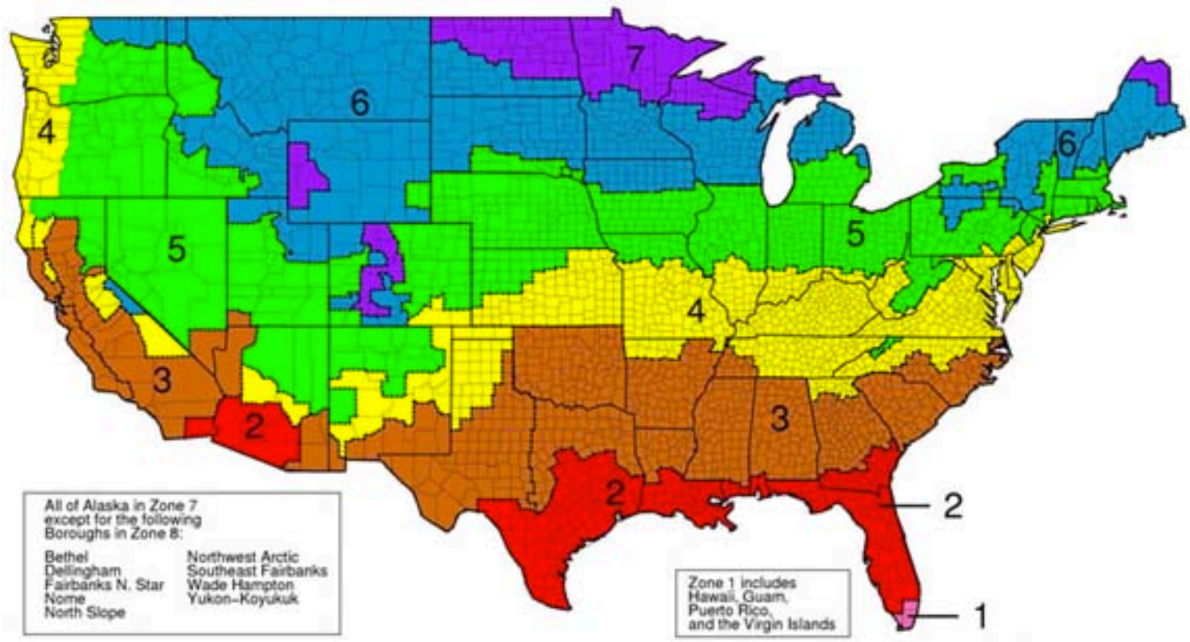
According to the National Park Service, insulating attics and basements or crawl spaces is the most cost and energy efficient manner of installing insulation in a historic building. Rarely do historic rehabilitation efforts offer the opportunity to improve the insulation of the walls without disturbing historic materials. However a lot of energy, 31% according to the Department of Energy, is lost through ceilings, floors and walls, therefore there is a significant improvement to be made, even with only two areas of focus.[142] Insulation should meet code standards, the Department of Energy has published a comprehensive list of the climate zones in the United States and recommended insulation R-values for basements and attics. R-value (measure of thermal resistance) is the inverse of U-value (measure of thermal transmittance) which is measures in W/m2/K, expressing the amount of heat transmitted across the material in watts, per meter squared, for each degree Celsius of temperature difference across the material (expressed in Kelvin.).

---

[141] "Everything Old Is New Again (cont.)" *Special Places Magazine*, The Trustees of Reservations, Winter 2012, accessed March 3, 2014. http://www.thetrustees.org/what-we-care-about/climate-change/everything-old-is-new-again-cont.html

[142] Weatherizing and Improving the Energy Efficiency of Historic Buildings, Technical Preservation Services National Park Service, accessed January 10, 2014. http://www.nps.gov/tps/sustainability/energy-efficiency/weatherization.htm

Superinsulation is a dramatic approach to construction and retrofit which results in buildings largely heated by their occupants and waste heat from appliances. It requires very high levels of insulation throughout, which is rarely possible in a historic rehabilitation, although achievable in a non-historic renovation.



Insulation Zone	Heating System	Attic	Cathedral Ceiling	Wall		Floor
				Cavity	Insulation Sheathing	
1	All	R-30 to R-49	R-22 to R-28	R-13 to R-15	None	R-13
2	Gas, Oil, Heat Pump Electric Furnace	R-30 to R-60	R-22 to R-38	R-13 to R-15	None	R-13 R-19 to R-25
3	Gas, Oil, Heat Pump Electric Furnace	R-30 to R-60	R-22 to R-38	R-13 to R-15	None R-2.5 to R-5	R-25
4	Gas, Oil, Heat Pump Electric Furnace	R-38 to R-60	R-30 to R-38	R-13 to R-15	R-2.5 to R-6 R-5 to R-6	R-25 to R-30
5	Gas, Oil, Heat Pump Electric Furnace	R-38 to R-60	R-30 to R-38 R-30 to R-60	R-13 to R-15 R-13 to R-21	R-2.5 to R-6 R-5 to R-6	R-25 to R-30
6	All	R-49 to R-60	R-30 to R-60	R-13 to R-21	R-5 to R-6	R-25 to R-30
7 & 8	All	R-49 to R-60	R-30 to R-60	R-13 to R-21	R-5 to R-6	R-25 to R-30

Fig A.8 Insulation Zones, via EnergyStar[143]

[143] "Recommended Levels of Insulation" EnergyStar, accessed April 2, 2014. http://www.energystar.gov/?c=home_sealing.hm_improvement_insulation_table

Bryant Homestead, 1799.[144] Cummington, MA [Climate: Humid continental]

The curators of this National Historic Landmark effected an energy audit in order to identify the weakest points in the building's energy performance. Auditors designed a strategy to preserve the historic character of the building while weatherizing it to have a tighter seal.

- ◊ Insulation: The vent stack allowed warm air to float straight out of the building, so sealing off the vent stack required using spray foam insulation in every unused plumbing conduit in the building. The attic was insulated to code, and the seams around doors and windows were caulked (recommended by the Secretary of the Interior's Standards for Rehabilitation Guidelines for Sustainability.)
- ◊ Windows: Most of the windows were structurally sound, but old, and cracked putty allowed heat emission. Staff removed the window panes and used latex acrylic rather than the original linseed putty (which contains lead) to glaze the panes back into place. The restoration team also added new weather stripping on all the sashes and silicone strips for tighter seals at the muntin. [This information also included in Chapter 3.]

Teackle Mansion, 1802-1819.[145] Princess Anne, MD. [Climate: Humid subtropical]

- ◊ Renewables: Geothermal heat pumps installed in 2010. A series of 25 wells 100 feet in the ground have been connected to the house's heating and

---

[144] Jane Roy Brown, *Let It Snow!,* Special Places Magazine, The Trustees of Reservations, Winter 2011-2012, accessed January 15, 2014. http://www.thetrustees.org/what-we-care-about/climate-change/let-it-snow.html

[145] "Maryland Mansion Goes Green - National Trust for Historic Preservation."*Preservationnation.org*. Accessed March 5, 2014. http://www.preservationnation.org/magazine/2010/todays-news/maryland-mansion-goes-green.html?utm_source=facebook&utm_medium=like&utm_campaign=Maryland Mansion Goes Green

cooling system. The planning took five years in order to map the system through the mansion's 10,000 square feet of varying ceiling height.

Geothermal Heat Pumps

A geothermal heat pump, also called a ground source heat pump, works by either transferring heat to or from the ground. At a certain depth, the earth has a predictably constant temperature between 50 F and 60 F. In winter, 50 F is still far warmer than the air conditions in many U.S. states, where temperatures routinely drop below freezing for many months, and in summer, 60 F is far cooler than the 100F temperatures experienced in southern climates. Fundamentally, the heat pump consists of a loop of refrigerant pumped through a vapor compression refrigeration cycle that moves heat.[146] There are various types of systems, which are more or less appropriate depending on climate, location and availability of resources- for example horizontal systems are simple when land is plentiful, however when real estate is limited, a vertical system can substitute. Proximity to an appropriate body of water can cut costs by requiring no digging or drilling.

U.S. Department of Energy explains

> "The biggest benefit of GHPs is that they use 25% to 50% less electricity than conventional heating or cooling systems. This translated into a GHP using one unit of electricity to move three units of heat from the earth. According to the EPA, geothermal heat pumps can reduce energy consumption – and corresponding emissions – up to 44% compared with air-source heat pumps and up to 72% compared with electric resistance heating with standard air-conditioning equipment. GHPs also improve humidity control by maintaining about 50% relative indoor humidity, making GHPs very effective in humid areas."[147]

---

[146] "Geothermal Heat Pumps," U.S. Department of Energy, accessed April 4, 2014. http://energy.gov/energysaver/articles/geothermal-heat-pumps
[147] Ibid

Climatemaster has developed a calculator which aids clients in understanding whether a system is appropriate for their climate.[148] EnergyStar published a 'Most Efficient 2014' list for Geothermal Heat Pumps[149] which identify the savings that the EPA estimates a geothermal heat pump could improve an HVAC energy use based on the system. The following is only one in a long list available through EnergyStar.

Bosch-Geo 6000 Series with RS Pro or RS Pro F Control

Features:
- Bosch-Geo 6000 series dual-capacity geothermal water-to-air heat pumps equipped with DDC control system.
- Digital communication via common DDC protocols. Advanced diagnostic reporting and simple plug in service connections.
- Closed loop EER's as high as 19.2 for full-load cooling and 28.2 for part-load.
- 10-year limited parts and labor warranty.

Configuration	Capacity	Energy Use:		Annual Energy Use	Annual Cost (National Average)*	Lifetime Cost to Operate**	% Saving over Federal Minimum
		EER	COP				
Closed Loop	28,500	23.4-23.5	4.3-4.4	1,769	$293	$2,893	46%
	38,200	23.4-23.5	4.3-4.4	2,371	$293	$2,893	46%
	52,000	23.4-23.5	4.3-4.4	3,228	$293	$2,893	46%
	67,000	23.0-23.1	4.3-4.4	4,201	$458	$6,869	45%
	74,000	21.5-21.6	3.9-4.0	5,027	$548	$8,220	41%
Open Loop	31,000	28	5	1,628	$177	$2,662	54%
	41,200	28.5	4.9	2,161	$236	$3,533	54%
	56,000	28.0-28.3	4.8-4.9	2,982	$325	$4,875	54%
	71,000	28.2	5.1	3,682	$401	$6,020	55%
	78,000	21.5-21.6	3.9-4.0	4,551	$496	$7,442	59%

Fig A.9 Example of estimated energy savings of one geothermal heat pump system, based on capacity.[150]

[148] "Geothermal Savings Calculator," Climate Master, accessed February 4, 2014. http://www.climatemaster.com/residential/geothermal-savings-calculator/sc01.php
[149] "Geothermal Heat Pumps," EnergyStar, accessed February 4, 2014. https://www.energystar.gov/index.cfm?c=most_efficient.me_geothermal_heat_pumps
[150] "Geothermal Heat Pumps," EnergyStar, accessed February 4, 2014. https://www.energystar.gov/index.cfm?c=most_efficient.me_geothermal_heat_pumps

Museums

Field Museum of Natural History, 1893.[151] Chicago, IL [Climate: Humid continental]

- ◊ HVAC: The museum uses an efficient Central Plant chiller system, which makes ice at night to reduce demand on the electrical grid, and then circulates the conditioned air based on demand and strict environmental parameters.

Brooklyn Children's Museum, 1899.[152] Brooklyn, NY. [Climate: Humid continental]

- ◊ HVAC: The museum's geothermal system draws stable-temperature water from Brooklyn's underground aquifers to a series of heat pump air handlers that control the temperature of the building.
- ◊ Renewables: Photovoltaic systems are publicly visible and used in education.
- ◊ Controls: The museum's ventilation system automatically adjusts to accommodate the number of visitors in each space at any given time, using CO2 monitors and computerized controls.
- ◊ Lighting: Occupancy sensors that detect body heat and motion control the lights in offices, classrooms and restrooms. The general lighting in the Museum uses CFL and LED lighting.
- ◊ Daylighting: Photoelectric cells adapt lighting to weather conditions.

---

[151] "The Field Museum of Natural History: Sustainable Practices in Collections Management," Sustainable Operations Toolkit, PIC Green, accessed January 10, 2014. http://www.pic-green.net/wp-content/uploads/FMNH-Sustain-Collect-Mgmnt-v3.pdf?utm_source=Jan+2014%2C+AAM+PIC+Green+-+Collection+Mngmnt+v2&utm_campaign=Jan+2014+PICGrn+Nwsltr&utm_medium=email

[152] "First 'Green' Museum in New York City," Brooklyn Children's Museum website, accessed February 21, 2014. http://www.brooklynkids.org/index.php/aboutus/greenmuseum

The Museum estimates a $100,000 saving in energy costs. Funding: The New York State Energy Research and Development Authority (NYSERDA) donated $250,000 toward photovoltaic panels and an energy analysis, while the New York Power Authority has provided $500,000 for the geothermal mechanical system.

Children's Museum of South Dakota, 1936.[153] Brookings, SD. [Climate: Continental]

- ◊ HVAC: highly efficient systems demonstrated a 26% improvement on the ASHRAE 90.1- 2007 requirements.
- ◊ Lighting: EYE Ceramic Metal Halide Lighting.

British Museum, 1753.[154] London, England. [Climate: Temperate oceanic]

- ◊ HVAC: Heat recovery systems on all ventilation systems and laboratory exhausts. Close control over fume cupboard extraction. Ground source heat transfer to mitigate basement heat loss and provide cooling to upper floors.
- ◊ Controls: Photosensors will identify whether enough light is present to provide natural daylighting before illuminating lights. Motion sensors identify whether people are present, and extinguish lights when rooms are empty.
- ◊ Renewables: roof mounted photovoltaic arrays.

Montclair Art Museum, 1914. Montclair, NJ. [Climate: Mesothermal]

---

[153]SDSU Daktronics Engineering Hall Addition, Children's Museum of South Dakota Awarded LEED Silver, Architecture Incorporated News, *Architecture Incorporated News,* June 14, 2013. www.architectureinc.com/news/archives?newsid=219

[154] "Biodiversity and Sustainability," The British Museum, accessed February 15, 2014. http://www.britishmuseum.org/about_us/the_museums_story/new_centre/explore_the_centre/biodiversity__sustainability.aspx

The museum completed a comprehensive master plan with the help of an architect and an engineer who made recommendations for improved building performance.

- ◊ Retrocommissioning

Phipps Conservatory and Botanical Gardens, 1893.[155] Pittsburgh, PA [Climate: Humid continental/humid subtropical]

The building achieved LEED Platinum certification, Sustainable Sites Initiative (SITES) pilot program status, and Living Building Challenge participant.

- ◊ Ventilation: innovative roof vent and shading system.
- ◊ Cooling: Earth tubes.
- ◊ Fuel: Solid Oxide fuel cell which powers structure.
- ◊ Monitoring: energy and water monitoring for real time monitoring of use for each building.

Boston Children's Museum, (19th C) Boston, MA. [Climate: Humid continental]

- ◊ Windows: High performance glazing
- ◊ Controls: Carbon dioxide monitors to identify real-time heating and cooling need.
- ◊ Lighting: highly efficient fixtures, including halide lighting.

Adirondack Museum, 1957.[156] Blue Mountain Lake, NY [Climate: Humid continental]

- ◊ Renewables: Photovoltaic array on roof of the special exhibits gallery.

---

[155] Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham, Altamira Press. 2008

[156] Ibid.

Historic Buildings

Empire State Building, 1929. New York, NY.[157] [Climate: Humid continental]
Given the improvements, the load was reduced to such a degree that the existing chiller plan could be renovated rather than replaced and expanded, saving $17 million dollars in expenditure.

- ◊ Windows: remanufactured on site to reduce solar heat gain and conduction. The staff estimate that this cut winter heat loss by at least 66% and summer heat gain by 50%.
- ◊ Insulation: radiant barriers inserted into perimeter heating units to ensure heat reflected into building rather than radiating out.
- ◊ HVAC: variable air volume air handlers
- ◊ Lighting: photosensors in perimeter areas reduce overhead lighting load, and plugload occupancy sensors inform tenants of use.
- ◊ Controls: real time feedback to help users understand and benchmark their energy use. Demand Control Ventilation (DCV) inside building uses CO2 levels to optimize outdoor air intake to reduce the conditioning load.
- ◊ Monitoring systems: Direct Digital Controls (DDC) optimize HVAC operation and provide a more granular sub-metering of energy use.

Estimated cost of retrofit: $106 million for energy related work.

Trinity Church, 1872. Boston, MA. [Climate: Humid continental]

- ◊ Renewables: six geothermal wells were installed close to the church's exterior. Trinity Church plans to keep the resolutions adopted in 2000 by the Episcopal Church's General Convention and Massachusetts' Diocesan

[157] "Empire State Building Case Study," Empire State Building, accessed February 20, 2014. http://www.esbnyc.com/documents/sustainability/ESBOverviewDeck.pdf

Convention, both encouraging the use of environmentally safe and sustainable energy sources.[158]

Federal Historic Buildings

Hipolito F. Garcia Federal Building and United States Courthouse, 1937.[159] San Antonio, TX. [Climate: Humid subtropical]

- ◊ Windows: Interior storm windows added to increase efficiency without affecting the exterior façade.
- ◊ HVAC: high efficiency boilers and chillers
- ◊ Controls: lighting control systems, building automation and energy recovery system.
- ◊ Renewables: photovoltaic panels.

Estimated energy savings: 38.8% and a cost savings of $87,515 per year.

Department of the Interior, Headquarters Building, 1936.[160] Washington, D.C. [Climate: Humid subtropical]

- ◊ Lighting: Submetered and dimmable CFL and LED lighting.
- ◊ HVAC: efficient mechanical systems installed with minimal impact on the historic materials, and a new chilled water plant was installed with dedicated outdoor air systems.
- ◊ Daylighting: maximizing interior daylight.
- ◊ Windows: Historic windows were retained and their energy efficiency was bolstered by the addition of the blast windows.

---

[158] David Trueblood, "Boston's Trinity Church begins renovations with drilling of geothermal wells," The Episcopal Church, January 9, 2002. http://library.episcopalchurch.org/article/bostons-trinity-church-begins-renovations-drilling-geothermal-wells

[159] Sylvia Hernandez, "GSA Completes Restoration of Hipolito Federal Building," General Services Administration blog, November 8, 2012. https://gsablogs.gsa.gov/gsablog/2012/11/08/gsa-completes-restoration-of-hipolito-federal-building/

[160] Kurt Stout, "A LEED System for Tenants: LEED-CI," Capitol Markets, January 25, 2014. http://www.capitolmarkets.com/sustainability/leed-system-tenants-leed-ci/

Commercial Historic Buildings[161]

<u>Doty and Miller Office</u>, 1934. Bedford, OH. [Climate: humid continental]
This former U.S. Post Office was renovated by architects Doty and Miller and achieved LEED Gold in 2007.

- ◊ Renewables: historic awnings restored as solar panels. Used as 'recommended' example by National Park Service in a Preservation Brief.


Fig A.10 Doty and Miller Office, courtesy of National Park Service

This building was used as an example by the National Park Service in its Technical Brief on *Incorporating Solar Panels into a Rehabilitation Project.*[162] The National Park Service states that given its unobstructed access to sunlight, the roof of a historic structure is 'an obvious location' for photovoltaic panels, as long as they are minimally visible and do not interfere with the historic character of the building.

In the United States, typical insolation ranges from 4 to 6.5 KWH/m2/day and panels have an average efficiency of 15% (meaning they can capture and process 15% of the energy they receive) while top end commercial panels can achieve

---

[161] The information on the Alliance Center, Beardmore Building, Christman Building, Northern Plains Resource Council, Lovejoy Building, 200 Market Building, and Mercy Corps are courtesy of the NEEA's Study of Existing Building Energy Efficiency Renewals, prepared for the Northwest Energy Efficiency Alliance and the New Buildings Institute.[161]
[162] Jenny Parker, *Incorporating Solar Panels in a Rehabilitation Project,* Technical Preservation Services, National Park Service, August 200-, ITS Number 52

upwards of 20% efficiency. In general terms, a typical 150 KW panel is about 1 m2 in size. Energy production varies by angle of orientation, location and climate.[163] Rebates can make solar cells very affordable to install.

Alliance Center, Denver, CO, 1908[164] [Climate: transitional zone between semi arid climate type and sub-humid dry-summer continental]

The actual energy use of the building is currently 42 kBtu/sf/yr, which is 55% better than the average for U.S. office buildings. The Alliance Center gets about 1,000 visitors a year given its role as a resource for implementing energy-efficient measures in businesses and homes.

- ◊ HVAC: Pneumatic temperature controls replaced with Direct Digital Controls (DDC) to allow building operators to set heating and cooling levels via computer. Capability for temperature monitoring and 'load shedding.'
- ◊ UV film: Mylar film applied to interior of east and west facing windows to reduce glare and reflect 60% of direct radiation. In winter the installation means that heat is reflected back into the internal space.
- ◊ Daylighting: Super-efficient ballasts installed on the fifth-floor east wing include photocell sensors that dim when daylight is present. Cubicles feature translucent wall panels which allow the interior spaces to receive natural daylight. Sixth-floor windows have window shade screens to control light and glare levels and reduce heating gains and losses.

---

[163] "Types of Photovoltaic Systems," Florida Solar Energy Center, accessed April 14th, 2014. http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/types_of_pv.htm

[164]"NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014. http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

◊ Controls: The lighting control system includes wall- and ceiling-mounted occupancy sensors in the private offices and meeting rooms. The time schedules for the air handling unit are set by a building automation system which interfaces through the direct digital control system.

◊ Retro-Commissioning: The company learned that the mechanical plans provided were not accurate. A rooftop unit was replaced, economizers were added and ventilation levels were increased.

◊ Renewables: 2.04 kW rooftop PV array.

◊ Monitoring systems: Sub-meters installed to provide detailed information on energy use.

Total project cost: $117,000 $3.07/sf (after incentives)Not including the local utilities Demand Side Management program for the bulb and lighting ballast upgrades. And an $11,200 grant from a local solar company for the PV. A $15,000 grant from the State Historic Fund in Colorado was awarded to provide a historic structure assessment and preservation plan, including detailed guidance on historic renovations, upgrades, and general upkeep. The upgraded lighting system alone was estimated to reduce that portion of its energy costs by over 40%, and that the retrofit would pay for itself in 26 years. The annual cost savings were estimated at $8,800.

Beardmore Building, Priest River, ID, 1922[165] [Climate: transitional zone between semi arid climate type and sub-humid dry-summer continental]

Excluding the theater, the Beardmore uses 32 kBtu/sf/yr (EUI1) – 66% less energy per square foot than the average for offices in the U.S. compared to average energy use for all U.S. office buildings through the Commercial Building Energy Consumption Survey (CBECS.)

- ◊ HVAC: Installed high-efficiency, packaged rooftop heat pumps with economizers, along with demand control ventilation (DCV) with CO2 sensors and modulating outside air dampers. This allows ventilation to be based on actual occupancy rather than assuming full occupancy, and thereby reduces energy needs for conditioning and moving the air. The mechanical engineer determined that the common area of the building did not require cooling and instead designed a barometric damper assisted by ceiling fans located at the curb of the skylights to exhaust air and create a convection-based air flow within the central atrium. Extensive insulation was added to the exterior walls, including R-50 for the roof cavities.
- ◊ Windows: Low-E insulated glazing.
- ◊ Solar Gain: Reduced heat island effect resulted through the use of improved roofing materials and coatings with a high solar reflectance index.
- ◊ Lighting: Vintage light shades were preserved and rebuilt with new fixtures using high-efficiency compact fluorescents. The central lighting system has a night set-back to ensure low-to-no energy use during unoccupied times.
- ◊ Controls: Restrooms have occupancy sensors. DCV with CO2 sensors.
- ◊ Renewables: The building is wired and ready for photovoltaic panels

[165]"NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

- ◊ Site: The site experienced a reduced heat island effect through the location of shaded parking areas.
- ◊ Monitoring systems: Whole-building and individual tenant electric meters are used throughout.

Funding and incentives: Because the Beardmore Building was on the historic register, the owner received a tax credit of $366,571 for construction costs from the National Park Service, which was awarded for adhering to the Secretary of the Interior's Standards for Rehabilitation. The local utility provided a LEED ertification and HVAC efficiency incentive of $71,079.

Estimated annual cost savings: The LEED modeling analysis estimated an annual cost savings when fully occupied of $23,370, a reduction of more than 50% compared to the national average of buildings of same type, size, occupancy, and climate zone.

<u>The Christman Building</u>, Lansing MI, 1928[166] [Climate: humid continental]

- ◊ HVAC: HVAC systems and selected equipment to minimize energy use while providing individually-controlled comfort conditions. Under-floor air distribution system estimated to be more energy-efficient than conventional ducted systems. All cooling equipment uses environmentally friendly refrigerants.
- ◊ Roof: White roof and 6″ of added insulation to reduce the urban heat island effect and energy use.
- ◊ Windows: The original front façade window frames restored and fitted with double-glazed glass. Side and rear exterior windows replaced with high-efficiency aluminum windows.
- ◊ Lighting: High-efficiency fixtures and T-5 fluorescent lamps with a very high color-rendering index (CRI). All workstations have individually controlled multi-level task lighting. There are occupancy sensors in private offices and stairways and programmed control panels in common spaces. Energy consumption is projected to be 27% lower than that observed with a standard system.
- ◊ Daylighting: Windows provide daylighting to 92% of occupied spaces building-wide, and outside views to 90% of the occupants.
- ◊ Controls: The web-based building management system (BMS) has several thousand control points which are used to operate the building systems for maximum efficiency and comfort. Energy use is metered at the building and tenant levels to encourage conservation. Lighting includes program control panels and occupancy sensors.

---

[166] "NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

◊ Computer network controls: IT program that enables central control of computers and monitors and allows equipment to be put into sleep mode when not in use.

◊ Commissioning: Re-commissioning and ongoing commissioning of all HVAC, lighting and domestic water systems ensure all systems operate as designed and are continually fine-tuned.

Northern Plains Resource Council, Billings, MT, 1940[167] [Climate: semi arid] Energy use of the building in 2010 of 46 kBtu/sf/yr (EUI1) and an average energy use since occupancy of just 44 kBtu/sf/yr - approximately half that of the average for offices in the U.S. [The Energy Information Agency's Commercial Buildings Energy Consumption Survey 2003]

◊ HVAC: The building has a high-efficiency boiler; a radiant-floor hydronic system, which uses less energy than an air-based system; and a direct evaporative cooling system, which is more efficient than refrigeration air conditioning in Billings' climate zone. Fans use variable frequency drives.

◊ Monitoring: CO2 levels allows Northern Plains to minimize the percentage of outside air exchanged in the building while meeting ASHRAE standards for commercial buildings.

◊ Envelope/Insulation: Energy demand was minimized with a building shell insulated to a higher degree than required by code.

◊ Windows: Low-E windows.

[167]"NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

◊ Solar Gain: Exterior walls and roofs were painted a light color, and the south windows incorporate the use of exterior louvers, awnings and trellises to reduce solar heat gain.

◊ Lighting: T8 fixtures are used throughout the building. Daylight sensors turn off or dim fixtures when there is sufficient ambient light. Only during the winter months is natural light insufficient for general illumination.

◊ Daylighting: Open floor plan to allow daylighting to penetrate the space. Openings in the existing building (virtually windowless) strategically located around the perimeter and on the roof (skylights) to deliver daylight. Perimeter windows have light shelves that evenly distribute daylight by reflecting it to the ceiling plane. Building is almost entirely day-lit. NEEA/BetterBricks provided a daylighting analysis and lighting technical assistance through the Daylighting Lab in Seattle.

◊ Controls: Lighting controls consist of on/off photoelectric daylight sensors and occupancy sensors. HVAC controls incorporated into the project are thermostats with night set-back and occupancy-based CO_2 demand control ventilation (DCV). DCV allows for ventilation to be based on actual occupancy rather than assuming full occupancy, thereby reducing energy for conditioning and moving the air.

◊ Commissioning: The commissioning agent identified problems with the installation of the radiant-floor hydronic system and worked closely with the controls contractor to fine-tune the control system and allow for easier identification of issues by the building operator. Resulted in substantial savings in both maintenance and energy costs.

◊ Renewables: The building has a 9.9 kW photovoltaic (PV) system and a solar water heater on the roof. The PV system has produced an average of 34% of the electricity and 15% of total energy over the 2006-2010 period, and the system includes net metering, which facilitates the sell-back of excess electricity produced in the summer. Purchased energy is offset with green tags for wind power supplied through Green-e renewable energy contract. The efficiency aspects of the building – particularly evaporative cooling and daylight sensors to reduce electric lighting – lead to a peak electricity need on hot days lower than the PV generation.

◊ Site: Permeable parking lot, thus instead of asphalt, the parking lot is made of recycled, pulverized glass whose reflectivity mitigates the urban heat island effect and allows the wattage of parking-area lighting to be reduced.

Estimated annual cost savings: Demolishing the existing structure and building a new office building the same size to the model energy code (ASHRAE-90.1-1999) would have cost approximately $325,000 more than the cost of renovating to LEED Platinum status. Northern Plains realized an upfront cost savings of more than 20% to create a building with operating costs estimated to be 72% lower over a 20- year period.

The Lovejoy Building LLC, Portland, OR, 1910[168] [Climate: oceanic or temperate marine. Cool wet winters, warm dry summers]

The building's actual energy use is 40 kBtu/sf/yr, 57% better than the average for office buildings in the U.S. [The Energy Information Agency's Commercial Buildings Energy Consumption Survey 2003]

- ◊ HVAC: An in-floor PEX pipe hydronic system provides the building's primary heating and cooling, coupled with an integrated natural ventilation strategy using windows, skylights and ventilators. In the winter, water runs through the thermal mass, creating a stable temperature range while introducing heat low in the space. In the summer, the building is set for a night purge: cool night air introduced into the building removes the heat gains of the previous day, leaving the space cool for the next morning. In addition, the radiant slab hydronic system collects heat out of the slab, running the water through a rooftop chiller where the heat is removed; the cool water is then recycled back through the in-slab piping system. The radiant floor strategy requires significantly less space for equivalent heating and cooling than a material- and energy-intensive forced air system, with the additional benefit of less recirculated air, resulting in improved air quality and human comfort.
- ◊ Envelope: New high fly-ash concrete perimeter walls and a concrete floor system were poured in place, with the added benefit of improving the efficiency of heating and cooling the building by increasing its thermal mass.

[168] "NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

◊ Windows: The original windows were enlarged to improve views and bring light deep into the space. The addition of 14 skylights provides additional natural light to the top floor of the building. Low-E high-efficiency glass is used to minimize heat, and operable windows are controlled by the building management system to maintain temperature and air quality. Automated sunshades on the west face of the building block unwanted light and heat gains.

◊ Lighting: The primary lighting system is suspended direct/indirect T8 fixtures with dimmable ballasts. The lighting system includes integrated daylighting controls to automatically dim electrical light.

◊ Daylighting: The office space was modeled for uniform natural balanced daylight using a heliodon at the Energy Studies and Buildings Laboratory in Portland. Daylighting strategies include open office space, enlarged windows, skylights and a white ceiling for reflective purposes. Daylight controls reduce electric lighting, and west facing exterior automated sunshades reduce glare and heat gain.

◊ Controls: The lighting and HVAC systems are controlled by a whole building Energy Management Control System (EMCS) and sensors. The digital system modulates lighting according to daylight levels with zoned photocell sensors located on the open office ceiling. Automated sunshades on the west face of the building are controlled by photocells set to an astronomical clock. Opsis uses carbon dioxide (CO_2) sensors in the office to interpret occupancy density. This Demand Control Ventilation (DCV), sends data to the building management system to modulate ventilation air (which requires energy for conditioning) to accommodate actual occupancy needs. The original Direct Digital Controls (DDC) purchased for the building were reasonably-priced, but they lacked clear feedback and guidance. After three years, Opsis bought higher-end, more user-friendly controls.

- ◊ Plug Load Management: Installed an electricity management monitoring system to review plug loads and energy usage in real time.
- ◊ Commissioning: The project included enhanced commissioning, and the electricity management monitoring system allows for feedback to direct ongoing commissioning.
- ◊ Renewables: A photovoltaic system on the roof provides 2,500-watt maximum output.

200 Market Building, Portland OR, 1973[169] [Climate: oceanic or temperate marine. Cool wet winters, warm dry summers]

- ◊ HVAC:Variable speed drives on all pumps and fans. Variable air volume air handlers with waterside economizers
- ◊ Insulation: addition of two inches of polyisocyanurate insulation with a white asphalt cap
- ◊ Sensors: Dimmable lighting ballasts with motion sensors: cut output in the garage by 25% at ground level and by 50% on the second and third underground levels. Direct Digital Control system: operates the pumps on the cooling tower, optimizes the chilled water loop and overrides the pressure controls on the water storage tanks when the building is occupied
- ◊ Shading: translucent cloth shades on the perimeter single-pane windows

---

[169]"NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

◊ Elevator efficiency: converting to alternating current drives that run only when the elevators are in use. These measures reduced the operating electric load of the elevators by about 40 percent.
◊ Water pumps: temperature sensors on the hot water pumps' return lines so they no longer ran continuously. This simple measure paid for itself in two weeks.
◊ Primary cooling tower operates through a plate-and-frame heat exchanger. This system allows the condenser loop to operate as a closed loop, which during unoccupied hours can recapture heat and reduce runtime for the cooling tower and boiler systems.
◊ Two 15 hp city water pumps that had run 24/7 were replaced with two rooftop pressurized water storage tanks with pressure sensors, enabling the facilities team to ensure the pumps were running only when needed and that they could be turned off nights and weekends.
◊ In 2006 the building team reconfigured existing smoke evacuation shafts as intakes for fresh air. This simple measure improved the ventilation rate by 70%, reduced the fan and pump energy needed to meet ventilation requirements and provided free cooling

The 200 Market Building's measured energy use is 65 kBtu/sf/yr (EUI1), 30% less energy per square foot than the average for offices in the U.S. [The Energy Information Agency's Commercial Buildings Energy Consumption Survey 2003]

Project costs: $25,000,000 (1989) for boiler upgrade, variable-speed drives added to all pumps and fans and asbestos removal, the reconfiguring of the ground floor and upgrading of the life-safety systems. $11,000 (2000) for pressurized water tank/pressure sensor replacement of water pumps. $1,000,000 (2004) for elevator upgrade including conversion to alternating current drives and new controls. $180,000 (2008) for garage lighting upgrade.

Mercy Corps, Portland, OR, 1892[170] [Climate: Climate: oceanic or temperate marine. Cool wet winters, warm dry summers]
This building is 50% historic renovation and 50% new construction because of a seismic retrofit. It has an energy use of just 36 kBtu/sf/yr and has an ENERGY STAR score of 93, placing it in the top 6% of office buildings nationally.

◊ HVAC: The building's primary heating and cooling are provided by a multi-variable refrigerant flow (VRF) fan coil system. The system consists of 10 outdoor variable-speed compressor heat pump condensing units mounted on the roof. Two insulated refrigerant pipes connect the unit to a BC Controller. A central ventilation and exhaust shaft provides fresh air to each major space through a variable air volume (VAV) box controlled by carbon dioxide sensors. Energy savings from this system are realized through reduced pumping energy, a variable speed compressor, fan coils and outside air (OSA) set up in parallel, with heat recovery.
◊ Envelope: original masonry walls were repointed to improve their performance as an air barrier, and R-15 insulation was added to roof cavities.
◊ Existing windows are operable, and the glazing was replaced with double-paned insulated low-E glass. At the central atrium, motorized clerestory windows open to exhaust air.
◊ Lighting: The overall lighting power density for the building is 0.91 W/sf. Actual energy use is reduced through the lighting control system. High-

[170]"NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

efficiency lighting includes direct/indirect T8 fixtures with automatic dimming ballasts located in the perimeter offices.

◊ Daylighting: Horizontal exterior shades are located at every floor on the south-facing façade. These shades are made with sage glass that darkens as the temperature increases and provides shading for the building. Large windows with views allow natural light to penetrate into the space. Perimeter office lighting operates with daylighting controls.

◊ Controls: Building Management System (BMS), daylighting controls, occupancy sensors, motorized clerestory controls and computer sleep mode are all incorporated into the building.

◊ Commissioning: Both fundamental and additional commissioning took place on the building, as required for LEED certification.

◊ Monitoring system: Monitoring is conducted by means of Whole Building Management System (BMS).

◊ Renewables: The building has the infrastructure for a 79kW photovoltaic array.

The Joseph Vance Building, Seattle, WA, 1929[171] [Climate: oceanic or temperate marine. Cool wet winters, warm dry summers]

Acquired with the purpose of transforming it into "the leading green and historic class B"[172] building in the marketplace. The initiatives implemented have led tenants to call the building "ground zero of the green movement" in Seattle. The Vance uses 64% less energy than the Energy Star estimate. The building's Energy Star rating of 98 (out of 100) places it in the top two percent of office buildings nationally, its measured energy use in 2011 was 39 KBTU/sf/yr. The building's pre-retrofit Energy Star rating of 93 is indicative that some older buildings perform better than anticipated due to less mechanical equipment, here a simpler HVAC system does not require fan power and incorporates natural ventilation.

- ◊ Windows: The team restored operability of the windows with new and refurbished hardware and weatherstripping, thereby allowing natural ventilation and improving performance without requiring the need for total glazing replacement. Window coverings were installed to improve occupant comfort.
- ◊ Lighting: A lighting retrofit replaced all inefficient fixtures with T8 and T5 fixtures. Occupancy sensors in all common areas and most tenant spaces.
- ◊ Daylighting: The 45-foot building width is the recommended width for passive design, and allows natural lighting and ventilation. Light shelves on the south and west reflect sunlight to light-colored ceilings, reducing the need for overhead lights.

---

[171] "NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014.
http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

[172] Ibid

◊ Controls: The building's original steam system was made more efficient by installing localized thermostats on each floor. Lighting efficiency is achieved via occupancy sensors in all common areas and most tenant spaces.

◊ Commissioning: Ongoing commissioning of all HVAC, lighting and water systems ensure that they operate as designed and are continually fine-tuned.

◊ Monitoring systems: The Vance uses an energy dashboard tool to track real-time energy and water consumption for individual floors. Next steps include real-time energy metering at the tenant level, adopting "green lease" conditions and creating incentives for conservation.

Harris Center for Conservation Education, Hancock, NH, 1913.[173] [Climate: humid continental climate]

This renovation consisted of 27% new construction, 73% renovation. Although must of the sustainable planning for the project went into the retention of the existing structure and septic system,

◊ Windows: The original openings were outfitted with triple-glazed windows (not recommended by the Secretary of the Interior's Standards for Rehabilitation Guidelines for Sustainability.)

◊ HVAC: Energy recovery ventilation is provided for the offices and the large meeting space. A pellet boiler fed by an auger and exterior silo is the building's main heat source.

◊ Lighting: Daylighting and high performance LED lighting.

◊ Renewables: An existing photovoltaic system, was removed and reinstalled after the renovation.

---

[173] "Harris Center for Conservation Education," Case Study, Building Green, accessed March 3, 2014. http://www.buildinggreen.com/hpb/overview.cfm?projectid=220

Appendix B: Historic Buildings Exhibiting Energy Efficiency Strategies, by Climate

Institution	Climate	Veranda/ Porch	Trellis	Awning	Shutters
Continental					
Children's Museum of South Dakota	Continental				
Humid Continental					
Bryant Homestead	Humid Continental				■
Bullitt Farmhouse	Humid Continental				
Mark Twain House	Humid Continental	■			
Westport Town Farm	Humid Continental				
Adirondack Museum	Humid Continental				
Boston Children's Museum	Humid Continental				
Brooklyn Children's Museum	Humid Continental				
Phipps Conservatory	Humid Continental			■	
The Field Museum	Humid Continental				
Empire State Building	Humid Continental				
Trinity Church	Humid Continental				
Christman Building	Humid Continental				
Doty and Miller	Humid Continental				
Harris Center for Conservation Education	Humid Continental				
The Copper Kettle	Humid Continental			■	
Humid Subtropical					
Drayton Hall	Humid Subtropical				■
Hooper Strait Lighthouse	Humid Subtropical				
Teackle Mansion	Humid Subtropical				
Villa Finale	Humid Subtropical	■			
National Building Museum	Humid Subtropical				
Department of Interior, HQ	Humid Subtropical				
Hipolito Courthouse	Humid Subtropical				
Oceanic					
Gibson Mill	Oceanic				
200 Market Building	Oceanic				
Joseph Vance Building	Oceanic				
Lovejoy Building LLC	Oceanic				
Mercy Corps	Oceanic				
Pacific Coastal					
Haas-Lilienthal House	Pacific Coastal	■			
Semi Arid					
Northern Plains Resource Council	Semi Arid		■	■	
Alliance Center	Semi Arid/ Sub Humid Continental				
Beardmore Building	Semi Arid/ Sub Humid Continental				
Temperate Oceanic					
British Museum	Temperate Oceanic				
Montclair Art Museum	Temperate Oceanic				
Tropical Savannah					
Truman White House	Tropical Savannah	■			■


Blinds
Caulking
Operable windows
Windows revealed
Storm Windows
Day-lighting
Natural ventilation
Water Turbine
High Velocity HVAC
Heat Recovery HVAC
C
B
B
M
W
A
B
B
P
T
E
T
C
D
H
C
D
H
T
V
N
D
H
G
2
J
L
M
H
N
A
B
B
M
T


Variable Air Volume Handlers
Heat Pump
Low-E Glazing
UV film
High Performance Lighting
Occupancy sensors
DCV
Photo-sensors
Direct Digital Controls
Insulation
C
B
B
M
W
A
B
B
P
T
E
T
C
D
H
C
D
H
T
V
N
D
H
G
2
J
L
M
H
N
A
B
B
M
T


Radiant Barrier
Weather-Stripping
Geo thermal
Central Chiller
Earth Tubes
Environ-mental Education
PV Array
Monitor-ing
Retrocom-missioning
C
B
B
M
W
A
B
B
P
T
E
T
C
D
H
C
D
H
T
V
N
D
H
G
2
J
L
M
H
N
A
B
B
M
T

Bibliography and Resources

A. Laouadi, Guidelines for Effective Residential Solar Shading Devices, Canadian Center for Housing Technology, March 01, 2010. P.25 http://archive.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr300.pdf

Aaron Ingle, Mithra Moezzi, Loren Lutzenhiser, Richard Diamond, *Better home energy audit modelling: incorporating inhabitant behaviours*, Building Research & Information, February 28, 2014. http://www.tandfonline.com/doi/abs/10.1080/09613218.2014.890776#.U0xF1eZdVKg Accessed March 4, 2014.

Aaron Lubeck, *Green Restorations : Sustainable Building and Historic Homes*. New York: New Society Publishers, 2010. p.7

"Air Conditioning Sizing Chart," AC Direct, accessed April 4, 2014. http://www.acdirect.com/systemsize.php

"Air Infiltration and Energy Efficiency in Your Home," CertainTeed Home Institute, March 2000, accessed March 1, 2014. http://www.certainteed.com/resources/30-21-1225.pdf

Allen Powell II, *Gretna struggles with rules to prevent neglect of historic properties,* The Advicate, New Orleans bureau, February 21, 2013. http://theadvocate.com/news/5218758-123/gretna-struggles-with-rules-to Accessed January 7, 2014.

Anne Grimmer, Jo Ellen Hensley, Liz Petrella, Audrey Tepper, *The Secretary of the Interior's Standards for Rehabilitation and Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings*, U.S. Department of the Interior, National Park Service, Technical Preservation Services. 2011. http://www.nps.gov/tps/standards/rehabilitation/sustainability-guidelines.pdf Accessed December 10, 2013.

Benjamin Leigh and Sarah Welniak, *"Energy Efficiency in Historic Buildings"* The Sustainability Institute, May 2010. shpo.sc.gov/events/Documents/EnergyEfficHyPres.ppt Accessed January 27, 2014.

Bill VonNeida, Dorene Maniccia, Allan Tweed, "An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems," Lighting Research Center at the Rensselaer Polytechnic Institute and U.S. EPA, August 16, 2000. http://www.lrc.rpi.edu/resources/pdf/dorene1.pdf

"Biodiversity and Sustainability," The British Museum, accessed February 15, 2014. http://www.britishmuseum.org/about_us/the_museums_story/new_centre/explore_the_centre/biodiversity__sustainability.aspx

Building Dashboard, Lucid Design Group. http://luciddesigngroup.com/buildingdashboard/kiosk.html Accessed March 10, 2014.

Bryan Eisenhower, *Introduction to Building Energy Modeling,* Institute for Energy Efficiency, Center for Energy Efficient Design, UC Santa Barbara Engineering School. Fall 2012. engineering.ucsb.edu/~bryane/BEM/Files/Week1.pdf Accessed March 29, 2014.

Carolyn Starks, *Neglect Leaves Its Mark On Historic House*, Chicago Tribune, November 29, 1999. http://articles.chicagotribune.com/1999-11-29/news/9911290126_1_historic-places-national-register-19th-century-house Accessed January 7, 2014.

"Caulking and Weather Stripping," Waste Reduction Partners, North Carolina Energy Office, March 2010, accessed April 1, 2014. http://wastereductionpartners.org/phocadownload/userupload/Resources/Energy_Saving_Fact_Sheet_Caulk_and_Weather_Strip.pdf

"Central Air Conditioning," U.S Department of Energy, accessed April 4, 2014. http://energy.gov/energysaver/articles/central-air-conditioning

"Cooling and Heating," Lee County Electric Cooperative, accessed April 4, 2014. https://www.lcec.net/energy-efficiency/green-energy-tips/cooling-and-heating.

Chad Randl, "The Use of Awnings on Historic Buildings, Repair, Replacement and New Design," National Park Service, Technical Preservation Services, Preservation Brief #44, April 2005. http://www.nps.gov/tps/how-to-preserve/briefs/44-awnings.htm Accessed December 10, 2013.

"Code of Ethics for Museums," American Alliance of Museums, Adopted 1991, Amended 2000. http://www.aam-us.org/resources/ethics-standards-and-best-practices/code-of-ethics Accessed January 27, 2014.

Consumption and Expenditures Table CE1.4, 2009 RECS Survey Data, Residential Energy Consumption Services, U.S. Energy Information Administration. Released December 14, 2012. http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#summary Accessed February 19, 2013.

"Cooling and Heating," LCEC – Lee County Electric Cooperative, accessed April 6, 2014. https://www.lcec.net/energy-efficiency/green-energy-tips/cooling-and-heating.

Craig Drumheller, Christian Kohler, Stefanie Minen, *Field Evaluation of Low-E Storm Windows,* Oak Ridge National Laboratory, 2007. http://web.ornl.gov/sci/buildings/2012/2007%20B10%20papers/022_Drumheller.pdf Accessed March 1, 2014.

David Harrje, Ake Blomsterberg and Andrew Persily, "Reduction of Air Infiltration Due to Window and Door Retrofits in an Older Home," Center for Energy and Environmental Studies at Princeton University, May 1979, accessed February 12th, 2014. http://www.princeton.edu/pei/energy/publications/reports/No.-85.pdf

David Trueblood, "Boston's Trinity Church begins renovations with drilling of geothermal wells," The Episcopal Church, January 9, 2002. http://library.episcopalchurch.org/article/bostons-trinity-church-begins-renovations-drilling-geothermal-wells

"Demand Reduction and Energy Savings Using Occupancy Sensors" prepared by the Lighting Controls Council, National Electrical Manufacturers Association, updated October 24, 2001, accessed April 2, 2014. http://www.nema.org/Policy/Energy/Efficiency/Documents/demandreduction.pdf

Editors Padfield, Tim and Borchersen, Karen. *Museum Microclimates: Contributions to the Copenhagen conference*. 19-23 November 2007. National Museum of Denmark. http://natmus.dk/fileadmin/user_upload/natmus/bevaringsafdelingen/billeder/far/Museum_Microclimate/Proceedings/musmic150.pdf Accessed November 19, 2013.

"Empire State Building Case Study," Empire State Building, accessed February 20, 2014. http://www.esbnyc.com/documents/sustainability/ESBOverviewDeck.pdf

"Energy Efficient Window Treatments," Department of Energy. September 25, 2012, accessed March 10, 2014. http://www.energy.gov/energysaver/articles/energy-efficient-window-treatments

"Energy Loss," The DraftStopper, accessed April 1, 2014. http://www.draftstopper.ca/energyloss.htm?

"Energy Savings Calculator," Lennox Residential, accessed April 4, 2014. http://www.lennox.com/resources/energycalculator.asp

"EnergyStar Success Story: Mark Twain House & Museum," EnergyStar, accessed March 5, 2014. https://www.energystar.gov/ia/business/entertainment/Success_Story_MarkTwainHouse_Museum.pdf

"Everything Old Is New Again (cont.)" *Special Places Magazine*, The Trustees of Reservations, Winter 2012, accessed March 3, 2014. http://www.thetrustees.org/what-we-care-about/climate-change/everything-old-is-new-again-cont.html

"Energy Use (kg of oil equivalent per capita)," The World Bank, Data. International Energy Agency Statistics, accessed December 10, 2013. http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE?order=wbapi_data_value_2012+wbapi_data_value+wbapi_data_value-last&sort=desc

Environmental Guidelines, American Institute for Conservation of Historic & Artistic Works Collaborative Knowledge Base Wiki, http://www.conservation-wiki.com/wiki/Environmental_Guidelines Accessed December 12, 2013.

"Environmental Standard for Cultural Collections," The National Archives. http://www.nationalarchives.gov.uk/about/environmental-standard.htm Accessed December 10, 2014.

Environmental Protection Agency "EPA Green Buildings" Last updated September 10, 2013 http://www.epa.gov/oaintrnt/projects/ Accessed October 1, 2013.

"First 'Green' Museum in New York City," Brooklyn Children's Museum website, accessed February 21, 2014. http://www.brooklynkids.org/index.php/aboutus/greenmuseum

"French Legation to Republic of Texas, Seventh & San Marcos Streets, Austin, Travis County, TX, 33-C1." *HABS/HAER/HALS Collection at the Library of Congress, Prints & Photographs Division*. February 15, 1934.

Gass,T. E., Geothermal Heat Pumps Geothermal Resources Council Bulletin 11(11), 3-8, 1982.

Hall, James A. *Performance Testing of Radiant Barriers* Tennessee Valley Authority, Third Symposium on Improving Building Systems in Hot and Humid Climates, Arlington TX, November 1986. http://repository.tamu.edu/bitstream/handle/1969.1/6869/ESL-HH-86-11-10.pdf?sequence=3 Accessed March 17, 2014.

"Harris Center for Conservation Education," Case Study, Building Green, accessed March 3, 2014. http://www.buildinggreen.com/hpb/overview.cfm?projectid=220

"Historic Museum Is Certified Green." *EcoBuildingPulse*. Accessed March 6, 2014. http://www.ecobuildingpulse.com/energy-efficiency/hindsight-is-2020.aspx

"Home Tightening, Insulation and Ventilation," Iowa Energy Center, Home Series 1. March 2012, accessed 4 March, 2014. http://www.iowaenergycenter.org/wp-content/uploads/2012/03/HomeSeries1.pdf

"Historic Structures Report for the French Legation Museum Main House," Volz & Associates, Inc, August 20, 1997.

"How to implement solar shading," The Carbon Trust, accessed March 20, 2014.http://www.carbontrust.com/media/19525/ctl065-how-to-implement-solar-shading.pdf

"Foresight Research Report: Environment and Resource Sustainability in Museums'" California Association of Museums Foresight Committee, March 2014.

http://futureofmuseums.blogspot.com/2014/03/towards-green-future-environment-and.html Accessed March 27, 2014.

"Geothermal Heat Pumps," EnergyStar, accessed February 4, 2014. https://www.energystar.gov/index.cfm?c=most_efficient.me_geothermal_heat_pumps

"Geothermal Heat Pumps," U.S. Department of Energy, accessed April 4, 2014. http://energy.gov/energysaver/articles/geothermal-heat-pumps

"Geothermal Savings Calculator," Climate Master, accessed February 4, 2014. http://www.climatemaster.com/residential/geothermal-savings-calculator/sc01.php

Gibson Mill, Hardcastle Crags, Hedenbridge HebWeb, 2009. http://www.hebdenbridge.co.uk/features/gibsonmill.html Accessed February 19, 2014.

Groat, Linda N.; Wang, David. Architectural Research Methods. Hoboken: Wiley, 2013, Accessed February 19, 2014.. http://UTXA.eblib.com/patron/FullRecord.aspx?p=1166322

Guba, Egon and Yvonne Lincoln, "Competing Paradigms in Qualitative Research," in *Handbook of Qualitative Research* (Thousand Oaks, CA: Sage, 1994)

Gwendolen Raley, *Making Changes: Beyond Rethinking the Historic House Museum Museum,* AASLH Historic House Affinity Group Committee http://www.mynewsletterbuilder.com/email/newsletter/1411406096 Accessed March 29, 2014.

Institute for Building Efficiency "Why focus on existing buildings?" http://www.institutebe.com/Existing-Building-Retrofits/Why-Focus-On-Existing-Buildings.aspx Accessed October 1, 2013.

Jane Roy Brown, *Let It Snow!,* Special Places Magazine, The Trustees of Reservations, Winter 2011-2012, accessed January 15, 2014. http://www.thetrustees.org/what-we-care-about/climate-change/let-it-snow.html

Jeffrey D. Carlisle, "TONKAWA INDIANS," *Handbook of Texas Online,* Published by the Texas State Historical Association, uploaded on June 15, 2010, accessed October 15, 2013. http://www.tshaonline.org/handbook/online/articles/bmt68

Jenny Parker, *Incorporating Solar Panels in a Rehabilitation Project,* Technical Preservation Services, National Park Service, August 200-, ITS Number 52

Jessica Snow, *Scotstarvit Tower Cottage, Cupar: Thermal Upgrades and Installation of Radiant Heating*, Historic Scotland Refurbishment Case Study 7. 2012, accessed April 2, 2014. http://www.historic-scotland.gov.uk/refurb-case-study-7.pdf

Jo Ellen Hensley and Antonio Aguilar, *Improving Energy Efficiency in Historic Buildings*, National Park Service, Technical Preservation Services, Preservation Brief #3, December 2011. http://www.nps.gov/tps/how-to-preserve/briefs/3-improve-energy-efficiency.htm Accessed December 4, 2013.

John Carmody and Kerry Haglund, "Awnings in Residential Buildings, The Impact on Energy Use and Peak Demand," Center for Sustainable Building Research, University of Minnesota, Yu Joe Huang, Lawrence Berkeley National Laboratory, December 2006. http://www.kaplanawning.com/images/energystudy22007.pdf

John Cluver and Brad Randall, *Saving Energy in Historic Buildings: Balancing Efficiency and Value,* Association for Preservation Technology Bulletin: Journal of Preservation Technology. Volume 41:1, 2010. http://www.apti.org/clientuploads/pdf/Cluver-Randall-41-1.pdf Accessed May 2013.

John E. Crowley, *The Invention of Comfort: Sensibilities and Design in Early Modern Britain and Early America.* Baltimore: Johns Hopkins University Press, 2001 p.292 http://muse.jhu.edu/journals/tech/summary/v043/43.4berger.html Accessed April 1, 2013.

Joseph Pine and James Gilmore, *Authenticity: What Consumers Really Want,* presented at the American Alliance of Museums, 2007. http://www.strategichorizons.com/documents/MuseumNews-May07-Museums&Authenticity.pdf Accessed March 23, 2014.

Jump, D.A. and M.P. Modera. *Impacts of attic duct retrofits in Sacramento houses*. Lawrence Berkeley Laboratory,1994. Proceedings of ACEEE.

Ken Bernstein, *Top Ten Myths About Historic Preservation,* Los Angeles Conservancy. http://www.preservation.lacity.org/files/Top%20Ten%20Myths.pdf Accessed December 12, 2013.

Kurt Stout, "A LEED System for Tenants: LEED-CI," Capitol Markets, January 25, 2014. http://www.capitolmarkets.com/sustainability/leed-system-tenants-leed-ci/

M. Lenzen "Primary Energy and Greenhouse Gases embodied in Australian Final Consumption: an Input-Output Analysis" Energy Policy, Vol 26, Issue 6, May 1998, Pp. 495-506.

"Maryland Mansion Goes Green - National Trust for Historic Preservation."*Preservationnation.org*. Accessed March 5, 2014. http://www.preservationnation.org/magazine/2010/todays-news/maryland-mansion-goes-green.html?utm_source=facebook&utm_medium=like&utm_campaign=Maryland Mansion Goes Green

Maureen Stevens, *Check it out: The French Legation Museum,* Maureen Stevens Styling and Design blog. January 14, 2011. http://maureenstevens.com/2011/01/check-it-out-the-french-legation-museum/#.U0XtB61dVKg

Mrs Barcalay (Margaret) Megarity, "Authenticated Research on French Legation," May 1, 1957, p. 3 Texas State Archives.

Meg Nowack,"Enlightening!: UV Blocking Window Films at Villa Finale," Villa Finale Museum Preservation Blog, March 30, 2011. http://villafinale.wordpress.com/2011/03/30/enlightening-uv-blocking-window-films-at-villa-finale/ Accessed December 15, 2013.

Michael C. Henry, "The Heritage Building Envelope as a Passive and Active Climate Moderator: Opportunities and Issues in Reducing Dependency on Air-Conditioning," (contribution to the Experts' Roundtable on Sustainable Climate Management Strategies, Tenerife, Spain, April 2007).

http://www.getty.edu/conservation/our_projects/science/climate/paper_henry.pdf

Michael Mills and George Fore, *Environmental Monitoring and Conservation Study of Drayton Hall in Charleston, South Carolina,* Association for Preservation technology Bulletin, Vol. 31, No. 2/3 (2000) pp. 63-70. http://eprints.sparaochbevara.se/473/1/environmental_monitoring_and_conservation_study.pdf Accessed January 14, 2014.

"NEEA Study: Examples of Deep Energy Savings in Existing Buildings," prepared for the Northwest Energy Efficiency Alliance, prepared by the New Buildings Institute, June 2011, accessed February 20, 2014. http://www.betterbricks.com/sites/default/files/nbi_neea_deep_savings_search_phase_1_final.pdf

Paul Baker, "Thermal Performance of Traditional Windows," Centre for Research on Indoor Climate & Health, Glasgow Caledonian University, for the Technical Conservation Group, Historic Scotland, accessed March 6, 2014. http://www.historic-scotland.gov.uk/thermal-windows.pdf

Pihlstrom, Sami. "Cheryl Misak, ed.: New Pragmatists." *Philosophy in Review* 28.5 (2008): 355+. *Academic OneFile*. Web. 19 Feb. 2014.

"Prestige Series PR 70: Sun Control Window Films" 3M Multimedia, accessed February 4, 2014. http://multimedia.3m.com/mws/mediawebserver?mwsId=SSSSSuH8gc7nZxtUm8mBox_9evUqe17zHvTSevTSeSSSSSS--&fn=Prestige%20PR%2070%20Sample%2070-0709-01

"Recommended Levels of Insulation" EnergyStar, accessed April 2, 2014. http://www.energystar.gov/?c=home_sealing.hm_improvement_insulation_table

"Rehabilitation: The Approach," National Park Service, accessed October 1, 2013. http://www.nps.gov/hps/TPS/standguide/rehab/rehab_approach.htm

"Residential Roof Savings Calculator Beta" Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory, accessed March 3, 2014. http://rsc.ornl.gov/rsc_main.htm?calc=res

Robert Grisso and Martha Walker, "Energy Series: What about Caulking and

Weather-Stripping?" Virginia Cooperative Extension. July 2009, accessed March 15, 2014.. http://pubs.ext.vt.edu/2908/2908-9017/2908-9017_pdf.pdf

Robert W. Mallard, *Avoiding the "Disneyland Façade": The Reach of Architectural Controls Exercised by Historic Districts Over Internal Features of Structures*. Widener L. Symp. J. Vol. 8 Issue 2. 2002. p.323-324.

Rogers, R. On sustainability and how it's changing the face of modernism. Gissen, D (Ed.). 2002. Big and Green: Toward Sustainable Architecture in the 21st Century. New York: Princeton Architectural Press, p. 172.

Sarah Brophy and Elizabeth Wylie, *The Green Museum: a primer on environmental practice*. Lanham, Altamira Press. 2008. p. 113

Sarah Darby, "The Effectiveness of Feedback on Energy Consumption," Environmental Change Institute, University of Oxford, April 2006, accessed April 4, 2014. http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf

SDSU Daktronics Engineering Hall Addition, Children's Museum of South Dakota Awarded LEED Silver, Architecture Incorporated News, *Architecture Incorporated News,* June 14, 2013. www.architectureinc.com/news/archives?newsid=219

"Selecting Windows for Energy Efficiency," U.S. Department of Energy, January 1997, accessed Jan 15, 2014. http://windows.lbl.gov/pub/selectingwindows/window.pdf

Standards for Rehabilitation, National Park Service. http://www.nps.gov/hps/tps/standguide/rehab/rehab_standards.htm Accessed October 12, 2013.

Stewart Brand, How Buildings Learn: What Happens After They're Built, Penguin, October 1, 1995. p. 2

Sylvia Hernandez, "GSA Completes Restoration of Hipolito Federal Building," General Services Administration blog, November 8, 2012. https://gsablogs.gsa.gov/gsablog/2012/11/08/gsa-completes-restoration-of-hipolito-federal-building/

Summary of "Gallery Illumination: LED Lighting in Today's Museums" Smithsonian Art Museum, March 1, 2013. Accessed April 6, 2014. http://www.americanart.si.edu/conservation/program_docs/aic_summary.pdf

"The Field Museum of Natural History: Sustainable Practices in Collections Management," Sustainable Operations Toolkit, PIC Green, accessed January 10, 2014. http://www.pic-green.net/wp-content/uploads/FMNH-Sustain-Collect-Mgmnt-v3.pdf?utm_source=Jan+2014%2C+AAM+PIC+Green+-+Collection+Mngmnt+v2&utm_campaign=Jan+2014+PICGrn+Nwsltr&utm_medium=email

"The Truman White House Renovation," National Trust for Historic Preservation, accessed January 15, 2014. http://www.preservationnation.org/support-us/marketing--sponsorships/partners/unico/unico-truman-case-study.html#.Uwo6jEJdVKg

"Types of Photovoltaic Systems," Florida Solar Energy Center, accessed April 14th, 2014. http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/types_of_pv.htm

Wade Lawrence, *"Re: UV Window Film?"* Museum-L Archives, February 26, 2003. http://home.ease.lsoft.com/scripts/wa-HOME.exe?A2=ind0302D&L=museum-l&F=&S=&P=58516 Accessed January 14, 2014.

Wayne Curtis, *A Cautionary Tale,* Preservation Magazine, National Trust for Historic Preservation, January/February 2008. http://www.preservationnation.org/magazine/2008/january-february/cautionary-tale.html#.Uo-mCmTEq38 Accessed December 10, 2013.

Weatherizing and Improving the Energy Efficiency of Historic Buildings, Technical Preservation Services National Park Service, accessed January 10, 2014, http://www.nps.gov/tps/sustainability/energy-efficiency/weatherization.htm "Windows and Overhangs For Efficient Solar Home Design," Solar for Energy. http://www.solar-for-energy.com/windows-and-overhangs.html Accessed February 25, 2014.

Useful Resources

Cassar, May. "Impact of Climate Change on Cultural Heritage: From International Policy to Action." *GCI Newsletter* 26:1 (Spring 2011). Retrieved August 9, 2013, from Getty website: http://www.getty.edu/conservation/publications/newsletters/26_1/impact.html

Noah's Ark: Global Climate Change Impact on Built Heritage and Cultural Landscapes http://www.window.state.tx.us/comptrol/fnotes/fn1111/green.php

Construction and Building Codes

Kaplan, Marilyn. E. "Safety and Building Codes: The Recent Past and Future for Historic Structures." APT Bulletin 40, No. 3/4 (2009): 11-18

Caroon, Jean C., Bayard Whitmore, Karl Stumpf. "Designing for Building Performance: The Management of Change." *APT Bulletin* 37, No. 4, (2006): 35-40.

Preservation

Shanon Peterson Wasielewski "Windows: Energy Efficiency Facts and Myths," facts and myths http://www.lakecityhistoricdistrict.com/Windows-Energy-Efficiency-Facts-and-Myths.pdf

Preservation Brief #16: The Use of Substitute Materials on Historic Building Exteriors

Preservation Brief # 17: Architectural Character – Identifying the Visual Aspects of Historic Buildings as an Aid to Preserving Their Character

Preservation Brief #18: Rehabilitating Interiors in Historic Buildings – Identifying and Preserving Character-Defining Elements

Preservation Brief #36: Protecting Cultural Landscapes: Planning, Treatment, and Management of Historic Landscapes

Secretary of the Interior's Standards for the Treatment of Historic Properties – http://www.nps.gov/history/hps/tps/standards_guidelines.htm

Illustrated Guidelines for Preserving Historic Buildings – http://www.nps.gov/history/hps/tps/standards/preservation.htm

Illustrated Guidelines for Rehabilitating Historic Buildings – http://www.nps.gov/history/hps/tps/standards/rehabilitation.htm

Illustrated Guidelines for Reconstructing Historic Buildings – http://www.nps.gov/history/hps/tps/standards/reconstruction.htm

Illustrated Guidelines for Restoring Historic Buildings – http://www.nps.gov/history/hps/tps/standards/restoration.htm

Guidelines for the Treatment of Cultural Landscapes – http://www.nps.gov/history/hps/hli/landscape_guidelines/index.htm

Conservation

American Institute for Conservation of Historic & Artistic Works Collaborative Knowledge Base Wiki, http://www.conservation-wiki.com/wiki/Main_Page

Poul Larsen, Morten Ryhl-Svendsen, Lars Jensen, Benny Bohm, "Ten Years Experience Of Energy Efficient Climate Control in Archives and Museum Stores" National Museum of Denmark, Department of Conservation. http://www.conservationphysics.org/musdes/tenyearexp.php

Energy Efficiency

"Energy Efficiency in Building Electrical Systems," Department of Energy of South Africa. http://www.energy.gov.za/EEE/Projects/Building%20Energy%20Audit%20Training/Training%20Modules/Building%20Energy%20Auditing%20Module%209_Final.pdf

Energy Modeling

What is Energy Modeling and Building Simulation, Energy Models http://energy-models.com/what-is-energy-modeling-building-simulation

"Building Energy Simulation," http://www.youtube.com/user/GARDAnalytics

Sustainable Historic Preservation

"Sustainable Historic Preservation," WBDG Historic Preservation Subcommittee, last updated: 12-02-2013 http://www.wbdg.org/resources/sustainable_hp.php

Sarah Staniforth, "Sustainability and Collections," http://www.getty.edu/conservation/publications_resources/newsletters/26_1/sustainability.html

"Sustainability, Energy Efficiency & Historic Preservation Resources," Kansas Historical Society https://www.kshs.org/p/sustainability-energy-efficiency-historic-preservation/15680

Alderson, Caroline. "HVAC Upgrades in Historic Buildings," GSA Center for Historic Buildings, April, 2009. Retrieved August 9, 2013 from GSA Website: http://www.gsa.gov/graphics/pbs/HVAC.pdf

"Sustainability and Historic Federal Buildings," WBDG Historic Preservation Subcommittee, http://www.wbdg.org/pdfs/achp_sustainability_hfb.pdf

Preservation Brief #3: Improving Energy Efficiency in Historic Buildings http://www.nps.gov/tps/how-to-preserve/briefs/3-improve-energy-efficiency.htm Jo Ellen Hensley and Antonio Aguilar

Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings – http://www.nps.gov/history/hps/tps/download/guidelines-sustainability.pdf

Incorporating Solar Panels in a Rehabilitation Project – http://www.nps.gov/history/hps/tps/tax/ITS/its52.pdf

Installing Green Roofs on Historic Buildings – http://www.nps.gov/history/hps/tps/tax/ITS/its.54.pdf

Interpreting the Standards Bulletin Series
http://www.nps.gov/tps/standards/applying-rehabilitation/standards-bulletins.htm

Pocantico Proclamation on Sustainability and Historic Preservation
http://www.preservationnation.org/information-center/sustainable-communities/additional-resources/index.html#.Uyd8ya1dVKg

No Longer Available

Sustainability by the Numbers: The Costs of Construction and Demolition, and Energy Efficiency of Historic and Older Buildings – http://www.preservationnation.org/issues/sustainability/sustainability-numbers.html