Department of Defense
Legacy Resource Management Program

PROJECT 11-382

Design Guidelines for Implementing Energy Efficiency Strategies in Historic Properties

CHERRY/SEE/REAMES ARCHITECTS

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PURPOSE OF THESE GUIDELINES

The purpose of these Guidelines is to facilitate the planning of rehabilitation projects that will result in improved energy efficiency in historic buildings operated by the Department of Defense (DoD). The Guidelines are intended to be used by DoD Cultural Resource Managers (CRMs), Facility Managers and Design Teams to help these groups meet Historic Preservation and Energy Saving design goals. The Guidelines have a secondary purpose of assisting DoD staff who manage historic buildings in meeting the legal obligations that all federal agencies have in the preservation of our national heritage, as detailed in the National Historic Preservation Act of 1966. The legal drivers for this project include Federal Executive Order (EO) 13514. All DoD construction project s regardless of scope and size must also meet the Unified Facilities Criteria (UFC). These Guidelines are meant to be used in conjunction with the UFC and provide potential options for meeting the established Criteria. In many cases, the Guidelines exceed the criteria set forth in the UFC, but in no case should they replace the UFC.

USING THE GUIDELINES

Guideline users should familiarize themselves with Part 1, Introduction, and the titles and scope of the guidelines contained in the document. As potential projects are identified, review Part II, Sections 01 01, 01 02, and 01 03 and applicable Guidelines with the intention of applying them to a specific project. The Guidelines are arranged in keeping with building industry categories as described in Part 1. The format of the document is arranged so that more Guidelines can be added in the future.

The Guidelines assume that the reader does not have a background in energy conservation or building design or construction. Abbreviations and a Glossary are included to assist with the understanding of the vocabulary and concepts of energy conservation in historic buildings (see Appendices K and L). Most Guidelines make reference to sources on the Internet that can expand one's knowledge and increase energy conservation awareness and options.

COST/BENEFIT ANALYSES

The major issue for energy conservation improvements is often the Cost/Benefit Analysis or Return on Investment (ROI). Section 3, in Part 1. Introduction, "The realities of Cost/Benefit Analyses", explains the issues involved in determining the cost and benefits of various improvements prior to their execution. They must be specific to place, climate, use, and the historic character of the facility. Wherever appropriate, a Guideline will provide a method for making an approximation of cost and benefit in terms of energy savings. However, it is important to realize that no such approach can guarantee a result because of the numerous factors beyond the control of the person doing the calculation. There is no way to predict future weather, staff behavior, fuel prices, etc. The calculation processes suggested should offer a good guide to selecting among various options for improvement, and that information can be very helpful.

HISTORIC PRESERVATION GUIDANCE

Historically, buildings were designed to conserve energy because energy was scarce and expensive. Use of these Guidelines can help preserve our history, make historic buildings useful, and once again conserve energy.

1. PURPOSE OF THESE GUIDELINES

The purpose of these Guidelines is to facilitate the planning of rehabilitation projects that will result in improved energy efficiency in historic buildings operated by the DoD. The Guidelines are intended to be used by DoD CRMs, Facility Managers and Design Teams to help these groups meet Historic Preservation and Energy Saving design goals for projects and the development of Requests for Proposal for design services by architects and engineers. They are not intended to be a technical analysis. The Guidelines have a secondary purpose of assisting DoD staff who manage historic buildings in meeting the legal obligations that all federal agencies have in the preservation of our national heritage, as detailed in the National Historic Preservation Act of 1966. The DoD is legally required to meet energy efficiency conditions due to Federal Executive Order (EO) 13514. All DoD construction project s regardless of scope and size must also meet the Unified Facilities Criteria (UFC). These Guidelines are meant to be used in conjunction with the UFC for permanent construction and provide potential options for meeting the established Criteria. In many cases, the Guidelines exceed the criteria set forth in the UFC, but in no case should they replace the UFC.

2. HOW TO USE THESE GUIDELINES

How are the Guidelines Arranged?

The landscape orientation of the Guidelines serves several purposes. First, landscape more closely matches computer monitor configurations, making it easier to read the document on the computer screen instead of printing the entire document. Not printing the document will save paper and energy, and thus is the more efficient option. This orientation also allows for a large graphic column adjacent to the text which facilitates greater use of graphics.

The Guidelines are loosely arranged according to the Construction Specifications Institute (CSI) Master Format. CSI is an organization founded in 1948 by the construction specification writers of government agencies to improve the quality of construction specifications, develop best practices, and establish standards and formats for those specifications. The CSI Master Format for construction specifications is widely used as a standard format for the construction industry. Additionally, this format allows Guidelines to be added throughout the document at a later time in the appropriate location, which would be difficult with a sequential format.

PAGE LAYOUT

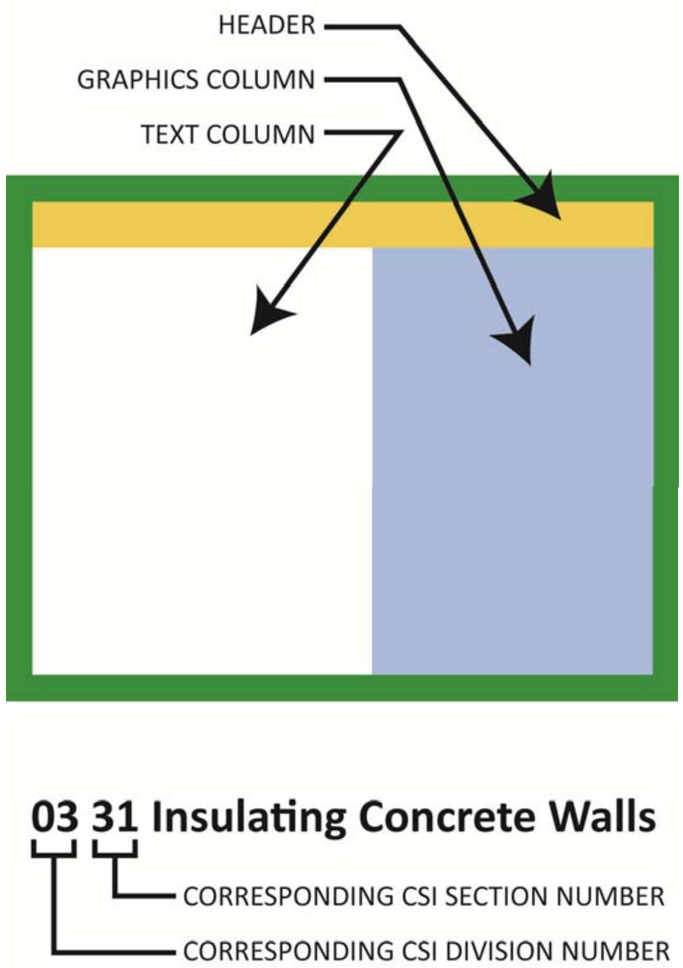


Figure P1-1

2. HOW TO USE THESE GUIDELINES continued

How are the Guidelines Arranged? continued

The first two numbers of the Guidelines match the corresponding CSI Division number. The second two numbers match the corresponding CSI Section numbers where possible. Since the Guidelines are relatively few in number in comparison to the CSI Master Format, the Guidelines are only four digits long instead of the CSI six-digit format.

There will be a cross-reference notice at the beginning of each Guideline to facilitate the use of items that overlap. For example, the placing of rigid insulation on the inside of a masonry wall will specifically be covered in 04 21 Insulating Masonry Walls, but important general insulation information will be covered in 07 21 Thermal Insulation. However, it is assumed that all readers will read the Introduction, 01 01, 01 02 and 01 03 before getting into more specific issues.

Format of Guidelines

Each Guideline generally follows the outline below:

- **Guideline Description:** A brief description of the content addressed in that Guideline
- **Related Guidelines**: are then itemized, if appropriate
- **General Notes**: related to all aspects of the Guideline are listed
- **Considerations**: for a particular type of work or product related to the Guideline. There may be several Considerations per Guideline, each having all the steps described below.
- **Approach**: a brief description of how the work is done or how the product is installed
- **Applicable Secretary of the Interior Standards:** for Rehabilitation, abbreviated "SOI Standards" throughout the document
- **Historic Preservation Effects:** A brief description of the issues that might be encountered
- **Energy Saving Potential:** In general points and formulas, where appropriate
- **Cost Considerations:** Always relative since cost is very specific to the building, location, etc.
- **Other Considerations**: and additional information, if appropriate

The Guidelines that are more general in content do not strictly follow the above outline. Guidelines 01 01, 01 02 and 01 03 address project organization and management rather than specific improvements to be made on a historic building. Other Guidelines, such as 07 21, also break from the above outline as needed.

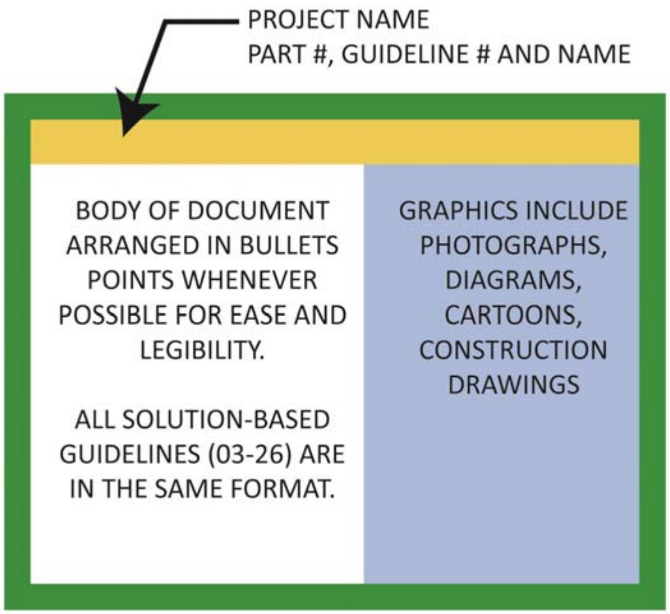


Figure P1-2

2. HOW TO USE THESE GUIDELINES continued

Starting a Project Using These Guidelines

First read the three Guidelines at the beginning: 01 01, 01 02, and 01 03. These Guidelines will help you organize your project tasks relative to the historic preservation and energy issues. Of course, any building rehabilitation project involves much more than these two topics, but issues of funding, consultant selection, scheduling and the host of other concerns are well beyond the scope of this report.

Review the list of Guidelines in the Table of Contents to know the topics available here. There are many more topics that could be included, but in this initial phase of Guideline preparation, these topics were selected to address the greatest potential for energy savings.

Keep in mind that these Guidelines are to be used in conjunction with all other applicable codes and standards including but not limited to the Unified Facilities Criteria (UFC)(latest edition), the International Building Code (IBC), and the National Fire Protection Association (NFPA). The Design Team should always consult all applicable codes and standards during the actual design process. These Guidelines may be used to help meet or exceed the code requirements.

Remember that while this document is intended for an audience with a wide range of skills from technical to historians, it is not a technical analysis. The intention is for those with a technical background to learn the historic preservation language and concerns, and those with preservation backgrounds to learn the technical language and concerns. It does not replace the expertise of a qualified design professional who is focused on a specific project with all of the nuances associated with that project.

Common Abbreviations used in this Guideline:

See Appendix L for a complete list.

AHU *– Air Handling Unit*

ASHRAE – *American Society of Heating, Refrigeration, and Air-Conditioning Engineers*

HVAC *– Heating, Ventilation, Air-Conditioning*

LEED – *Leadership in Energy and Environmental Design*

MAU – *Makeup Air Unit*

RTU *– Roof Top Unit*

SMACNA *– Sheet Metal and Air Conditioning Contractors National Association*

DX *– Direct Expansion (Refrigeration Cycle)*

VRF *– Variable Refrigerant Flow*

EER *– Energy Efficiency Ratio*

SHPO *– State Historic Preservation Officer*

SOI *– Secretary of the Interior*

3. THE REALITIES OF COST / BENEFIT ANALYSES

Every building owner wants to know the Return on Investment (ROI) for improvements. Owners always want to know the answers BEFORE the project begins. The realities are that the answers can only be known after the project has been occupied for a few years.

The reasons that predictions on installation costs compared to benefits (Return on Investment or ROI) cannot be accurately estimated include countless unpredictable variables. These are:

- "What will the weather be like for the years being measured?"
- "How much will energy costs go up in the life-time of this improvement?"
- "Exactly what equipment/materials will be specified and provided?"
- "How many times will the staff and visitors open windows and doors?"
- "How many times will the staff and visitors remember to turn off the lights when leaving?"
- "How many times will the staff and visitors adjust the thermostats; etc?"
- As well as other unpredictable aspects of human behavior that impact energy use.

In addition, the circumstances of each historic building are very different. A great deal of energy is transferred through windows, perimeter walls, roofs, and floors. Because the total area of windows, walls, roofs and floors varies in every building, there are no simple approaches which can determine eventual cost benefits compared to initial cost for each project.

While the big picture of cost/benefit comparison is very difficult to predict, more can be known in advance about individual improvements in terms of energy saving <u>potential</u>. There are many online calculators that can be used to these ends and take into account the efficiencies of the different equipment. Please refer to the Interactive Excel Tables on pages 8 and 9 for a similar calculation that can also be used. These calculations, customized to the building in question, can predict a cost savings resulting from energy savings for <u>a single improvement</u>. That amount can be compared to the cost of purchase and installation of that improvement. In other words, a reasonable cost benefit may be predicted regarding individual improvements. It is not possible to test this prediction after construction and occupancy because the specific savings on that improvement will not be discernible from the energy bills nor do many military installations have individual meters.

Figure P1-3
An example of a 1940's DOD office.
Pentagon Building History Exhibit, July 12, 2012. DOD photo by U.S. Army Sgt. 1st Class Tyrone C. Marshall Jr.

Unlike the two dimensional cutouts in the Pentagon display, building users are not static. How they use a facility is constantly changing. This makes figuring out a cost/benefit analysis highly specific to a particular building and location.

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

In Part II, sections beginning with 23 involve Heating, Ventilation, and Air Conditioning (HVAC) systems. Because these systems must be custom designed to the specific situation of a building, these guidelines cannot provide a potential square foot cost. These sections recommend a life cycle analysis or assessment (LCA) prepared by a professional. An LCA, as defined by the United States Environmental Protection Agency (EPA), is "a technique to assess the environmental aspects and potential impacts associated with a product, process, or service." (Life Cycle Analysis Definition, 2012) For a more in-depth discussion on LCAs read EPA document EPA/600/R-06/060 "Life Cycle Assessment: Principles and Practice," which can be found on the EPA website (www.epa.gov). Typically, the savings predictions that compare two or more systems will be covered by the energy savings.

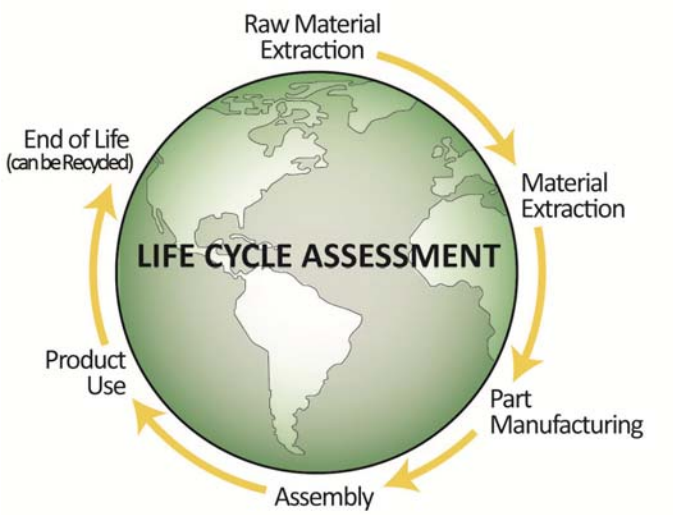


Figure P1-4

It is also important to remember that cost alone is not the only consideration. There are numerous advantages to increasing the thermal comfort of a building and reducing energy use that cannot be readily quantified. These benefits include increased productivity of staff with improved HVAC systems, reduction of dependence on foreign sources of imported energy, and reduction of CO_2 in the atmosphere. Benefits of reusing historic buildings can include greater productivity due to the use of natural light, a more interesting work environment depending upon the design of the historic building, and often a higher quality of material finishes and details than can be afforded in contemporary buildings.

Keep in mind, buildings built in the 1970's used the most energy (Btu/ft2) of any time period from pre 1920's through 2010.

- Buildings from the 1960's are starting to become eligible for historic status.
- Even though these buildings might not be the most efficient, it is still important to preserve them as part of our history.

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Energy Savings Potential and Cost Considerations as presented in the Guidelines:
Guidelines 03 – 08, except 07 21, discuss Energy Savings Potential and Cost Considerations as presented below. It is recommended that either the online calculators or the Interactive Excel Tables on page 8 are utilized for the actual calculations. Below are the key concepts that will be repeated throughout the Guidelines and example calculations. Guidelines 07 21, 22 – 23 discuss Energy Savings Potential and Cost Considerations in more general terms without calculations.

- **Heating and Cooling Degree Days:** Different areas of the country require different amounts of heating and cooling to achieve comfort in buildings.
  - **Heating Degree Days** (HDD) refers to the demand for heating in that area.
    - For HDD, a value would be the number of days multiplied by the average temperature difference between the outside temperature and a desired average indoor temperature, typically 65 degrees (averaging desired day and night temps).
    - For example, Albuquerque, NM has 919 HDD in January (averaged from 2007 to 2011). This information means that in January with 31 days, there was an average (919/31) of 29.6 degrees (called Delta T) that had to be made up with energy for heating. This can also be done on an annual basis.
  - **Cooling Degree Days** (CDD) refers to the demand for cooling in that area.
    - For the same years, Albuquerque had 424 CDD in July, meaning that in 31 days there was an average DeltaT of 13.67 degrees (424/31days) to be reduced by cooling.
  - To determine the HDD and CDD for your area see http://www.degreedays.net/.
  - Similar information may be obtained by contacting your local weather bureau.

- **R –values**: R-values are used to represent the insulation value of materials.
  - **Insulation** is the resistance of heat (energy) transfer and higher insulation (higher R-values) reduce the heating or cooling requirements of spaces.
  - R-values generally have the units (hour x sf x degF)/BTU for a given material.
    - Sometimes defined on a per-unit-thickness basis, with the units hour x sf x degF/(BTU x in). BTU is British Thermal Unit, see Appendix K for the Glossary.
      - If the R-value is defined per inch of thickness then the actual material thickness needs to be known. For example, if a rigid insulation is R-5 per inch, and the material is 2” thick, the total R-value will be R-10.

Common Abbreviations Used in Calculations:

x	*multiply*
/	*divide*
sf	*square feet*
degF	*degrees Fahrenheit*
in	*inches*
kWh	*kilowatt hours*
hr	*hour*
HDD	*heating degree days*
CDD	*cooling degree days*
COP	*coefficient of performance*
EER	*energy efficiency ratio*
Insul	*insulation*
bd	*board, as in gypsum bd*
BTU	*British Thermal Unit, see definition in Glossary, Appendix K*

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Key concepts Defined continued

- **U –factors**: U-factors are the inverse of R-values and measure how well heat is conducted through the assembly.
    - Materials with lower u-factors reduce heating and cooling losses. For example, high-performance windows can be u-0.3 (equivalent to R-3.33) while lower performing windows can be u-0.6 (equivalent to R-1.67).

- **COP:** The **coefficient of performance** is the ratio of heating or cooling provided (watts) divided by the electrical energy consumed (watts).
    - Better performing equipment has a higher COP. COP is unit-less because it's a ratio of watts/watts.
    - COP is listed on manufacturer's specifications.

- **EER:** The **energy efficiency ratio** is similar to COP and is the ratio of output cooling (BTU/hr) to electrical energy input (watts).
    - EER is equal to COP multiplied by 3.412 because there are 3,412 BTU in one kWh.

- **Gas Heating Efficiency:** Gas heating equipment is commonly measured in a percentage of heat output versus gas energy input. It is also listed on manufacturer's specifications.
    - Indoor gas heating equipment can be up to 95% or 98% efficient while outdoor equipment is normally only 80% efficient because the condensation that occurs at higher efficiencies is difficult to design for.

- **Using the Tables and Online Calculators:** Online calculators are available to help estimate the energy and cost savings that could be realized if better insulation were installed in an existing building (one example is http://chuck-wright.com/calculators/insulpb.html). Page 8 has examples of the calculator in a spreadsheet format. The spreadsheet calculation is valid for gas heating and electric cooling but online calculators allow for heat pump or electric resistance heating. The calculators can be used for any materials, including windows, as long as the R-values (or u-factors) of the materials and assemblies are known.

Example Analysis of Energy Saving/Cost Benefit:
for adding insulation to a concrete wall

Note the following assumptions:

1. *The installed costs are 2012 prices. Add 2.5% for inflation for each additional year.*
2. *The following example explores the cost of installing one square foot of insulation to the concrete wall compared to the increased R-Value energy savings.*
    a. *The thermal mass of the concrete wall may impact the performance of the wall, but is not considered in this example. A professional analysis is recommended.*
3. *The savings achieved below assume that the concrete wall being insulated is not a basement wall and is exposed to outside temperatures. These calculations assume that all walls are the same regardless of orientation.*

R-Values in Example Analysis
Note that some R-Values require simple calculations to be in the proper form.

- *Poured concrete wall 8" thick* — *R = 0.64*
  R = 0.08/in x 8 inch wall = 0.64
- *Rigid insulation (beadboard)* — *R = 4/in*
- *Batt Insulation 3 5/8 in* — *R = 13*
- *2x4 Wood Studs* — *R = 4.38*

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Example Analysis:

Note – Since the R-Value is the amount of heat flow resisted (in BTUs) per degree F per hour, one square foot of the new insulation should resist the flow of 8.56 BTUs per hour for every 1 degree difference in temperature (Delta T).

Calculating Cost Savings for Rigid Insulation

1st Determine the Inputs in the blue box on the right and note the assumptions on page 6

2nd Using the Interactive Excel Tables on page 8, calculate the energy savings going from zero insulation wall assembly to an R-8.56 by doing the following

1. Calculate energy cost requirements for R-1 (assume R-1 rather than R-0 for more realistic values)
2. Calculate energy cost requirements for R-8.56
3. Subtract the two

Result (Total Cost Savings): is the amount of money saved for the given area over a course of a year. See the table on the following page.

Comparing Multiple Types of Insulation: Repeat the above steps as outlined for rigid insulation with the correct R-Value for the specific type and / or thickness of insulation desired. This can also be done for the same insulation with different thicknesses. It is important to note that comparing insulation is different than comparing whole wall assemblies. A variety of factors affect R-values for wall / roof assemblies. Walls framed with metal or wood studs cannot have continuous insulation due to the interruption of framing members, and therefore have less insulative value than walls with continuous insulation. ASHRAE 90.1 is a resource document used to determine the R-value of walls and roofs, but the framing spacing and R-value of the insulation needs to be known. **The assembly R-value can be 1/2 or less than the insulation R-value itself because the framing members act as a conduit for heat transfer.** For example, a 6-inch wall with steel framing on 16 inch centers with R-19 batt insulation has an assembly R-value of only R-7.1 (per ASHRAE 90.1-2007 Table A9.2B). If energy transfer calculations are performed for this wall, it is important that R-7.1 is the R-value and not R-19.

Determine the following for rigid insulation:

1. *R-Values and installed cost for insulation application.*
   a. *Good source for R-Values:* www.coloradoenergy.org/procorner/stuff/r-values.htm
   b. *Good source for Installed Cost:* *RS 2012 Means Cost Data publication*
   c.

Material	*R-Value*	*Installed Cost/sf*
2" rigid insl.(4/in)	*8.0*	*$1.82*
5/8" gypsum bd	*0.56*	*$4.23*
"z" channels	*negligible*	*$1.23*
	8.56	*$7.28/sf*

2. *Heat and Cooling Sources: building is heated by natural gas and cooled by electricity*
3. *Location: Kansas City, MO*
4. *Cost of Electricity and Natural Gas:*
   a. *Good Source:* energy-models.com/tools/average-electric-and-gas-cost-state*, or actual utility bill*
   b. *Cost of natural gas = $0.72/therm*
      i. *(1 therm = 100,000 BTUs)*
   c. *Cost of electricity = $0.07/kWh*
5. *Total Annual HDD and CDD (2011 reference)*
   a. *Good Source:* www.degreedays.net/
   b. *Total Annual HDD(65 degrees): 5357*
   c. *Total Annual CDD(65 degrees): 1536*

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Example Analysis continued:

Comparison of Two Types of Insulation

Interactive Excel Table for 2" of Rigid Insulation added to a concrete wall
Inputs in yellow are the only numbers required (see previous page), all other inputs are automatically calculated.

DESCRIPTION	INPUTS	UNITS
Initial R-value	1	(hr x sf x degF)/BTU
Final R-value	8.56	(hr x sf x degF)/BTU
HDD	5,357	days x degF/yr
CDD	1,536	days x degF/yr
Heating Efficiency	0.8	% gas heating efficiency
Cooling Efficiency	3.5	COP
Cost of Gas	$ 0.80	$/therm
Cost of Electricity	$ 0.10	$/kWh
Area of Insulation	1	sf
Inverse of initial R-value	1.00	BTU/(hr x sf x degF)
Constant	24	hours/day
Initial Heating Energy	128,568	BTU/yr
Convert to Therms	1.61	therms/yr
Initial Heating Energy Cost	$ 1.29	$ heating/year
Initial Cooling Energy	36,864	BTU/yr
Convert to kWh	10.8	kWh
Initial Cooling Energy Cost	$ 0.31	$/year
Initial Total Cost Calculation	$ 1.59	$/year
Inverse of final R-value	0.12	BTU/(hr x sf x degF)
Final Heating Energy	15,020	BTU/yr
Convert to Therms	0.19	therms/yr
Final Heating Energy Cost	$ 0.15	$ heating/year
Final Cooling Energy	4,307	BTU/yr
Convert to kWh	1.3	kWh
Final Cooling Energy Cost	$ 0.04	$/year
Final Total Cost Calculation	$ 0.19	$/year
Total Cost Savings	$ 1.41	$/year

Interactive Excel Table for 3 5/8" of Batt Insulation
The only input to change is for the Final R-Value (shown in the lighter yellow).

DESCRIPTION	INPUTS	UNITS
Initial R-value	1	(hr x sf x degF)/BTU
Final R-value	13	(hr x sf x degF)/BTU
HDD	5,357	days x degF/yr
CDD	1,536	days x degF/yr
Heating Efficiency	0.8	% gas heating efficiency
Cooling Efficiency	3.5	COP
Cost of Gas	$ 0.80	$/therm
Cost of Electricity	$ 0.10	$/kWh
Area of Insulation	1	sf
Inverse of initial R-value	1.00	BTU/(hr x sf x degF)
Constant	24	hours/day
Initial Heating Energy	128,568	BTU/yr
Convert to Therms	1.61	therms/yr
Initial Heating Energy Cost	$ 1.29	$ heating/year
Initial Cooling Energy	36,864	BTU/yr
Convert to kWh	10.8	kWh
Initial Cooling Energy Cost	$ 0.31	$/year
Initial Total Cost Calculation	$ 1.59	$/year
Inverse of final R-value	0.08	BTU/(hr x sf x degF)
Final Heating Energy	9,890	BTU/yr
Convert to Therms	0.12	therms/yr
Final Heating Energy Cost	$ 0.10	$ heating/year
Final Cooling Energy	2,836	BTU/yr
Convert to kWh	0.8	kWh
Final Cooling Energy Cost	$ 0.02	$/year
Final Total Cost Calculation	$ 0.12	$/year
Total Cost Savings	$ 1.47	$/year

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Example Analysis continued:

Calculator Formulas Using 2" Rigid Insulation Example

The following spreadsheet shows how the formulas that result in the Total Cost Savings bottom line of $1.41 per year were derived. This spreadsheet can also be found in Appendix F for individual use.

DESCRIPTION	CALCULATION	INPUTS	UNITS
Initial R-value		1	(hr x sf x degF)/BTU
Final R-value		8.56	(hr x sf x degF)/BTU
HDD		5,357	days x degF/yr
CDD		1,536	days x degF/yr
Heating Efficiency		0.8	% gas heating efficiency
Cooling Efficiency		3.5	COP
Cost of Gas		$ 0.80	$/therm
Cost of Electricity		$ 0.10	$/kWh
Area of Insulation		1	sf
Inverse of initial R-value	=1/(Initial R-value)	1.00	BTU/(hr x sf x degF)
Constant	=hours in a day	24	hours/day
Initial Heating Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x HDD	128,568	BTU/yr
Convert to Therms	=(Initial Heating Energy)/(100,000 x Heating Efficiency)	1.61	therms/yr
Initial Heating Energy Cost	=Therms/yr x $/therm	$ 1.29	$ heating/year
Initial Cooling Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x CDD	36,864	BTU/yr
Convert to kWh	=Initial Cooling Energy / 3,412	10.8	kWh
Initial Cooling Energy Cost	=kWh/COP x $/kWh	$ 0.31	$/year
Initial Total Cost Calculation	=Initial Heating Energy Cost + Initial Cooling Energy Cost	$ 1.59	$/year
Inverse of final R-value	=1/(Final R-value)	0.12	BTU/(hr x sf x degF)
Final Heating Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x HDD	15,020	BTU/yr
Convert to Therms	=(Final Heating Energy)/(100,000 x Heating Efficiency)	0.19	therms/yr
Final Heating Energy Cost	=Therms/yr x $/therm	$ 0.15	$ heating/year
Final Cooling Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x CDD	4,307	BTU/yr
Convert to kWh	=Final Cooling Energy / 3,412	1.3	kWh
Final Cooling Energy Cost	=kWh/COP x $/kWh	$ 0.04	$/year
Final Total Cost Calculation	=Final Heating Energy Cost + Final Cooling Energy Cost	$ 0.19	$/year
Total Cost Savings	=Difference of Final Energy Cost and Initial Energy Cost	$ 1.41	$/year

Part II, The Design Guidelines, include twenty-one topics selected for their high energy saving potential. The reader should note that the numbering system for the Guidelines is not completely sequential. As noted in the Introduction, the Guidelines are arranged based upon the Construction Specifications Institute (CSI) Master Format. Where there is no Guideline included from a particular CSI division (the first two numbers), the division number is omitted. For example, there are no Guidelines included from Division 05, Metals.

CSI DIVISIONS

CSI DIVISIONS	INCLUDED / OMITTED
00 Procurement and Contracting Requirements	OMITTED
01 General Requirements	INCLUDED
02 Existing Conditions	OMITTED
03 Concrete	INCLUDED
04 Masonry	INCLUDED
05 Metals	OMITTED
06 Wood, Plastics, Composites	INCLUDED
07 Thermal and Moisture Protection	INCLUDED
08 Openings	INCLUDED
09 Finishes	OMITTED
10 Specialties	OMITTED
11 Equipment	OMITTED
12 Furnishings	OMITTED
13 Special Construction	OMITTED
14 Conveying Equipment	OMITTED
22 Plumbing	INCLUDED
23 HVAC	INCLUDED
26 Electrical	INCLUDED
28 Electronic Safety and Security	OMITTED
31 Earthwork	OMITTED
32 Exterior Improvements	OMITTED
33 Utilities	OMITTED

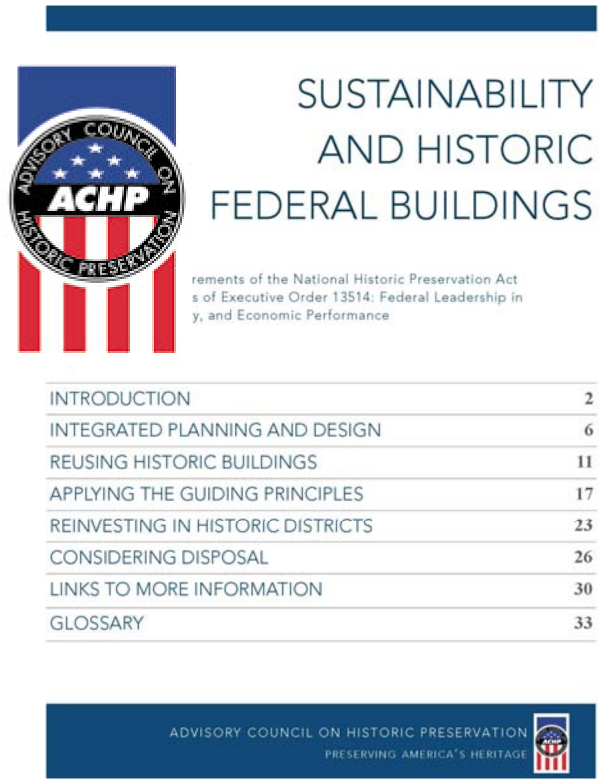
APPROACH: This guideline outlines key steps at the beginning of the project that will help DoD Cultural Resource Managers (CRMs), Facility Managers and the Design Team meet Historic Preservation and Energy Saving design goals. Many installations have their own CRMs who coordinate Section 106 consultations with the State Historic Preservation Officer (SHPO). Any project which affects historic properties must be coordinated with the CRM. CRMs are also helpful in collecting historic information about the building.

Step 1: Become informed regarding Federal Law and Policies related to historic structures and energy conservation.

A good introduction to this topic can be found in the Advisory Council on Historic Preservation's publication, "Sustainability and Historic Federal Buildings", www.achp.gov/docs/SustainabilityAndHP.pdf, (ACHP, et al, 2011).

This document answers basic questions such as:

- What is a "Historic Property"?
- What are the major, applicable laws and policies related to Historic Structures and Energy Conservation?
- What is "Historic Character"?
- What is "Historic Integrity"?
- What is a Life-Cycle Cost Analysis?
- What are the Secretary of the Interior's Standards that govern rehabilitation of federal historic structures?
- What is the Section 106 compliance process? (See page 17 for more information about Section 106.)



SUSTAINABILITY AND HISTORIC FEDERAL BUILDINGS

rements of the National Historic Preservation Act
s of Executive Order 13514: Federal Leadership in
y, and Economic Performance

ADVISORY COUNCIL ON HISTORIC PRESERVATION
PRESERVING AMERICA'S HERITAGE

Figure 01 01-1

Step 2: Understand the current energy use of the historic structure.

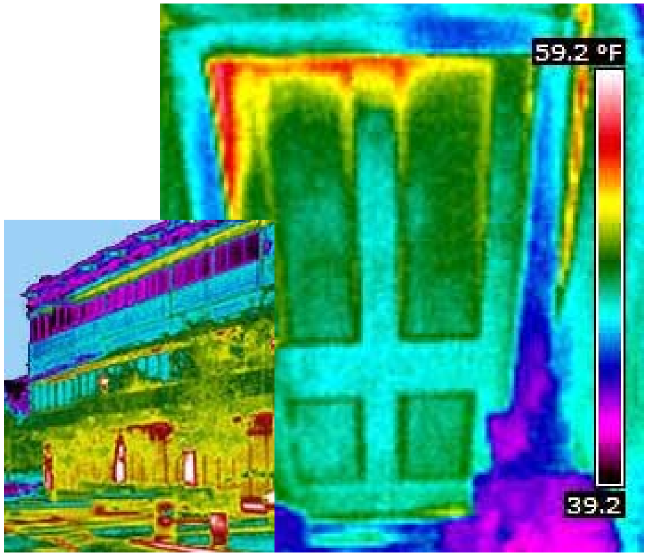
In order to know what energy savings should be accomplished in the remodel of a historic structure, it is necessary to establish the pattern of energy use for the building in its current state. This pattern of use will be compared to energy use when the project is occupied to determine the extent of energy savings. Many factors can affect that comparison, especially if the functions in the building are different before and after remodeling. Regardless, it is important to establish the "before" pattern of energy use.

ENERGY AUDIT: The best way to understand how energy is being used in an existing building is to have a qualified professional with experience in historic construction conduct an energy audit. Energy auditors will analyze energy bills, conduct heat gain and loss studies, perhaps use thermograph imagery to see where energy is escaping, and other diagnostic methods to determine where and how energy is being used. The results of the energy audit should indicate which improvements may accomplish the most in reducing energy use. Energy auditors can provide guidance on which strategies are the most cost effective and which strategies will produce the most comfortable environment for the occupants.

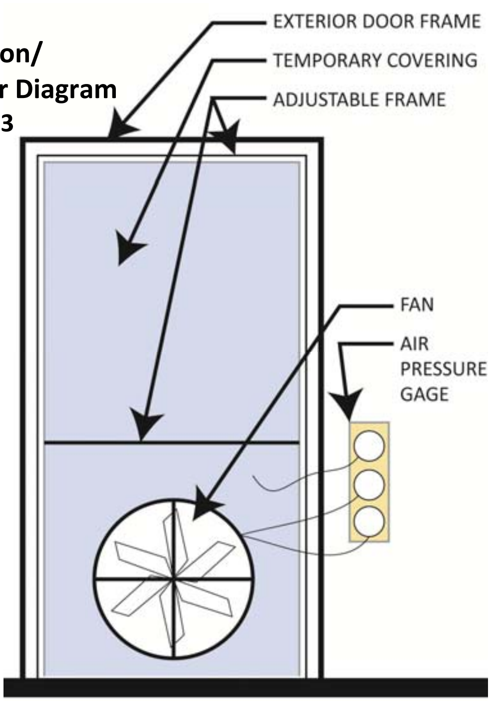
Note: Because many military installations do not meter buildings separately, it may not be possible to determine existing energy use from energy bills. If the building is in use it may be possible to add line meters and monitor building energy use during project planning.

- **Types of tests:**
    - The most common are Infrared Thermography (thermal imaging) and air infiltration (blower door) tests.
    - Depending on resources and budget, computerized energy analysis, computerized hygrothermal modeling and thermal transfer modeling can also be done.
- **Conducted When:** should be when there is a significant temperature difference between the interior and exterior of the structure (mid-summer and/or mid-winter)
- **Additional**: periodic monitoring regardless of type of insulation should be done to ensure that the insulation is performing the way it was intended.
    - Should provide information on whether the building already has insulation, how much (R-value and thickness) and where.

Figure 01 01-2 Thermographic Imagery



Air Infiltration/ Blower door Diagram
Figure 01 01-3



Step 2: Understand the current energy use of the historic structure continued.

If funds are not available for a professional energy audit, the facility manager can collect energy use data by recording the energy bills for the most recent 12 month period of building use. (See Note on previous page.) The measure of energy use that is common is the amount of British Thermal Units (BTUs) used per square foot of building per year: BTU/sf/year. This informal study can provide a base line of energy use for the building; however, it will not be specific about where energy is being used efficiently or inefficiently.

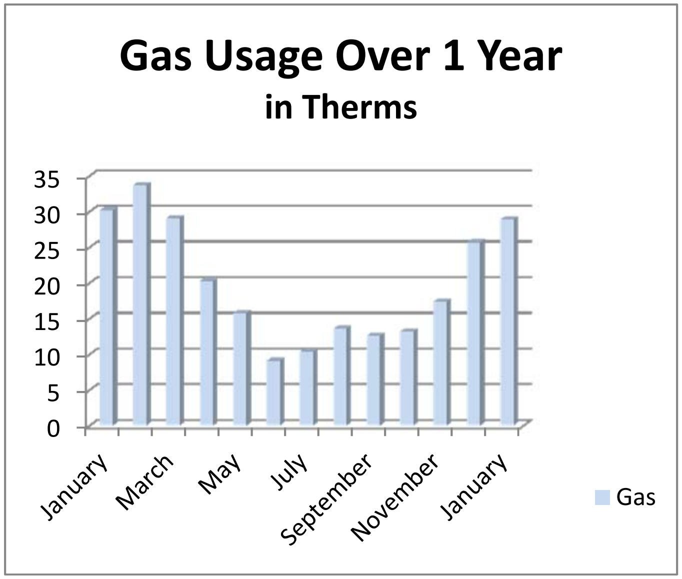


Chart 01 01-1

A simplified description of the method of determining the base line follows:

a. Determine the total Kilowatt Hours (Kwh) of electrical use from the electric bills.
b. Determine the total Therms of gas use from the gas bill.
c. Determine the total gallons of fuel oil used from the fuel oil bill.
d. Refer to the Appendix B, Conversion Factors, in this study to determine the way to convert Kwh, therms and gallons of fuel oil to BTUs. Convert all the energy uses and total them up.
e. Determine the square footage area of the building.
f. Divide the total energy use in BTUs by the area of the building to determine the BTUs / square foot for the year. This number is your base line energy use.

The exercise above assumes that the building to be remodeled is currently in use. This exercise would not be applicable for a building currently not in use.

Step 3: Collect information on the history of the building's development.

The more you and your architect understand about the building and its structural history, the fewer surprises will present themselves during construction. Surprises may require expensive change orders, a circumstance worth avoiding. If funds are available, the sources and types of information can be researched by consultants. If funds are not available, many of these sources can be contacted or researched by staff members of the agency.

Useful types of information include:

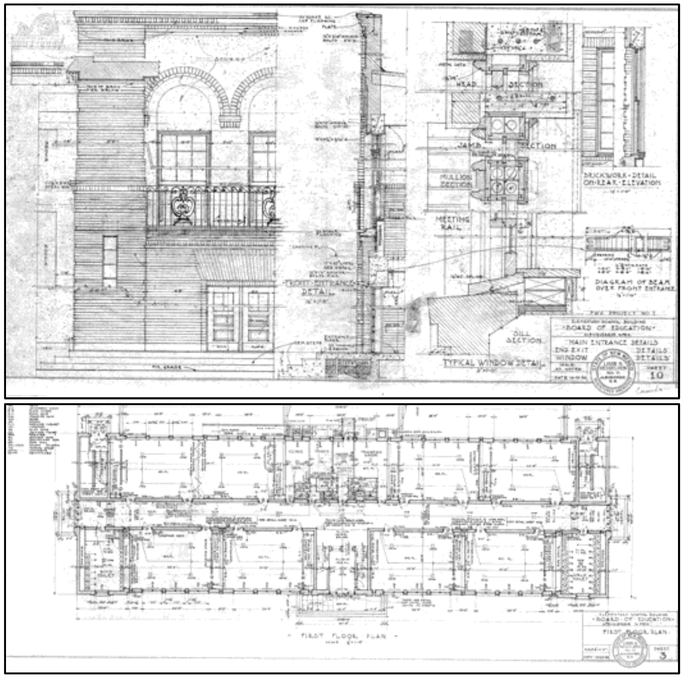
a. Architectural / engineering drawings for the original building and remodels:

These drawings provide useful information on materials, measurements, methods of construction, and intentions of the original design and subsequent remodels. They can reveal hidden conditions that can eliminate the need for destructive investigations. They can also reduce the cost of the preparation of drawings of the existing conditions that will be the starting point for a remodeling project.

It is important to remember that all the projects that are drawn and cataloged in an archive are not necessarily executed. Also, some remodels are drawn, constructed, and later removed. The architect will need to verify the drawn record with the existing installation.

b. Archives of procurement documents such as contracts for architects, engineers, and contractors; or invoices from materials suppliers, and installers can be useful. These documents can indicate information as varied as dates in the chronology of the building's changes, locations of quarries for stone, or decorative ironwork manufacturers.

Coronado School, Original Drawings



Courtesy of Albuquerque Public Schools **Figure 01 01-4**

Step 3: Collect information on the history of the building's development continued.

c. Photographs taken of the building exterior or interior:

Photographs that show any portion of the building can be helpful in determining the sequence of changes to the building. Photos of people standing at the main entry or in the major interior space may have been intended to commemorate an event. They also reveal the architectural conditions at the time of the photograph. If the date for the image is known the information is even more valuable. Analysis of the photos can reveal the sequence of changes to the building and provide clues to determining why changes were made. These images can verify whether the drawings for changes were executed or not.

The photographs and drawings collected can be archived and used for exhibit and informational publications to celebrate the opening of the building when the project is completed.

Coronado School, 1939 Photograph

Figure 01 01-5
Courtesy of Georgia Otero (fifth from the left)

Sources of information include, but are not limited to:

a. Every state has a State Historic Preservation Officer (SHPO) that has information about properties on the National Register of Historic Places and the State Register, if one exists.
b. The agency that is responsible for the building may have document archives.
c. Local libraries and museums.
d. Local historical societies.
e. The state where the building is located may have a state archive and/or records center that houses historical documents.

Step 4. Select Design Professionals with experience with historic preservation projects

Most procurement processes for architectural services allow for selection criteria defined specifically for the project at hand. Experience with historic preservation projects and energy conservation in historic buildings should be two criteria for a project of this nature.

GUIDELINE DESCRIPTION: This Guideline provides guidance for working with the State Historic Preservation Officer (SHPO) or his or her designee assigned to the project. It covers the preparation for initial meetings with the SHPO, involvement of the Cultural Resource Managers (CRMs), design team, project managers, and building managers. On installations with Cultural Resource Management Branches/Sections/ Offices, they are the ones who work with and initiate consultation with the SHPO. If there is no CRM office someone usually in Environmental is designated to consult with the SHPO.

RELATED GUIDELINES:

- 01 01 Project Organization
- 01 03 Strategies for Major Preservation Issues

Why is the SHPO involved?

The National Historic Preservation Act (NHPA) of 1966, as amended, is the guiding force behind the federal historic preservation policy. In Section 1(b), the Act states in part:

- The spirit and direction of the Nation are founded upon and reflected in its historic heritage;
- The historical and cultural foundations of the Nation should be preserved as a living part of our community life;
- Historic properties significant to the Nation's heritage are being lost or substantially altered, if inadvertently, with increasing frequency; and
- The preservation of this irreplaceable heritage is in the public interest so that its vital legacy of cultural, educational, aesthetic, inspirational, economic, and energy benefits will be maintained and enriched for future generations of Americans.

The SHPO is the local official responsible for enforcing the NHPA. While SHPOs are usually state officials, the federal government contracts with SHPOs to review projects that use federal funds. Some Native American or First Nation tribes have an equivalent official that fills the same role on native owned lands. They are called Tribal Historic Preservation Officers (THPO). In reviewing federally funded projects, the SHPO or his or her designated staff is working on behalf of the federal government. In some states, there is a citizens' committee, often appointed by the governor, which has a say in the operations and decisions of the SHPO's office. In most jurisdictions, the SHPO is responsible for the Section 106 review (see box).

SECTION 106 REVIEW

Section 106 directs federal agencies to consider how their undertakings affect historic properties. The federal Advisory Council on Historic Preservation's (ACHP's) regulations implementing Section 106, "Protection of Historic Properties" (36 CFR Part 800), outline a process for the consideration of alternatives that promote preservation and offer the public and stakeholders the opportunity to influence federal decisions:

- *Initiate the review and determine if it applies to a given program or project,*
- *Identify historic properties that may be affected,*
- *Assess the effects of the project on the identified historic properties,*
- *Resolve adverse effects by exploring alternatives to avoid, minimize, or mitigate the effects.*

This review process encourages, but does not mandate, preservation. When historic properties will be adversely affected by a federal undertaking, the review usually ends with a negotiated and legally binding agreement that outlines how the affects will be resolved.

For more information, see: http://www.achp.gov and for how-to guidance including NHPA Sec 106 and treatment of historic buildings, see: https://cs.eis.af.mil/a7cportal/CEPlaybooks/AM/EM/CRM/Pages/default.aspx .

Common Terms Used by the SHPO as defined by the NHPA:

The following are used to describe or discuss properties that fall under the protection of the NHPA:

Building– a category of historic properties. Buildings refer to places that shelter human activity.

Eligible – the status of a structure 50 years or older that has not been placed on the NRHP, but is deemed by the SHPO to be eligible. A building or structure that has been declared "eligible" for the NRHP is afforded the same protections as a registered building.

Character defining features – aspects that are integral to a building or structure's historic and architectural significance and integrity. They are usually physical aspects such as the overall shape, design, materials, windows, craftsmanship, decorative features and landscape context. The SHPO determines what features are "character defining features."

Historic resource / historic property – means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the NRHP.

Historic district – a significant concentration, linkage, or continuity of sites, building, structures, or objects united historically or aesthetically by plan or physical development. A single building might not be eligible by itself, but might require the SHPO's review because it is in a historic district, and it is designated as contributing to that district.

Individually eligible property – a historic property, or object that meets the National Register criteria for designation. If it is a building or structure, it may include interior and exterior features. It could also include landscaping features immediately surrounding the property.

Structure – a category of historic properties, for purposes other than human shelter.

Site – a category of historic properties. Sites are locations of significant events with historical, archaeological, or cultural value regardless of whether or not there is a standing structure.

Undertaking – A project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency, including those carried out by or on behalf of a federal agency; those carried out with federal financial assistance; and those requiring a federal permit, license, or approval (36 CFR §800.16(y)).

Common Abbreviations Used by the SHPO:

ACHP – Advisory Council on Historic Preservation

NHPA – the National Historic Preservation Act of 1966

NRHP – the National Register of Historic Places, the National Register

SHPO –State Historic Preservation Officers

THPO –Tribal Historic Preservation Officers

For more definitions see the Glossary at www.achp.gov/docs/SustainabilityAndHP.pdf page 30.

When should the SHPO become involved?
The SHPO's office should be contacted at the very beginning of a project when a building over 50 years old is proposed for remodeling or other major change. Sometimes, buildings that are younger than 50 years old require consultation with the SHPO if they are associated with historic sites or districts. The term used for remodeling or other change is called an "undertaking." Undertakings using federal funds are subject to review by the SHPO.

The reasons to contact the SHPO at the very beginning of the project are:

- All the federal regulations can be explained.
- By reaching an accord with the SHPO, the status of the building to be remodeled can be determined.
- If the building is determined to be on the NRHP or eligible for the register, the character defining features of the building can be identified. These features need to be protected if at all possible in the renovation process.
- A schedule of reviews can be set up so that the project schedule is not adversely impacted by these required reviews.
- An early meeting shows respect for the responsibilities of a fellow federal representative. It indicates a commitment to cooperation that all parties appreciate.
- The SHPO has experience with professionals whose expertise may be helpful to the project. The SHPO may also know of buildings with similar problems that have been successfully rehabilitated.

Understanding the Role of the Secretary of the Interior's Standards for Rehabilitation:

The National Park Service (NPS) is the federal agency that has developed the Secretary of the Interior's Standards for Historic Preservation, Rehabilitation, Restoration and Reconstruction to guide projects that are of value to the history of the American people. The NPS has the last word on review of preservation projects that use federal funding. For most issues, the decision of the SHPO is final, but occasionally, decisions are moved up to the regional office of the NPS. Many federal agencies have employees that are designated to work with the NPS and help provide guidance in working with historic properties. In the Department of Defense there are Cultural Resource Managers (CRMs) that are appointed for larger installations.

Secretary of the Interior's Standards for Rehabilitation:
www.nps.gov/tps/standards/rehabilitation.htm
The Secretary of the Interior's Standards for Rehabilitation, codified as 36 CFR 67, are regulatory for federal undertakings.

Secretary of the Interior's Guidelines for Rehabilitation:
www.nps.gov/tps/standards/rehabilitation.htm
The Guidelines assist in applying the Standards to rehabilitation projects in general.

"The National Register of Historic Places is the official list of the Nation's historic places worthy of preservation. Authorized by the National Historic Preservation Act of 1966, the National Park Service's National Register of Historic Places is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect America's historic and archeological resources." (National Register of Historic Places. 2011)

Checklist for Initial Meeting with SHPO:

At the initial meeting with the SHPO the following can take place:

- Exchange contact information
- Present any historic information gathered on the building (See Guideline 01 01, Project Organization; Step 3: Collect Information on the history of the building's development,)
- Ask if the SHPO has photographs and other information on file on the building that can be copied.
- Explain the status of the project. Is it funded? Funding is being requested? What is the schedule? Is the budget tight or ample?
- Request concurrence with the following:
    - NRHP listing or eligibility for the building
    - Identification of Character Defining Features and other areas of concern from the SHPO's perspective. Ask for these in writing so that they can be transmitted later to the design team, and perhaps even included in the Request for Proposals for the Architect.
- Discuss the impact of any possible energy saving approaches that have been mentioned, or perhaps suggested by the Energy Auditors (See Guideline 01 01, Project Organization; Step 2: Understand the current energy use of the historic structure.)
- Discuss the schedule for the SHPO's reviews. What is the submittal content?
- Invite the SHPO or his or her representative to visit the site.

With this initial meeting you will have received valuable information and established a communication process and can avoid many schedule interruptions later.

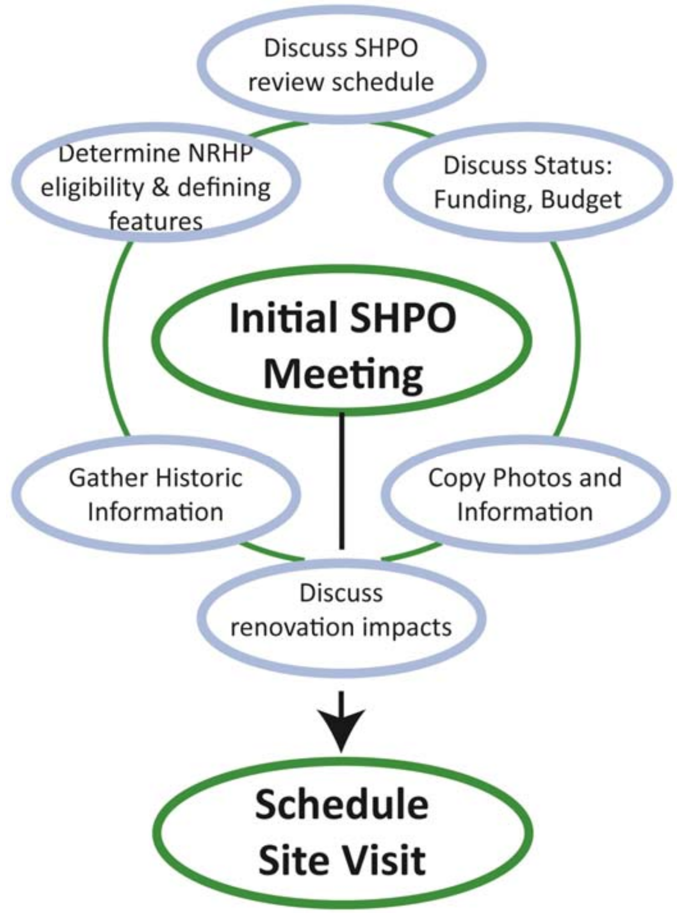


Figure 01 02-1

GUIDELINE DESCRIPTION: This guideline introduces the basic physics of heat transfer in buildings, and the strategies that historic buildings used to minimize energy use. It describes the changed ideas of human thermal comfort and illumination expectations. It discusses how to make use of the energy saving strategies inherent in many historic buildings, refers to the strategies described in the guidelines in this report, and suggests criteria for selecting strategies for energy saving in the upcoming rehabilitation project.

RELATED GUIDELINES:

- 01 01 Project Organization
- 01 03 Strategies for Major Preservation Issues
- 23 08 Selecting HVAC Systems.

BACKGROUND CONSIDERATIONS:

A Brief Introduction To How Buildings Use Energy:

Basic physics

- Heat is energy. Cold is the absence of heat. Instead of saying “It’s really cold in here,” one would be more accurate to say, “There is really an absence of heat in here.”
- 2nd Law of Thermo Dynamics (Thermo = heat; Dynamics = moves): Heat flows from a region of high temperature to a region of low temperature.
- How heat transfer is measured?

British Thermal Units per hour per square foot of area per °F
written
$BTU/hr/ft^2/°F$

- Heat transfers at different rates through different materials. The thickness of the material makes a difference, too. We measure the resistance of a material to heat transfer with the material’s “**R factor**.” An insulation pad with an R factor of 19 resists heat transfer better than an insulation pad with an with an R factor of 6. The higher the number, the better the insulator pad.

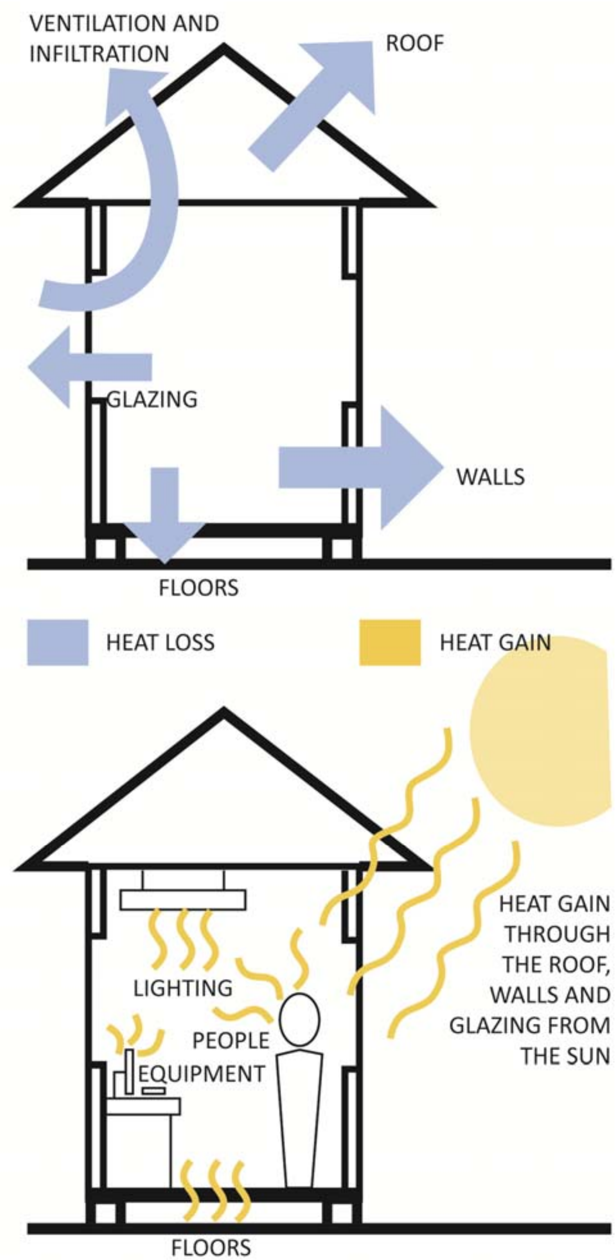


Figure 01 03-1

BACKGROUND CONSIDERATIONS continued:

How Historic Buildings Approached Energy Use: Prior to the post WWII era; most buildings relied on the sun for light and sometimes heat during the day, and breezes and massive construction to temper the warm temperatures of summer. Buildings were designed to use as little energy as possible because energy was hard to obtain. Often heat energy was wood obtained from a near-by source. Light energy was often from burning oil of some type, also difficult to obtain. Gradually, as local fuel sources were used up, people began importing fuel from farther and farther away.

In warm climates, buildings were cooled by designing for cross-ventilation systems, including porches. Porches shaded the walls so that the heat of the sun didn't hit directly on the wall. The porches were useful as shaded functional spaces, as well.

The common assumption was that no one would use energy for lighting during the day. Buildings had lots of windows. Buildings were narrow so that natural light could get to the center of the interior spaces; we could say they were "skinny" buildings. When lighting was used in the evenings, it was often used sparingly for specific tasks. As the electric lighting technology developed expectations for general as well as task lighting increased.

Other energy conservative approaches of historic buildings included using the direct gain of the winter sun on the south side of the building (in northern latitudes) to warm the interior spaces during the day. Deciduous trees, planted on the west side of a building, could shade the west wall during the summer and allow the sun to hit the wall in the winter.

The WWII industrial efforts developed efficient transportation routes and plentiful sources of fuel. Most fuel sources were relatively inexpensive compared with earlier times or today. Air conditioning became an accepted initial construction expense in exchange for greater comfort levels in the 1950s. Electric lighting during the day also became an acceptable expense. Many buildings built during the 1950s and 1960s had fewer windows, were completely air conditioned and de-humidified, if necessary, and anticipated the use of electric lighting during the full working day. Some of the buildings of this mid-century era are now eligible for the National Register of Historic Places.

The oil embargo of the early 1970s changed people's attitudes toward energy use. Many of the "old ideas" began to find their way back in the design of buildings. Buildings built before the 1950s already have in their architecture an approach to energy conservation that we should preserve and enhance with modern technologies.

Figure 01 03-2

From Fort Bliss Archives: This 1910 photo is of a building at Ft. Bliss, Texas. It had porches on the west side, many windows, was heated by fire places and ventilated by opening the windows. It is currently used as an office building meeting all modern expectations of comfort having been retrofitted with modern heating and cooling.

BACKGROUND CONSIDERATIONS continued:

Making Use of Historic Energy Strategies: Physics does not change over time. While the expectations of occupants are more stringent, many of the energy characteristics of historic buildings can still be useful today, enhanced by new technologies and equipment.

Building Shape: The "skinny buildings" that were designed with lots of windows to provide natural light to the interior of the building are still an excellent strategy today. While the Secretary of the Interior's Guidelines for Historic Preservation strongly advocate for the reuse of historic windows whenever possible, new back-up windows can often be added and make use of new glass products that block a certain amount of heat transfer (see Guideline 08 52). Back-up windows also slow down heat transfer through the window area.

The "skinny buildings" have a longer perimeter than a building of equal area that is a square. A lengthy perimeter allows for more heat transfer at the building walls. To deter this heat transfer, insulation can often be added to the walls, most likely to the interior of the walls to allow the historic facade to be unchanged (see Guidelines 03 31, 04 21, 06 81 and 07 21).

Windows: There are numerous studies that contend that workers are more efficient with access to natural light. In contemporary buildings much of the energy use is expended on cooling the space that is heated by the electric lighting system. Both are good arguments for using buildings with many windows and little need for artificial lighting. The unwanted direct gain of the sun at certain times can be addressed with shades and the new types of glass in back-up windows. (see Guidelines 08 01, 08 02 and 08 52.)

Wall Thickness: Since the thickness of a wall of brick or masonry worked to slow down the heat transfer, a careful analysis by professional designers can retain some walls as un-insulated to the overall advantage of the building's energy use.

Building Orientation: Historic buildings were often oriented to take advantage of the winter sun and summer shading. Such features should be retained and celebrated.

High Ceilings: Many historic buildings have high ceilings to allow the summer heat to move to the top, unoccupied area, naturally. Sometimes these areas were ventilated by transom windows above doors. These methods still work and can usually be retained in renovations.

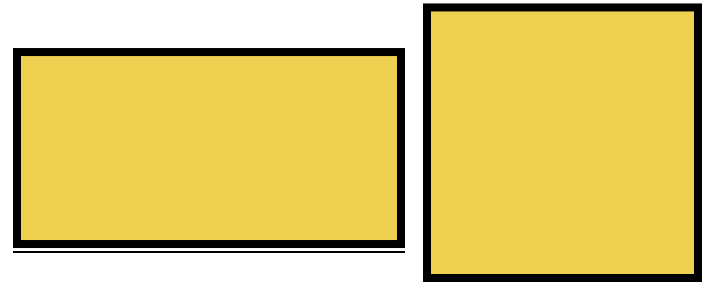


Figure A **Figure B**

Figure 01 03-3

Figures A and B contain the same area. Fig. A has approximately 16% more perimeter than Fig B

Figure 01 03-4

1851, Joseph Paxton, the Crystal Palace, Hyde Park, London

Making Use of Today's Energy Strategies:

Historic preservation and energy conservation measures can often work synergistically. Because historic buildings, at least up until the 1950s, assumed features like natural lighting and low energy use, restoring features can often reduce energy use. The major, modern improvements include better insulation of the building envelope and more efficient heating. The additional expectation of mechanical cooling has added an energy requirement that must be addressed as efficiently as possible. Today's energy strategies can enhance the energy conservations strategies of old. They include:

- Better insulation to prevent heat transfer in walls, ceilings, and floors.
  - Guideline 03 31 Insulating Concrete Walls
  - Guideline 04 21 Insulating Masonry Walls
  - Guideline 06 81 Insulating Wood Structures
  - Guideline 07 01 Adjusting Historic Features for new Insulation on Roofs
  - Guideline 07 21 Thermal Insulation
  - Guideline 07 31 Insulation for Sloped Roofs
  - Guideline 07 51 Insulation for Flat Roofs
- New types of glazing (if historic glazing is not in place) or installing back-up windows.
  - Guideline 08 52 Wood Back-Up Windows
- Reducing air infiltration at building material joints.
  - Guideline 07 92 Joint Sealants
  - Guideline 08 01 Increasing Energy Efficiency in Historic Windows.
- More efficient lighting and the use of task lighting.
  - Guideline 08 02 Natural Lighting
  - Guideline 26 51 High Efficiency Lighting
- More efficient heating, ventilating, and air conditioning (HVAC) systems.
  - Guideline 23 08 Selecting HVAC Systems
  - Guideline 23 11 HAVC Interior Placement, and HVAC Exterior Placement.
- More efficient electrical supply.
  - Guideline 26 01 Solar Photovoltaic Panels
- More efficient hot water supply
  - Guideline 22 33 Hot Water Energy Conservation

Specific Strategies for Your Historic Building:

Selecting the specific energy saving strategies for your historic building will make use of the Energy Audit suggested in Guideline 01 01, Project Organization. It makes sense to devote rehabilitation resources (funding and time) to address the areas of greatest energy waste. Usually, but not always, reducing the heat transfer of the building shell (roof, walls, and floor) is the number one priority. If the building shell is leaking energy like a sieve, then resources spent on a more efficient heating/cooling system is a waste of money and energy.

The Architect/Engineer Design Team will have recommendations based upon their experience in historic preservation and energy savings. In discussing strategies with Design Team representatives, consider the following criteria:

1. Does the strategy address the areas of the building where the most energy is currently being wasted?
2. What energy saving strategies respect the building's character defining features most effectively?
3. What are the most cost effective strategies that address criteria 1 and 2?

Figure 01 03-5

Figure 01 03-6

South Carolina Navy Yards, Building 76
Repurposed for offices and testing labs.

GUIDELINE DESCRIPTION: This guideline will look at different insulation types for concrete walls (rigid, spray, batt insulation, and Exterior Insulation and Finish Systems (EIFS)). It will discuss insulation location, general aspects that pertain to the historic structure and discuss key points in the decision making process. These insulation types have similar approaches, the same SOI Standards and Historic Preservation effects. The information provided in this guideline are ideas; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 04 21 Insulating Masonry Walls review for additional information on basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.

GENERAL NOTES:

- Non-significant interiors allow for more insulation options.
- Determine the affect insulation would have on the Thermal Mass properties.
- Basements / crawl spaces with concrete walls that are non-living, service spaces provide great opportunities for insulation.
    - o Ensure vapor barrier is facing the proper direction
    - o Ensure proper anchoring.
    - o Consider adding rigid foam to the bottom of exposed floor joists in the basement.
- This guideline will not discuss the insulation of solid ground floors
    - o Not very common in the United States. The marginal benefit of the added insulation is offset by the loss of the historic floor and expense of floor removal and reinstallation.
- Buildings built in the 1970's used the most energy (Btu/ft2) of any period from 1920's-2010.
    - o Buildings from the 1960's are starting to become eligible for historic status.
    - o It is still important to preserve these buildings as part of our history.
- Buildings with concrete walls typically expose the concrete on both faces of the wall, therefore adding insulation to either the interior or exterior may affect the historic character. However, adding insulation to the interior might be acceptable.
    - o Poured concrete walls are solid without cavities which could be filled with insulation.
        - ▪ This type of construction is more commonly reaching historic status at this time.
        - ▪ Therefore, the addition of insulation is applied to the face of the wall.

Figure 03 31-1

Rigid

Figure 03 31-2

Spray foam

Figure 03 31-3

Batt insulation

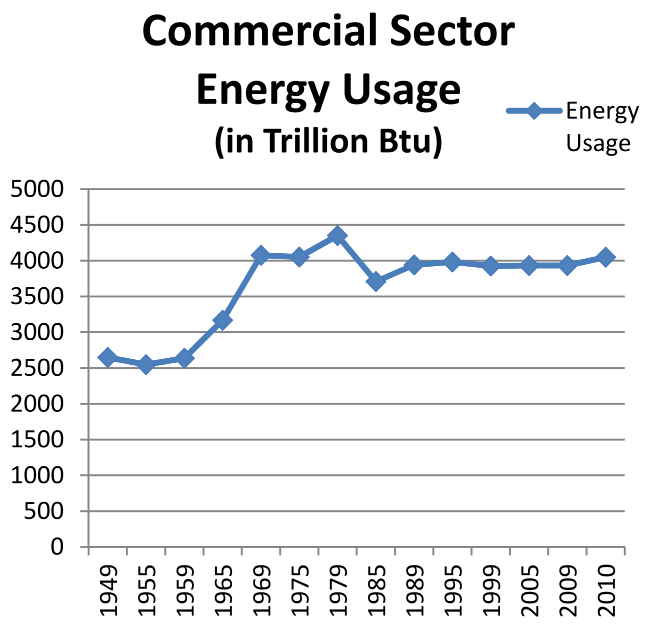


Chart 03 31-1 U.S. Energy Information Administration, Commercial Sector Energy Consumption Estimates 1949-2010, Released October 19, 2011, Updated August 2012

CONSIDERATION FOR RIGID INSULATION: applied to the interior

- **Approach:**
  - Ensure that the interior surface to be covered is non-significant
  - Work with Design Team to determine how the wall assembly works
    - Are there moisture issues?
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
  - Determine the appropriate amount of insulation to achieve the desired energy goals.
  - Apply rigid insulation to the interior face of wall, fastening it to z furring channels
    - Has significant cultural resource concerns as this action would permanently change the concrete wall
    - Less expensive than full studs
  - Build a furrout with studs (wood or steel) and add insulation between the studs.
    - Installed properly, leaves wall intact, therefore no cultural resource concern or structural concerns. Must emphasize importance of keeping the wall intact.
    - More expensive but a heavier duty structure.
    - Can achieve greater thickness of insulation = higher R value.
    - Reduces usable sf in interior space more than direct application to wall.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Adding insulation can cause interstitial condensation which can damage the structure. The Design team must be knowledgeable about the combined effects of vapor barrier location and insulation.
  - If the interior is historically significant, careful collaboration with the CRM/SHPO is required to find acceptable solutions for all concerned parties.

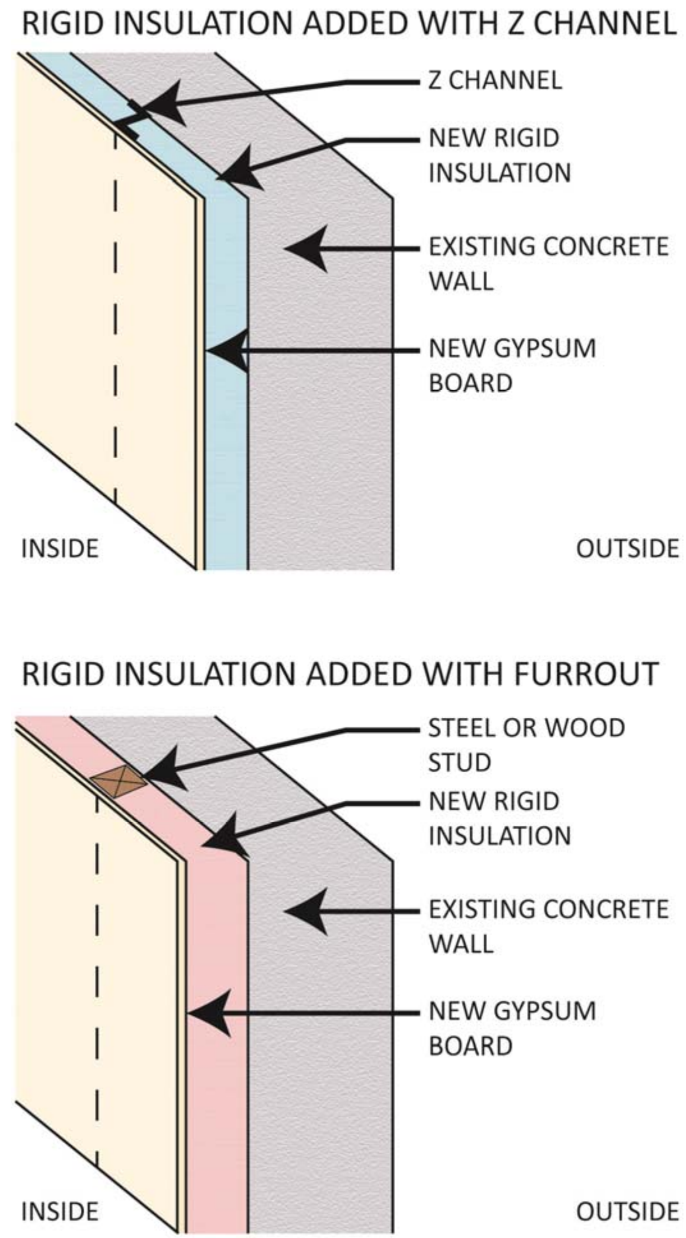


Figure 03 31-4

CONSIDERATION FOR RIGID INSULATION continued: applied to the interior

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: Concrete walls have a thermal mass (see Glossary) that absorbs and releases heat due to the density of the concrete. In some climates, that have high temperature swings in a 24-hour period, the thermal mass might be used to heat the building in the colder parts of the day and it might be best to leave these walls un-insulated. The actual thermal mass of a wall should be figured by a professional who can analyze the specific situation of the wall, orientation of the wall and the climate.
    - The thermal mass of the concrete wall may impact the performance of the wall, but is not considered in these calculations. A professional analysis is recommended.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Poured concrete wall thickness R = X/in x (wall thickness in inches) ___________
      - Rigid insulation (beadboard) ______________
      - Insulation structure (z channels) ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the concrete wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source -** ______________
    - **Cost -** ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Concrete wall – American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 2004*
- *Rigid Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE OR CELLULOSIC), FIBERGLASS BATT, NATURAL FIBER BATT INSULATION: These types of insulation will have similar approaches, fall under the same SOI Standards and have the same Historic Preservation effects.

- **Approach:** Similar approach to rigid insulation
  - Ensure that the interior is non-significant or is being significantly altered for other reasons, thus making the addition of insulation a potential option.
  - Work with Design Team to determine how the wall assembly works
    - Are there moisture issues?
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
  - Determine the appropriate amount of insulation to achieve the desired energy goals.
  - Differs from Rigid Insulation in that it requires the construction of an interior stud wall to provide a cavity for the insulation to go into.
    - Reduces the usable sf of the interior space.
    - Leaves concrete wall intact, therefore no Historic Preservation or structural concerns if properly discussed before construction.

      *** Special instructions needed for spray foam as it will bond to most surfaces (the concrete wall) that it is sprayed onto. This is almost always an adverse effect.***

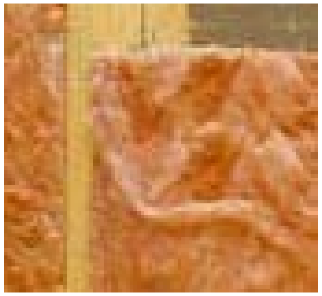
- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM and Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Adding insulation can cause interstitial condensation which can damage the structure. The Design team must be knowledgeable about the combined effects of vapor barrier location and insulation.
  - It is also important to determine whether or not the interior is historically significant.
  - The addition of interior studs wall is not easily reversible
  - The original wall will not be visible from the interior.

Figure 03 31-5

Spray Foam

Figure 03 31-6



Fiberglass Batt Insulation

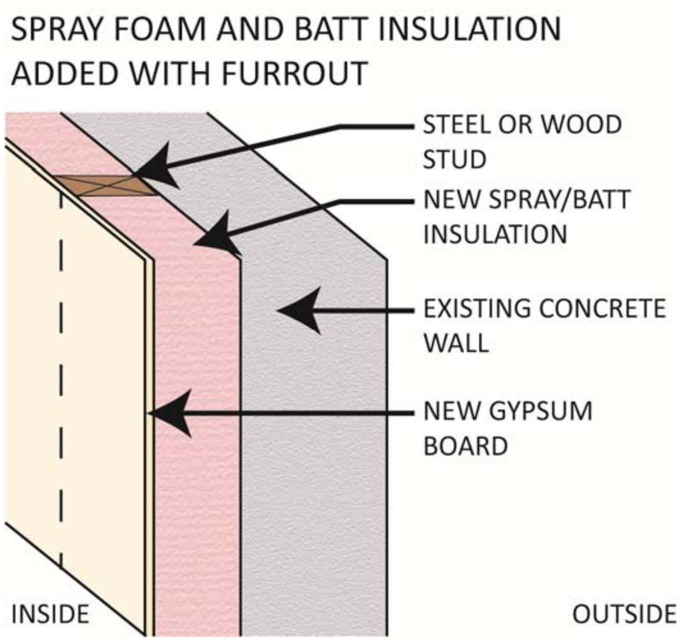


Figure 03 31-7 Very similar to rigid insulation in a furrout, except that with spray foam and batt insulation, the studs are typically much larger. Spray foam and batts rely much more on the stud structure whereas rigid insulation, as the name implies, is rigid by itself.

CONSIDERATION FOR SPRAY FOAM INSULATION (POLYURETHANE OR CELLULOSIC), FIBERGLASS BATT, NATURAL FIBER BATT INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: See description of and information regarding thermal mass on page 27.
  - Each insulation type has a different R-value.
  - Each insulation type has different air barrier and sound attenuation characteristics, which vary depending on the amount (thickness) of insulation installed.
  - Batts are a less expensive material, but can sag over time, reducing their effectiveness
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Poured concrete wall thickness R = X/in x (wall thickness in inches) ___________
      - Spray/Batt insulation ______________
      - Insulation structure (steel or wood stud) ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the concrete wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - There is significant cost associated with any of these options, as an entirely new stud wall must be built onto the inside of the existing concrete wall to house the insulation.
  - Different types of insulation have different manufacturing impacts – polyurethane spray foam insulation vs. cellulosic spray foam.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Concrete wall – ASHRAE Standard 90.1 2004*
- *Spray / Batt Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR EIFS:

Exterior Insulation and Finish Systems, multi-layered, exterior wall systems (EIMA)

- **Approach**: EIFS were first introduced in the United States almost 40 years ago.
  - EIFS typically consist of the following components:
    - Insulation board, made of polystyrene or polyisocyanurate foam, which is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment - the insulation layer
    - A durable, water-resistant base coat, which is applied on top of the insulation and reinforced with fiber glass mesh for added strength
    - A finish coat
- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
- **Historic Preservation Effects:**
  - “Adding rigid foam insulation to the exterior face of buildings…is never an appropriate treatment for historic buildings.” (Hensley and Aguilar n.d., 12)
  - The addition of EIFS covers the historic façade of a building and changes the relationship to other historic elements like windows and doors.
    - The facades are usually the most easily recognizable historic element. They are often “Character Defining Features”.
    - EIFS are modern materials and change the recognized time period of a building.
    - It is difficult to differentiate between the old and new since the new covers the old.
  - **Such a drastic change as adding EIFS, violates the tenants of Historic Preservation and therefore cannot be recommended as a viable insulation technique. The impact to the structure is greater than what any energy saving might be.**

ABBREVIATION:

EIMA – EIFS Industry Members Association

Figure 03 31-8

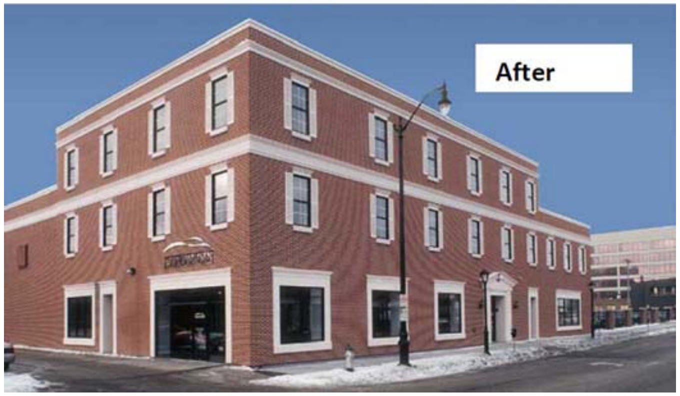


Figure 03 31-9

Dryvit (EIFS) Renovation completely changes the appearance of a building.

BMW Car Dealership, Springfield, Illinois

Designer: CDG Architects Engineers and Planners

GUIDELINE DESCRIPTION: This guideline will look at different types of insulation for masonry walls (rigid, spray, batt insulation, and EIFS). It will discuss insulating inside versus outside, and will provide advice for decision making that is appropriate for the historic condition. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for additional information on basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.

GENERAL NOTES:

- For the purposes of this document Concrete Masonry Units (CMU) will be covered here since the applicable insulation techniques for CMU match those used for of other types of masonry walls, such as stone masonry.
- Review Guideline 07 21 Thermal Insulation for steps in evaluating the existing building conditions for the specific building. Basement insulation follows similar principles outlined under this section and 03 31 Insulating Concrete Walls as basements and crawl spaces are typically masonry or concrete construction.
- Walls designed with Thermal Mass – adding insulation within the wall affects these properties
- Non-significant interiors allow for more insulation options
- Basement/crawl spaces that are non-living, service spaces provide great opportunities for insulation. However, older masonry foundations, especially stone, can have uneven walls making adding insulation to the walls nearly impossible. Therefore, adding insulation to the basement ceiling is recommended as an alternative.
    - Vapor barrier must face up to keep any moisture from condensing on the floor structure side of the insulation.
    - Ensure proper anchoring for moist situations.
    - Rigid insulation over the bottom of the floor joist is common practice

Figure 04 21-1 CMU Wall, above

Figure 04 21-2 Repointed Historic brick wall, above

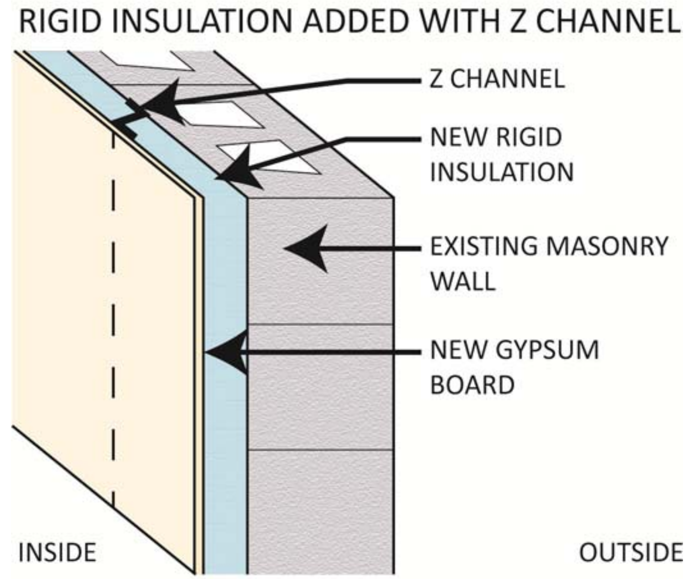
Figure 04 21-3 Stone wall, above

CONSIDERATIONS FOR RIGID INSULATION: applied to the interior

- **Approach:**
  - Ensure that the interior is non-significant or is being significantly altered for other reasons, thus making the addition of insulation a potential option.
  - Work with Design Team to determine how the wall assembly works
    - Moisture issues – Determine whether or not there are any
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
  - Determine the appropriate amount of insulation to achieve the desired energy goals.
  - Apply rigid insulation to the interior face of wall fastening to z furring channels
    - Permanently changes the wall, a significant cultural resource concern
    - Might not be possible if the historic wall has settled significantly and is not plumb, or if the material is too brittle and fragile to hold additional load.
    - Less expensive than full studs
  - Build a furrout with studs (wood or steel) and add insulation between the studs.
    - Leaves wall intact, therefore no cultural resource concern or structural concerns.
      - Must emphasize importance of keeping the wall intact to ensure that it is done.
    - More expensive but more significant structure.
    - Can achieve greater thickness of insulation = higher R value.
    - Reduces more usable sf of interior space than direct application

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM and Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building, especially if the interior is historically significant.
  - Adding insulation can cause interstitial condensation which can damage the structure. Be knowledgeable about the combined effects of vapor barrier location and insulation.



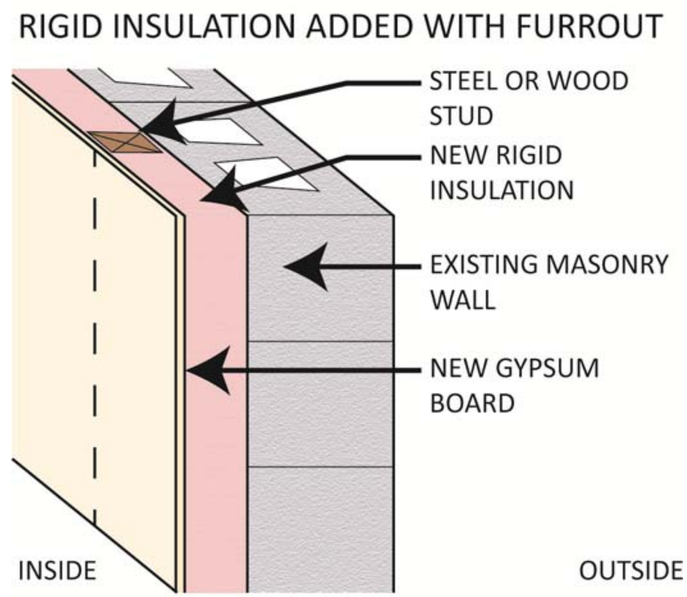


Figure 04 21-4

CONSIDERATION FOR RIGID INSULATION continued: applied to the interior

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - **Thermal Mass**: Masonry walls have a thermal mass (see Glossary) that absorbs and releases heat due to the density of the masonry, and infill. In some climates, that have high temperature swings during a 24-hour period, the thermal mass might be used to heat the building in the colder parts of the day and it might be best to leave these walls un-insulated. The actual thermal mass of a wall should be figured by a professional who can analyze the specific situation of the wall, the orientation of the wall and the climate.
    - The thermal mass of the masonry wall may impact the performance of the wall, but is not considered in these calculations. A professional analysis is recommended.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Masonry wall thickness R = X/in x (wall thickness in inches) ______________
      - Wall infill (grout, insulation) ______________
      - Rigid insulation (beadboard) ______________
      - Insulation structure (z channels or studs) ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the masonry wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Rigid Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE):

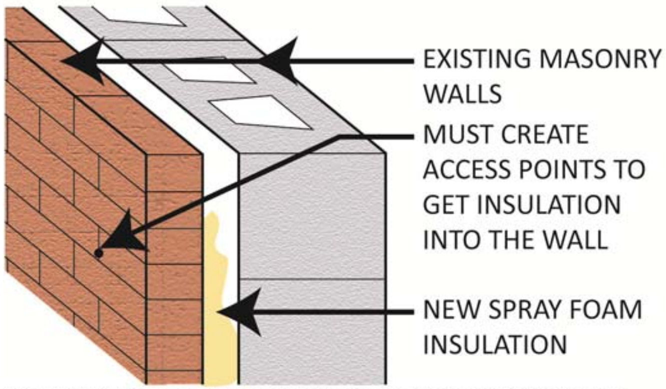
- **Approach:**
  - Typical insulation used to fill cavity spaces in historic masonry walls (Walls and Foundations of Historic Buildings n.d., 8).
  - Also can be used to fill the hollow cells of Concrete Masonry Units (CMU)
  - Pneumatically applied, polyurethane expands to fill a space once it reacts with the air.
  - General Recommendations prior to application (Gonçalves n.d., 5).
    - Repair all holes to ensure a sound substrate for insulation. Remove all loose materials (mortar, plaster parging) and clean all surfaces to ensure that the insulation will adhere.
    - The air barrier and insulation (sprayed polyurethane foam) should be continuous at the floor joists, floor slabs and adjacent components, including window interface, to ensure continuity of the air barrier and insulation system.
    - Transition membranes are suggested at critical locations, like window perimeters.
    - The International Building Code stipulates specific requirements with regards to fire stops in wall assemblies. It is important that these requirements be verified with the local building code professional.
    - Indoor relative humidity levels and building pressurization should be controlled to minimize vapor pressure gradients (and moisture migration) across wall assemblies.

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Can cause interstitial condensation (See 07 21 Thermal Insulation)
    - If not properly ventilated, moisture stays, causing major damage over time.

Figure 04 21-5

SPRAY FOAM INSULATION ADDED WITHIN MASONRY CAVITY



NO WAY TO ADD AN AIR BARRIER IN THIS SITUATION

SPRAY FOAM INSULATION ADDED WITH FURROUT

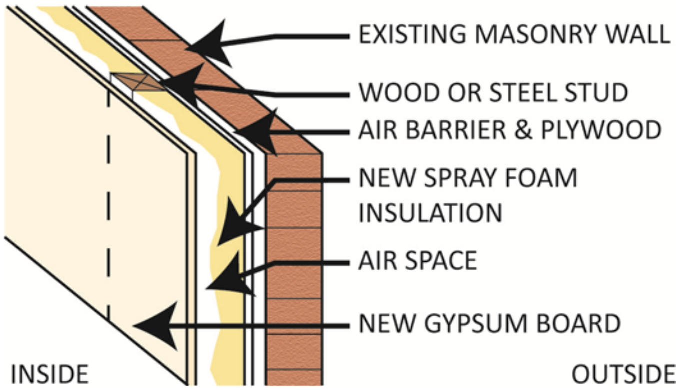


Figure 04 21-6

CONSIDERATION FOR SPRAY FOAM INSULATION (POLYURETHANE) continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: See description of and information regarding thermal mass on page 27.
  - Advantages of using spray foam insulation (polyurethane) (Gonçalves n.d., 4):
    - The polyurethane foam acts as the main air barrier material of the wall assembly with transition membranes installed at critical locations, like window perimeters.
    - It provides excellent air tightness characteristics.
    - It provides continuity at junctions with floor joists and slabs, walls, ceilings, floors and window perimeter, which is important to avoid flow of indoor air at these areas.
    - It can be applied over irregular surfaces, and total thickness can be controlled.
  - Vapor permeance depends on insulation thickness & substrate (Gonçalves n.d., 4).
  - Addition of liquid vapor barrier applied directly to the interior face of the insulation is recommended to provide a continuous high-performance vapor barrier to wall assembly (Gonçalves n.d., 3).
    - Main moisture transfer addressed with an effective and continuous air barrier, therefore vapor permeance isn't as critical.
  - The alternative to a liquid vapor barrier is a sheet barrier system: typically a sheet barrier (also known as building wrap) acts as both an air and water barrier and is mechanically fastened to the building substrate.
  - Advantages of liquid vapor barrier over sheet barrier system:
    - Continuity at junctions (ceilings, floors, window perimeters, etc.) is easily achieved without interfering with services within finished wall assembly.
    - The coating, which is applied directly to the insulation, is protected from punctures during construction or by occupants.
    - Long term effects are not fully documented.
  - Both liquid and sheet barriers can be difficult, if not impossible to add in historic buildings. The Design Team must consider if the risks to the historic structure and historic characteristics are worth the advantages of adding the vapor barrier and even the insulation itself.

Figure 04 21-7 Liquid barrier, looks like black tar

Figure 04 21-8 Sheet barrier, looks like opaque plastic

CONSIDERATION FOR SPRAY FOAM INSULATION (POLYURETHANE) continued:

- **Energy Savings Potential continued:**
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Note: Depending on each particular situation, not all of the below R-values will be present in the wall assembly.
      - Masonry wall thickness R = X/in x (wall thickness in inches) ___________
      - Wall infill (grout or spray foam insulation) ______________
      - Spray foam insulation (polyurethane) ______________
      - Insulation structure (z channels or studs) ______________
      - Air space ______________
      - Gypsum board (sheet rock) ______________
      - Vapor barrier (liquid or sheet) ______________
  - **Assumptions** (both for the calculator and table)
    - That the masonry wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Spray Foam Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR BLOWN IN / INJECTED: Mineral wool, beads or granules.

- **Approach**:
  - For Masonry, must access from the top of the wall
  - Applied pneumatically
  - Vapor retarders might not be necessary for above ground walls depending on specific conditions

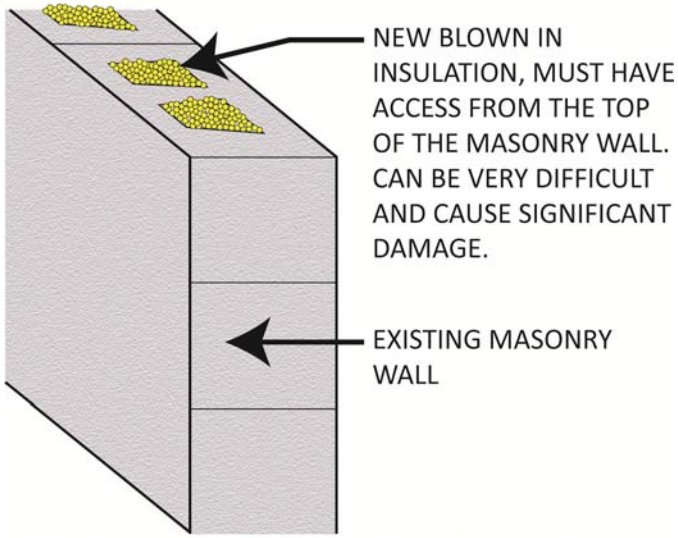
- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is Compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - **Difficult access increases the chances of damaging historic details**

Figure 04 21-9

INSULATION GRANULES

BLOWN IN INSULATION ADDED WITHIN MASONRY CELLS / CAVITIES



NOTE: YELLOW ADDED SIMPLY FOR DIAGRAM CLARITY

Figure 04 21-10

CONSIDERATION FOR BLOWN IN / INJECTED continued: Mineral wool, beads or granules.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: See description of and information regarding thermal mass on page 27.
  - Blown in / injected insulation provides more complete fill than other insulations, therefore giving a more consistent R-value throughout the entire assembly.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Masonry wall thickness R = X/in x (wall thickness in inches) ___________
      - Blown in / Injected Insulation ______________
  - **Assumptions** (both for the calculator and table)
    - That the masonry wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Blown in / Injected Insulation -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR EIFS:

Exterior Insulation and Finish Systems – multi-layered exterior wall systems (EIMA)

- **Approach**: EIFS were first introduced in the United States almost 40 years ago.
    - EIFS typically consist of the following components:
        - Insulation board, made of polystyrene or polyisocyanurate foam, which is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment - the insulation layer
        - A durable, water-resistant base coat, which is applied on top of the insulation and reinforced with fiber glass mesh for added strength
        - A finish coat
- **Applicable Secretary of the Interior Standards:**
    - 2: Historic Character Preservation
    - 3: Avoid False Historic Changes
    - 5: Distinctive Qualities Preservation
    - 9: New Work is Compatible with Historic
- **Historic Preservation Effects:**
    - "Adding rigid foam insulation to the exterior face of buildings…is never an appropriate treatment for historic buildings." (Hensley and Aguilar n.d., 12).
    - The addition of EIFS covers the historic façade of a building and changes the relationship to other historic elements like windows and doors.
        - The facades are usually the most easily recognizable historic element. They are often "Character Defining Features".
        - EIFS is a modern material and changes the recognized time period of a building.
        - It is difficult to differentiate between the old and new since the new covers the old.
    - **Such a drastic change, as adding EIFS, violates the tenants of Historic Preservation and therefore cannot be recommended as a viable insulation technique. The cost to the structure is greater than what any energy saving might be**.

Figure 04 21-11

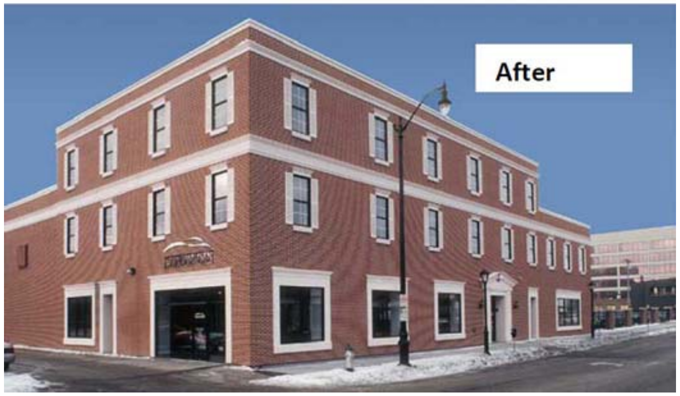


Figure 04 21-12

Dryvit (EIFS) Renovation completely changes the appearance of a building.

BMW Car Dealership, Springfield, Illinois

Designer: CDG Architects Engineers and Planners

GUIDELINE DESCRIPTION: This guideline will look at the different types of insulation and how each affects wood construction. It will establish applicable techniques (when to remove and replace wood; how to address the process of removing and replacing, keeping track of pieces; which side to insulate; and blown in insulation). It will also provide a decision making process that is appropriate for the historic condition. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 03 31 Insulating Concrete Walls, review for Basement insulation.
- 04 21 Insulating Masonry Walls, review for Basement insulation.
- 07 31 Insulation for Sloped Roofs, review for Attic insulation.

GENERAL NOTES:

- Moisture entrapment is the critical issue when discussing adding insulation to historic buildings, especially to wood structures. Moisture entrapment can not only lead to mold growth but to the rotting of the wood structure itself, causing irreparable damage. (National Trust for Historic Preservation 2012).
- National Trust states "Like masonry walls, timber framed walls are also difficult to insulate without altering their appearance or creating a potentially damaging situation. Depending on the original construction method and the extent to which the walls have deteriorated and/or need maintenance/replacement, infill insulation could be installed within a timber frame wall. But again, this is for walls that have irreparable damage or prior renovations or alterations." (National Trust for Historic Preservation 2012).
- Non-significant interiors allow for more insulation options.

Figure 06 81-1

Figure 06 81-2

Images of mold, rot and termite damage in a 30 year old structure that did not have proper exterior water drainage or proper barriers. Repair was extensive both on the interior and exterior. Such situations are even more critical with historic structures.

CONSIDERATIONS FOR NATURAL FIBER INSULATIONS: (wood, plant fiber)

- **General Info:**
    - especially recommended by the National Trust
        - Breathability, especially in attic spaces
        - Sustainability – tend to be more renewable, can be made from recycled materials, do not release harmful substances during decomposition, etc.…
        - Because they are organic materials, they can support mold if not kept dry.

- **Approach:**
    - Installed via blown-in or as batts, see following sections on the specific approach.
    - Can be difficult to find a manufacturer in specific areas.

- **Applicable Secretary of the Interior Standards:**
    - 2: Historic Character Preservation
    - 3: Avoid False Historic Changes
    - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
    - Natural fibers are most compatible with historic materials
    - These materials will cause the least damage to the structure, but the full effects cannot be evaluated without considering the specific installation technique used.
    - Some organic fibers, being organic material, can support mold. Mold can damage historic and other materials. Check the manufacturer's recommendations, and be sure that no moisture can accumulate in the fibers.

Figure 06 81-3

Figure 06 81-4

Figure 06 81-5

CONSIDERATION FOR NATURAL FIBER INSULATIONS continued: (wood, plant fiber)

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Natural fiber insulations vary greatly in individual R-values based not only on material but also on installation technique.
  - They also tend to be a little lower than poly insulations but comparable or a little better than fiberglass batts.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Exterior Sheathing ______________
      - Wood frame structure ______________
      - Natural Fiber Insulation ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the wood framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Natural fiber insulation is not as wide-spread, and so is still more expensive than fiberglass batts.
  - Cost of natural fiber insulation is comparable to spray foam insulation (see sources)
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Wood Structure –ASHRAE Standard 90.1 2004*
- *Natural Fiber Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm and http://www.ecorate.com/content/products.aspx?cid=28

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR BLOWN-IN INSULATION:

- **Approach:**
  - Walls: Insulation can settle at the bottom of the wall over time, reducing its effectiveness (over time, gravity can cause batts to sag also)
  - Dense-packed cellulose or fiberglass causes the least amount of damage to historic material/finishes when there is access (taking a siding board from the top, exterior that can be reinstalled easily)
    - Density will reduce settling
  - Dense-packed cellulose most common
    - R-value, relatively simple installation, etc…
  - Access
    - Have to drill holes as access points
      - Inside or outside but very dusty
    - Also used in cantilevered floors, under attic stairs and odd spaces behind kneewalls.
  - Comes in at least 2 grades based on fire retardant added
    - Mix of ammonium sulfate and boric acid
    - Boric acid only – borate only – recommended for historic buildings as sulfates react with moisture and can corrode metal (Hensley and Aguilar n.d.).

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is Compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Difficult access, such as cutting access holes in the exterior, historic wood siding, increases the chances of damaging historic details

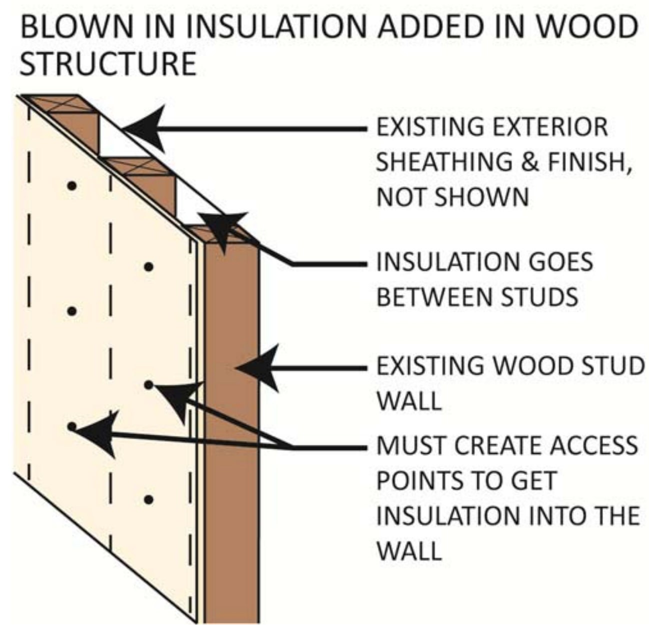


Figure 06 81-6

Figure 06 81-7 **Figure 06 81-8**
Interior and Exterior Renovation Applications

CONSIDERATIONS FOR BLOWN-IN INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Blown-in insulation provides more complete fill than other insulations, therefore giving a more consistent R-value throughout the entire assembly.
  - Air-seal: insulation material is crammed in, not fluffed in. At 3.5 pounds per cubic foot, it is too dense for air to infiltrate but still has R-value (Lugano 1996).
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Exterior Sheathing _____________
      - Wood frame structure _____________
      - Blown-In Insulation _____________
      - Gypsum board (sheet rock) _____________
  - **Assumptions** (both for the calculator and table)
    - That the wood framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Inexpensive option (Lugano 1996).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Wood Structure -ASHRAE Standard 90.1 2004*
- *Blown-In Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR FIBERGLASS BATT INSULATION:

- **Approach:**
  - Only feasible if wall cavity is already open or if the interior isn't historic and will be redone for other reasons.
  - Need tight fit so air spaces are not created. If insulation is too short or it is too long and bunched up, air pockets are created which reduces thermal performance
  - Unfaced, friction-fit batt insulation, fluffed to fill entire cavity recommended
  - Split around obstacles instead of compressed on one side
- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Difficult access increases the chances of damaging historic details

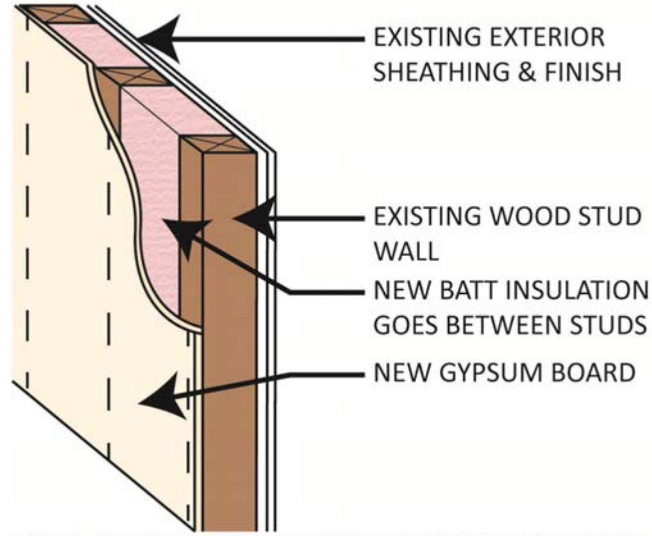


Figure 06 81-9

Figure 06 81-10 Installed faced batts in a wood stud wall.

CONSIDERATIONS FOR FIBERGLASS BATT INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Fiberglass batt insulation likely has the least energy savings of all other insulations.
    - Insulation can settle
    - Inconsistent R-value throughout assembly
    - Provides no air barrier
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Exterior Sheathing ____________
      - Wood frame structure ____________
      - Fiberglass Batt Insulation ____________
      - Gypsum board (sheet rock) ____________
  - **Assumptions** (both for the calculator and table)
    - That the wood framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Inexpensive option (Lugano 1996).
  - Very common so most know how to install (but not necessarily in historic buildings).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source -** _____________
    - **Cost -** _____________
    - **Location -** _____________
    - **Total Heating Degree Days (HDD)-** _____________
    - **Total Cooling Degree Days (CDD) -** _____________

Sources:

R-Values

- *Wood Structure -ASHRAE Standard 90.1 2004*
- *Fiberglass Batt Insulation and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE):

- **Approach:**
  - **Is not recommended for historic wood structures as wall cavity insulation because it hinders air flow and can lead to wood rot.**
  - Guideline will only provide basic information.
    - Might be acceptable in a certain, project-specific situation, but would require in-depth/careful analysis on the part of the design team of both the energy savings, monetary and historic cost to the structure.
  - Pneumatically applied polyurethane expands to fill a space once it reacts with the air.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:** All considered Disadvantages
  - Adding insulation to an existing wood structure is always difficult, especially when trying to maintain the historic integrity of the space.
  - Spray foam can be considered a chemical treatment.
  - Not easily reversible – bonds tightly to framing
  - Expansion rate of the foams can damage interior historic features
  - Relatively new material so there are questions about long term health affects

- **Energy Savings Potential:** Considered Advantages
  - High R-value, compared to other insulations
  - functions as an air barrier
  - tight fit around obstacles
  - **The advantages of Spray Foam over other insulations do not outweigh the significantly higher risks and costs associated with this product. Therefore, it is not recommended as a viable insulation technique.**

Figure 06 81-11 Notice when the foam is initially sprayed, it is relatively flat, but expands beyond the extent of the studs.

Figure 06 81-11 Trimming is not a feasible option in an Historic Structure

GUIDELINE DESCRIPTION:

This guideline will discuss the issues of making the appropriate adjustments to an historic structure related to the new addition of roofing insulation. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 31 Insulation for Sloped Roofs, review for attic insulation and specific techniques.
- 07 51 Insulation for Flat Roofs, review for specific techniques.

GENERAL NOTES:

Consider the uniqueness of the building:

- the characteristics of its materials
- the climate of its location
- the specific construction methods that were used in its construction

Improperly adding insulation to a building can potentially damage on its overall energy performance. One can (perhaps unknowingly) do irreparable damage to historic features by adding insulation where it is not needed, inappropriate, or ineffective. Many older and historic buildings were not designed with insulation, so it requires great care to select compatible insulating systems and materials. See Section 07 21 Thermal Insulation.

"Older buildings, or those built before modern HVAC systems existed, were actually built to deal with the movement of air naturally through certain design features. If the building was constructed before 1950, careful consideration will need to be given before upgrading insulation. All systems – new and old – need to work in harmony." (National Trust for Historic Preservation 2012).

Roof Detailing varies from building to building from climate to climate.

3.

2.

1.

Figure 07 01-1 Numbers reflect different additions and renovations that can be seen in the cornice detailing and brick color.

Cambridge City Hall Annex, Cambridge, MA

Figure 07 01-2 Tower and decorative parapets are just a couple of the unique details on this Historic Building.

Old Airport Terminal Building, Albuquerque, NM

GENERAL NOTES continued:

Consider the shape of the building's roof to narrow down the options:

- sloped
- flat
- combination

In addition to a roof's shape, the elements and details found on an historic roof significantly contribute to its design. Some of the most commonly found roof elements and details include:

- cornices
- parapets
- coping
- pent house roofs
- eaves
- dormers
- towers
- chimneys
- finials
- cresting
- gutters and downspouts

In addition to the shape, elements and repetitive details, the materials used to cover sloping roofs are important to defining the character of an historic building because of the visibility of that feature. The most commonly found sloping roof materials are:

- metal
- slate
- clay tile
- asphalt shingles
- wood shingles
- wood shakes

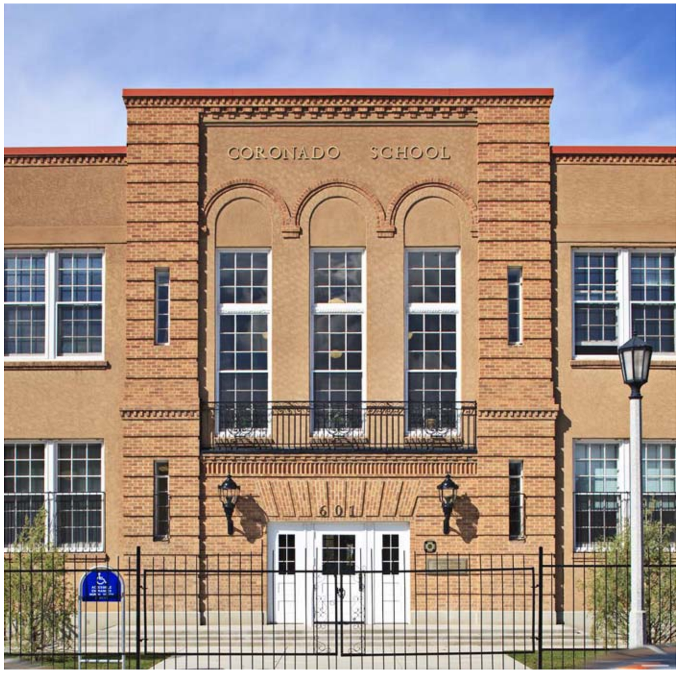


Figure 07 01-3 Historic Flat Roof, Coronado School, Albuquerque, NM

Figure 07 01-4 Historic Sloped Roof, 46 Blackstone, Cambridge, MA

GENERAL NOTES continued:

On the other hand, the appearances of materials used to cover flat roofs are usually not character defining because of their lack of visibility from the ground. They include:

- built-up roofing
- rubber roofing

Insulation can be installed in the attic space or in the roof structure. The least obtrusive method of adding insulation is in the attic space, this allows existing roof features and finish materials to remain intact and untouched. Section 07 31 Insulation for Sloped Roofs discusses this approach more in depth.

When adding insulation to the roof structure, exterior features or materials may need to be removed or replaced. Insulation adds thickness to the roof structure and may raise the overall appearance of the roof and change the relationship between the roof, overhangs, walls and parapets. This method should be a last resort and should be discussed with CRM/SHPO prior to design.

In addition, adding insulation may cause roof materials to deteriorate if it is not properly installed. This concern pertains to the 'breathing' aspect of the historic materials.

CONSIDERATIONS FOR ADDING INSULATION TO A ROOF:

- Ensure that the intervention or loss of historic fabric is kept to an absolute minimum.
- Time renovations to when routine roof maintenance is already required to pose the least impact to the roof and existing structure.
- Make sure that the structural performance of the roof will not be adversely affected.
- Be confident that the traditional 'breathing' performance of the roof is maintained, or reinstated. Take time to carefully select the materials and methods to be used, to ensure that they are compatible with traditional performance requirements. This concern usually means that the materials and 'systems' need to be vapor permeable.
- Any increased height of roof surface will impact roof drainage details. Be aware of these impacts and discuss with CRM/SHPO.

Common Historic Roofing Materials: (Top to Bottom)
Metal, Slate, Clay tile, Wood, Built-up, Rubber

Figure 07 01-5

Figure 07 01-6

Figure 07 01-7

CONSIDERATIONS FOR ADDING INSULATION TO A ROOF continued:

See 07 31 for warm and cold roof conditions. Determine whether the building has a:

- "warm roof" - has insulation between or just under or over the sloping rafters, the whole volume under the roof can be heated and used.
- "cold roof" - a pitched roof with insulation at the level of the horizontal ceiling of the uppermost floor, leaving an unheated roof space (attic or loft) above the insulation.
- combination of the two

CONSIDERATIONS FOR REMOVING, REPLACING AND RAISING THE ROOF FEATURES:

- **Approach:**
  - A potential significant change; must confer with CRM/SHPO about the changes.
  - When a rehabilitation/renovation project requires that the roof features be raised to allow for insulation installation, the following items may be affected:
    - Cornices, Finials, Cresting, gutters and downspouts and roofing materials in general
  - Photograph existing conditions
  - Remove, number, and store existing feature. Keep good records of numbered items, photos and original locations.
  - Reinstall existing features.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - **If the existing roof is in good condition, do not disturb it and find other options; or delay changes until reroofing is needed.**
  - Consult with the CRM/SHPO before design work begins. Elevations may be affected and changes will need approval (presumably all the buildings being dealt with are listed).
  - Existing removed roofing materials, such as original slate shingles, may be required to be numbered and reinstalled in the same manner they were originally installed.
  - Parapet changes often change roof drainage affecting scuppers, downspouts, etc.

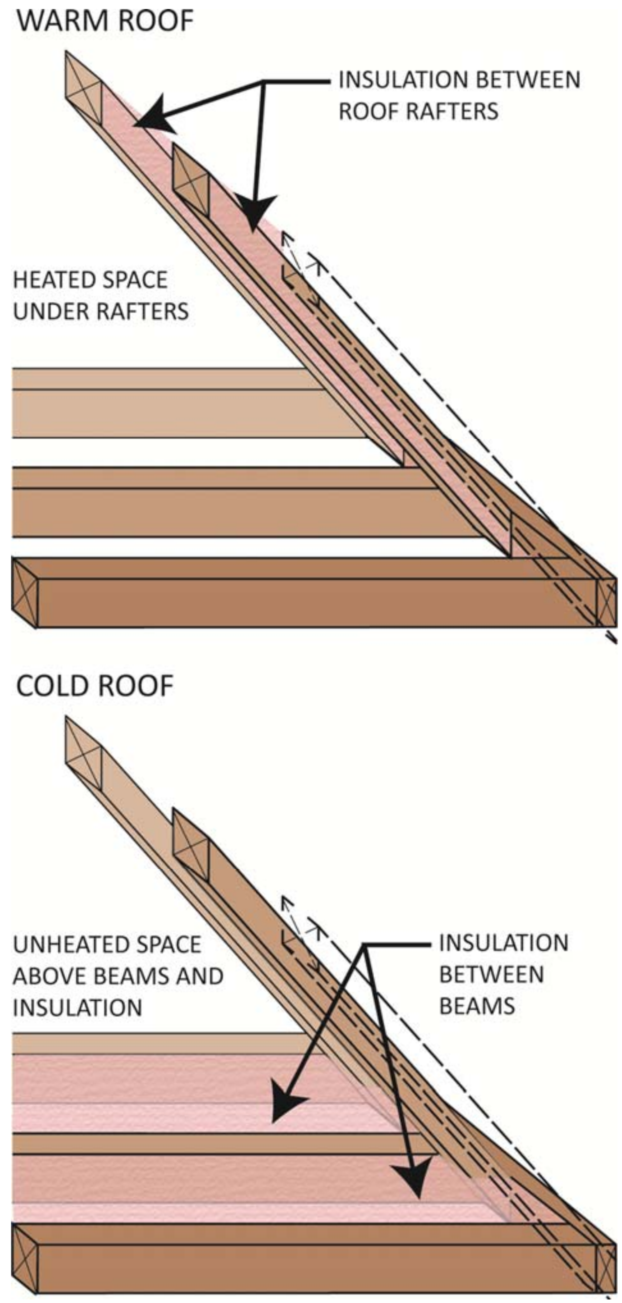


Figure 07 01-8

CONSIDERATION FOR REMOVING, REPLACING AND RAISING THE ROOF FEATURES continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding roof insulation, depending on the depth of the insulation added, will save energy accordingly.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Wood Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Extremely expensive option.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source -** ______________
    - **Cost -** ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

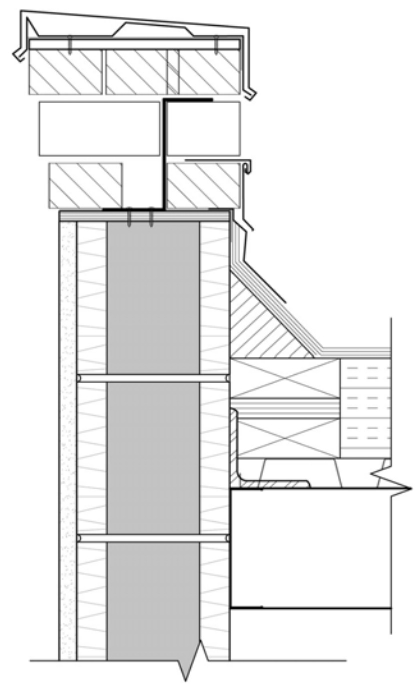
CONSIDERATIONS FOR RAISING THE PARAPETS FOR INSULATION:

- **Approach:**
  - Receive CRM/SHPO approval for the change.
  - When a rehabilitation/renovation project requires that the parapets be raised to allow for additional thickness for insulation installation, the following items may be affected:
    - Coping, eaves, gutters and downspouts
  - Photograph existing conditions.
  - New height of building must remain in scale to surrounding environment.
  - Replace existing features.
  - Should only be considered if there is another reason to raise the parapet in addition to adding insulation.
    - For example: A new elevator penthouse is required and raising the parapet will help shield the penthouse from view at the street level.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Increasing parapet height due to increased insulation should be avoided if it is possible to add insulation without such changes.
  - A change in building elevations can alter the entire character of a building. Changing the dimensions of the façade requires prior approval by the CRM/SHPO.
  - Parapet changes often require roof drainage changes that can affect historic scuppers, downspouts, etc.
  - Where new parapet caps are required, profile and color of the material must be very carefully selected to be compatible with the existing materials. Consultation with the CRM/SHPO staff is recommended.

Figure 07 01-9



Construction Detail of the parapet condition shown above. Photo does not show the reconstructed brick detailing.

Coronado School, Albuquerque, NM

Figure 07 01-10

CONSIDERATION FOR RAISING THE PARAPETS FOR INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding roof insulation, depending on the depth of the insulation added, will save energy accordingly.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Roof Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This guideline will provide a general discussion of insulation and will cross reference to the other materials where insulation is discussed. It will provide a general discussion on what insulation can provide for a building, insulation value, and additional information with energy savings data. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls for specific information on insulating concrete walls
- 04 21 Insulating Masonry Walls for specific information on insulating masonry walls
- 06 81 Insulating Wood Structures for specific information on insulating wood structures
- 07 01 Adjusting Historic Features for new insulation on roofs for discussion related to the unique conditions found on historic roofs
- 07 31 Insulation for Sloped Roofs for information on insulating attic spaces
- 07 51 Insulation for Flat Roofs for specific flat roof applications
- 07 92 Joint Sealants for information on sealing before insulation

GENERAL NOTES:

- Part one of this guideline assumes that insulation is being considered.
- Part two of this guideline discusses which insulation to install.
    - o Perform an energy audit or have a qualified energy assessment performed to identify areas of the building that are in need of energy loss reduction.
    - o Verify if the building already has insulation, how much (R-value and thickness) and where
- For the Historic Preservation Effects: See applicable sections in the Related Guidelines.

Air Escape Routes in a Building

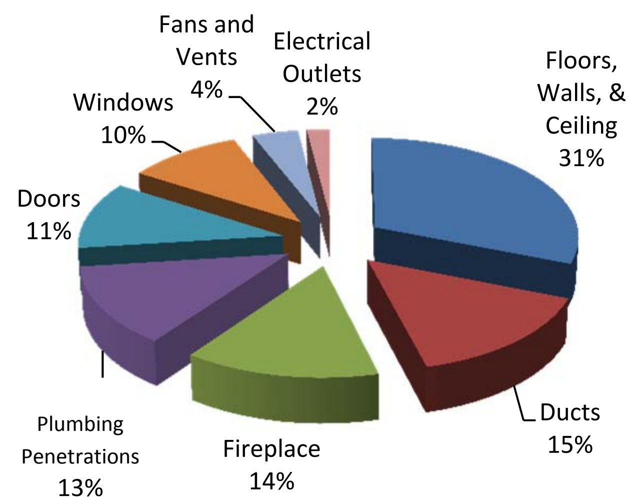


Chart 07 21-1
Energy Savers Data, U.S. Department of Energy

PART 1: PRIOR TO INSULATION

1. **Perform an Energy Audit.** For more information see 01 01 Project Organization on page 12.

2. **Check and Fix Seals and Weatherstripping.** For more information see 07 92 Using New Joint sealants on Historic Components on page 74.

3. **Improve existing systems.**
   - Regularly clean and service furnace / boiler
   - Regularly change air filters or drain the rusty sludge from boilers
   - Insulate distribution lines (ductwork or steam pipes)
   - Ensure that registers and radiators are not blocked by curtains or furniture

4. **Address Moisture Issues.**
   - Insulation can exacerbate moisture issues
     - Many buildings were designed with the knowledge that moisture would enter.
     - Insulation can entrap moisture by absorbing it or sealing the flow of air that dried it.
       - Entrapped moisture can cause wood to Rot, Pop mortar / grout joints, Corrode steel, and Foster mold growth
   - **Moisture**: Old walls were designed to allow air movement through the wall to dry moisture that seeped in. Therefore, one MUST conduct careful analysis of wall assembly to determine the extent of any moisture/ventilation conditions.
     - Building specific since many factors influence
       - Climate & microclimates (one side shaded, etc), Building geometry, Ease of air flow, Condition of building materials, Construction details, Etc…
     - Most of the United States is in a heating/cold climate which means that the most appropriate location for insulation is on the exterior wall face. Preservation dictates that insulation can only (typically) go on the inside face of the exterior wall, if at all.
     - Insulation typically reduces air infiltration which helps dry out moisture in the walls. Reducing air infiltration increases interior comfort but can cause more freeze/thaw stress issues within the cavity. This can lead to MOISTURE ENTRAPMENT.
   - **Basics:** Moisture in relatively warm air will condense on a cooler surface. It can then run down and moisten materials it touches.

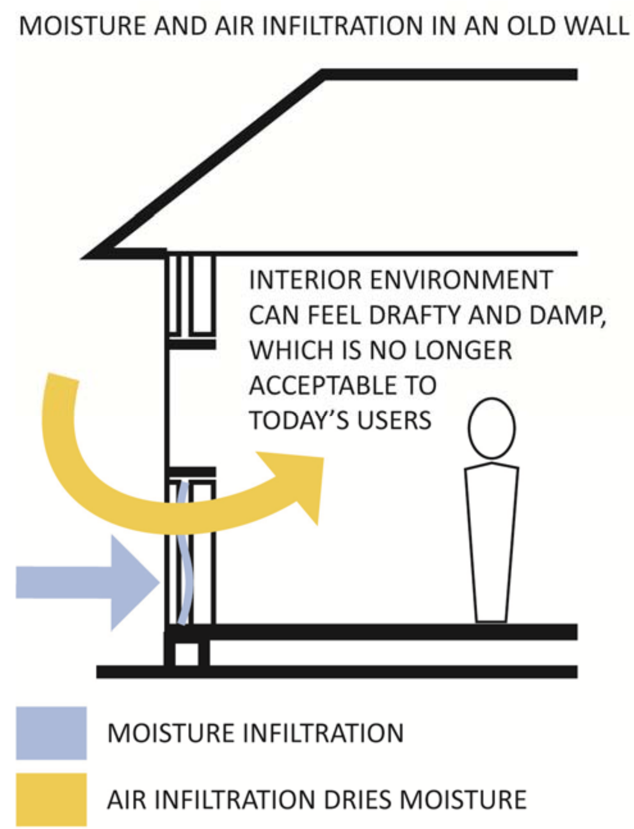
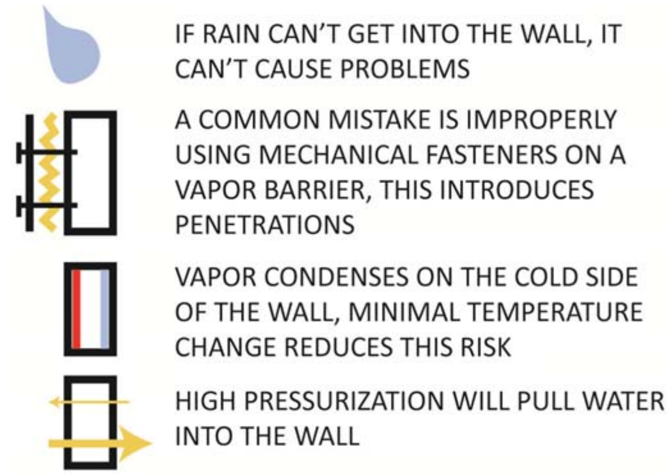


Figure 07 21-1

PART 1: PRIOR TO INSULATION continued

4. **Address Moisture Issues continued**.
   - **Moisture Entrapment**: In a study on solid masonry walls conducted by the Canada Mortgage and Housing Corporation, computer modeling showed increased condensation but visual observations did not show significant damage attributable to the retrofit.
     - The preliminary/short term results show that insulating solid masonry walls does not appear to deteriorate the exterior solid masonry wall when the retrofit approach involves the installation of a suitable air and vapor barrier.
     - While conditions for freeze-thaw action may be present, this action may not be sufficient to damage the masonry assembly.
     - An air-space behind the exterior masonry on the cold side of the new air barrier is beneficial: to reduce the rate of diffusion condensation, to provide improved drainage in pressure equalized walls, to reduce moisture entrapment, and to improve the drying rate of the exterior masonry through convection and air travel.
   - **Minimizing Moisture Issues:** Aimed to help control humidity attacking the wall assembly
     - **Minimize rain penetration into the wall assembly**
     - **Provide a continuous vapor barrier within the wall assembly to minimize interior moisture getting into the assembly.**
       - Location of the barrier depends on several factors: wall materials, their order of installation, the temperature and relative humidity conditions maintained.
     - **Minimize the temperature drop within the wall assembly:**
       - Balance between objectives of durability, thermal performance and comfort.
     - **Minimize the air pressure differential across the exterior wall assembly:**
       - Balance mechanical systems so a relatively neutral air pressure exists.



5. **Before adding insulation consider:**
   - Has attic and basement insulation already been done?
   - Can energy savings be achieved another way?
   - Can insulation be added without causing significant loss of historic material or deterioration of the wall assembly?
   - Will it be cost effective?

PART 2: DETERMINING WHICH INSULATION TO USE AND WHERE IT SHOULD BE LOCATED

1. Most people automatically assume insulation in walls first. However, in historic structures, walls should be the last place to add insulation because of the difficulty and cost of the installation, and the risk it poses to historic elements. Consider Attics and Basements/Crawlspaces first as these spaces tend to be uninhabited, service spaces.

2. **Attics:** These are great places to insulate because the historic materials found in attics are not typically character defining, and the spaces are not regularly inhabited. See 07 31 Insulating Sloped Roof for specific information on insulating attic spaces.

3. **Basements/Crawlspaces:** Like attics, these are also great places to insulate. See 03 31 Insulating Concrete Walls and 04 21 Insulating Masonry Walls for more specific information.

4. **Walls**: Not recommended for many reasons, can be very difficult and expensive
   - Exterior wall insulation is rarely, if ever, appropriate for historic buildings because:
     - Likelihood of damage to the exterior finishes.
     - Increased thickness changes relationship of wall to roof, windows, eaves, thus compromising the architectural integrity and appearance, interferes with details, etc
   - Insulation in general is not recommended by the National Trust unless for a major rehab
     - Destroys historic detailing if surfaces need to be removed to add the insulation.
       - National Trust states that with historically-significant interiors, adding insulation poses too high of a risk to the historic aspects (ie cornices), moisture intrusion with insufficient energy savings.
     - Non-original, non-significant materials can hinder application, too, if they have been applied overtop of historic materials.(Walls and Foundations of Historic Buildings, 9)
       - Will removal further damage the historic material beneath?
       - Is the added risk, cost of removal and probable repair of underlying material worth the increased efficiency?
   - Covering an original wall is almost never appropriate
   - If non-original material already exists and shouldn't be removed and is not significant in itself, it may be appropriate to cover it – as long as the new material is compatible with the wall assembly.

ALWAYS CONSIDER ATTIC, BASEMENT AND CRAWLSPACE INSULATION **BEFORE** WALL INSULATION

Figure 07 21-2

PART 2: DETERMINING WHICH INSULATION TO USE AND WHERE IT SHOULD BE LOCATED continued

4. **Walls continued:**
   - As previously stated in Part 1 page 56, conduct a careful analysis of wall assembly, especially regarding possible moisture/ventilation issues.
     - Determine the type of construction
       - Wood
       - Masonry: Solid, Cavity, Early cavity (tied with brick/masonry leaves, no insulation, unpredictable cavity depth, not easy to discover)
     - Determine Dampness – walls that have been wet for years can take years to dry out
     - Try to determine the movement of heat and water. This is very difficult to assess because data isn't available and models reflect idealized situations.
     - Determine the hardness of materials
       - Lime-based mortars are softer and "breath" more than cement based products
     - Determine the Thermal Mass if any
     - Determine if there is any wildlife and if it is a protected species. Birds/bats can make homes in cavity walls.

5. Determine the Amount of Historic Material on the building:
   - The greater the retrofit and the more historic material that needs to be replaced for other reasons provide more available options for insulation. The key is to find the balance between preservation, increased energy efficiency and cost.
   - Non-significant interiors do allow for more insulation options.

6. Location of mechanical equipment is an important consideration when determining the thermal envelope, i.e. the location of the insulation
   - Mechanical equipment should be in the thermal envelope of the building, if possible.

7. Some states have specific requirements regarding insulation. Work with local CRM/SHPO to determine what meets preservation goals, energy goals and is best for the specific bldg. (Building Energy Codes Program: Status of State Energy Code Adoption 2012).

Resources:
All SHPO: http://www.nps.gov/nr/shpolist.htm

SHPO Inventories of Historic Places on the Web
http://www.cr.nps.gov/nr/shpoinventories.htm

National Park Service provides additional useful links:http://www.cr.nps.gov/nr/preservation_links.htm#shpo

Insulation Basics :
http://www.ornl.gov/sci/roofs+walls/insulation/ins_01.html

Insulation Guides:
http://www.climatechangeandyourhome.org.uk/live/saving_energy_in_buildings_intro.aspx

Holding the Line: Controlling Unwanted Moisture in Historic Buildings NPS Brief 39:
http://www.nps.gov/history/hps/TPS/briefs/brief39.htm

Additional Wall Insulation Information:
http://www.oldhouseweb.com/blog/adding-wall-insulation/

GUIDELINE DESCRIPTION: This guideline will explore the different sloped roofing exterior materials. It will discuss the design/technology of the historic roofing systems and how insulation can be applied. It will also look at adding insulation in the horizontal plane of the attic area and discuss pros and cons of insulating or not insulating the entire interior space. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 01 Adjusting Historic Features for new insulation on roofs
- 07 21 Thermal Insulation for basic considerations on insulating historic buildings
- 07 51 Insulation for Flat Roofs for issues related to flat roofs
- 07 92 Joint Sealants for sealing joints in roof and other building features
- 23 12 HVAC Exterior Placement for rooftop and attic equipment considerations

GENERAL NOTES:

- Historic, free-standing buildings often have sloped roofs which vary in shape:
  - Gable
  - Hipped
  - Cross Gable
  - Mansard
  - Gambrel
  - Shed
- Design Technology of Historic Roofing Materials: In many older buildings, the original architects designed the roof structure with liberal slope for drainage. Typically, low-slope decks employing masonry or cementitious materials were protected by built-up coverings or sheet metal. A common practice on low slopes was to use an organic felt bituminous-membrane system adhered directly to the deck, without rigid insulation. In our research – and depending on the age of the structure – it is not unusual to discover several membrane layers applied one over the other, sometimes with rigid insulation installed between some of the layers, as well. Also, older building designs often include attic spaces, providing access to mechanical, plumbing, and electrical services.

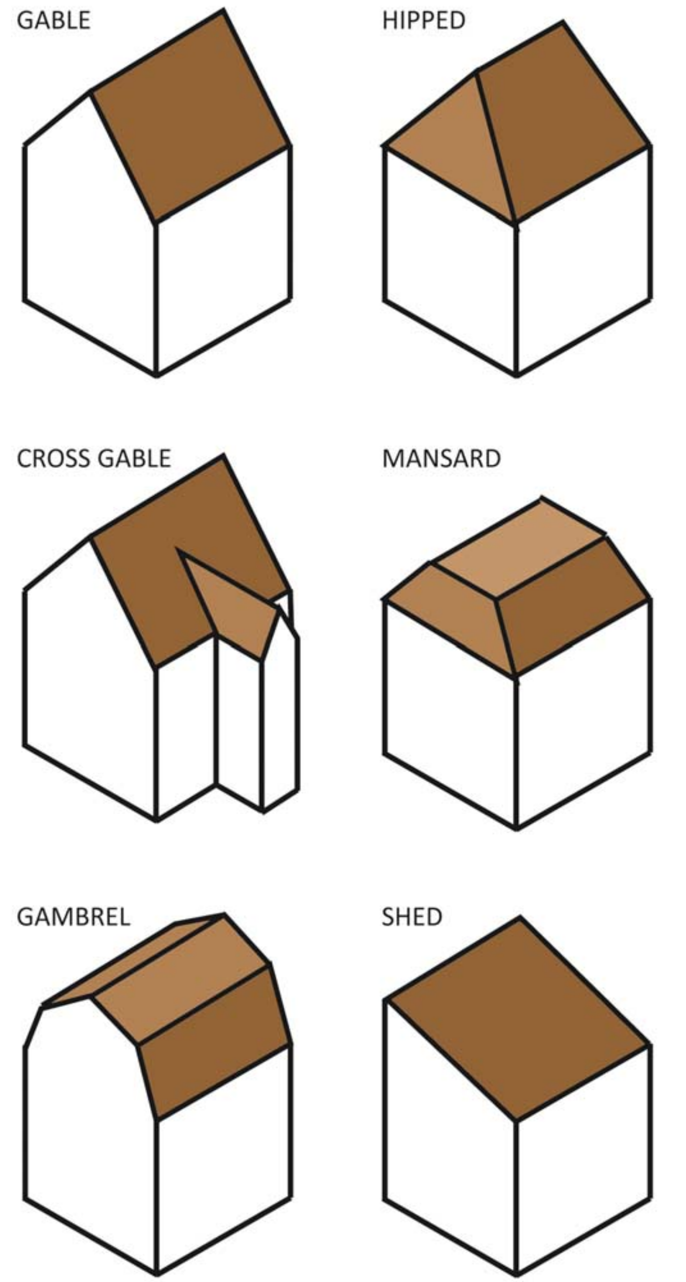


Figure 07 31-1

GENERAL NOTES continued:

- Roof Insulation Applications:
  - First choice – in the attic
  - Second choice – in the roof assembly, being careful with removal and replacement of historic roofing materials.
  - The addition of insulation to the roof assembly may be desired, but it may not be necessary if an attic space exists. Insulating the attic rather than the roof system is a more viable option in order to meet energy code requirements. Insulation can also be used in the roof assembly where the substrate is uneven and irregular to provide a smooth, uniform surface for the roof membrane.
- Roofs are insulated to reduce energy consumption. The location of roof insulation when installed in the attic space rarely affects the appearance of a building and thus will usually not alter its character. However, adding insulation may cause roof materials to deteriorate if it is not properly installed.

GENERAL CONSIDERATIONS:

- Ensure that the intervention or loss of historic fabric is kept to an absolute minimum.
- Make sure that the structural performance of the roof will not be adversely affected.
- Be confident that the traditional 'breathing' performance of the roof is maintained, or reinstated. Take time to carefully select the materials and methods to be used, to ensure that they are compatible with traditional performance requirements. This consideration usually means that the materials and 'systems' need to be vapor permeable.
- Determine whether the building has either a:
  - "cold roof" - a pitched roof with insulation at the level of the horizontal ceiling of the uppermost floor, leaving an unheated roof space (attic or loft) above the insulation.
  - "warm roof" - has insulation between or just under or over the sloping rafters, the whole volume under the roof can be heated and used.
  - combination of the two

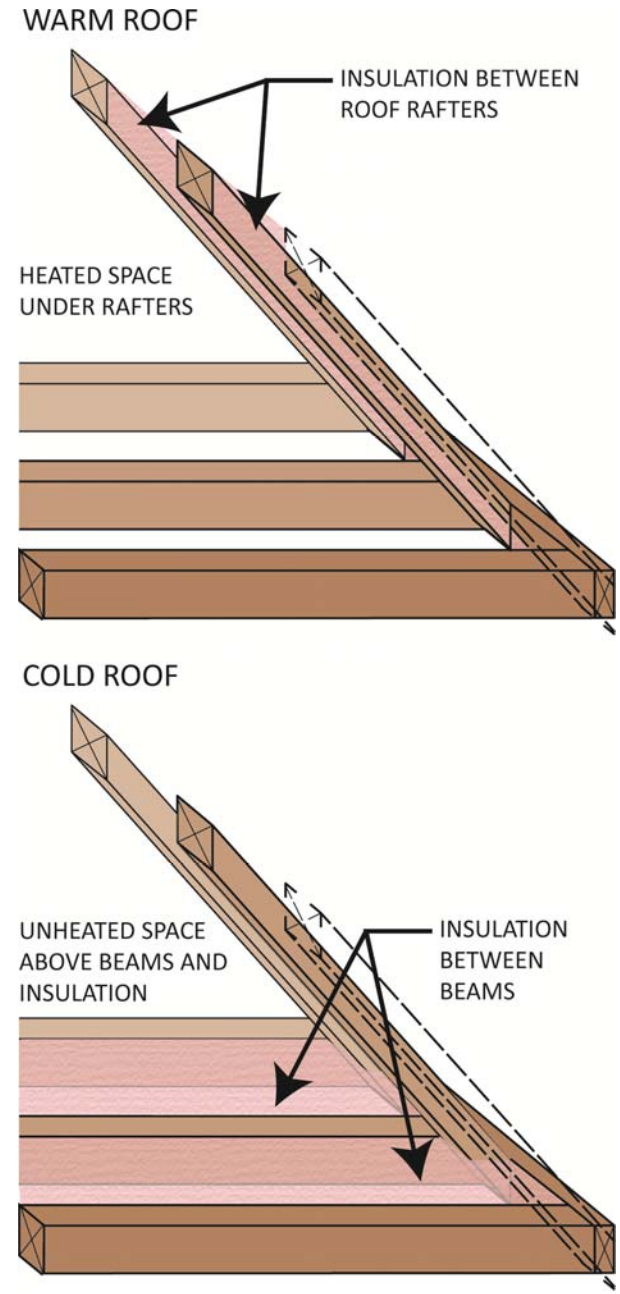


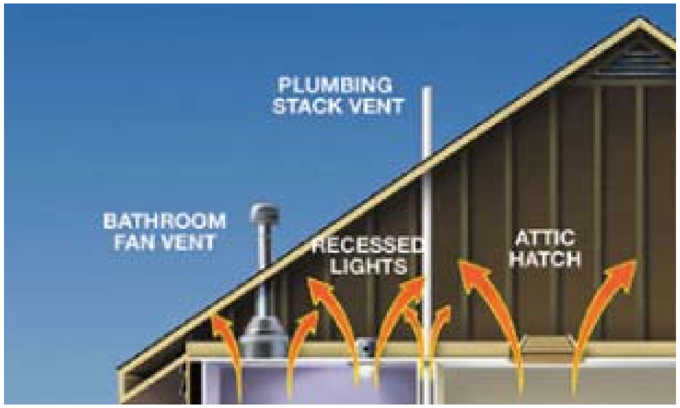
Figure 07 31-2

CONSIDERATIONS FOR INSTALLING ATTIC INSULATION OR COLD ROOF APPLICATION:

Attics are great places to insulate because the historic materials found in them are not typically character defining, and the spaces are not regularly inhabited.

- **Approach:** This guideline assumes that all attics are of similar construction, typically timber-framed (or steel frames with the newest buildings becoming eligible).
  - Insulating attics is preferable to insulating roof deck which contain a larger envelope and more difficult installation, but might consider roof deck if mechanical equipment is housed in the attic. (Hensley and Aguilar n.d., 8).
  - In the vented attic of older buildings insulation goes between the ceiling joists. Make sure that the insulation does not incorporate any vapor barrier or paper facing. The insulation should be prevented from getting dirty as this reduces its effectiveness.
  - Before installing any type of insulation in an attic, follow the steps outlined in Part 1 of 07 21 Thermal Insulation and those that follow below.
  - Seal all attic-to-living/working space air leaks.
    - Duct exhaust fans to the outside. Use a tightly constructed box to cover fan housing on attic side. Seal around the duct where it exits the box. Seal the perimeter of the box to the drywall on attic side.
    - Cover openings—such as dropped ceilings, soffits, and bulkheads—into attic area with plywood and seal to the attic side of the ceiling.
    - Seal around chimney and framing with a high-temperature caulk or furnace cement.
    - At the tops of interior walls, use long-life caulk to seal the smaller gaps and holes. Use expanding foam or strips of rigid foam board insulation for the larger gaps.
  - Install blocking (metal flashing) to maintain fire-safety clearance requirements for heat-producing equipment found in an attic, such as flues, chimneys, exhaust fans, and light housings/fixtures unless the light fixtures are IC (insulation contact) rated. IC-rated lights are airtight and can be covered with insulation.
  - Make sure insulation doesn't block soffit vents to allow for attic ventilation.
  - Check the attic ceiling for water stains or marks. They indicate roof leaks or lack of ventilation required to dry moisture intrusion. Make repairs before insulating. Wet insulation is ineffective and can damage the building.
  - Insulate and air seal the attic access if it is located in a conditioned part of the building.

(Heated) Air Leaking out of a building



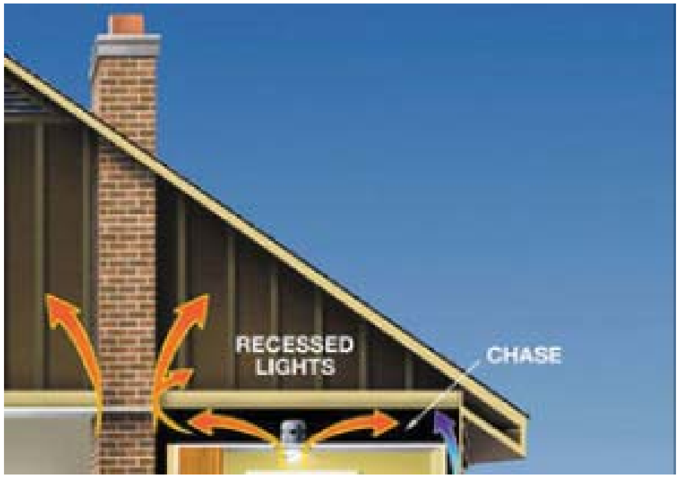


Figure 07 31-3
Graphics Courtesy of the U.S. Department of Energy

CONSIDERATIONS FOR INSTALLING ATTIC INSULATION OR COLD ROOF APPLICATION cont.:

- **Approach continued:**
  - **Types of Insulation:**
    - Rigid foam or batts common
      - Discuss use of vapor retarder with Design Team.
      - Possible to add new insulation over existing.
        - use unfaced batts, placed perpendicular to old and over top of joists to reduce thermal bridging. (Hensley and Aguilar n.d., 7).
    - Open-cell spray foam only to be used when there are no gaps in roof sheathing
      - Permanent and Higher possibility that roof leaks could go undetected.
    - Use Blown-in where fiberglass batts can be difficult to install. (Lugano 1996).
      - Ensure proper preparation is taken prior to installation to minimize insulation getting into the wrong places or potentially causing a fire.
      - Use low pressure and speed on top of existing material to yield higher R-values.
  - **REMEDIATION** of existing insulation: Vermiculite and perlite insulation materials are common in attic insulation installed before 1950. Vermiculite insulation materials sometimes contain asbestos. However, asbestos is not intrinsic to vermiculite. (U.S. EPA 2012). If there is vermiculite insulation in the attic, do not disturb it. Have it tested for asbestos content by a reputable hazardous material testing company.
    - Sequence for remediation:
      1. Test insulation material
      2. If asbestos is present – have a professional prepare a removal specification
      3. Abatement conducted by professional hazardous material removal service
      4. Regular insulation contractor to proceed with new insulation installation
- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
- **Historic Preservation Effects**
  - No adverse effects, however, spray foam generally has an adverse effect because it is not reversible. The easiest and least intrusive installation method is adding batts between the ceiling joists. It can be easily removed without damage to the building.

Figure 07 31-4
Fiberglass Batts: Insulation still needs to be added perpendicular to the joists to reduce thermal bridging.

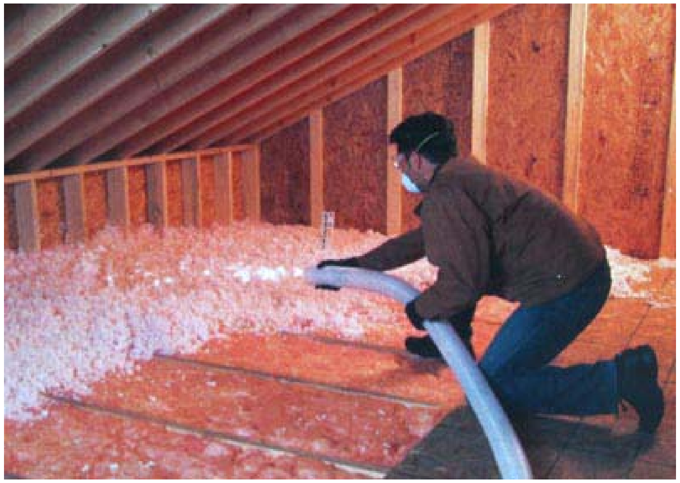


Figure 07 31-5
Blown in Insulation Installation

CONSIDERATIONS FOR INSTALLING ATTIC INSULATION OR COLD ROOF APPLICATION cont.:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - Adding insulation in an area that had little to no insulation will only benefit the building's energy savings. The savings potential will be dependent on:
    - Whether the attic was air-sealed properly
    - The amount of new insulation installed
    - The R-value of the insulation installed
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Roof Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Loose-fill or batt insulation is typically installed in an attic. Installation costs may vary, loose-fill insulation is usually less expensive to install than batt insulation. When installed properly, loose-fill insulation also usually provides better coverage.
    - Typically, a low cost, highly effective retrofit.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR A WARM ROOF:

- **Approach:** If the attic is not vented, the easiest solution is to use a radiant barrier over the attic rafters. This will prevent 95 percent of the heat from the roof from coming into the attic in the summer. Make sure that the radiant barrier has an air space between the material and the underside of the roof.
  - o A radiant barrier is highly reflective sheet/coating (aluminum) applied to one or both sides of a flexible material.
    - ▪ Foil surface faces an air space.
  - o A radiant barrier's effectiveness depends on proper installation. Therefore, it's best to have a certified installer do it.
  - o It is NOT recommended for the radiant barrier to be installed on top of attic floor insulation. It will be more susceptible to dust accumulation and trap moisture on the underside.
  - o Radiant barriers – in lieu of insulation, "to reduce thermal radiation across the air space between the roof deck and attic floor in order to reduce summer heat gain" (Hensley and Aguilar n.d., 8).

- **Applicable Secretary of the Interior Standards:**
  - o 2: Historic Character Preservation
  - o 3: Avoid False Historic Changes
  - o 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - o Because mechanical attachment to rafters is necessary, it will take minor effort to remove and fill holes if required to remove radiant barrier.
  - o If historic roofing is not salvageable, the radiant barrier can be installed before new roofing is installed.

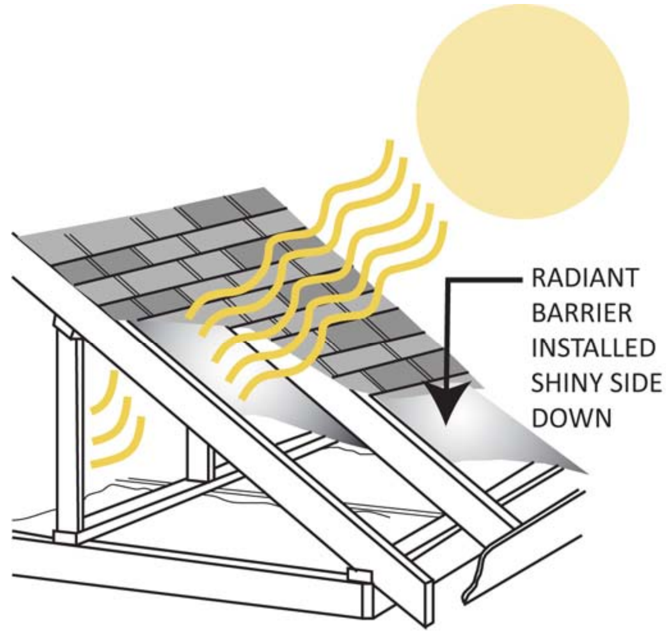


Figure 07 31-6

Figure 07 31-7

CONSIDERATIONS FOR A WARM ROOF continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding a radiant barrier in an area that has little to no insulation will only benefit the building's energy savings. The savings potential will be dependent on:
    - Climate – radiant barriers can be used in hot climates to reduce cooling loads.
    - Reflectivity of surface – barriers are only effective if the surface remains reflective.
    - Placement - don't use against insulation, as it can act as vapor barrier.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Roof Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Radiant Barrier ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Radiant Barrier and other materials - www.coloradoenergy.org/procorner/stuff/r-values.htm*

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This guideline will discuss the re-roofing of flat roofs and adding rigid tapered insulation on top of the roof deck, and using different color roofing materials while providing appropriate drainage. It will also discuss applying insulation to the underside of the roof and the pros and cons to this method. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 01 Adjusting Historic Features for new insulation on roofs
- 07 21 Thermal Insulation for general insulation information
- 07 51 Insulation for Sloped Roofs for similar concepts
- 07 92 Joint Sealants for how to seal roof penetrations
- 23 12 HVAC Exterior Placement for roof top equipment considerations

GENERAL NOTES:

- The term flat roof is somewhat misleading. Flat roofs are rarely absolutely flat, they usually slope toward the rear of the building to drain water. Since a flat roof is typically not visible from the ground, its design does not normally contribute to the character of the building. However, the cornice, parapet, pent house roof or other feature at the edges of a flat roof are often visible, potentially, contributing to the character of a building.
- The materials used to cover flat roofs are usually not character defining. They include:
  - built-up roofing
  - rubber / membrane roofing
- An Owner can increase the energy efficiency of a flat roof system by:
  - Adding insulation and increasing R-value
  - Applying the insulation in a more efficient manner (seams staggered or “screw and mop”)
- The location of roof insulation on a flat roof rarely affects the appearance of a building. However, adding insulation may cause roof elements to be raised higher than their original location, and additional height can impact façade proportions, drainage features and other façade details. See more under Section 07 01.

Figure 07 51-1
New insulation and built-up roof applied to historic Coronado School, Albuquerque, New Mexico.

CONSIDERATIONS FOR NEW FLAT ROOFS (WARM ROOF):

- **Approach:**
  - Often it will be easier and less damaging to remove roof coverings to upgrade a roof than to take down and replace historically significant ceilings. The installation of insulation above the decking will require the roof to be raised externally to accommodate proper drainage, which may or may not be acceptable. This installation above the decking and below the waterproof layer is called the 'warm deck' system.
    Basic Principle: Insulation placed above the structural deck and beneath the waterproof layer (warm roof construction) reduces the risk of condensation but, because the waterproof layer is thermally isolated from the rest of the roof construction, it is exposed to wide temperature fluctuations with consequent increased risk of premature failure.

- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - By adding insulation to the roof system, the required thickness of insulation may require the roof elevation to be raised, thus affecting parapet heights and downspout heights. Discussion with the CRM/SHPO may be necessary to get the approvals for these changes.
  - Historically significant ceilings can be preserved with this method.

WARM DECK ASSEMBLY

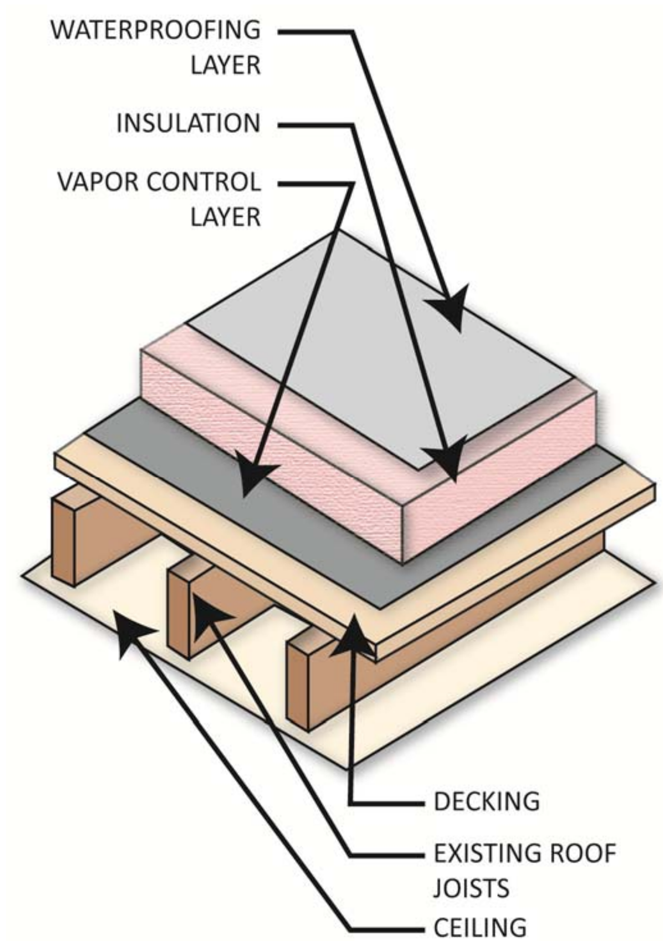


Figure 07 51-2

CONSIDERATIONS FOR NEW FLAT ROOFS (WARM ROOF) continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Depending on the height of parapets and downspouts, the amount of insulation installed can vary. Energy Savings Potential is high.
  - New roofing material can be incorporated because flat roofs are not visible from the ground. By using material with higher reflectance, less heat is absorbed, thus saving on cooling costs.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - New Exterior Roofing Material ______________
      - Vapor Retarder / Waterproofing ______________
      - Insulation Material ______________
      - Roof Framing (deck, joists and beams) ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - A Thermoplastic Polyolefin (TPO) membrane roof is the most cost effective.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

- **Other Considerations**
  - Care should always be taken not to force insulation down onto the ceiling from above because it can distort the ceiling surface.

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation, new roof and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR ADDING INSULATION <u>ON</u> A NEW FLAT ROOF (INVERTED WARM ROOF):

- **Approach:** Another option to the installation for a "Warm Roof" application is to install the insulation above the decking AND the waterproofing layer. This is called the 'inverted warm deck' system.

  Basic Principle: The inverted roof concept overcomes the problem by placing thermal insulation above the waterproof layer, maintaining it at an even temperature close to that of the building interior and protecting it from the damaging effects of UV radiation and from mechanical damage. The risk of condensation is eliminated.

- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - By adding insulation to the roof system, the thickness of insulation may require the roof elevation to be raised, thus affecting parapet heights and downspout heights. Discussion with the CRM/SHPO may be necessary to get the approvals for these changes.
  - Ceilings can be preserved with this method.

INVERTED WARM DECK ASSEMBLY

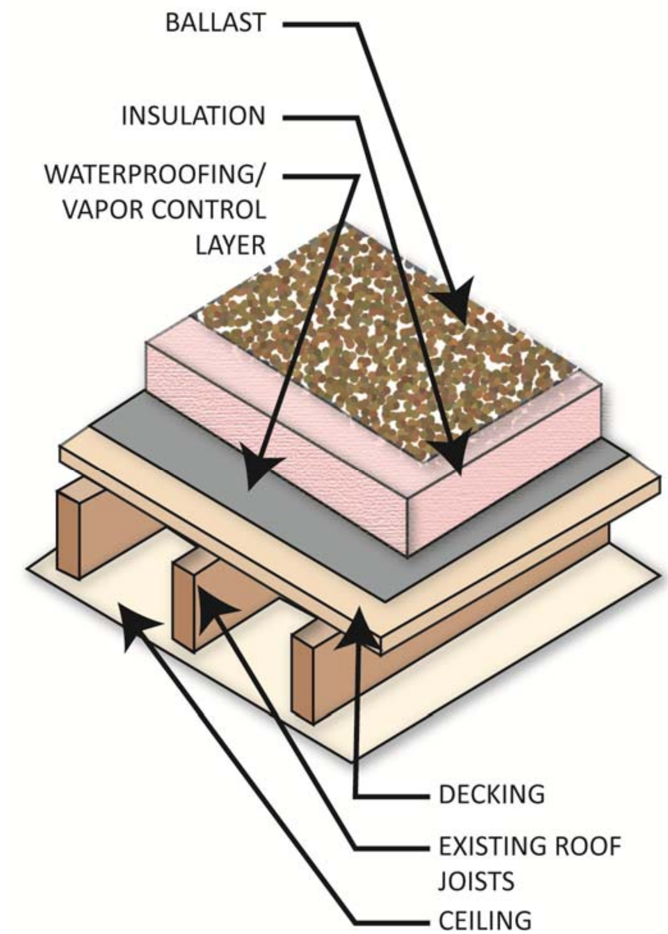


Figure 07 51-3

CONSIDERATIONS FOR ADDING INSULATION ON A NEW FLAT ROOF (INVERTED WARM ROOF) continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - Depending on the height of parapets and downspouts, the amount of insulation installed can vary. Energy Savings Potential is high.
  - New roofing material can be incorporated because flat roofs are not visible from the ground. The 'inverted warm deck' system usually works with a ballast roof system.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - New Exterior Roofing Material ______________
      - Vapor Retarder / Waterproofing ______________
      - Insulation Material ______________
      - Roof Framing (deck, joists and beams) ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

- **Other Considerations**
  - Care should always be taken not to force insulation down onto the ceiling from above because it can distort the ceiling surface.

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation, new roof and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR ADDING INSULATION UNDER A NEW OR EXISTING FLAT ROOF:

- **Approach:**
  - Insulation within the roof construction can be installed below the decking and above the ceiling, called the 'cold deck' system,
  - Insulating with the 'cold deck system' is perhaps the most frequently used arrangement in historic buildings, but not necessarily the most appropriate. Ceilings need to be removed in order for the insulation to be installed.
  - **Basic Principle:** If insulation is placed below the structural deck (cold roof construction) the structure remains cold and there is a considerable risk of condensation; for that reason cold deck roofs are not recommended and are now seldom used.
  - Ensure that the intervention or loss of historic fabric is kept to an absolute minimum.
  - Make sure that the structural performance of the roof will not be adversely affected.
  - Take time to carefully select the materials and methods to be used, to ensure that they are compatible with traditional performance requirements - this usually means that the materials and 'systems' need to be vapor permeable.
  - Roof slope – adding thickness to a roof slope may affect the parapet heights.
  - Roof drainage – adding insulation creates new slopes to existing roof drains. Drains need to be raised in some cases.
  - U.L. Fire Classification Requirements
  - Repair vs. Replacement

- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - Ceilings need to be removed for this installation.
  - Sometimes it is discovered that the roof structure and/or roof deck, has been damaged and will need repair.
  - Maintain or reinstate the traditional 'breathing' performance of the roof.

COLD DECK ASSEMBLY

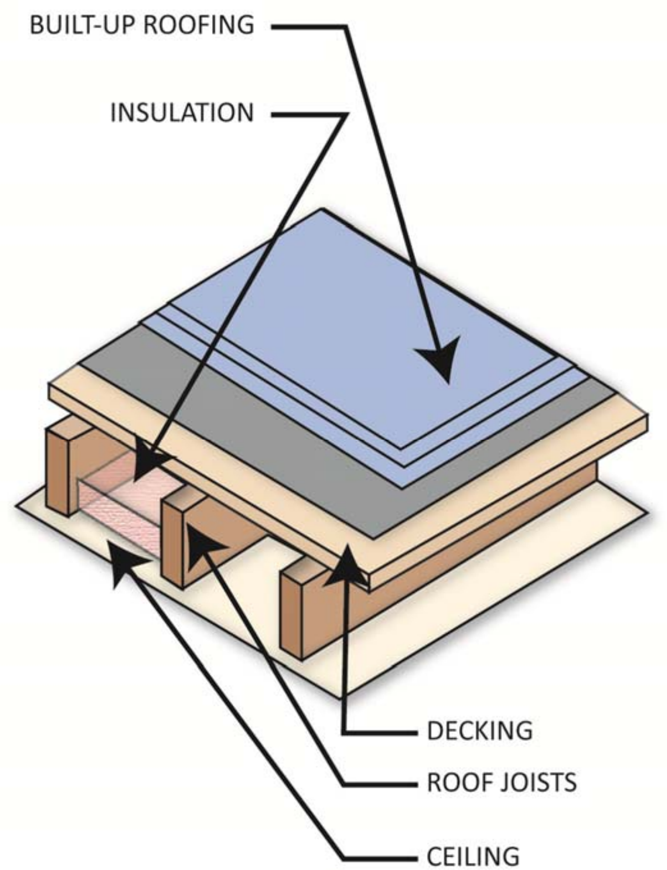


Figure 07 51-4

CONSIDERATIONS FOR ADDING INSULATION UNDER A NEW OR EXISTING FLAT ROOF continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding any insulation into the roof system is an energy savings benefit. Just how much depends upon the roof structure space.
  - R-Value – verify the building code requirements for insulation R-values
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - New or Existing Exterior Roofing Material ______________
      - Vapor Retarder / Waterproofing ______________
      - Roof Framing (deck, joists and beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Can be more expensive depending on the ceiling type to replace.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation, roof and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This guideline will provide a general discussion of sealants (caulking) and focus on applications for blocking drafts and closing gaps for energy efficiency. It will discuss considerations when using a new joint sealant on an historic component. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, 04 21 Insulating Masonry Walls, and 06 81 Insulating Wood Structures for appropriate strategies in preventing infiltration/exfiltration in walls.
- 07 21 Thermal Insulation, 07 31 Insulation for Sloped Roofs, and 07 51 Insulation for Flat Roofs for information on eliminating air infiltration/exfiltration from the roof.
- 08 01 Increasing Energy Efficiency in Historic Windows for window specific sealants.

GENERAL NOTES:

- There are five common caulk chemistry types:
  1. **Butyl** - solvent-based and characteristically stringy, which makes it difficult to apply in a finish-quality joint, but its adhesion and weather resistance make it applicable for sealing gutters, chimney flashings, walks, and other exterior joints.
  2. **Latex** - rubber-based and water-soluble, applied as a liquid. They are the least stretchy (7% to 10% elasticity). Work best on the interior where little movement is expected.
  3. **Acrylic** - a family of synthetic resins that are clear and water-soluble. Like latex caulks, they are easy to work with and paintable. Good for touch-ups and for filling small gaps.
  4. **Silicone** - formulated from silicone elastomers. It is virtually non-porous so it can make something watertight. It is most often used in plumbing applications (shower and sink installations) and some glasswork. Silicone is extremely rubbery (50% elasticity) but does not stick as well as other caulking and in its pure form, it cannot be painted.
  5. **Polyurethane** - based on the reaction of a glycol with an isocyanate, is solvent-based and is preferred for outdoor applications (exterior life span of 10-20 years). Bonds to most surfaces, including masonry and metal, hold up to heavy movement (25% elasticity), and can be painted. Also great for filling indoor gaps in floorboards because polyurethane can take the high-traffic stresses of floors. Due to their adhesive strength, removal usually involves cutting out or sanding off unwanted caulk.

Figure 07 92-1 1. Butyl Rubber Caulks

Figure 07 92-2 2. Butyl Tapes

Figure 07 92-3 3. Acrylic Latex Caulks and Sealants

Figure 07 92-4 4. Neutral Cure Silicone Sealants

Figure 07 92-5 5. Polyurethane Sealants

GENERAL NOTES continued:

- When specifying the appropriate sealants (caulking) in historic structures, consider location (interior or exterior), the goal to be achieved by sealing a joint (weatherproofing, blocking drafts, or closing gaps), and how much movement is expected. Factors to consider are:
  - Effectiveness and Durability: withstanding UV exposure, heating/cooling cycles, and flexibility when joining two components with different expansion/contraction rates.
  - Removable: Can it be removed without extreme measures?
  - Appearance: Does it attract dirt/dust?
- Sealants play an integral role in ensuring the effectiveness of insulation in any assembly by lowering the air exchange rate inside the envelope, thus in turn increasing the efficiency of the heating/cooling system.
- Caulking sealants are designed to prevent, **Vapor, Water, Gas/fumes and heated or cooled air** from travelling from one side of a building assembly to the other.
  - Any time a building is made more vapor-tight, there is a risk of trapping high moisture levels inside, which can lead to serious problems; from peeling paint to rotting wood. When caulking exteriors, remember that water primarily travels down, so caulking the undersides of window trim, door trim, or siding such as clapboards is recommended. This practice creates a path for some moisture migration out of the structure.

- **Locations to check and repair or replace Seals and Weatherstripping.**
  - No amount of insulation will help if air has a direct path to the exterior
  - Some common details to check for penetrations to prevent air infiltration are:
    - Fireplace dampers and chimneys
    - Weatherstripping on existing doors and windows
    - Exhaust fans
    - Electrical receptacles
    - Utility holes where they enter the building
    - Mortar joints
    - Joints between dissimilar materials
    - Tops of interior walls
    - Ductwork connections

SEALANT AND BACKER ROD DIAGRAM

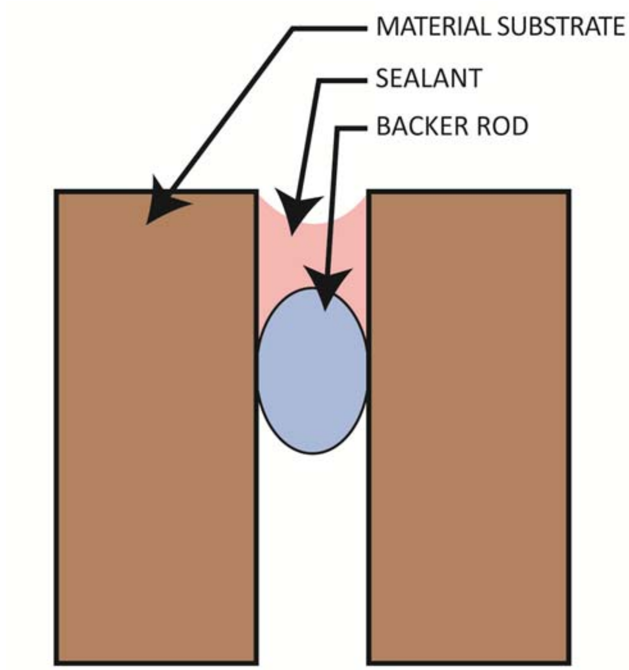


Figure 07 92-6

Never depend upon caulk alone to fill a gap any wider than ¼". If the joint is bigger, first insert backer rod (foam cording) in the gap, and then fill to the surface with the caulk.

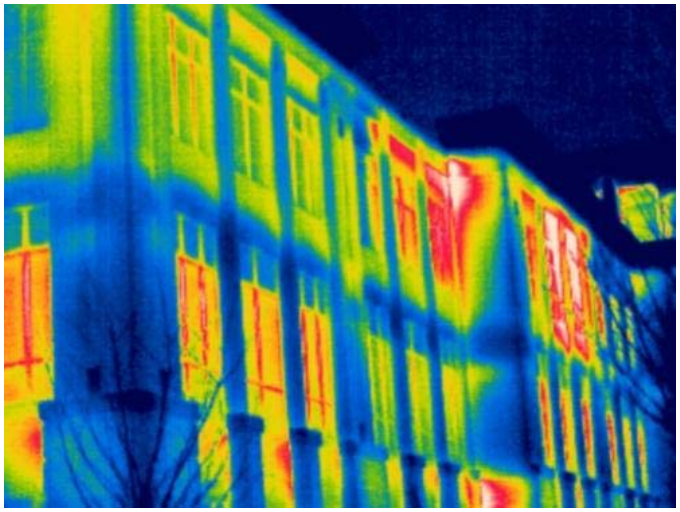
Typical "hourglass" shaped joint showing material substrate on either side filled first with a non-adhering backer rod then with sealant that fills the joint cavity with a slightly recessed front. Note that the sealant adheres only to the substrate material.

CONSIDERATIONS FOR APPLYING SEALANT TO OPENINGS IN THE BUILDING ENVELOPE:

- **Approach:**
  - Conduct an infrared thermal imaging inspection to determine where the air infiltration/exfiltration occurs
  - Evaluate the materials that will be receiving the sealant
  - Evaluate the exposure of the sealant to UV, cold/heat cycles, likely movement
  - **Infiltration/Exfiltration:** Caulking is best applied to the envelope exterior, or the thermal boundary. Begin caulking at the periphery of the building's heated space: doors, windows, foundations, crawl spaces, attics, utility penetrations, and any other penetration from conditioned to unconditioned spaces (exhaust fans, lighting, IT data boxes, power lines, flues, gas lines, etc). In addition, seal all attic-to-building air leaks and seal around chimney and framing with a high-temperature caulk or furnace cement.
    - Duct exhaust fans to the outside. Seal the perimeter of the fan housing on attic side.
    - Seal around chimney and framing with a high-temperature caulk or furnace cement.
    - At the tops of interior walls, use long-life caulk to seal the smaller gaps and holes. Use expanding foam or strips of rigid foam board insulation for the larger gaps.

- **Applicable Secretary of the Interior Standards:**
  - 7: Gentle Treatment of Historic Materials
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Any sealant that is used must be completely removable from the historic fabric.
  - The use of sealants is advised wherever a gap exists between two disparate materials.
  - **The design professional and owner** must remember the distinction between preventing conditioned air from escaping and preventing the envelope from breathing in the manner in which it was first built. (Refer to the discussion of this topic in *Walls and Foundations of Historic Buildings,n.d.,* 9-11*).*
  - **Maintaining the appearance:** The application of (caulking) sealants in historic projects must have no effect upon the historic appearance of the structure.
    - Visible sealant beads should be kept to a 3/8" maximum on an historic façade
    - Visible sealant beads should be selected for color match with an adjacent color



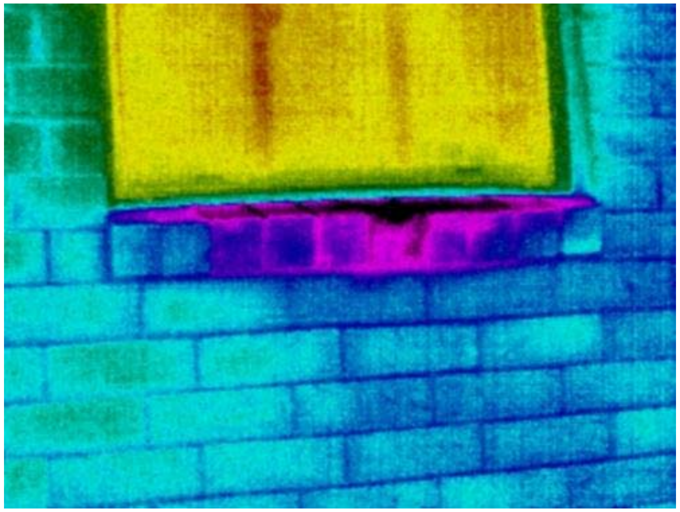


Figure 07 92-7
Installation voids, air leakage, structural defects, poor workmanship and moisture ingress are frequently located.

CONSIDERATIONS FOR APPLYING SEALANT TO OPENINGS IN THE BUILDING ENVELOPE continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - The Energy Efficiency Potential and Cost Considerations for this Guideline do not follow the same format as laid out in previous Guidelines and as discussed in the Introduction.
  - According to the U.S. Department of Energy, caulking drafty areas can cut energy costs 10%; and about 50% of the average fuel bill is the result of heat loss from air infiltration.
  - Sealants can help address the infiltration problem that allows cold air to enter a building at the lower elevations when heated air escapes at the higher points.
  - Depending on the severity of the problem, appropriately applied sealants can reduce conditioned air loss by a large factor. Calculating the loss is difficult, and each building will be different. The main idea is to allow conditioned air to remain in the heated envelope long enough to have a thermal effect on the interior fabric and contents.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Most common sealant packaging is the ubiquitous "tube of caulk," which is 10.3 fluid ounces, usually priced in the $2.50 to $10.00 range. It can apply a quarter-inch bead approximately 31 feet in length. Such a gap can be thought of as an area (¼" x 31 feet = 93 square inches). (Interestingly, a smaller bead, 3/16" will fill a gap 55 feet in length. This area works out to be 123.75 square inches).
  - In terms of energy loss, this area can be responsible for the loss of a variable quantity of cubic feet of conditioned air per hour, depending on the pressure gradient present in the structure at any given time. Refer to the DAP website (http://www.dapspecline.com/products) for feet, inches, and mL.
  - Any gunned sealant (whether 10.3 fl. oz. or 40 fl. oz.) can effectively stop the flow of many cubic feet of conditioned air per hour. The cost of the sealant (and its application) must be weighed against the year-round loss of that energy for as many years as the sealant remains viable.

Sealant Classification by Performance (Movement Capacity)

Low Performance Sealants	Medium Performance Sealants	High Performance Sealants
Oil and resin based materials	Hydrocarbon based elastomeric polymers	Fluorosilicone and fluorophlymers
Asphaltic and bituminous materials	Acrylic	Polysulfide
Polyvinyl acetate	Chlorosculfonated polyethylene	Styrene butadiene copolymer
Epoxy	Hot melt sealants based on synthetic rubber	Polyurethane
Polyvinyl chloride plastisol		Silicone

Low performance: +/- 0-5% movement capabilities, 10 year service life, and low cost.

Medium performance: +/- 5-12% movement capability, a 5-15 year service life, and medium cost.

High performance: greater than 12% movement capability, 10-50 years of service life, and relatively high cost.

Chart 07 92-1

GUIDELINE DESCRIPTION: Addresses the two principal causes of poor energy performance in historic windows, air infiltration and single glazing, and describes possible solutions to each. Unless noted otherwise, this guideline applies to both historic wood and steel framed windows. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 01 01 Project Organization, Understand the current energy use of the historic structures
- 07 92 Joint Sealants for information on sealing windows
- 08 52 Wood Windows – Backup Windows for additional Historic Preservation Effects

GENERAL NOTES:

- Developing a Plan: Developing a plan of modifications and repairs that will improve the performance and increase the useful life of the historic windows in the facility requires the completion of the following 3 steps:
  1. Assessment of Historic Significance of the windows
  2. Assessment of Physical Condition of the windows
  3. Determination of Repairs required, considering the following: Cultural resource concerns, Energy efficiency improvement measures, Cost / Benefit analysis

GENERAL HISTORIC PRESERVATION EFFECTS:

- Historic windows are almost always important Character Defining Features. Therefore, their preservation requires special attention.
- Visual Appearance:
  - o Carefully consider all new and/or replacement products prior to installation in order to ensure that the appearance of the historic building remains unaltered.
  - o Any action taken to rehabilitate and/or increase energy efficiency in historic windows should, whenever possible, retain the historic colors, textures and profiles of window frames, muntins, mullions and glazing.
- Operability:
  - o Should be maintained unless the building's intended function dictates otherwise.
  - o Permanently closing an historically operable window could have adverse effects on the efficiency and operation of the existing HVAC system.

Components of Historic Windows

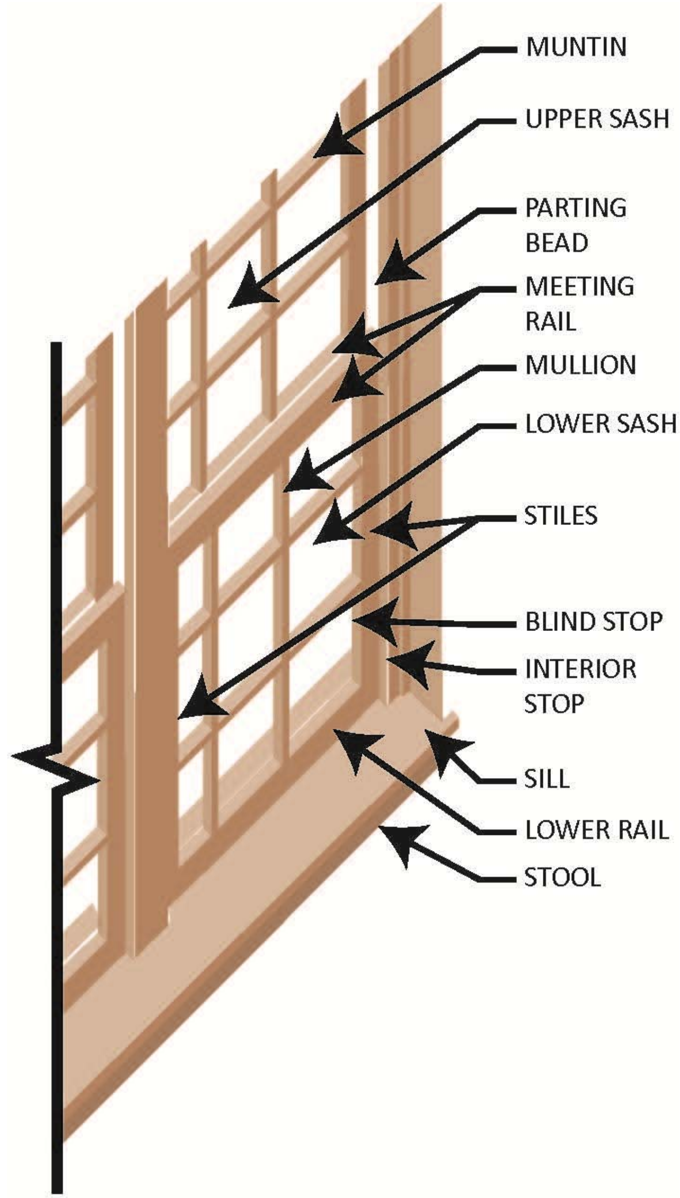


Figure 08 01-1

CONSIDERATIONS FOR AIR INFILTRATION:

- **Approach:**
  - Possible corrective actions to increase energy efficiency in historic windows in which air infiltration is a principle problem include, but are not limited to, the following:
    - Caulking or re-caulking around frames
    - Ensuring that glazing putty is sound, replace if it is not
    - Tightening loose fitting sashes / properly aligning all sections (in Steel Windows)
    - Replacing cracked or broken panes
    - Installing appropriate weatherstripping
    - Replacing ropes and broken pulleys
  - Health & Safety Risks:
    - Glazing putty often contains asbestos and should be tested before removal so that proper precautions may be taken. See 01 03, Hazardous Materials.
    - Use of acid compounds is an option when removing corrosion from steel window frames. These compounds can be dangerous, and must be treated with care.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 7: Gentle Treatment of Historic Materials

- **Effects: See GENERAL HISTORIC PRESERVATION EFFECTS page 78**
  - Weatherstripping:
    - Some of the historically used products did not function well.
    - When installing weatherstripping, try to match the historic if possible. If not, use the most functional, best contemporary option with the least visual impact.
    - Sash locks installed on meeting rails help keep the sash tightly closed, increasing the effectiveness of the weatherstripping.
      - They "will usually be viewed as an acceptable contemporary modification in the interest of improved thermal performance." (Fisher, III 1986, 7).

Figure 08 01-2

Figure 08 01-3

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - If air infiltration is the cause of poor energy efficiency, it is difficult to precisely determine the amount of energy savings which may result when those areas of air infiltration are sealed. The savings will vary from case to case, depending on R-values of frame and glazing, R-values of the new sealant product and current amount of air infiltration.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures.
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Cost considerations vary from project to project, due to the physical condition and energy performance of the historic windows being considered.
  - “Windows provide views, daylighting, ventilation, and heat from the sun in the winter. Unfortunately, they can also account for 10%-25% of the heating bill by letting heat out.” (U.S. Department of Energy; Energy Efficiency & Renewable Energy 2012)
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SINGLE GLAZING:

- **Approach:**
  - Possible corrective actions to increase energy efficiency in historic windows in which single glazing is a principle problem include, but are not limited to, the following:
    - Installing exterior or interior mounted storm windows
    - Retro-fitting insulating glazing into the existing frame
    - Installing aluminum frame storm panels on the interior of each light
    - Replacing entire historic unit with an in-kind replacement window
  - Health & Safety Risks: Paint from the era of historic windows often contains lead. Removal of lead containing paint can create toxic dust, and should be tested beforehand so that proper precautions may be taken.
    - Do not use heat to remove paint, this can damage the glass and release toxic fumes.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 7:Gentle Treatment of Historic Materials

Examples of original Historic Single Pane Windows.

Figure 08 01-4

Figure 08 01-5

Figure 08 01-6

CONSIDERATIONS FOR SINGLE GLAZING continued:

- **Historic Preservation Effects: See GENERAL HISTORIC PRESERVATION EFFECTS page 78**
  - Storm Windows:
    - Exterior storm windows will likely have a greater adverse effect on the visual appearance of the historic window than interior storm windows.
    - Interior storm windows may cause condensation between the two windows, which could damage the historic window.
    - Proper installation of weatherstripping, caulking and weep holes reduces risk.
  - Insulating Glazing / Aluminum Frame Storm Panel:
    - Ensure that the existing frame can handle the additional weight of the insulated glass or aluminum frame storm panel.
    - If one of these options is pursued, the existing muntins / mullions must be wide enough to be retro-fitted without perceptibly changing the appearance of the frame. Maintain the historic profile of the muntins / mullions as much as possible.
    - If aluminum frame storm panels are used, provide proper venting in the sash stile.
  - If new aluminum frame storm panel is added, select a frame color carefully to be compatible with historic materials and colors.
  - In-Kind Replacements:
    - "Consider energy efficiency as one of the factors for replacements, but do not let it dominate the issue. Energy Conservation is not an excuse for the wholesale destruction of historic windows which can be made thermally efficient by historically and aesthetically acceptable means." (Myers 1981, 7).
    - In-kind replacement units will surely alter the character and appearance of the historic building, and should be used as a last resort.
      - In wood windows, even when there is evidence of much deterioration, an option exists of reinforcing the wood frame with steel rods and epoxy and/or Dutchman Repair of wood compartment.
    - When used, replicate the historic shapes of the muntins, mullions and sash, even if using a completely different frame material.
    - They are to be custom measured and manufactured for each opening, rather than using a standard window size and installing blocking in the opening for tight fit.

Examples of In Kind Replacement Windows

Figure 08 01-7
46 Blackstone, Harvard Campus, Cambridge, MA

Figure 08 01-8 **Figure 08 01-9**
Cambridge City Hall Annex, Cambridge, MA

CONSIDERATION FOR SINGLE GLAZING continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - If single glazing is the cause of poor energy efficiency, it can be assumed that the solution will involve adding insulation to the glazing in some way. While the savings will always vary from case to case, depending of the R-values of the existing window and those of the proposed addition or replacement or back-up products, there is slightly more information available which can be used to approximate this number.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Cost considerations vary from project to project, due to the physical condition and energy performance of the historic windows being considered.
  - "Windows provide views, daylighting, ventilation, and heat from the sun in the winter. Unfortunately, they can also account for 10%-25% of the heating bill by letting heat out." (U.S. Department of Energy; Energy Efficiency & Renewable Energy 2012).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This guideline will look at different ways of bringing natural light into a building. It will first consider the original fenestration design intent and then supplement with other natural lighting strategies. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 31 and 07 51 for Roof information
- 08 01 and 08 52 for additional information on Window renovations
- 26 51 High Efficiency Lighting. Electric lighting systems can be programmed to work in conjunction with Natural Lighting to maximize efficiency.

GENERAL NOTES:

- Does the original configuration of the building provide adequate illumination for the purposes the building is intended to serve? If so, the strategy should be to maximize the original fenestration.
- If additional lumens are required, the strategy of installing skylights can be investigated. The costs associated with adding these features can then be compared to the annual costs of installing and operating artificial lighting.
- Consider creating (or re-creating) transoms and clerestory windows in interior walls to allow daylight to penetrate further into the interior of a building.

Figure 08 02-1
Before: The original windows are partially covered by a new lay-in new ceiling.

Figure 08 02-2
After: Original windows opened to full height, admitting twice the light as in the “office” configuration.

CONSIDERATIONS FOR RE-OPENING FULL-HEIGHT WINDOWS:

In instances where a ceiling has been lowered in a previous remodel and the original windows have been partially obscured, the windows should be fully re-opened to their original size and the ceiling should be restored, or the ceiling can be reconfigured with a furr-down at an angle to provide a "skirt" or reflector to bounce more daylight into the interior space.

- **Approach:**
  - Determine the amount of lumens (lighting) necessary for the proposed use.
  - Determine the amount of repair necessary to restore the original windows to use; a spreadsheet can assist in cost estimation and help the contractor in preparing a bid.
  - Determine the R-value of the existing windows, and if storm/ back-up units are viable.
  - Determine whether utility upgrades are needed.
  - What are the heating/cooling consequences of restoring full-height ceilings?

- **Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - Restoring full-height windows has virtually no ill effect on the exterior character.
  - Carefully evaluate interior features to determine that a new dropped plenum does not conflict with the SOI Standards.

Figure 08 02-3
Before: This image shows the exterior impact of the lowered ceilings, complete with lightweight white foam boards installed above the acoustic lay-in ceilings to mimic drawn shades.

Figure 08 02-4
After: The exterior following restoration of the full-height windows.

CONSIDERATION FOR RE-OPENING FULL HEIGHT WINDOWS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - The cost/benefit analysis of this Approach requires comparing the costs of installing and operating artificial lighting (with assumed future energy costs) against the more easily-determined one-time expense of re-configuring the full-height windows and ceilings.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials:
      - Window Frame ______________
      - Window Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Associated expenses include:
    - Restoration of the entire window unit.
    - Removal and disposal of dropped ceiling (if present).
    - Restoration of the historic ceiling.
  - Back-up or interior storm windows costs.
  - Installation of dimming/daylight lighting controls.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR INSTALLING SKYLIGHTS:

- **Approach:**
  - Determine a location on the roof that is not visible on the significant façades of the structure. This may include a side view, or all views.
  - Examine the ceiling in the interior space to be illuminated. Is it historically significant?
  - Was an existing skylight or roof lantern removed or covered up because of potential leaks? Perhaps it can be restored using photographs as a guide.
  - Examine the existing roof structure.
    - Can it support the additional weight of the proposed skylight?
    - Will the addition of a skylight adversely affect the roof drainage? How can that be addressed?
    - Will the addition of a skylight interfere with any necessary foot paths that exist or may be added on the roof for mechanical equipment maintenance?
  - Additional Information
    - Energy Star® products. Refer to DOE guidelines under section 103 of the Energy Policy Act or 2005 (Energy Policy Act of 2005, Sec. 104)
    - Enhance Indoor Environmental Quality. *Daylighting*. Achieve a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all spaces occupied for critical visual tasks. Provide automatic dimming controls or accessible manual lighting controls, and appropriate glare control. (ACHP, et al 2011, 5) and (Federal Leadership in High Performance and Sustainable Buildings n.d., 4).

- **Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - If the SOI Standards cannot be met, then another lighting strategy may be necessary, depending on the proposed use of the building.

Gerding Theater, Portland Armory, Portland, OR

Figure 08 02-5
The structure was deemed historic, but not the roof. Skylights were strategically placed around the structure.

Figure 08 02-6
Full view of upper level with the skylights and structure.

CONSIDERATION FOR INSTALLING SKYLIGHTS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - This topic can be dealt with in almost the same way as the full-height window issue. The cost of a skylight is generally a one-time expense. Installation of artificial light involves purchase and installation costs, operation expense, and replacement costs.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Demolition of ceiling and roof.
  - Purchase and installation price.
  - Restoration of ceiling and roof, or skylight.
  - Insulation of the skylight walls in a "cold roof" situation.
  - Selection of glazing type (Low Emissivity; Low "E") can boost energy.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This guideline will discuss adding vestibules either to the exterior of the building or to the interior. It will also cross reference with other applicable divisions. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation for general insulation information
- 07 92 Joint Sealants for general sealant information
- 08 01 Energy Efficiency in Historic Windows for weatherstripping information

CONSIDERATIONS:

- **Approach:**
  - Very closely discuss with CRM/SHPO
  - Create a secondary air space or "air lock"
    - Effectively, it reduces air infiltration when the exterior door is open.
  - Retain if already existing: Exterior and interior vestibules are common architectural features of many historic buildings and should be retained wherever they exist. (Hensley and Aguilar n.d., 10).
  - Before:
    - Energy Audit – how much energy is really being lost through the door?
      - Will other energy saving retrofits be more beneficial?
    - Other options – Can weatherstripping achieve significant energy savings?
  - Adding:
    - Can be appropriate to add "For example, new glazed interior vestibules may be compatible changes to historic commercial and industrial buildings." (Hensley and Aguilar n.d., 10).
    - "…usually result in too great a change to the character of primary entrances, but may be acceptable in very limited instances, such as at rear entrances. [They] should be compatible with…the historic building." (Hensley and Aguilar n.d., 10).
    - Determine location based on energy savings and cultural resource impact
    - Can also help meet UFC requirements for glass resistance.

Figure 08 41-1
Interior of Botts Hall after construction of vestibule is complete. Notice stylistic similarities between these new doors and the original doors.

Figure 08 41-2
Exterior of Botts Hall after construction of vestibule is complete. The only change to the exterior was to repair the original doors.

CONSIDERATIONS continued:

- **Approach continued:**
  - Example: Botts Memorial Hall in Special Collections Library, Albuquerque, New Mexico
    - Background
      - Built in 1925, with Botts Hall (a public meeting room) added in the 1950's
      - It is on the National Register of Historic Places and is an Albuquerque Landmark
      - It was "modernized" in the 1970's; the original doors were retained.
    - Issue
      - Air and noise leaked through the major entry door into Botts Hall
    - Solution
      - A new vestibule was added to control the outside noise and reduce the loss of conditioned air.
      - The vestibule design allows for removal without damage to original space, and respects the original building design.
      - Retains the original front doors; provides inner doors that imitate the original door panels with glass; repeats the transom design
      - Deep enough to allow for wheelchair passage with one set of doors closed.

- **Applicable Secretary of the Interior Standards:**
  - 1: Use for intended historic purpose
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - Addition of a vestibule must follow a respectful design; should be removable, and should clearly be a contemporary addition.
  - The addition of a vestibule, whether interior or exterior, is one of the greatest potential energy savings measures discussed in this report. Careful analysis is critical to avoid/minimize detrimental impacts.

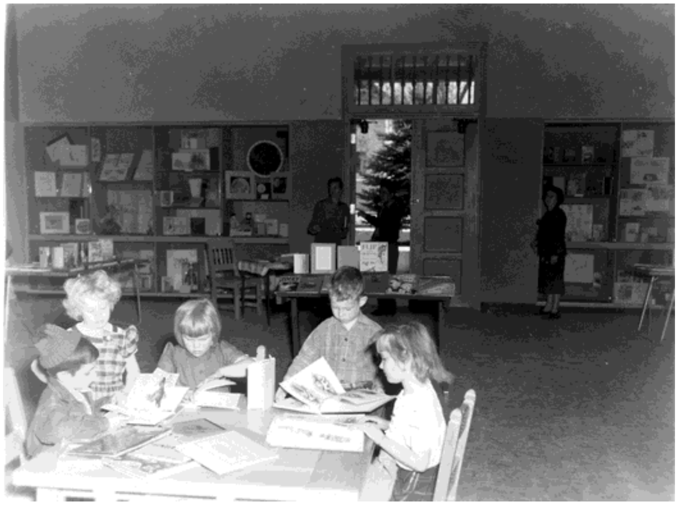


Figure 08 41-3
Historic photograph of Botts Hall in the 1950's

Figure 08 41-4
Same space as the above photograph, this photo was taken prior to construction of the vestibule. Notice the light (and air) seeping in around the now blocked transom.

CONSIDERATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Door/Entrance Frame ______________
      - Door/Entrance ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the doors/entrances are exposed to outside temperatures.
    - That all doors/entrances are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: The addition of a new interior double paned window is a solution to provide additional thermal comfort and reduce heat transmission when the frame profile of the historic window does not allow for the addition of a second pane of glass. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

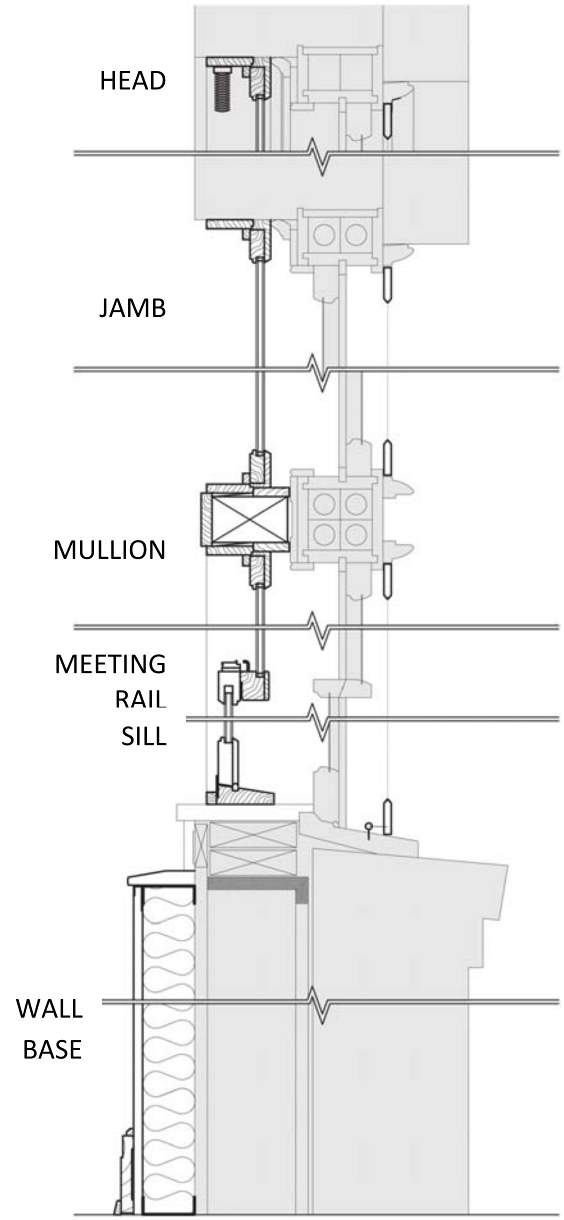
- 07 92 Joint Sealants for general sealant information
- 08 01 Increasing Energy Efficiency in Historic Windows for general window information
- 23 08 Selecting HVAC Systems

CONSIDERATIONS:

- **Approach:**
    - **Qualitative aspects**:
        - The thermal comfort of occupants
        - Minimizing air infiltration in old windows
    - **Wall thickness**: It must be thick enough to contain the new back-up window behind the historic window without detracting from historic, interior features. The illustration above was installed in a double width, un-reinforced, brick, masonry wall.
    - **Cleaning:** Allow for cleaning both windows.
        - IE: if the historic window is a single hung window, the new back-up window could be a double hung allowing for cleaning both sashes of the historic window from the inside. Many wood windows today snap out of the frame which allows for cleaning.
    - **Operability:** Should be kept or restored whenever possible. Coordinate with the HVAC system to provide natural ventilation when feasible.
    - **Window Swing:** If the historic windows swing out, the new windows could swing in. If the historic windows swing in, the back-up windows may have to take a different configuration, or back-up windows may not be a suitable solution.
    - Recommended: identify, retain and preserve windows important in defining the historic character of the building. Important features include frames, glazing, sills, heads, hoodmolds, jambs, shutters and blinds, as well as others. For more information see: http://www.nps.gov/history/hps/tps/standguide/preserve/preserve_windows.htm

Construction drawing showing the addition of a Wood Back Up Window to an Historic Window

Figure 08 52-1



CONSIDERATIONS continued:

- **Applicable Secretary of the Interior Standards**:
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - **Profile:** Back up windows should retain the profile of the historic windows.
    - IE: sash frame and meeting rails thickness should be the same or less than the original frame members
  - **Frame Finish:** A darker shade of finish on the frame will show through to the outside less than a lighter shade of finish.
  - **Pane Dividers:** Back-up windows may have fewer pane dividers than the exterior, historic windows with CRM/SHPO approval. If there are fewer pane dividers, the "double image" produced by the back-up windows will be reduced.
  - **Glass Color:** The glass in the back-up window should not change the apparent color of the historic glazing.
  - **Force Protection / Anti-Terrorism:** The UFC contains clear requirements regarding windows if the building is located within the Explosives Safety Quantity Distance (ESQD). Many of the UFC requirements conflict with the Secretary of the Interior Standards for Historic Preservation, but will still take precedence over the Secretary of the Interior Standards. Careful planning by the Design Team is needed to ensure that if this situation arises, the best option is chosen to try and meet both the UFC and SOI Standards. See the following page for an example of a possible solution.

Figure 08 52-2
Installed Back up Windows

Figure 08 52-3
Close-up of installed interior back-up window

CONSIDERATIONS continued:

- **Historic Preservation Effects continued:**
  - **Force Protection / Anti-Terrorism continued:**
    - Ideally, in an historic building, force protection and anti-terrorism measures would be handled in the site, rather than at the building.
    - The action suggested in this guideline – installing a back-up window – would be a good solution to use in an historic building located outside of the UFC defined Explosives Safety Quantity Distance (ESQD).
    - Removable Blast Guard – If force protection and anti-terrorism need to be handled at the building.
      - Meets the functional requirements in the UFC
      - Leaves the historic window intact
      - New construction is visibly new, but still emulates the historic window configuration.

Removable Blast Guard

Figure 08 52-4
Possible solution for Force Protection and Anti-Terrorism at an historic building. Build a removable blast guard at the interior of the space, taking care to mimic the configuration of the existing windows.

CONSIDERATIONS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Can be evaluated using a simple formula:

    Rh (historic window) + Ra (air space) + Rb (back up window)
    = x/Rh = Increase in insulative value of window system
    - IE: Most historic windows are single paned. The back up is double-paned, and specified to have a minimum R-factor of 2.85. There is a one inch air space between the windows.
    - The R-Factor for a single pane of glass is 0.9. Rh = 0.9
    - Ra = 1.0
    - Rb = 2.85
    - The installation of the back up window increases the insulative value of the system by a factor of 0.9 + 1 + 2.85 = 4.75/0.9 = 5.28.
  - **Emissivity**: Using low emissivity glass can also contribute to energy savings.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Existing Window Frame ______________
      - Existing Glazing ______________
      - New Window Frame ______________
      - New Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the windows are exposed to outside temperatures.
    - That all windows are the same regardless of orientation.

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - There is a wide variety of quality levels of wood windows that will affect the cost. Costs vary with the quantity of windows to be purchased and installed, whether the sizes are standard or special, proximity to manufacturer, and local market factors.
  - Depending on the Code Officials interpretation, the historic windows may not need to meet the local wind resistance factors if the historic windows have withstood local winds for many years.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

GUIDELINE DESCRIPTION: This guideline will discuss adding solar hot water heating systems, heat pump tank-type water heaters, tankless hot water system recommendations, hot water recirculation systems, piping locations (baseboards versus ceilings), and piping insulation. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 01 03 Major Preservation Issues and Energy Use
- 07 31 Insulation for Sloped Roofs
- 07 51 Insulation for Flat Roofs
- 26 01 Solar Photovoltaic Panels

GENERAL NOTES: Hot water piping should be insulated to increase energy efficiency.

CONSIDERATIONS FOR SOLAR HOT WATER SYSTEMS:

- **Approach:**
  - Components:
    - a water storage tank with internal heat exchanger
    - solar panels
    - Piping – New supply and return loop piping are required from the storage tank to the solar panels. Routing can be difficult in an existing (historic) building depending on the specific building and the distance pipes need to travel from the mechanical room to rooftop.
      - Can be possible to reuse existing piping from water heater room to fixtures
    - Controls
    - Supplemental electric or gas hot water heater
      - Recommended to ensure sufficient hot water early in the day since the solar system cannot keep the water hot at night or on cloudy days.
  - Freeze-protected circulating fluid flows from the solar panels through the heat exchanger to warm the water in the storage tank.
    - Ordinary water can be used if it is drained to a tank at night to prevent freezing.

Solar Hot Water System Diagram

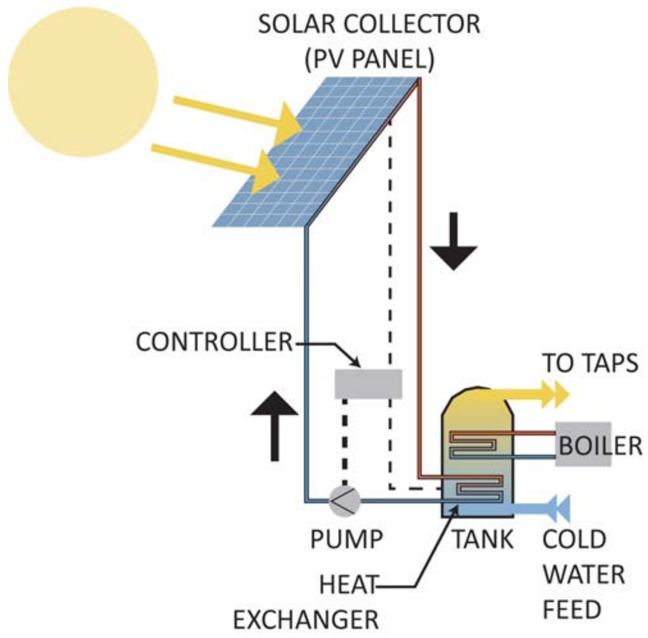


Figure 22 33-1

CONSIDERATIONS FOR SOLAR HOT WATER SYSTEMS continued:

- **Approach continued:**
  - Solar Hot Water systems are not difficult to install, especially in a building with sufficient mechanical room space, available rooftop area, and space to route piping. Depending on climate, the systems can require overheating protection.
  - Solar hot water panels are 50-70% efficient compared to <20% for photovoltaic panels. Therefore, more solar energy can be captured in a hot water system than in a photovoltaic system for the same solar panel area.
  - There are two main panel types: Discuss with the Design Team for a specific project
    - Flat-plate collector: durable design due to tempered glass
    - Vacuum tube collector: can heat water up to higher temperatures than flat-plate and can replace individual tubes.

- **Secretary of Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Roof mounted solar panels are not often approved by CRM or SHPO on a sloped roof unless they are on a very minor elevation of the building, and are not visible from a major elevation.
  - Roof mounted panels may be appropriate on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building. Panels are most effective if they are sloped to be more closely perpendicular to the sun's rays. The slope may have to be reduced if an historic parapet is not high enough to hide it at optimal slope.
  - Ground mounted panels can be hidden from view with landscaping or an appropriately designed fence. The fence/landscaping must not shade the panels.
  - Heated fluid from ground mounted panels can lose heat with distance from the building; so, closer is better for efficiency.
  - Hot water tanks can be located in basements or other areas designated for mechanical equipment. The closer to the point of use, the better for efficiency.
  - Piping will need to be hidden from view in interior rooms.

Construction photographs of the Solar Hot Water Install. Installation and piping is very similar to conventional hot water systems. Access for routing is of primary concern in historic buildings.

Figure 22 33-2 Overhead, insulated hot water pipes

Figure 22 33-3
Storage tank and piping in the mechanical room

CONSIDERATIONS FOR SOLAR HOT WATER SYSTEMS continued:

- **Energy Efficiency Potential:**
  - Solar hot water systems greatly reduce electric or gas energy usage at the hot water tank but add a small energy load for the pump and controller.
  - A typical design could satisfy about 80% of the hot water requirement for a commercial building.
  - A small solar hot water system could save 4,000 kWh per year compared to a conventional electric water heater, or 300 therms per year compared to a gas water heater.

- **Cost Considerations:**
  - Moderately sized solar hot water systems can cost $6k-$8k but are becoming less expensive as manufacturers increase production of the systems.
  - A 40 gallon energy star certified electric hot water tank costs an average of $500/year to operate. An 80% reduction in energy cost would be $400/year, meaning a simple payback on a $7k solar hot water system would take 17 years.
  - A 40 gallon energy star certified gas hot water tank costs an average of $294/year to operate. An 80% reduction in energy cost would be $235/year, meaning a simple payback on a $7k solar hot water system would take 30 years.
  - Specific payback periods are dependent on the efficiency of the existing water heater and the cost of adding solar water heating to the existing building.

Figure 22 33-4

Figure 22 33-5

2 PV panel installations for Solar Hot Water Systems on new facilities. Notice the angle of the panels; this would probably not be approved for an historic project. A lower panel angle might result in more panels being required.
Top: Thomas Bell Community Center, Bottom: Gerald Martin office building, both in Albuquerque, NM.

CONSIDERATIONS FOR TANK-TYPE HEAT PUMP WATER HEATERS:

- **Approach:**
  - Components: A heat pump water heater looks like a typical electric tank-type water heater.
    - Typical electric water heaters connect to 208V single phase electrical, and heat pump water heaters have the same requirement
  - Heat pump type water heaters are over twice as efficient as standard electric water heaters. They operate on the refrigeration cycle by transferring heat from the surrounding air into the water more efficiently than typical heating elements.

- **Energy Efficiency Potential:**
  - Heat pump type water heaters can save over 2,500 kWh of energy per year compared to a standard electric water heater which uses over 5,000 kWh per year.

- **Cost Considerations:**
  - Energy Star lists the electrical cost of a typical electric water heater at $520 per year, and a heat pump type water heater at $230 per year for a savings of $290 per year.
  - Heat pump type water heaters were only introduced to the mainstream market recently and are two to three times more expensive than a standard water heater. A life cycle cost analysis can be done to determine payback period. Due to the high electric bill savings, the payback period will likely be less than four years.

HEAT PUMP WATER HEATER

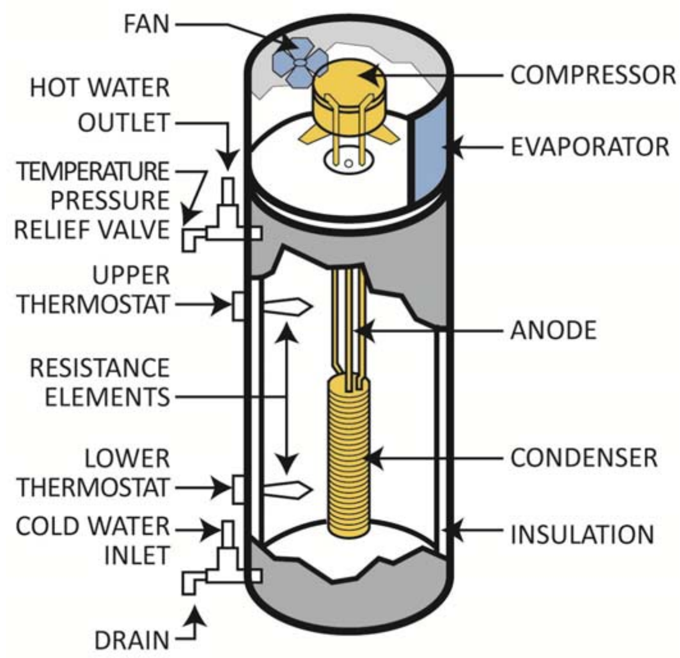
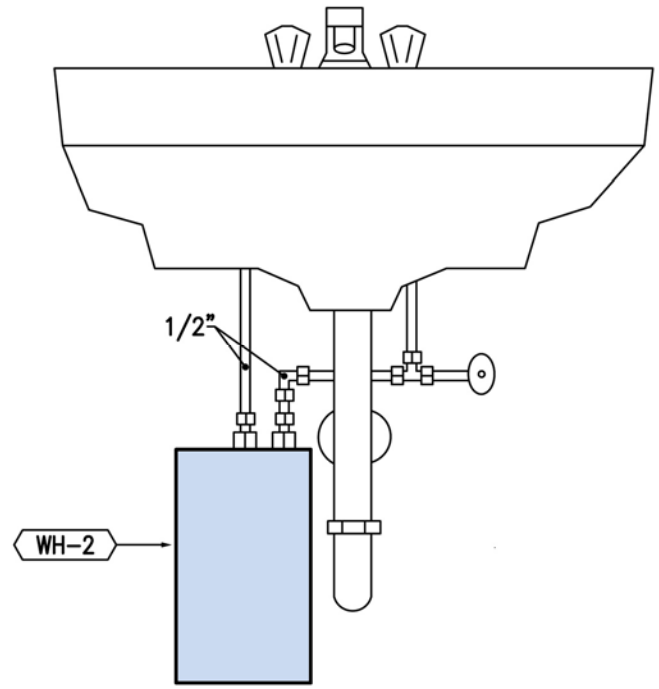


Figure 22 33-6

CONSIDERATIONS FOR TANKLESS HOT WATER SYSTEMS:

- **Approach:**
  - Determine whether or not a tankless hot water system is feasible for a specific project:
    - How many fixtures require hot water?
    - What flowrate (gallons per minute or GPM) will be required?
    - Water heaters are sized based on flowrate and the temperature rise required, since it requires less energy to heat water 40 degrees rather than 60 degrees.
  - Advantages:
    - Can reduce energy usage. Instead of continually maintaining a tank of hot water, a tankless system heats water as it's needed.
    - Takes up much less space than tank-type.
  - Disadvantages:
    - Require higher bursts of energy (electric or gas) than tank-type heaters because they have to heat the water up as quickly as possible, rather than being able to use energy at a slower rate and storing the water as it warms up.
    - Has to mix hot water with cold water to deliver the right temperature at the fixture, so the hot water temperature at the fixture is less consistent than with a tank type.
  - Gas vs. Electric: Gas tankless water heaters are more common than electric because the electric models can require service upgrades to meet power requirements. Electric units generally require power other than 120V single phase. For example, a 3 GPM unit (enough for a shower or tub and faucet) requires as much power as three (four-ton) HVAC units.
  - Small tankless electric units that deliver only enough hot water for one or two sinks can operate off a 120V wall outlet, and may be a good solution for a building with an existing hot water tank a long distance away from a new restroom.
  - Maintenance: Tankless water heaters require maintenance to prevent scale buildup and are more susceptible to hard water. If a building has hard water and tankless heaters are going to be used, a water softener is required. Tank-type water heaters have sacrificial anodes to prevent scale buildup on the tank and element, but the water heaters can still eventually become scaled and require replacement.

TANKLESS HOT WATER SYSTEM INSTALLED UNDER SINK



NOTES:

1. PROTECT WATER HEATER FROM EXPOSURE TO DAMP, HUMID AND FREEZING CONDITIONS.
2. WATER HEATER MUST BE INSTALLED TO CONFORM WITH CURRENT NATIONAL ELECTRIC CODE, AND ANY APPLICABLE LOCAL PLUMBING, ELECTRICAL, HEATING AND AIR CONDITIONING CODES.
3. FOLLOW MANUFACTURER'S INSTALLATION INSTRUCTIONS.

Figure 22 33-7

CONSIDERATIONS FOR TANKLESS HOT WATER SYSTEMS continued:

- **Secretary of Interior Standards:**
  - 2: Historic Character Preservation

- **Historic Preservation Effects:**
  - Usually these units are located in designated mechanical rooms or in restrooms. These locations rarely have character defining features to be preserved. However, in the few cases, for example, an historic room that is to be used as a conference room with a new coffee bar with a sink, a small unit could be placed in the cabinet under the sink.

- **Energy Savings Potential:**
  - Tankless hot water systems can reduce energy usage, especially at infrequently used fixtures, since the water is heated at point-of-use rather than constantly losing heat through the water heater and piping.
  - The US Department of Energy estimates the energy savings potential for tankless water heaters to be about 30% for lower demand installations (40 gal/day) and about 10% for higher demand installations (86 gal/day). (Tankless or Demand-Type Water Heaters 2012).

- **Cost Considerations:**
  - Tankless water heaters are about 50% more expensive than conventional storage water tanks and the payback period can be longer than the expected lifespan. However, in applications with lower demand (<45 gal/day), gas piping, and water that isn't too hard, tankless water heaters can be life cycle cost effective.

CONSIDERATIONS FOR HOT WATER RECIRCULATION SYSTEMS:

- Depending upon hot water needs, adding a recirculating hot water system is a possible renovation in an historic structure. However, they have a considerable installation cost and do not use less energy; so, they will not be discussed in this guideline. Discuss the possibilities of such a system with the Design Team and CRM / SHPO.

Figure 22 33-8
Mechanical Room gas Tankless Hot Water heater

Figure 22 33-9
Mechanical Room electric Tankless Hot Water heater

GUIDELINE DESCRIPTION: First, general information is presented on thermal comfort, building energy usage, natural versus mechanical ventilation, zoning, noise and vibration, ductwork, and life cycle cost. Second, various types of HVAC systems are presented: forced air, centralized versus distributed, constant air volume, variable air volume, fan coil, variable refrigerant flow comparison, split systems, heat pumps, geothermal, two-pipe, and four-pipe systems, including controls. Third, information on how to select an HVAC system is discussed in general terms. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 01 03 Major Preservation Issues and Energy Use
- 07 31 Insulation for Sloped Roofs and 07 51 Insulation for Flat Roofs
- 23 11 HVAC interior placement
- 23 12 HVAC exterior placement
- All of the guidelines tackle energy efficiency: the higher the efficiency, typically, the smaller the demand on HVAC system. Therefore, all of the guidelines are related.

GENERAL NOTES:

- **Secretary of the Interior Standards: Applicable for all systems listed under this Guideline**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
- The Energy Efficiency Potential and Cost Considerations for this Guideline do not follow the same format as laid out in previous Guidelines and discussed in the Introduction. HVAC system selection is building specific and highly variable. It is recommended that final selection and cost estimates be done by a qualified engineer.
- When considering different HVAC systems, all systems need to conform with the UFC Series 4 Multi-Disciplinary and Facility Specific Design requirements.

Basic HVAC System Definitions and Concepts:

Forced Air *systems use fans, ductwork, heating and cooling sections to temper and distribute air.*

Variable Air Volume *systems are 'forced-air' but can operate effectively at lower airflows when conditions allow the reducing of energy usage.*

Heating and cooling can use ***refrigerant piping*** *or* ***hydronic heating and cooling water piping*** *instead of ductwork but fans are still used to distribute the heating/cooling air.*

Ventilation *is an important factor in the comfort and safety of building occupants. Ventilation is fresh 'outside air' brought into the space.*

There is no one size fits all HVAC solution. HVAC selection should be done on a building-by-building basis taking specific building factors into account.

HVAC equipment is continually being improved to provide better comfort and use less energy in order to meet or exceed the latest guidelines.

GENERAL NOTES continued:

- Thermal criteria changes: Prior to 1900, the standard for heating was 65-70 deg F (McGuinness, Stein and Reynolds). Today, 65-70 deg F is only borderline comfortable (70-72 deg F is typical). Later in the 20th century after air conditioning was developed, humidity was included as a factor. Higher temperatures are more comfortable at a lower humidity.
    - ASHRAE Standard 55 titled 'Thermal Environmental Conditions for Human Occupancy' considered other factors in addition to temperature and humidity level. (See Chart 23 08-1.)
        - Activity levels (metabolic rate) and clothing levels are added to the criteria.
            - Someone doing sedentary office work feels more comfortable at a higher temperature than someone working out in a gym.
- Building Energy Usage:
    - ASHRAE 90.1 'Energy Standard for Buildings Except Low-Rise Residential Buildings' is a document which lists minimum requirements for energy efficiency. The building envelope, HVAC systems, power and lighting are discussed.
        - In 2005, the US federal government mandated that buildings must be designed to meet ASHRAE 90.1-2004, and new buildings constructed after 2007 should be 30% more efficient than an ASHRAE 90.1-2004 baseline if it is life-cycle cost-effective. (ASHRAE Standard 90.1 2004).
        - Can earn LEED credits for designs that are more efficient than the ASHRAE baseline.
        - Computer modeling programs like Trane Trace and eQUEST provide engineers with ways to compare proposed building energy usage to the ASHRAE baseline.
- Lifecycle cost:
    - Modern energy modeling software (Trane Trace, eQUEST) can calculate the energy requirements of a building on an hour-per-hour basis throughout a year. Various HVAC systems can be modeled and compared and energy usage can be estimated, so that a life cycle cost calculation with capital, energy, and maintenance costs can be used in determination of the best HVAC system to install.

Common Abbreviations used in this Guideline:

AHU *– Air Handling Unit*

ASHRAE – *American Society of Heating, Refrigeration, and Air-Conditioning Engineers*

HVAC *– Heating, Ventilation, Air-Conditioning*

LEED – *Leadership in Energy and Environmental Design*

MAU – *Makeup Air Unit*

RTU *– Roof Top Unit*

SMACNA *– Sheet Metal and Air Conditioning Contractors National Association*

DX *– Direct Expansion (Refrigeration Cycle)*

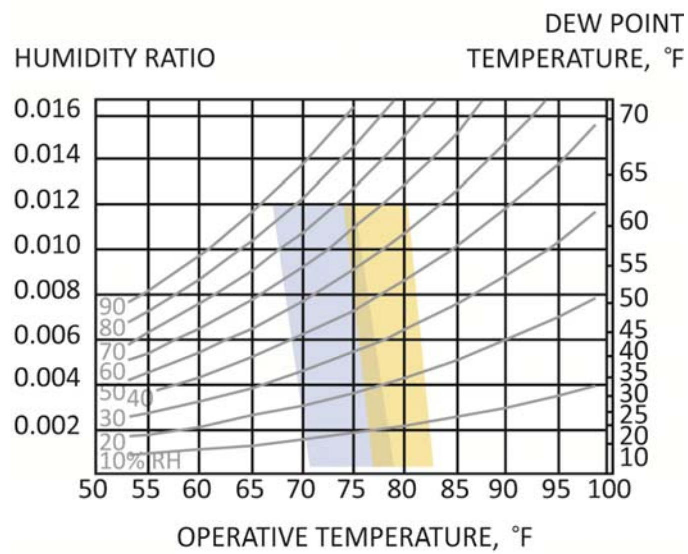
VRF *– Variable Refrigerant Flow*

EER *– Energy Efficiency Ratio*

GENERAL NOTES continued:

- Ventilation:
  - ASHRAE Standard 62.1 specifies the amount of ventilation (outside air) required for various types of spaces.
    - Spaces with operable windows (natural ventilation) can be served by HVAC systems that do not deliver ventilating air, as long as the windows are within 25 feet and can open to 4% of the floor area (refer to ASHRAE Standard 62.1, paragraph 5.1.1) In these cases, ductless split system heat pumps/VRF systems or fan coils that use water can be used because both of these HVAC systems are 100% recirculating.
    - Spaces without operable windows generally require ventilation at about 5 cfm (cubic feet per minute) per person plus 0.06 cfm per sq.ft. (ASHRAE Standard 62.1 2010). This ventilation air can come from a roof top unit (RTU) or air handling unit (AHU) set to a minimum outside airflow or from a 100% makeup air unit with an energy recovery wheel. Makeup air units are used in conjunction with other heating and cooling systems serving the space, like fan coils, radiant floor heating or chilled beam cooling.
- Zoning of HVAC systems is an important factor in user comfort. A higher quantity of zones (thermostats) can lead to greater control and comfort but also comes at a cost.
  - Certain areas should be zoned differently based on building orientation, fenestration and space use.
    - Zone interior rooms together since they have less heat loss/gain to the outside.
    - Zone exterior rooms together because they require more HVAC. Rooms facing south and/or west require more cooling, and rooms facing north require more heating.
    - Rooms should also be zoned according to uses. For example, a conference room that is used a portion of the time should be on a separate zone to reduce energy.
  - Well-designed HVAC zoning improves a building's energy efficiency because the heating and cooling are delivered where needed.
    - For example, if interior and exterior rooms are zoned together, then the exterior rooms can require more heating and cooling to be comfortable than the interior. Too much heating or cooling is delivered to the interior rooms and energy is wasted.
  - Increased HVAC zoning requires more equipment and installation expense.

ASHRAE STANDARD 55: Acceptable range of operative temperature and humidity for spaces.



NOTE:
UPPER RECOMMENDED HUMIDITY LIMIT 0.012 HUMIDITY RATIO.
THERE IS NO RECOMMENDED LOWER HUMIDITY LIMIT.

Chart 23 08-1

GENERAL NOTES continued:

- Noise and vibration for HVAC systems:
  - Open ceiling plenums, where air can transfer from above one room to the next room and back to the HVAC equipment, can increase sound transmission from room to room. Walls to deck with air transfer duct elbows and return grille sound boots reduce noise.
  - Interior acoustical lining of certain supply, return, and exhaust ductwork can be an inexpensive way of reducing the noise level. If duct lining is used, it should be non-shedding. Duct elbows, sufficient straight duct into and out of fans, and manufactured silencers can also be an effective means of reducing sound.
  - Vibration isolation connectors and flexible connections can be used to minimize transmittal of vibration from mechanical equipment.
- Ductwork:
  - There are four main types of ductwork in a building.
    - Exhaust ducts – move air from the spaces to the exterior
    - Outside air ducts – duct fresh air through HVAC equipment and into the spaces
    - Supply ducts – move air from HVAC equipment and distribute the air to the spaces
    - Return ducts – deliver air from the spaces back to the HVAC equipment, to be mixed with fresh air and heated/cooled and then redelivered as supply air
  - Insulation – insulate supply and return ductwork located in uninsulated spaces to improve energy efficiency of the HVAC system.
    - The International Energy Conservation Code (IECC) and ASHRAE 90.1 both provide minimum R-values of duct insulation that should be installed.
    - ASHRAE 90.1, IECC, and SMACNA guides provide direction on duct installation including sealing and allowable leakage. Leaky and/or uninsulated ductwork in unconditioned spaces will reduce energy efficiency of the system.
    - Ductwork exposed to the spaces served is commonly uninsulated and does not significantly reduce energy efficiency because the heating and cooling is still transferred to the space. Exhaust and outside air ducts are often uninsulated.

4 MAIN TYPES OF DUCTWORK

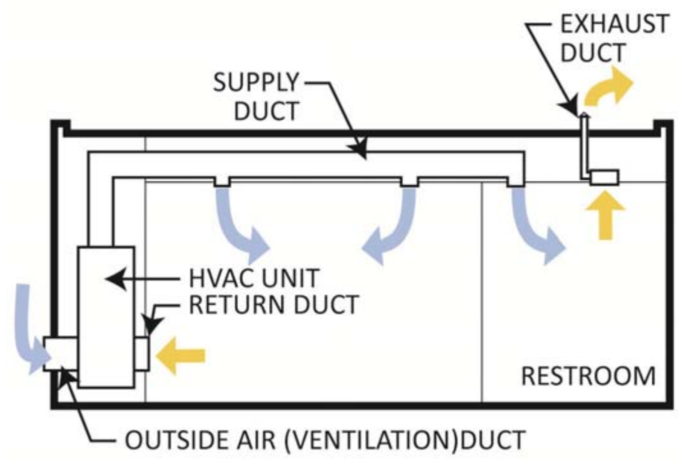
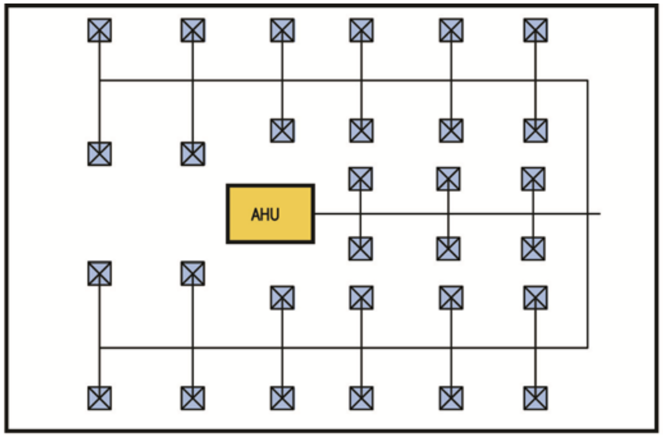


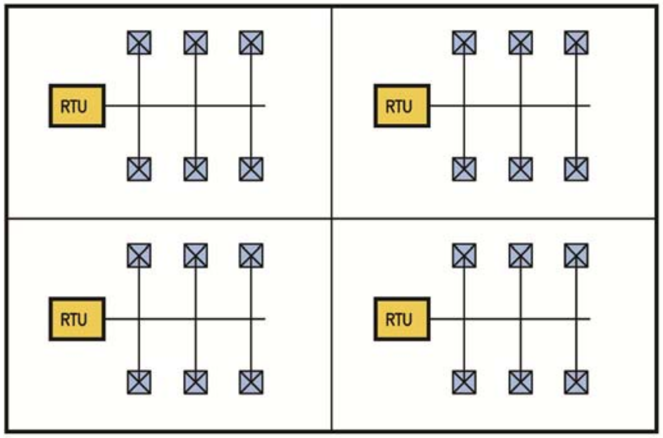
Figure 23 08-1

CONSIDERATIONS FOR FORCED AIR SYSTEMS:

- **Approach:**
  - Centralized or distributed forced air systems
    - Centralized HVAC systems, like a large AHU (air handling unit, either constant or variable air volume) in a central location, generally require larger main ducts because all supply and return air have to connect to one unit.
      - High velocity ducts and variable volume terminals where the air is reduced to low velocity can reduce the supply duct sizes.
    - Distributed HVAC systems like multiple RTUs (roof top units) installed throughout the building provide a certain amount of zoning.
      - Constant volume RTUs/AHUs are at a ratio of one per zone
      - Variable speed RTUs/AHUs with variable volume terminals can have more zones
  - Energy requirements
    - AHUs require electricity for fans, dampers, and controls.
      - Cooling provided by chilled water or DX cooling (direct expansion cycle).
        - Chilled water can be provided from a central plant or be produced at a specific building via an air-cooled chiller or cooling tower/chiller combination.
        - DX cooling utilizes the refrigeration cycle to cool the air. DX cooling can be built into a ‘packaged unit’ or can be provided by a separate exterior condensing unit and evaporator inside the AHU.
      - Heating utilizes natural gas, propane, heated water, electric heat pump or resistance heat.
      - Heat pumps provide cooling like a typical air conditioner but the cycle is reversed for the heating cycle. The equipment can either be air cooled or water cooled. The efficiency of heat pumps drops drastically at lower outside air temperatures and if used in a cold climate supplemental electric resistance heat should be used.



OFFICE BUILDING - CENTRALIZED HVAC WITH AHU



OFFICE BUILDING - DISTRIBUTED HVAC WITH RTUs

Figure 23 08-2

CONSIDERATIONS FOR FORCED AIR SYSTEMS continued:

- **Approach continued:**
    - Constant volume or variable volume forced air systems.
        - Constant air volume (CAV) systems are generally less expensive because variable speed fans and terminal units (which are equipment in the ductwork that can vary the flow of air and also provide additional heating and/or cooling) are not required.
            - only have one zone (one thermostat) per unit
            - also have the highest energy usage since the fan never winds down and turns slower to satisfy the heating/cooling load without over-cooling/heating.
                - When a building is occupied, it's required to have ventilation through either windows or HVAC, so a CAV system can be required to run full speed during occupied hours even when heating/cooling are not required.
        - Variable air volume (VAV) systems are tailored to provide airflow where it's needed.
            - Multiple terminal units tap off the main AHU ductwork. Each is connected to a thermostat.
                - Typically, 55 degree air is provided from a VAV AHU and the air is reheated as needed at the VAV terminal via a hot water coil or electric heat.
                    - Where hot water coils are used, associated piping and heating equipment (boilers, heat pumps, etc) are also required.
                - Rooms can have their own thermostats, or multiple rooms can be connected to the same thermostat and terminal unit.
                - The increased equipment requirements translate into increased cost.
                - VAV systems typically use less energy than CAV systems because the AHU fan speed is adjustable to provide only the amount of heating/cooling and ventilation required.

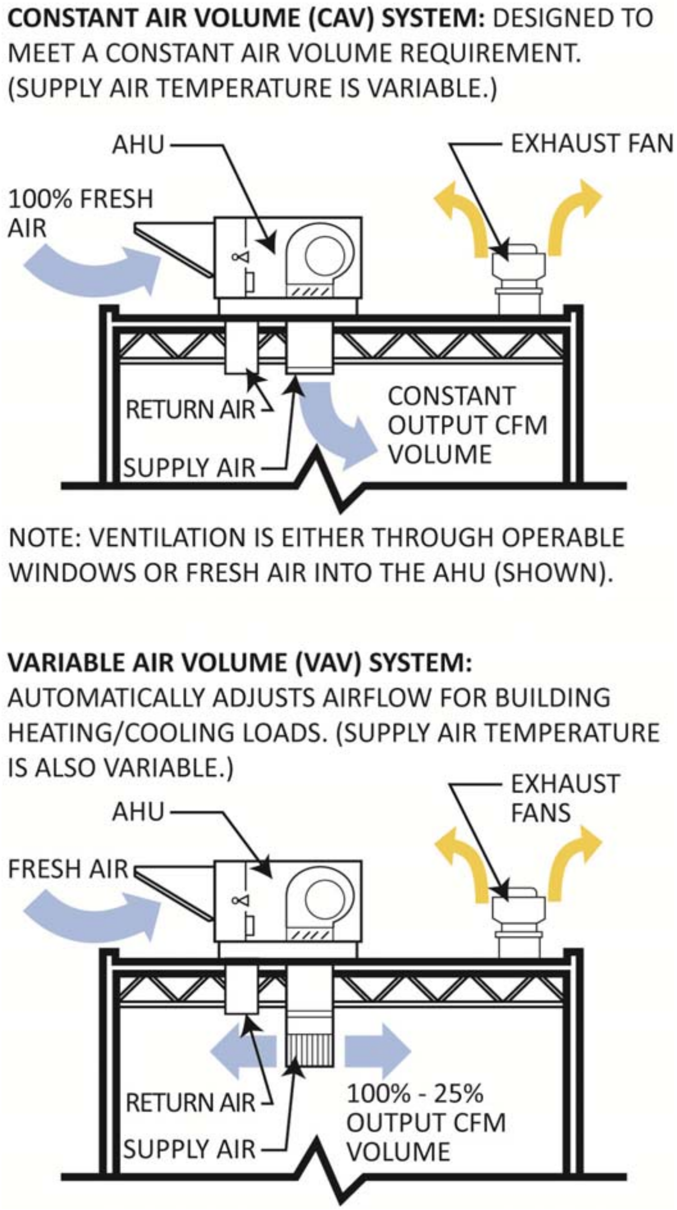


Figure 23 08-3

CONSIDERATIONS FOR FORCED AIR SYSTEMS continued:

- **Historic Preservation Effects:**
  - Existing ductwork in buildings may be reused to reduce the amount of demolition required. However, the duct sizes may not be the optimum dimensions. More often, the location where the original ductwork ran may be appropriate for new ductwork. Roof top units (RTUs) are not often approved by CRM or SHPO on a sloped roof unless they are on a very minor elevation of the building, not visible from a major elevation.
  - Roof top units (RTUs) may be appropriate on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building.
  - Buildings with sloped roofs often have attic spaces. If proper ventilation can be provided to the attic, AHUs can be located there.
  - Ground mounted units can be hidden from view with landscaping or an appropriately designed fence. The fence/landscaping must allow for air intake and heat disbursal from the unit. Ground mounted units need to be very close to the building to avoid a loss of efficiency in delivering the conditioned air.
  - Ducts can be located in basements and existing chases to reach upper floors. When there is no basement or chases connecting upper floors, new furred out areas must be created to locate horizontal ducts. Some alternatives include furring down a portion of the ceiling, or a portion of a hallway. Vertical chases can be furred out in inconspicuous corners of rooms, or in former closets or other utility spaces.
  - Fresh air intakes can be located where historic attic vents were located or where under-floor vent openings existed.
  - When historic buildings receive new heating systems, some CRMs/SHPOs prefer that historic heating fixtures (fireplaces, radiators, etc.) remain to exhibit the way the room appeared.

Ft. Stanton, New Mexico

Figure 23 08-4

Figure 23 08-5

As part of the Historic Renovation of this building, new fresh air vents were added. The half dome, slotted vent style was compatible to other, historic vents found on buildings throughout the site.

CONSIDERATIONS FOR FORCED AIR SYSTEMS continued:

- **Energy Efficiency Potential:**
  - Well designed forced-air systems, installed properly and using efficient components, can be energy efficient.
    - Energy efficiency can be improved by using variable air flowrates, zoning similar spaces together, or even using geothermal energy.
  - Manufacturers continue to improve the energy efficiency of rooftop equipment. For example, Daikin McQuay has a new 'Rebel' model that uses half the energy of current standards.
  - Electric resistance heat should be used a minimal amount to increase the energy efficiency.

- **Cost Considerations:**
  - Forced air is the most common form of HVAC because of its flexibility, efficiency potential, and cost.
    - CAV systems are the least expensive to install.
    - VAV systems are about 50% more expensive than CAV systems but provide better efficiency and zoning capability.
  - Equipment with higher energy efficiency typically has a higher first cost but can pay back and provide long term savings. A life cycle cost calculation can be performed to determine the pay back period once all of the project variables are known.

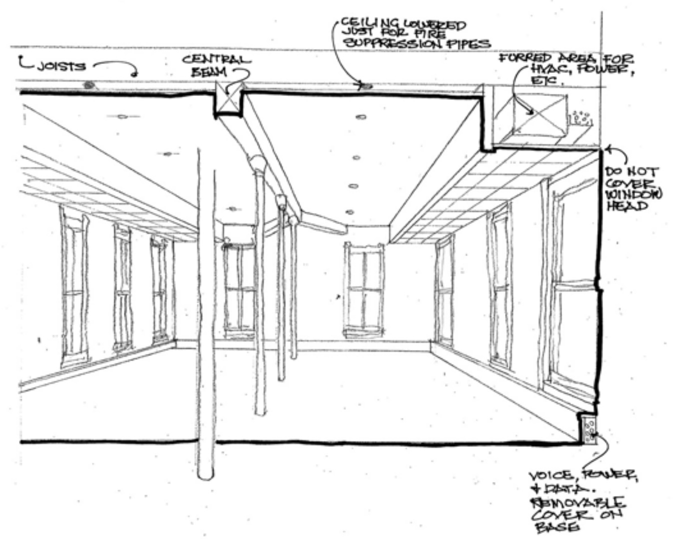


Figure 23 08-6
Sketch of new soffit for the Forced Air HVAC system in an historic structure at Ft. Bliss, El Paso, TX

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS:

- **Approach:**
  - Fan coils (FCs) are small terminal units with a powered fan and heating and/or cooling coils.
    - FCs recirculate the air in the space and typically add heating/cooling to the air through chilled/hot water coils, or through variable refrigerant flow (VRF) with refrigerant piped to the terminal unit rather than hot/cold water.
    - FC systems require far less ductwork than forced air systems because the air is recirculated/heated/cooled locally.
      - If chilling/heating water coils are used, then associated piping/chillers/boilers are also required.
      - A VRF system is basically a more complicated 'ductless split system,' and the arrangement uses less interior space for ductwork but adds refrigerant piping.
    - Fan coil/VRF systems can have many zones (thermostats).
  - Ductless split systems operate on electricity and do not use heating/cooling water.
    - Ductless split systems consist of one or multiple indoor fan-coil type unit(s) connected to an outdoor condensing unit with refrigerant piping in between.
    - Split systems can provide cooling-only or cooling and heating (like a heat pump).
    - They are often used to cool computer server rooms since the space requires cooling only without ventilation (outside air), but they can also be used for other purposes where ventilation is through a separate system or operable windows.
  - When ventilation is required, small ducts served by an Energy Recovery Ventilator (ERV) or Makeup Air Unit (MAU) are connected to the FC or VRF terminal.
    - An ERV supplies outside air but recovers the energy (hot or cold) from the air leaving the space. Outside air (ventilation) ducts are connected to the VRF terminal, and exhaust air is ducted out of the space through the ERV. A heat wheel recovers the energy of the leaving air and transfers it to the ventilation air.
    - A MAU provides slightly tempered ventilation air to the FCs and VRF terminals. The ventilation air is a small percentage of the recirculated air and does not need to be heated or cooled to a large extent before going to the FC or VRF terminal.

DUCTLESS SPLIT SYSTEM DIAGRAM

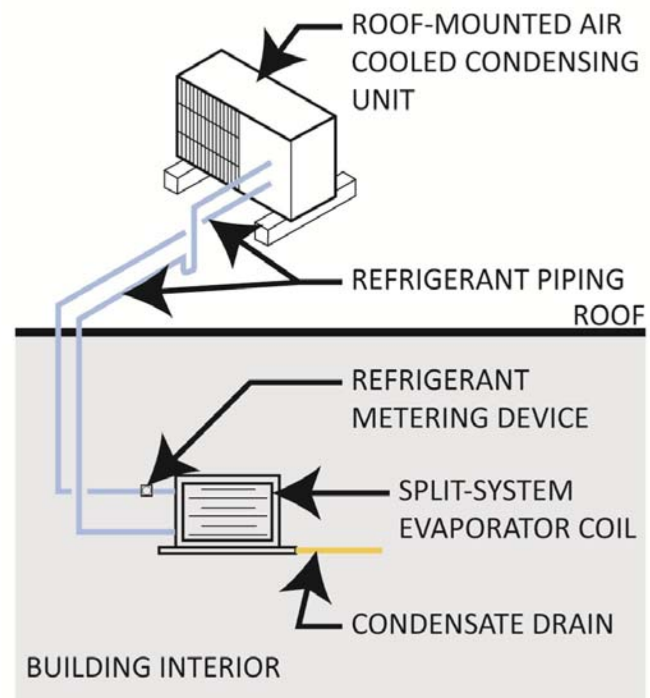


Figure 23 08-7

Figure 23 08-8
Installed Fan Coil VRF unit

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS continued:

- **Historic Preservation Effects:**
  - Fan coils and ductless split systems require a minimal amount of interior space and they can be either furred-in or exposed. However, the equipment does require refrigerant or water (hydronic) piping from the boiler/chiller or exterior condensing unit.
  - Condensing units can be located on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building.
  - Ground mounted condensing units can be hidden from view with landscaping or an appropriately designed fence. The fence/landscaping must allow for heat disbursal from the unit. Ground mounted units need to be very close to the building to avoid a loss of efficiency in receiving and delivering the piped fluid.
  - Condensers can be located in attics if there is sufficient ventilation.
  - Fan coil units can be located and screened in locations where historic boiler radiator units were housed.
  - Existing penetrations can be reused, but not enlarged. If new holes are required they should be below grade and all penetrations must be made water tight upon completion of the work.
  - Limit the number of units around a building so as not to clutter the landscape.

Figure 23 08-9
VRF and Makeup Air Unit on Roof

Figure 23 08-10
Old Terminal Building, Albuquerque International Sunport, New Mexico

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS continued:

- **Energy Efficiency Potential:**
  - Fan coils and ductless split systems can be energy efficient because the air is circulated a minimal amount compared to forced air systems.
    - Instead of the air needing to return back to an AHU or RTU to be conditioned, the air is just circulated through the fan coil or split system unit inside the room.
    - Fan coil efficiency depends on the heating and cooling equipment for the four-pipe system more than on the fan coils themselves.
      - Boilers can range from 80% up to 95% efficient, meaning the most efficient boilers can reduce gas utility costs by 20%.
      - Air cooled chillers generally have efficiency around 10 EER.
    - Ductless split systems often have an EER of 12-13 compared to about 10 for standard forced air units.
  - 'Heat Recovery' VRF systems are unique in their ability to transfer heating or cooling from one zone to another with a minimal amount of electricity input.
    - For example: 6 VRF terminal units are connected to 1 condensing unit. If 4 units are calling for heating and the other 2 calling for cooling, the cooling 'taken in' by the four units in heating mode is transferred to the two rooms that need cooling.
    - 'Heat Recovery' VRF systems often have an EER of 15 or higher compared to about 10 for standard forced air units. The reduced fan energy of a VRF system can lead to half the energy usage of a forced air system.

- **Cost Considerations:**
  - VRF systems can be the most expensive to install but also the most energy efficient. A life cycle analysis can be performed to show how long the payback period is.
  - As with forced air systems, equipment with higher energy efficiency typically has a higher first cost but can pay back and provide long term savings.

Figure 23 08-11
Pad Mounted Ductless Split Condensing Unit

Figure 23 08-12
Roof-Mounted Air Cooled Condensing Unit,

Figure 23 08-13 Interior Split-System Evaporator Coil,
For Figures 23 08-11 & 12, see diagram on page 110 for component locations.

CONSIDERATIONS FOR GEOTHERMAL HVAC SYSTEMS:

- **Approach:**
  - Geothermal heat pump systems use the ground as a stable-temperature 'heat sink' that can absorb or reject heat to/from a circulating fluid, such as water.
    - The earth, at around 55-60 deg F, can absorb heat from fluid above that temperature and transfer heat into fluid below that temperature.
    - Geothermal heat pump systems boost or lower the temperature of the fluid and provide heating/cooling to a building.
      - Use a water/glycol mix when chilled water is expected to go below freezing.
  - Use either a vertical borefield with wells, or horizontal trenches for piping.
    - The borefield or trenching size requirements vary with the size of the geothermal system, determined by the energy model for the heating/cooling required in the building and the soil test data.
    - If more land area is available and the soil temperature up near the ground level is stable enough, then a horizontal borefield could be more cost effective.
    - If the borefield needs to take up less land, a vertical arrangement can be used.
      - Borefield depth varies by geographic location.
    - A borefield can be installed under a parking lot, accessed by simple manholes.
    - Trenches can also be installed under a parking lot, but are more difficult to access.
  - Geothermal systems can be open loop or closed loop.
    - Closed loop systems recirculate the same fluid through the system and use heat transfer between plastic piping/grout and the earth.
    - Open loop systems bring in fluid from a body of water, extract or reject heat into the fluid, then discharge the fluid back into the body of water. The body of water must be clean and regulations regarding groundwater discharge must be met.
  - The piping can run in a parallel or series configuration (two-pipe or four-pipe).
    - If the piping is in series then the field temperature can be more uneven.
    - The best configuration for a certain project can be determined by an engineer specializing in geothermal systems.

GEOTHERMAL HEAT PUMP SYSTEM (HEATING CYCLE)

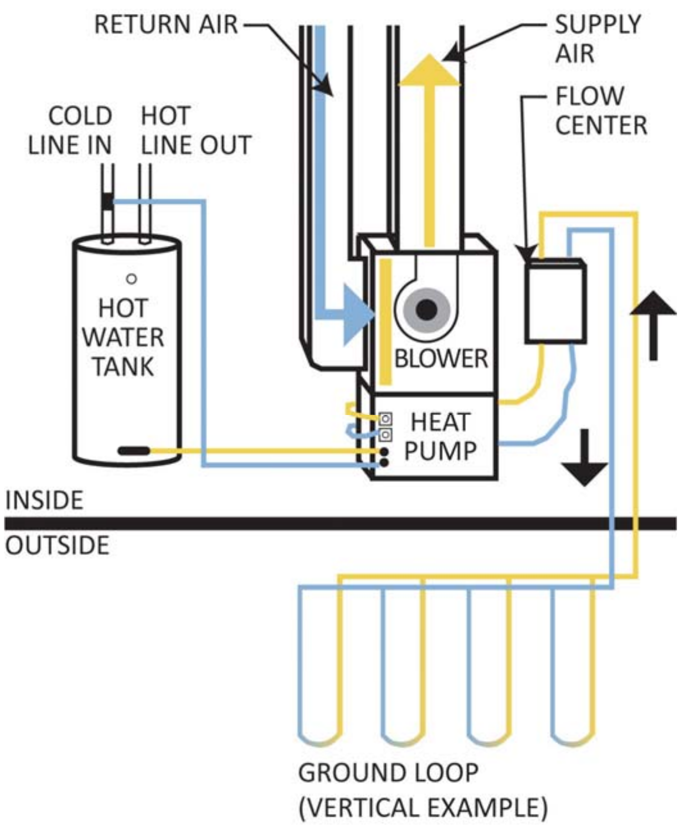


Figure 23 08-14

Figure 23 08-15
Geothermal piping in Trinity Church, Boston, MA

CONSIDERATIONS FOR GEOTHERMAL HVAC SYSTEMS continued:

- **Historic Preservation Effects:**
  - Geothermal equipment can preserve the exterior look of an historic building because the heat transfer is to/from the earth rather than to/from the atmosphere around a building.
  - These are very quiet systems with minimal vibration. Therefore, they can be a good option for buildings in which there are noise related concerns.
  - Since Geothermal HVAC systems can be used with AHUs, or piped fluids, the interior impacts are similar to those noted with these systems above.

- **Energy Efficiency Potential:**
  - Geothermal heat pumps are typically 30% more efficient than air-source heat pumps and geothermal heat pump systems can have low energy usage similar to VRF systems.
    - The geothermal aspect of the system is only part of the equation. The efficiencies of the heat pump and water pumps and heating/cooling equipment like air handlers and fan coils are as important as the geothermal field.

- **Cost Considerations:**
  - Geothermal systems are at least 30% more expensive than conventional air-cooled systems, but because of their greater efficiency they can have long-term cost savings.
  - A life cycle cost analysis should be performed to compare the options since the cost of geothermal systems vary greatly based on geographic location.

Figure 23 08-16
Heat pumps and blowers at Trinity Church

Figure 23 08-17 Supply/return diffuser carefully incorporated into historic fabric of Trinity Church.

CONSIDERATIONS FOR TWO-PIPE RADIANT HEATING:

- **Approach:**
  - Two-pipe radiant heating systems provide supply and return piping for heating water circulation through a radiator.
    - A building with a two-pipe radiant heating system can only provide heating because radiant cooling is largely ineffective.
      - The system could be changed from radiators to fan coils that could provide heating or cooling.
        - Two-pipe systems restrict the zoning of a building, since different zones cannot be heated **and** cooled at the same time.
      - A two pipe system could also be upgraded to a four pipe system with fan coils, so that the fan coils could be in either heating or cooling mode and provide temperature zoning.
    - Ventilation is an important consideration with two pipe and four pipe systems. Operable windows or dedicated outside air systems should be provided to ensure adequate ventilation.

- **Historic Preservation Effects:**
  - Existing heating/cooling water piping can generally be reused. However, upgrading a two-pipe system to a four-pipe system requires additional piping and equipment.
  - See Historic Preservation Effects for Fan Coils and Ductless Split Systems for additional effects. These systems are similar in that they all use piping.

- **Energy Efficiency Potential:**
  - The energy efficiency of a two-pipe or four-pipe system is determined by the boilers, chillers, or heat pumps that heat and cool the water rather than the piping itself (although the piping should be insulated to reduce energy loss).

- **Cost Considerations:**
  - As is the case with other HVAC equipment, high efficiency boilers, chillers, and heat pumps are typically more expensive.
  - A life cycle cost analysis should be performed to compare the options.

Figure 23 08-18
Historic steam radiator for a Two-Pipe Radiant Heating system. Not only can the radiator be reused, but it also might be considered a character-defining feature. If steam radiators are present in the building being renovated, discuss option with the Design Team and CRM/SHPO.

CONSIDERATIONS FOR SELECTING THE BEST CONTROL SYSTEM FOR THE HVAC SYSTEM:

- **Approach:**
  - Control systems for HVAC can be very simple or very complex. Simple controls can be easier to operate but lead to higher energy usage while complex control systems can be expensive to install but can also have user-friendly interfaces and reduce energy usage.
    - **Simplest** – Install a basic thermostat, with manual input to set room temperature.
    - **Simple** – Install programmable thermostats, which are common, inexpensive, and allow the temperature setpoint to be programmed with a 'setback' temperature for unoccupied or night periods. Automatic setback thermostats are required in most of the current energy codes (like IECC 2009).
    - **Complex** – Building automation systems (direct digital controls) have room temperature sensors instead of thermostats and allow remote viewing and programming of the temperature setpoints.
      - Well-designed control systems can operate the HVAC equipment most efficiently as parameters change (like outside air temperature and CO2 levels).
      - Sensors can be equipped with an LCD screen and allow a manual override.
      - The control system can be tied into sensors and controls on the HVAC equipment to run the equipment most efficiently, monitor the equipment and send an alarm if anything abnormal occurs.
      - Examples
        - In a LEED building that requires a certain amount of ventilation, an airflow sensor on the outside air duct can send a signal to the building automation system so that the current ventilation flow can be viewed through a web interface. An alarm can be sent if it is below setpoint.
        - HVAC filters can be monitored and send an alarm when they are dirty. New filters have less resistance to air movement and save fan energy.
  - The control system capabilities depend on which type of HVAC system is installed and which parameters can be 'controlled.' For example, a VAV air handler requires motorized dampers on the outside air intake for the control system to adjust outside air. VRF systems have built in complex control systems, and the controls can be left 'standalone' or tied into a webpage interface.

Figure 23 08-19
Basic Thermostat

Figure 23 08-20
Programmable Thermostat

CONSIDERATIONS FOR CONTROL SYSTEMS continued:

- **Historic Preservation Effects:**
  - Building automation systems require sensors, controls, wiring, and computers and these components require a certain amount of space and should not be conspicuously placed.
  - See Historic Preservation Effects for Fan Coils and Ductless Split Systems for additional effects. These systems are similar in that they all use piping.

- **Energy Efficiency Potential:**
  - Basic thermostats typically lead to higher energy usage since people do not set back the temperature at night. Simple thermostats are now obsolete for most new HVAC installations because they do not meet current energy codes.
  - Programmable thermostats can automatically setback the temperature and are required for most HVAC systems per the International Energy Conservation Code.
  - Building automation systems allow remote monitoring and viewing of HVAC setting. Large organizations which have temperature setpoint standards can verify that the standards are being met and that people are not setting the thermostat to be warmer or cooler than the standards which would lead to excessive energy use.
    - Some control systems also monitor the actual energy usage (kWh) of specific HVAC equipment so the equipment can be monitored for excessive energy use and the system can be optimized.
    - Variable speed drives are often installed with control systems which allow fans to run at slower speeds when conditions allow, reducing energy usage and providing equal occupant comfort.

- **Cost Considerations:**
  - Building automation systems range from simple and less expensive to highly advanced and costly. Advanced systems lead to higher energy efficiency through increased knowledge of the HVAC equipment performance and controllability. Programmable thermostats are less than $100, and building automation systems costs vary widely but start around $1.50 per square foot.

BUILDING AUTOMATION SYSTEM DIAGRAM WITH POSSIBLE COMPONENTS

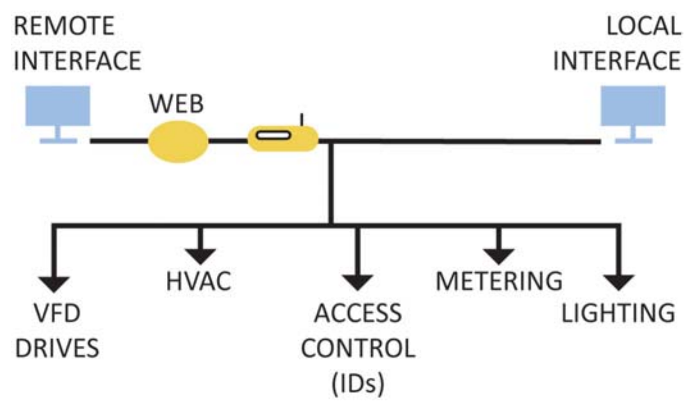


Figure 23 08-21

CONSIDERATIONS FOR HVAC EQUIPMENT SELECTION:

Factors for selecting certain HVAC systems are numerous.

- **Energy sources available**
  - Gas can be used in a boiler or gas heat section of an AHU to provide heat.
  - Electricity can be used efficiently in a heat pump or VRF system for heating and cooling.
  - Geothermal systems operated by electricity can be used with a heat pump to provide heated/chilled water or in a packaged heat pump to provide heated/cooled air.
- **Interior HVAC equipment space available**
  - Existing ductwork, hydronic piping, and mechanical rooms can often be reused.
  - Spaces that require the mechanical equipment to be hidden require a different design than spaces where ductwork and other equipment can be exposed.
- **Exterior HVAC equipment space available**
  - Exterior equipment can be installed to conserve space inside the building but is also required for air-cooled cooling systems.
    - Air conditioners work by moving heat from the conditioned space to the exterior which requires exterior equipment.
    - Geothermal heat pumps transfer heat from the space to or from the earth. Underground piping is required, but is not visible beyond man-hole covers.
  - Existing rooftop equipment or rooftop mechanical penthouse spaces can often be reused by new equipment.
  - Pad-mounted equipment is an option if no equipment is allowed on the roof.
    - Can be concealed in walls, fencing or landscaping but the top must remain open.
  - A geothermal bore field could be used if there can be no exterior equipment at all.

- **Historic Preservation Effects**
  - HVAC equipment selection can have a very large effect on historic properties.
  - Placement of exterior units must be carefully considered to avoid detracting from the character of the historic property. See Historic Preservation Effects under Forced Air Systems, Fan Coils and Ductless Split Systems.
  - Interior HVAC equipment selection can be minimized with systems that use piped fluids rather than air ducts that require more interior volume.

Maps produced by NREL for the US DOE

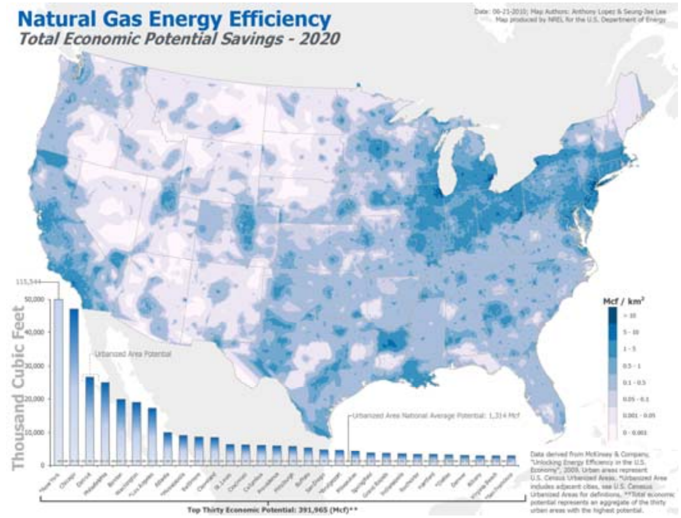


Figure 23 08-22

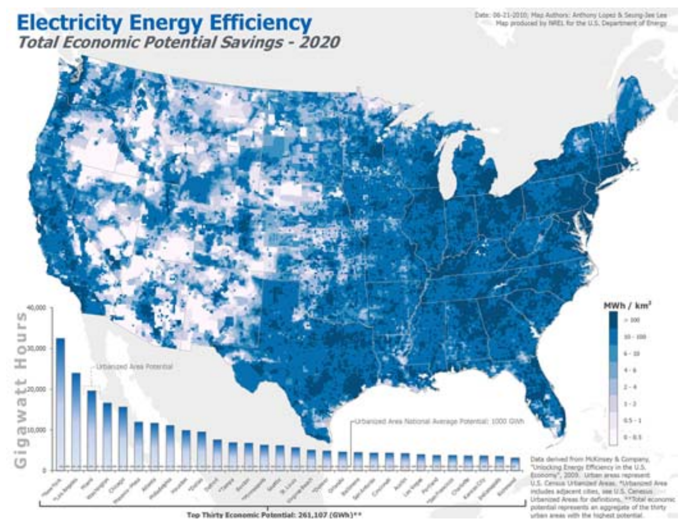


Figure 23 08-23

See Appendix G for larger versions of both maps

CONSIDERATIONS FOR HVAC EQUIPMENT SELECTION continued:

- **Energy Efficiency Potential:**
  - HVAC equipment is a very large factor in a building's energy usage. More efficient equipment is almost always more expensive. Building insulation and infiltration also factor into the HVAC energy usage.
    - Examples of energy efficient equipment include:
      - Fan coils with efficient boilers and chillers
      - VRF systems
      - Ductless split systems
      - Packaged units with 80%+ gas heat efficiencies and EER greater than ASHRAE 90.1 requirements.
      - Packaged unit heat pumps with backup electric resistance heat
      - Geothermal heat pumps
    - Examples of non energy efficient equipment include:
      - Equipment past its useful life expectancy with leaky housings and worn-out fan motor bearings.
      - Constant volume airflow systems which have to remain on at full speed during occupied hours (for ventilation) and provide over-heating and over-cooling to some areas while maintaining other areas at a comfortable level.
      - Electric resistance heating.

- **Cost Considerations:** The cost of upgrading or installing new mechanical equipment is always an overriding factor.
  - It is often less expensive to demolish an old system and install a new one than to upgrade and refurbish the existing system, although the interior and exterior space available for new HVAC equipment will have to be taken into account.
  - In certain cases the historic preservation of the building would overrule the new HVAC equipment and the HVAC design would need to reuse and refurbish all or some of the existing equipment.

GEOTHERMAL RESOURCE OF THE UNITED STATES:
Locations of Identified Hydrothermal Sites and Favorability of Deep Enhanced Geothermal Systems (EGS), produced by NREL for the US DOE.

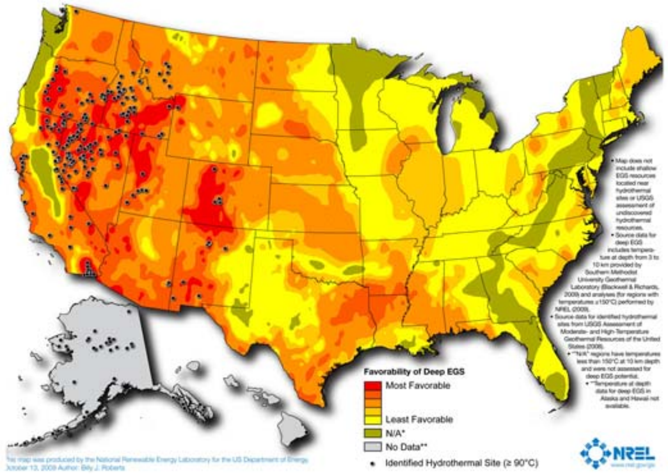


Figure 23 08-24
See Appendix G for larger versions of the map

HVAC systems can have a dramatic effect on the energy usage and, therefore, the energy efficiency of a building. When determining the right HVAC renovation project for an historic building consider the following:

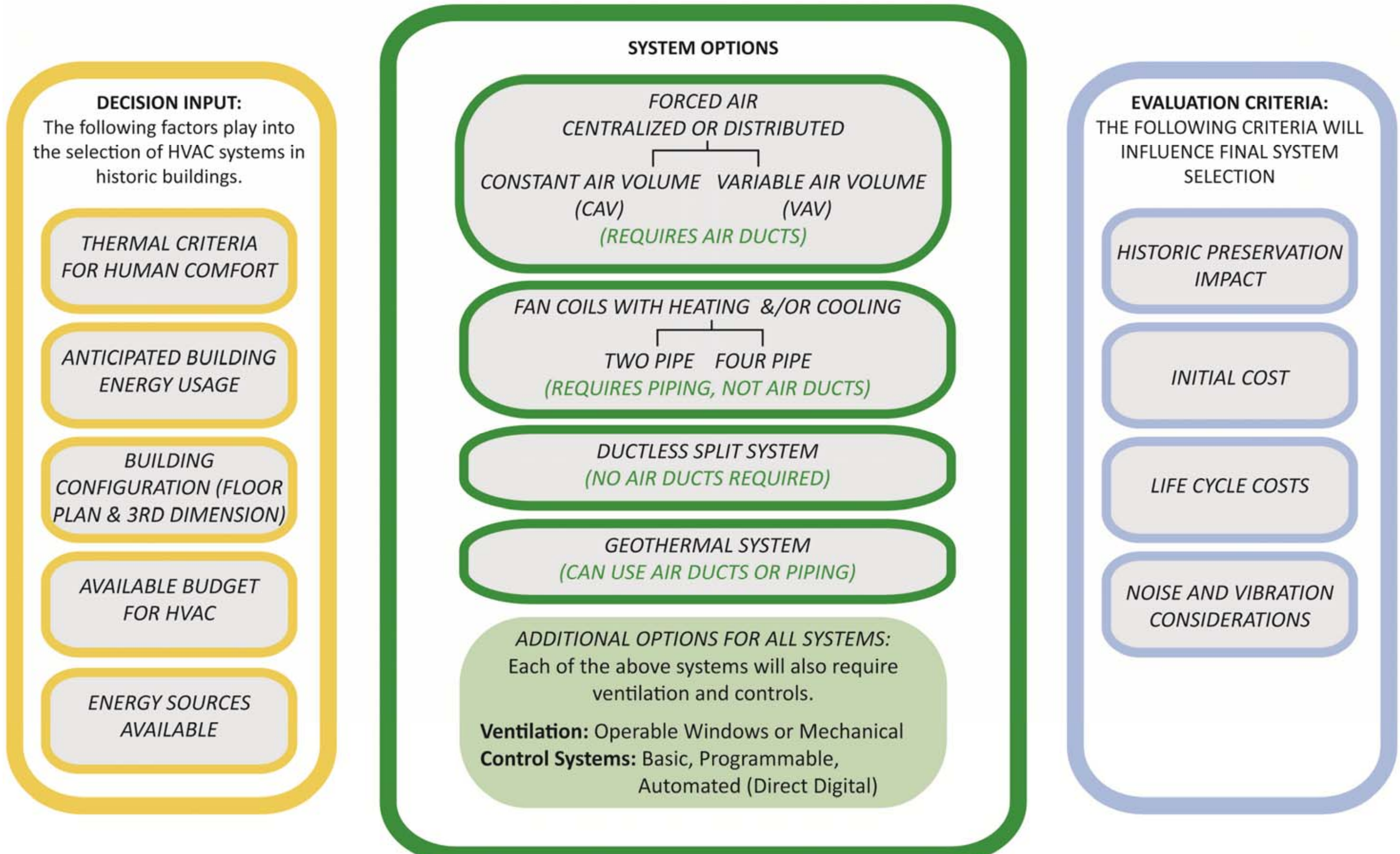


Chart 23 08-2

GUIDELINE DESCRIPTION: Background information on HVAC nomenclature will be presented and zoning discussed. Ductwork and piping, hot-water radiant coils, fan coils, indoor sections of split systems, VAV terminal units, mechanical room space and existing floor plan, air distribution and equipment concealment will be evaluated. Selecting an HVAC system (see Guideline 23 08) narrows down the interior equipment options, but specific interior equipment, still needs to be determined. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 23 08 Selecting HVAC Systems
- 23 12 HVAC Exterior Placement

GENERAL NOTES:

- **Secretary of the Interior Standards: Applicable for all systems listed under this Guideline**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
- **Air volume heating/cooling is both sensible and latent.**
  - Cooling air is delivered around 55 deg F, and heating air is delivered at 90-95 deg F, so that the HVAC air is 20 deg F from the room temperature.
  - Latent cooling is the energy required to dehumidify the air before it can be cooled.
    - Warmer air can have more moisture, so that when it is cooled it also has to be dehumidified (producing condensation off the cooling coil).
    - Condensate should be piped to the building drain with an air gap.
  - Cooling airflow is typically 300-500 cfm (cubic feet/minute) per ton.
    - For example, 12 MBH (one ton) of cooling at 400 cfm requires a 10" duct.
- **Interior placement of HVAC equipment depends on the zoning requirements.**
  - When adjacent rooms need to separate zones (controlled by separate thermostats), the HVAC system needs to be able to deliver independent heating and cooling to the zones.
  - One AHU/ RTU to all rooms cannot deliver varying zones without additional equipment.
  - Examples of zoning equipment: Separate ducts to each zone from a VAV reheat system. Fan coils in each zone with heating/chilled water piping and valves

Common Terms used for Heating and Cooling:

BTU/hr *– measurement of heating and cooling*
1 BTU is the energy required to heat 1 pound of water 1 degree.

MBH *– 1,000 BTU/hr, 12 MBH = 1 ton*

Ton *– measurement for cooling only (1 ton of cooling is 12,000 BTU/hr or 12 MBH).*

Kilowatts *(kW) converted into BTU/hr and tons*
1 kW = 3412 BTU/hr = 3.4 MBH
3.5 kW of electrical energy requires 1 ton of cooling

delta T *– difference in temperature. In hydronic (heating/cooling water) calculations, typically 10-20 deg F.*

GPM *– gallons per minute, the flowrate of heating/cooling water.*

Hydronic energy is calculated by:
BTU/hr = delta T x GPM x 60 min/hr x 8.33 lb/gal, simplified to BTU/hr = delta T x GPM x 500. (Therefore, 12 MBH, 1 ton, with delta T of 15 degF requires 1.6 GPM, which can flow through ¾" supply and return piping compared to a 10 inch duct for the equivalent forced airflow).

CONSIDERATIONS FOR DUCTWORK AND PIPING:

- **Approach:**
  - Nearly all HVAC systems use interior ductwork, water piping, and/or refrigerant piping.
  - Ductwork can be installed in existing building cavities: ceilings, floors, soffits, and in renovated spaces designed around ductwork, like new dropped ceilings and soffits.
    - Both round and rectangular ductwork are available. Rectangular ductwork can move more air through tight and narrow spaces, but round ductwork is less expensive.
  - Hydronic (heating/cooling water) and refrigerant piping requires less room than ductwork to deliver equivalent cooling/heating but also requires terminal units to transfer the cooling/heating to the air, like radiators, baseboards, and fan coils.
    - Supply and return piping have to be installed. A four-pipe system can provide heating and cooling to different zones at the same time, and a two-pipe system can be in heating or cooling mode at one time.

- **Historic Preservation Effects:**
  - Existing ductwork and piping can often be reused if it is still in good condition.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Poorly insulated ductwork and piping cause a loss of energy efficiency. Ductwork and piping should be insulated per the relevant codes (eg UFC, UMC, UPC).
  - Leaky ductwork loses energy efficiency if tempered air is being supplied to areas that don't require HVAC. For example, leaky supply ducts in ceiling spaces waste energy.

- **Cost Considerations:**
  - Sealing leaky ductwork or insulating piping or ductwork has a cost, but gaining access to the ductwork or piping then patching the wall/ceiling can also be a large expense.
    - New ductwork and piping should always be thoroughly sealed, tested, and insulated before covering it up in wall and ceiling cavities.

Figure 23 11-1
New drop ceiling allows ductwork to be in the ceiling plenum. Notice that the drop ceiling stops several feet before the windows so that the historic windows are not covered or damaged.
Coronado School, Albuquerque, NM

Figure 23 11-2
Exposed ductwork before the ceiling is installed. While painting and leaving ductwork exposed is very common, it is rarely an acceptable solution in an historic renovation project.

CONSIDERATIONS FOR RADIANT HEATING:

- **Approach:**
  - Radiant heating is more effective than radiant cooling. Radiant heating from equipment placed low in the room provides a comfortable space temperature, while radiant cooling from the same equipment does not address the fact that heat rises and the cooling load is at the top of the room, and it leads to uneven temperatures in the room. Radiant heating is commonly used with fin tube radiators and radiant floors.
    - Chilled beams placed in the ceiling are a modern take on radiant cooling, and are much more effective because they provide more comfortable and even temperatures. Chilled beams work by bringing in warm air above a cooling coil then allowing the cooled air to exit below the coil.
    - Fin tube radiators consist of a main serpentine tube with fins attached to the tube to increase the surface area of heated metal exposed to the air.
      - Fin tube radiators require hydronic piping from the boiler system to the radiators, and also take up a block of space in the room.
      - Radiators can be furred in to be less visible, but some clearances to combustible construction materials are still required.
    - Baseboard heating is a fin tube radiator in a short form factor, commonly installed up against exterior walls.
      - Occupies long sections of the wall but is effective at keeping the room comfortable when the equipment is placed properly.
      - Furniture has to be kept away from baseboard heating.
  - Historic buildings with fin tube or baseboard radiators can potentially re-use the radiators and piping during an HVAC upgrade.

- **Historic Preservation Effects:**
  - Existing radiant heaters can be an integral part of the historic building. In some cases, removing them would take away from the building's character.
  - If the radiant heaters are still in good condition, and it is desired to conceal them, the units can be furred in with sufficient clearances and appropriate grills or other perforated covers.

Figure 23 11-3 Radiators are typically located low in the room, like under a window.

Figure 23 11-4 Contemporary chilled beam

CONSIDERATIONS FOR RADIANT HEATING continued:

- **Energy Efficiency Potential:**
  - The energy efficiency of a radiant heating system depends on all the components including the boiler(s), piping, and radiant heaters. A well designed system with efficient boiler(s) and good piping insulation can be energy efficient.
    - Boilers can range from 80% up to 95% efficient.
    - Radiant heating does not use energy to power fans but does require heating and pumping energy.
      - Fan energy is a large factor in most non-radiant HVAC systems.
      - Radiant heating alone cannot provide ventilation so operable windows or a dedicated ventilation unit are required.

- **Cost Considerations:**
  - Radiant heating systems are not as common as they once were because most buildings now require heating <u>and</u> cooling. New or upgraded HVAC systems can use radiant heating with 'perimeter zoning' to heat interior space next to an exterior wall but a separate cooling system would still be required.
  - If an historic building has existing radiant heating, then the cost of reusing an existing radiant heating system depends on the condition of all the components and piping. If the heaters and piping are in good condition but the boiler is beyond its estimated lifespan, it would likely be cost effective to install a new high efficiency boiler to reduce maintenance and energy usage.

Figure 23 11-5 Examples of different types of fin tube radiators

Figure 23 11-6 Radiator furred into the wall

Figure 23 11-7 Baseboard heater

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS:

- **Approach:**
  - Fan coils provide heating and/or cooling to specific zones. A fan coil contains a heating and/or cooling coil and a fan to circulate the air through the coil(s).
    - Take precautions to ensure low noise levels from the fan coils. Sufficient straight duct before and after fan coils and elbows in the ductwork reduce noise levels.
    - Fan coils come in many different configurations
      - Concealed: hidden in soffits, ceiling space, or furred in. Supply / return ductwork connect to the fan coil. The visible portion is a supply diffuser and return grille.
      - Exposed: visible to the room, either in horizontal or vertical configurations. Duct-less split systems have exposed interior fan coils, installed high on a wall.
  - Do not provide ventilation unless outside air is provided through a separate duct.
  - The cooling coils of fan coils collect condensate which is collected in a pan underneath the coil. The condensate can either be gravity drained or pumped to a place it can connect to a building drain with an air gap fitting.

- **Historic Preservation Effects:**
  - Fan coils, VRF systems, and ductless split systems can be well concealed.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Fan coils, VRF systems, and ductless split systems can have high energy efficiency. The biggest factor in the energy savings is the reduced fan power that is required to circulate air within a room compared to circulating air through long stretches of ductwork and through an air handling unit.
    - Hydronic fan coil efficiency depends on the boiler and chiller that provide the heating or cooling water. Equipment that exceeds the minimum ASHRAE 90.1 requirements will provide better energy efficiency.
    - VRF and ductless split systems typically have a higher EER commonly 16 or higher than RTUs which are typically around 11.

- **Cost Considerations:**
  - Costs vary widely with fan coils, VRF systems, and ductless split systems. Fan coils require other components like boilers, chillers, and piping. VRF and ductless split systems can be cost effective because of their low energy use but the installed cost will vary from building to building because of specific building conditions. A life cycle cost analysis can be calculated to determine which options are cost effective.

Figure 23 11-8 Installed VRF Fan Coil

Figure 23 11-9 Interior fan coil of a ductless split system

CONSIDERATIONS FOR VAV TERMINAL UNITS:

- **Approach: This guideline talks about the VAV configurations and how they can fit in the interior**
  - VAV terminal units control the volume and heat of air from a central air handler to the rooms. Typically the main AHU high velocity supply ducts are installed above corridors, and small ducts tee off into the rooms, with the VAV terminal unit being installed directly above or near the room.
  - VAV supply ductwork takes up less ceiling space because the airflow can be at a higher velocity up until the VAV terminal. For example, 1,000 cfm would require a 14” diameter duct at low velocity in a constant volume system but only a 10” diameter duct in a VAV high velocity system.
  - Each VAV terminal is connected to a thermostat and is considered a ‘zone’.
  - VAV terminal units typically have hydronic or electric reheat. Hydronic reheat requires piping from the boiler equipment to the VAV terminals. Electric reheat only requires wiring, although electric resistance heat is more energy-intensive than gas hot water heat.

- **Historic Preservation Effects:**
  - VAV terminal units can be well-concealed in interior cavities but do require ductwork and a source of airflow (AHU or RTU).
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Systems with VAV terminal units are more efficient than constant volume systems because the amount of heating and cooling to each zone varies with the load. When there is a smaller cooling or heating load, fan, heating and cooling energy are all reduced.

- **Cost Considerations:**
  - Systems with VAV terminal units are approximately 40% more expensive than constant volume systems but provide better efficiency and zoning.

Figure 23 11-10 VAV terminal with Hot Water Coil

Figure 23 11-11 VAV terminal with Reheat Coil

CONSIDERATIONS FOR MECHANICAL ROOMS AND EXISTING FLOOR PLANS:

- **Approach:**
  - Mechanical rooms are an effective way of concealing and isolating mechanical equipment. Existing buildings can have existing mechanical rooms, or new areas may be designated as mechanical rooms.
    - AHUs in mechanical rooms provide heating/cooling air through ductwork
    - An AHU is typically configured with a heating water coil and cooling water coils or refrigerated coil.
      - Heating water coils are fed with hot water from a boiler or another source (eg ground source heat pump)
      - Cooling water coils are fed with chilled water from a chiller or another source (eg ground source heat pump)
        - Water cooled chillers can be installed inside, but are connected to pumps and exterior cooling towers.
      - Water source (geothermal or boiler/cooling tower) heat pumps can be installed in mechanical rooms.
      - Boilers are typically installed in mechanical rooms, but require piping to the exterior for combustion air and exhaust.
  - Existing floor plans should be reviewed and coordinated with interior HVAC placement.
    - Hydronic piping can either be in a loop or 'out and back' configuration from the mechanical room to all the terminal units.
    - Ductwork can be designed in a variety of ways and must be coordinated with available interior space. One large supply duct or multiple smaller ducts can transfer the air to the rooms.
    - HVAC equipment requires space in a building but, with careful planning, its architectural impact can be lessened.

Figure 23 11-12 AHU in a mechanical room
AHUs are large pieces of equipment with required clearances. Careful planning is needed if existing mechanical rooms are to be used with newer (often larger) equipment.

Figure 23 11-13 2 AHU's for a hospital

CONSIDERATIONS FOR MECHANICAL ROOMS AND EXISTING FLOOR PLANS continued:

- **Historic Preservation Effects:**
  - Existing mechanical rooms can often be reused. The spaces should be checked for code compliance issues like fire walls and combustion air openings.
  - A building's floor plan is a determining factor in what HVAC system should be used to preserve the historic nature of the building.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - The energy efficiency of a system depends more on the specific HVAC equipment and system rather than the mechanical rooms themselves.
  - Examples of energy efficient equipment in mechanical rooms include: efficient condensing boilers, variable volume air handling units (AHUs), and efficient chillers with exterior cooling towers.

- **Cost Considerations:**
  - Reusing existing mechanical rooms, if available, is often the lowest-cost solution, although the rooms require sufficient access and a way to remove old equipment and bring in new equipment. Sometimes, additional funds are required to bring old mechanical rooms up to code.
  - Floor plans should be studied to assist in determining which is the best interior HVAC equipment to install, rather than selecting equipment and trying to make it fit the building.
  - Existing ductwork and piping should be evaluated for its condition and possible reuse.

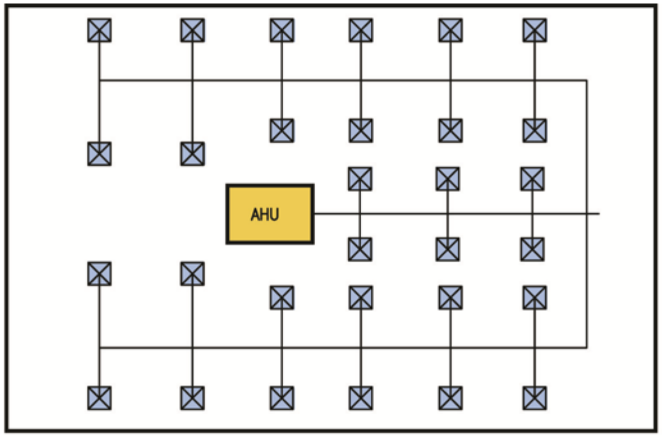


Figure 23 11-14 The AHU is housed in a mechanical room. Building configuration is critical in determining what space (if any) is available for mechanical room.

CONSIDERATIONS FOR AIR DISTRIBUTION AND EQUIPMENT CONCEALMENT:

- **Approach:**
  - Air distribution and equipment concealment can be accomplished a variety of ways.
    - Ductwork can be concealed in ceiling spaces, soffits, or underground
      - Underground duct connected to floor level registers can be installed to reduce or eliminate ductwork from the walls and ceilings.
      - Ductwork can be installed in basements or attic spaces.
      - Ceiling plenums or transfer grilles can be used to return air back to an air handler or fan coils while ductwork is used for the supply air. The path of the return air isn't obvious and visible but is effective.
        - Wood or other flammable construction requires the return air to be ducted back to the HVAC equipment instead of returning via a ceiling plenum.

- **Historic Preservation Effects:**
  - Existing air distribution ductwork can often be reused if it's in good condition.
  - Concealed ductwork and equipment are a big factor in historic building renovations.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Ductwork is an important factor in a HVAC system's energy efficiency and should be well sealed, insulated, and sized correctly. Properly sized, sealed and insulated ductwork will improve HVAC energy efficiency. Ductwork that is too small requires more fan energy, and poorly insulated ductwork contributes to heat loss.

- **Cost Considerations:**
  - Costs for concealing ductwork and equipment are part of the general construction of a building renovation and depend highly on architectural design.
  - Round ductwork is less expensive than rectangular ductwork although rectangular ductwork can supply more air through tight spaces.

Figure 23 11-15 Ductwork concealed in a new dropped ceiling space, but detailed to respect the historic windows.
JW McCormick Place, Boston, MA

Figure 23 11-16 Insulated ductwork installed above new lay-in ceiling (ceiling tiles not installed yet)

GUIDELINE DESCRIPTION: Background information will be discussed about why exterior HVAC equipment is required, placement options, and the architectural options for hiding the exterior equipment. The guideline will describe rooftop and pad-mounted (ground-level) equipment: packaged HVAC units, chillers and cooling towers, and split system condensing units. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 23 08 Selecting HVAC Systems

GENERAL NOTES:

- **Secretary of the Interior Standards: Applicable for all systems listed under this Guideline**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- HVAC requires exterior equipment in order to reject or absorb heat from the atmosphere or earth. An air conditioner works by removing heat from interior spaces and rejecting it outside to keep the interior space cool. A heat pump works the opposite way, absorbing heat from the exterior and rejecting the heat inside.
  - Ground source (geothermal) heat pumps reject and absorb heat into the earth rather than the atmosphere. Even though geothermal systems require exterior equipment, it is hidden underground.
- Exterior equipment is typically placed on a rooftop or at the ground level on a concrete housekeeping pad, depending on the space available. Rooftop equipment can be placed in a penthouse if no heat rejection is required.
- Air-cooled rooftop and pad-mounted equipment can be installed with walls, fences or landscaping that shield the equipment from view where the heat rejection fans can still discharge air upward. Manufacturer required clearances need to be maintained.

Figure 23 12-1 Rooftop Screen Wall, screens can make the installation of both roof mounted and pad mounted HVAC equipment more acceptable for historic buildings.

CONSIDERATIONS FOR PACKAGED HVAC UNITS:

- **Approach:**
  - Packaged units come in multiple configurations.
    - Packaged units can be installed on a roof curb with heating/cooling air typically supplied and returned vertically to the building
    - Packaged units can also be installed on a ground-level concrete pad with air ducted horizontally into the building.
  - Packaged units are typically air cooled and reject heat into the atmosphere.
    - Water cooled (geothermal) heat pumps are different and reject heat to water instead of air.
  - Packaged heat pumps can be air or water cooled and provide both heating and cooling from electrical power. The cooling operates like a typical air conditioner, and the cycle is reversed for the heating cycle.
    - Heat pumps are less efficient at cooler temperatures and can be ineffective below about 40 deg F. For cold climates, backup electric resistance heat is required.
  - Packaged units can use a variety of energy sources
    - Hydronic cooling and/or heating coils can be used if chillers and/or boilers are installed.
    - Electric (DX refrigeration cycle) cooling is often used.
    - Heat can also come from gas or electricity.
      - Gas heat is often used when propane or natural gas is available
      - Electricity can provide heat via a heat pump or electric resistance heater.
        - Resistance heat is energy intensive and should only be used where gas is unavailable, or electricity from renewable sources is abundant and inexpensive.
  - Cooling coils, including those in packaged HVAC units, produce condensate which should be piped to a drain with an air gap where possible. Condensate should not be drained onto a roof or cause a freeze and slip potential on a sidewalk.
  - Packaged HVAC units produce noise from fans and other components and should be located in areas where they will not bother occupants.

Figure 23 12-2 Packaged Roof Top Unit (RTU) VRF Rooftop Units installed within a screen wall. This is a bird screen to protect the equipment.

Figure 23 12-3 Packaged Rooftop Unit with Economizer

CONSIDERATIONS FOR PACKAGED HVAC UNITS continued:

- **Historic Preservation Effects:**
  - Packaged HVAC units can be a good fit in an historic building if designated roof or pad-mounted space is available because they are relatively easy to install and maintain and all the components are contained in one area.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Packaged HVAC units can be an integral part of an energy efficient system. Packaged units are available in a range of efficiencies and more efficient units are typically more expensive.
  - Economizers improve the energy efficiency of packaged equipment. Economizers bring in more outside air when the air temperature is favorable, for instance, when it's cool outside and the building requires cooling.
  - Compare the energy efficiency (EER and/or COP) of packaged HVAC equipment to the minimum requirement in ASHRAE 90.1 to determine the relative efficiency.

- **Cost Considerations:**
  - If the existing building has an existing packaged HVAC unit that is being replaced and serving existing ductwork, only the cost for the packaged unit and installation need to be considered. If the ductwork is new or redesigned, there will be significant added cost.
  - Packaged HVAC Rooftop Units are typically about $1,600/ton for constant volume and $1,900/ton for variable air volume units.

Figure 23 12-4 Packaged Rooftop Unit with Gas Heat

Figure 23 12-5 Variable Air Volume (VAV) Packaged RTU (gas and condensate piping are visible)

CONSIDERATIONS FOR CHILLERS AND COOLING TOWERS:

- **Approach:**
  - Chillers provide chilled water to cooling coils. Cooling coils can be installed in a variety of HVAC equipment like AHUs, RTUs, and fan coils.
  - Chillers can be air cooled or water cooled.
    - Air cooled chillers are exterior equipment that reject heat to the outside air and cannot be completely closed in
    - Water cooled chillers are more efficient and are typically located indoors but require additional exterior connected equipment. Exterior cooling towers, piping, and pumps are required for water cooled chillers.
      - Glycol is added to the chilled water in cold climates to reduce freezing potential.
  - Cooling towers and chillers are noisy like other HVAC equipment and the distance to building occupants should be kept in mind during the design.

- **Historic Preservation Effects:**
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Water cooled chillers are more efficient than air cooled chillers but require more associated equipment like cooling towers.
  - As with other HVAC equipment, more efficient products are more expensive but can payback in a reasonable timeframe.

- **Cost Considerations:**
  - An HVAC system with chillers and cooling towers needs to be associated with a complete system containing the necessary piping, heating and air distribution system.

Figure 23 12-6 Chillers

Figure 23 12-7 Cooling Tower

CONSIDERATIONS FOR SPLIT SYSTEM CONDENSING UNITS:

- **Approach:**
  - Condensing units are half of a split system and reject or absorb heat from refrigerant to the outside air. They are installed outside and cannot be closed in, and they come in various sizes depending on the cooling requirements.
    - Split systems are typically cooling only or heating/cooling combination.
      - The heating/cooling versions are heat pumps.
      - The interior fan coil is the other half of the split system
  - A condensing unit fan moves air through the coil which can have noise levels that should be considered.
  - Manufacturers limit the distance and elevation difference between the outdoor condensing unit and interior fan coil of a split system.
  - Can be installed on roofs or concrete pads on the ground, and have two pipes for refrigerant to flow to and return from the interior fan coil.

- **Historic Preservation Effects:**
  - The condensing unit also requires an interior fan coil in addition to exterior space.
  - See comments on exterior installations in Historic Preservation Effects for **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Split systems are energy efficient because the fan energy is less than alternatives (like packaged RTUs). The heating/cooling energy is transferred through the pumped refrigerant piped to the interior coil, rather than the larger fan of a packaged unit moving airflow through ductwork to transfer the heating/cooling.

- **Cost Considerations:**
  - Split systems can be relatively inexpensive to install if the exterior equipment and piping location has good access, and the refrigerant piping distance is short.

Figure 23 12-8 Exterior Condensing unit for a ductless split system (fan visible)

Figure 23 12-9 Roof Mounted Condensing Unit for ductless split system

GUIDELINE DESCRIPTION: This guideline discusses installation and location of solar photovoltaic panels for electrical energy on roof and ground systems to insure the integrity of the historic building and surrounding areas. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 22 33 Hot Water Conservation

GENERAL NOTES:

- Part 1 assumes that the owner is considering a Solar Photovoltaic (PV) Panel System.
- Part 2 assumes that the owner has done the previous steps and is now considering installation.
- Part 3 provides Applicable SOI Standards, Historic Preservation effects, Energy Efficiency Potential and Cost Considerations that apply to all applications of PV panel installation.
- The Guideline then goes on to discuss the differences between different installations.

PART 1: (National Renewable Energy Laboratory 2012)

- Analyze whether the installation of solar PV system will benefit an historic building or site without compromising its character with the CRM and/or SHPO
- Analyze Site Location
  - Building orientation to due south is the most ideal
  - Building location in relation to obstacles that may interfere with PV production, such as trees, roof equipment and nearby buildings.
  - Determine retrofitting of solar panels will not alter the buildings architectural integrity
- Contact/work with the applicable Stakeholders in the project
  - Federal agencies overseeing cultural resource regulations in the area of construction
  - Local preservation commissions
  - Local government
  - Adjacent property owners
  - Contractors
  - Engineers
  - Planner
  - Utility company

Why to consider a Photovoltaic System

1. *Reduce energy grid consumption*
2. *Provide a renewable energy source*
3. *Meet LEED certification requirements*
4. *Owner motivations*

Common Terms when discussing Photovoltaics:

Array – *Solar panels arranged in a group to capture sun light to convert it into usable electricity*

Free standing / Stand alone system – *Electrical system which receives its power from solar panels which are independent of the utility grid. System may be used in conjunction with batteries and wind turbines.*

Grid-tied – *Solar panels which are connected to the facility electrical system and the utility grid, with excess power being fed back to the utility.*

kWh – *Kilowatt-hours, how electricity is measured*

Off-grid – *Same as Free standing/Stand alone*

Tracking System – *Solar panels mounted on a tracking system that maintains the optimal angle to the sun to provide the maximum efficiency from the solar panels*

PART 2: INSTALLATION CONSIDERATIONS

- **Components:** Solar photovoltaic systems consist of solar modular panels, disconnect switches, inverters, utility disconnect. Off-grid and/or back up system also consist of batteries and charger controller. (National Electrical Code, Article 690 Solar Photovoltaic (PV) System). The main component considerations for Historic buildings and structures are the type of panel and the mounting system.
  - Three main types of panels (U.S. Department of Energy, National Renewable Energy Lab): Discuss with Design Team and chose type based on Efficiency, Cost, Manufacture, Warranty and Aesthetics.
    - Single Crystal: Made from silicon, usually flat-plate and is 14-19% efficient.
    - Multi-Crystalline: Similar technology to single crystal but are only 13-17% efficient
    - Thin-film: Made from amorphous silicon or nonsilicon material and the least efficient at 6-11%
  - Solar Panel mounting system (has the biggest impact on Historic Preservation): Mounting types should be based on the area that will be needed to accommodate the number of panels which will provide the Kwh needs per each project.
    - Permanently affix array to roof
    - Free standing, pole mounted
    - Free standing, pole mounted with tracking system
    - Ground mounted
  - Secondary Components/Considerations (engineer responsibility).
    - Determine Solar Panel voltage needed
      - Grid tied applications uses either 18 or 42 volts
      - Off –Grid system uses either 12 or 24 volts
    - Combiner box: Allows multiple solar panels to be combined in parallel
    - Solar Charger Controller: Regulates the amount of current PV feed into battery
    - Batteries: Storage of PV modules voltage, Common voltages are 6 and 12 volts
    - Solar inverters: Take (DC) voltage from PVs or batteries and turns it into (AC) voltage
    - DC / AC Disconnects: from the DC and AC voltage to the PV system

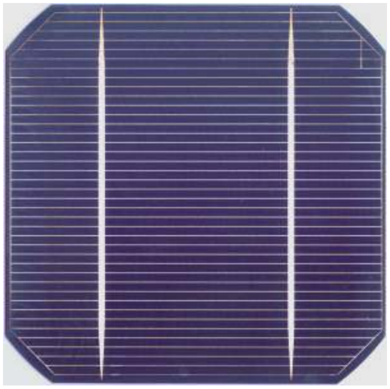


Figure 26 01-1 Single Crystal Silicon Panel

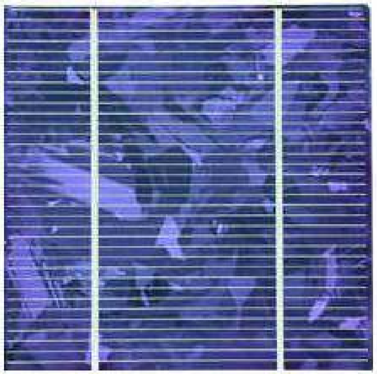


Figure 26 01-2 Multi-crystalline Silicon Panel

Figure 26 01-3 Thin-film/Amorphous Silicon Cells

PART 2: INSTALLATION CONSIDERATIONS

- **Site Installation Considerations:**
  - In Part 1, it should already have been determined:
    - If it is feasible to install free standing solar panels on the site.
    - Panel orientation (due south is best in the northern hemisphere)
    - Where minimal shading occurs between 0900 and 1500 for peak performance
  - Determine if a tracking system is needed
  - Determine visibility of panels from the public right of way
  - Location may encroach onto other historic sites in the area.
  - Distance between the solar panels and the historic building may be a concern due to voltage drop in the feeder conductors.
  - Determine the routing of underground conduit runs so not to damage historic sites

- **Grid connected and net metering:** Benefits for a grid connections is that there is no additional cost for providing batteries and/or a generator back up power. One will often generate more electricity than one is capable of consuming which gives the excess electricity produced to the utility which lowers one's electric bill. It is the least expensive solution. (EnergyInformation.org 2012)
  - A grid-connection solar PV system receives back-up power from a utility grid when the PV system is not producing enough power
  - Under a net metering arrangement the utility company essentially pays the building owner a retail price for electricity that the building system feeds back into the grid.

GRID TIED PV SYSTEM

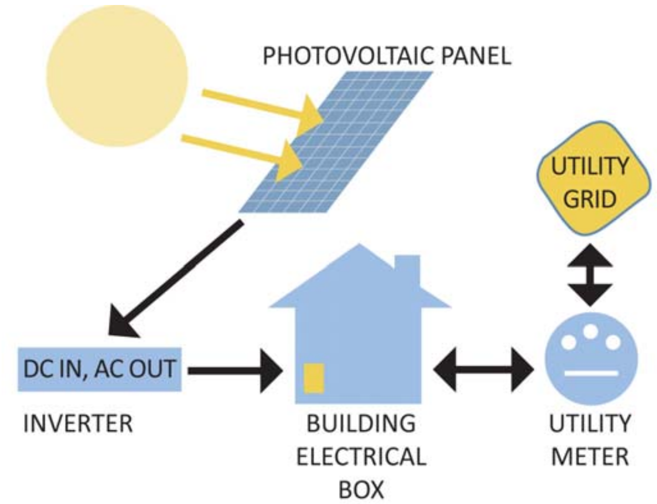


Figure 26 01-4

PART 2: INSTALLATION CONSIDERATIONS continued

- **Off-Grid and/or Battery backup:** Benefits for an off-grid connection include that it may be cheaper than a grid connection, depending on the building proximity to the closest existing utility grid. This would need to be determined based on the cost of batteries per Kwh requirements and the cost of the extension per area. Average cost per a ½ mile of utility line extension is approx. $30,000. Off-grid PV systems offer the satisfaction of self-sufficiency. Utility power failure will not affect the building. (EnergyInformation.org 2012).
  - On cloudy days or in facilities with night time operations, the owner will need to determine if a battery backup system can benefit the facility by protecting sensitive equipment or allowing operations to continue during utility power outage. Cost of the batteries, based on the facility load, will play a big role in determining the amount of backup time needed
  - If a facility is completely off-grid with no utility power available, battery backup can provide power to the electrical system for night time operation.
  - The cost of batteries is a major factor in determining whether or not backup power is needed. Another factor is whether or not there is adequate space available to house the batteries.

OFF-GRID PV SYSTEM

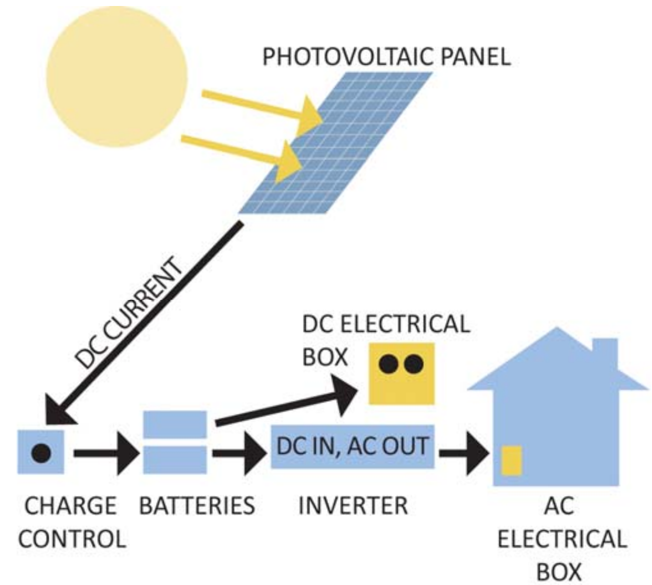


Figure 26 01-5

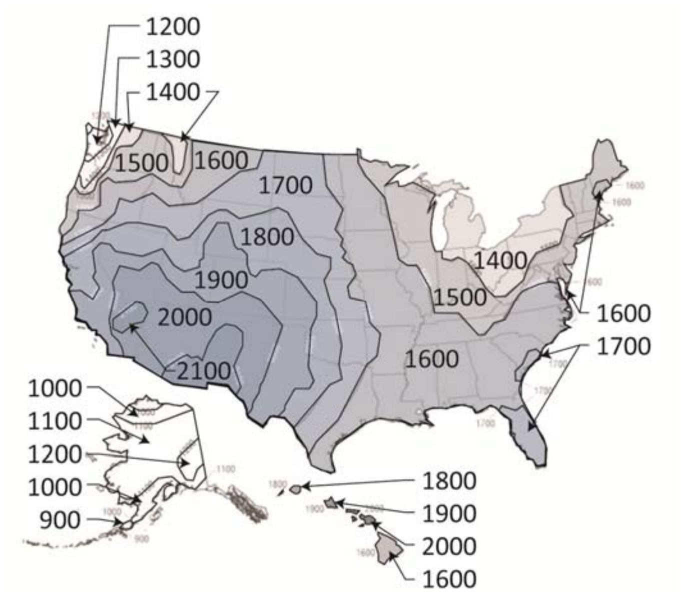
PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 9: New Work is compatible with Historic

- **Historic preservation effects:**
  - The angle of installation has a direct effect on the historic character of the building.
    - Mounted flush has the least impact but can affect energy production.
    - Angled to the sun would be more visible, thus affecting the historic character.
    - A balance must be reached between Historic Preservation and Energy Savings.
  - New conduit from PV system to and within the building can damage interior historic elements. Such endeavors must be taken with careful planning.

- **Energy savings potential:** (U.S. Department of Energy, Energy Saver n.d.)
  - Use the equation below to estimate annual electricity production and electrical savings for a *Grid-connected small solar electric system* with a *net metering arrangement.*
  - **Inputs Needed:**
    - The photovoltaic (PV) system size in kilowatts (kW) ______________________ kW
    - Select the energy production factor, based on geographic location. See adjacent map ________________ kWh/kW-year
    - Electrical rate (commercial) found in Electric Bill __________________ $ per kWh
  - EQUATION: PV system Electricity production =(kW of PV) x (Commercial Rate) = $/years
  - EXAMPLE: a 9.3 kw system (kW of PV) in Albuquerque , NM , at an average Commercial energy rate of 10 cents/kWh will save $1,953 per year: (10 cents/kWh based on US average from U.S. Energy Information Administration 2012)
    - 9.3kW x 2100 kWh/kW-year x $0.10 kWh =$1,953 (or $162.75/month)

Energy Production Factor Map in kWh/kW-year



Note: The uncertainty of the contoured values is generally +/- 10%. In mountainous and other areas of complex terrain, the uncertainty may be higher. See Appendix H for a larger version of this map.

Figure 26 01-6

  - Operating an *Off-Grid PV system with battery backup or Generator (Stand-Alone System)* may or may not be cost-effective depending on the cost to run a power line from the existing electricity grid and the size of the battery bank required.
    - The battery bank backup system should be sized to provide power for a minimum of 5 days without recharging.
    - An Off-Grid system is specified when independence from the power provided is desired or required. It also demonstrates a commitment to non-polluting energy sources.
    - Commercial Off-Grid system will be range from 5 to 10 kw or larger, depending on the type business.

PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Cost considerations:**
  - **Determining system size:** Estimate the size of solar array needed (Solar Power Authority):
    1. Calculate the kWh per day, this can be accomplished in two ways:
       a. Calculating by using the monthly electric bill
          - Total kWh used from monthly bill for one year. ______________
          - Divide by 12 (months / year) to determine average monthly kWh usage. ______________
          - Divide 30 (average day's in a month). This will determine daily kWh usage. ______________

       b. Calculating usage by listing the power consumption for each appliance to get the total kWh usage per day. Recommend creating an excel table for this option.
          - List all the electrical appliances in the facility.
          - List the wattage from the equipment name plate. If the equipment only lists the equipment Volts and Amps, multiply Volts x Amps which equals Watts.
          - List the hours in a day the equipment is used.
          - Take each piece of equipment and multiply it by its Watts, then multiply that by Hrs/Day used. This will give the total kWh usage for that equipment per day.
          - Total all the kWh for each piece of equipment and that will give the daily kWh usage and/or the total kWh goal.
    2. Determine total kWh goal (desired production of the system) ______________
    3. Determine Insolation hours kW (total number of hours in a day the PV panel will produce its rated voltage, depending on the area of installation) ______________
       - Location specific, use http://aom.giss.nasa.gov/srlocat.html (NASA and GISS)
    4. Determine the number of kW needed to be produced per hour to reach kWh goal Goal kWh (Step 2) divided by Insolation hours (Step 3) ______________
    5. Determine Energy losses (Multiply kW in Step 4 by 1.3) ______________
       - A PV system will lose up to 30%, increase kW size by 1.3 to account for this loss
       - **This number shows how much is needed to meet the target kWh goal per day.**

Determining System Cost Example

1. Calculate kWh/day using first option:

a. Total kWh for 1 year = 11,808 kWh/year

b. Monthly 11,808/12 = 984kWh/month

c. Daily usage 984/30 = 32.8 kWh/day

2. Determine daily kWh goal= 36 kWh

3. Determine Insolation hours for Albuquerque, NM = 5 hrs

4. 36kWh/5hrs =7.2 kW

5. Energy Loss 7.2kWx1.3 = 9.3kW

Therefore, the example project will need a 9.3 kW (or 9,300 Watt) system to produce 36 kWh per day.

The installation cost for the example system at $6.30 to $8.49 per Watt would be approximately $58,590 - $78,957 (U.S. Department of Energy, Berkeley Lab).

PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Cost considerations continued:**
  - **System Costs:**
    - Grid connected PV system payback – With the lower end cost for a 9.3 kW PV system at $58,590 (see previous page example and link). This includes solar panels, fixed roof mounting, invertor, wiring, fuses, switches, etc. for a complete system.
    - Off-Grid PV system with Battery backup payback – With an estimated cost for a 9.3 kW PV system at $82,890 ($9.10/watt). Cost – PV system @ $6.30/watts, 5 day battery bank @$15,000, Invertor @ $9,300 = $82890. This includes solar panels, fixed roof mounting, invertor, 5 days battery bank, wiring, fuses, switches, etc. for a complete system (Infinite Power of Texas 2012).
  - **Utility extension**
    - A 1000' new overhead utility line extended from an existing primary pole will cost approx. $11,850 (Consumers Power Inc. 2012).
  - **Calculating PV System Payback for Grid Connected and Off-Grid PV Systems:**
    - Calculate the cost for the PV system including installation costs, and deduct all Federal and State incentives from the total.
    - Determine the initial annual savings from the PV System: Calculate the output of the proposed system in kilowatt hours and determine what percentage the PV system will save in energy cost per year.
    - Set assumption regarding future increase in electric costs: A conservative estimate assumes that the electricity rates will increase at a rate of 4% per year for the next 25 years.
    - Multiply the annual saving by energy inflation rate: Take the amount you will save after year 1 and then multiply that saving by 1.04 for each year for the next 25 years.
    - Accumulate the savings by year: Add the prior year's saving to the current year's saving for each year. Add amount of any any pay-back to the owner for the kWh generated and sold back to the utility company.
    - Subtract the initial cost from the accumulated savings.
    - For more information, go to: energybible.com/solar_energy/typical_costs.html

National Renewable Energy Laboratory (NREL) GIS maps, 2011 data

Figure 26 01-7 Simple Payback for PV Systems with Incentives

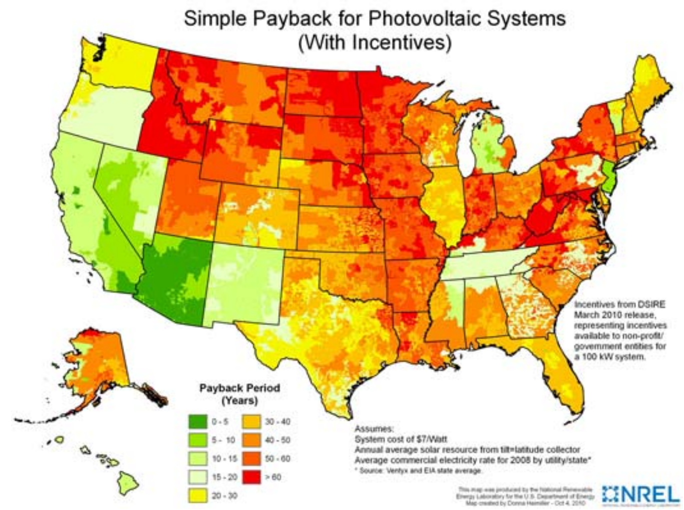
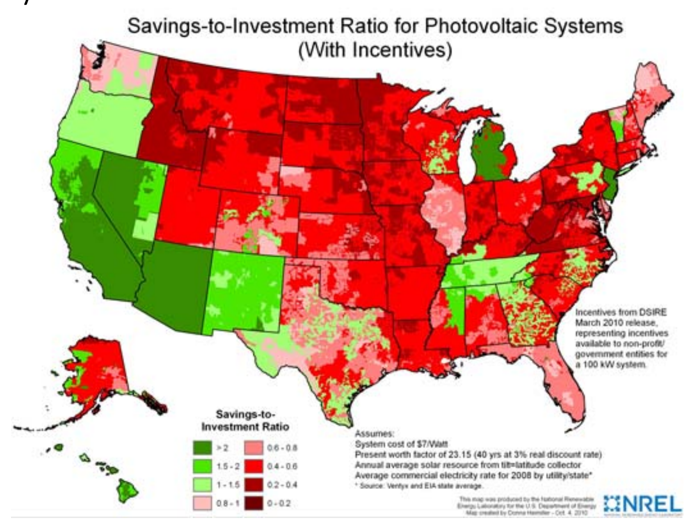


Figure 26 01-8 Savings-to-Investment Ratio for PV Systems with Incentives



See Appendix I for larger versions of these maps

PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Cost considerations continued:**
  - **Mounting system and installation cost:** (Tracking the Sun IV: An Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998-2010)
    - Fixed tilt array on the roof, pole and ground mounted system cost is approximately $0.70/watts of the total cost per watt
    - Solar tracker mounting system will add approximately an additional 19% to the total cost per watt.
  - **Residential and Commercial PV Systems are eligible for Federal and State Incentive Programs:**
    - The Federal Government offers a business energy investment tax credit program with up to 30% tax credit for PV systems. For more information, go to : http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1
    - The Federal Government offers a Residential Renewable Efficiency Tax Credit program with up to 30% tax credit for PV systems. For more information, go to: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F&re=1&ee=1
    - State by State incentive programs widely range from tax credits, and sales and property tax deductions. Each individual will need to contact their state government to determine what incentive programs, if any, are available. For more information, go to: http://www.dsireusa.org/
  - **Residential and Commercial PV Systems are eligible for Local Utility Company Incentive Programs:**
    - Utility incentive programs provide a wide range of programs depending on the size of the PV system.
    - California Pacific Power provides an incentive program which offers from $1.13/Watt for residential systems to $0.36/W for Commercial systems, sized between 1kW and5kW. For more information, go to: http://www.dsireusa.org/
    - New Mexico PNM has an incentive program with a range of $0.04/kWh for small systems, sized up to 10 kW, to $0.05/kWh for larger systems, sized between 10 kW to 100 kW. For more information, go to: http://www.dsireusa.org

National Organizations and Resources

DSIRE *is the Database of State Incentives for Renewables and Efficiency under NREL subcontract no. XEU-0-99515-01*
www.dsireusa.org

Energy Bible *is a non-governmental website "dedicated to providing the public with up-to-date information on renewable energy."*
Energybible.com

IREC *is the Interstate Renewable Energy Council, a non-profit organization.*
www.irecusa.org

NREL*is the National Renewable Energy Laboratory of the U.S. Department of Energy*
www.nrel.gov

CONSIDERATIONS FOR INSTALLING A PV SYSTEM ON A FLAT ROOF WITHOUT A PARAPET:

- **Approach:**
  - Panels can be mounted flush, parallel and flat on roof
    - Least visible, therefore, least impact on the historic character
    - Installing panels flat on roof may reduce the maximum electricity production due to the angle of the panels to the direction of the sun.
  - Locate in the rear of the building to further reduce the visibility of panels
  - Determine location of inverters, disconnect switches and metering device
    - Coordinate the location of the metering device and utility disconnect switch with the local utility company
    - Preferred location of inverter and disconnect switches would be adjacent to the incoming service and/or electrical room
  - For off-grid systems, determine the location of the battery bank or generator
  - Determine conduit routing on the roof and through the building to related Solar PV system equipment
    - Maintain the building integrity
    - Minimizes the routing of conduit on the exterior walls.
  - Verify if roof structure is capable to handle the additional weight of the PV system
    - Consult with a Structural Engineer who is experienced with the structural system of the specific historic structure.

- **Additional/ Specific Historic Preservation Effects: also see page 139**
  - Install solar PV panels in a manner that does not damage historic roofing material

Figure 26 01-9
PVs mounted on a flat roof without a parapet.
Note: PV panels must be installed flat or mostly flat as there is no parapet to block the view.

CONSIDERATIONS FOR INSTALLING A PV SYSTEM ON A FLAT ROOF WITH A PARAPET:

- **Approach:**
  - Parapets allow for more installation options since panels can be hidden by the parapets:
    - Panels can be mounted flush
    - Panels can be mounted vertically or horizontally, depending on parapet height
    - Panels can cover a large roof area, since panels are more easily hidden
    - Panels can be tilted towards the sun to maximize the electricity production
  - Determine location of inverters, disconnect switches and metering device
    - Coordinate the location of the metering device and utility disconnect switch with the local utility company
    - Preferred location of inverter and disconnect switches would be adjacent to the incoming service and/or electrical room
  - Determine conduit routing on the roof and through the building to related Solar PV system equipment
    - Maintain the building integrity
    - Minimizes the routing of conduit on the exterior walls.
  - Verify if roof structure is capable of handling the additional weight of the PV system
    - Consult with a Structural Engineer who is experienced with the structural system of the specific historic structure.

- **Additional/ Specific Historic Preservation Effects: also see page 139**
  - Install solar PV panels in a manner that does not damage historic roofing material

Figure 26 01-10

PVs mounted on a flat roof with a parapet.

Note: PV panels can be mounted at a slight angle as the parapet will serve to block visibility.

CONSIDERATIONS FOR INSTALLING A PV SYSTEM ON A HIPPED OR GABLED ROOF:

- **Approach:**
  - Panels can be mounted flush on roof
  - Panels may be visible from public right of way
  - Panels should be mounted on the back roof section of the building to provide minimal visibility of the solar panel from the public right of way
  - Minimizes the area in which panels can be located
  - Preferably the back roof section should be facing south to maximize the electricity production.
  - Determine location of net metering device
    - Coordinate the location of the device with the local utility company
  - Determine conduit routing on the roof and through the building to related Solar PV system equipment
    - Maintain the building integrity
    - Minimizes the routing of conduit on the exterior walls.
  - Installing solar PV panels in a manner that does not damage historic roofing material
  - Verify that roof structure is capable to handle the additional weight of the PV system
    - Consult with a Structural Engineer who is experienced with the structural system of the specific historic structure.

- **Additional/ Specific Historic Preservation Effects: also see page 139**
  - Mounting PV panels on a Hipped or Gabled roof will be visible from at least one angle, which will impact the historic character of the building or structure.
    - This approach must be carefully considered with the CRM and SHPO.
  - Install solar PV panels in a manner that does not damage historic roofing material

It is the position of this document that the cultural resource impact would be too great to recommend this approach as a viable option for installing a PV system on an historic building or structure.

Figure 26 01-11
PVs mounted on a sloped roof.
Note: Not a viable option on an historic building or structure.

CONSIDERATIONS FOR INSTALLING A FREE STANDING PV SYSTEM:

- **Approach:**
  - First, investigate and determine if it is feasible to install a free standing PV system.
    - Is there the space required for the size of system desired?
    - How does the separate PV system structure impact the historic character of the historic building, structure or site?
    - What would the distance be between the solar panels and the historic building?
      - May be a concern due to voltage drop in the feeder conductors.
      - May be an additional expense
  - If it is feasible:
    - Determine if a tracking system is needed or will a stabile system suffice
    - Panels should be orientated due south in the northern hemisphere, angle to the ground depends upon latitude of the site
    - Determine the routing of underground conduit runs so not to damage historic sites
    - Locate panels in areas that will not be shaded between the hours of 9 a.m. – 3 p.m. for peak performance.

- **Additional/ Specific Historic Preservation Effects: also see page 139**
  - This option is potentially both the most visible and least impactful installation technique. It leaves the historic building completely intact, and by its nature clearly represents its own time.
  - Location may encroach onto other historic sites in the area.
    - Consider the entire site and surrounding area for potential impact.
    - If the building that the PV system supplies is part of a larger historic site or district, this option could have a significant impact on the character of the entire area.

It is not recommended to install a free standing PV system in an historic district or historic landscape if visible from public rights of way or public paths. According to the NPS, a historic district "possesses a significant concentration, linkage, or continuity of sites, buildings, structures, or objects united historically or aesthetically by plan or physical development." (NPS website). Therefore, the site and greater environment of any alterations are important, and the addition of a free standing PV system could significantly alter, detract from, or reduce the integrity of the associated historic district.

Figure 26 01-12

Free standing solar tracking array.

Note: Not recommended in a historic district or historic landscape if visible from public right of way or public paths. But, they may be a good option for a historic building if the array can be installed far enough away from the building so as not to detract from its historic character.

GUIDELINE DESCRIPTION: This guideline will discuss upgrading the lighting system in historic buildings. It will look at how a comprehensive lighting strategy, which includes natural lighting and task lighting considerations, can improve overall energy efficiency. The information provided in this guideline are suggestions; it is up to the design team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 08 02 Natural Lighting
- 08 52 Wood Storm Windows
- 23 08 Selecting HVAC Systems
- 26 01 Solar Photovoltaic Panels

GENERAL NOTES:

- The applicable SOI Standards, Historic Preservation Effects, Energy Savings Potential, and Cost Considerations apply to all installation applications and therefore appear first. The specific applications appear after these topics.
- First, Determine Lighting Goals, aspects to consider:
  - Energy conservation
  - Preservation of historic material and character
  - Occupant comfort
  - Initial cost
  - Operation cost
  - Maintenance requirements
  - Disposal costs and environmental impact.
  - Aesthetics
- Second, Determine the Lighting qualities desired in the building, aspects to consider:
  - Electric lighting supplementing daylight
  - Lighting levels to support tasks and architectural design
  - Lamps temperature range “warm light”
  - Maintaining authenticity
- Change lamps will not affect the UL rating. Recreating fixture will have to be rated by UL or an independent testing lab.

Trends in Recommended Minimum Lighting Levels (in Footcandles)

Category	From Mechanical and Electrical Equipment for Buildings		Illuminating Engineering Society (IES)
	2nd Edition 1945	5th Edition 1971	2011-2012
Offices			
Accounting	30	150	50-100
Regular	20	100	50-100
Conference	10	Not listed	20-70
Corridor/stairs	5	30	20
Schools			
Auditoriums	10	30	10-20
Classrooms	20	70	20-100
Drafting	30-50	100	20-100
Sewing	50-100	150	20-100
Libraries			
Reading Room	20	70	20-100

Chart 26 51-1

See Appendix J for a more complete table of current IES footcandle recommendations.

CONSIDERATIONS:

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - "Identifying ways to reduce energy use, such as installing fixtures and appliances that conserve resources, including energy-efficient lighting or energy-efficient lamps in existing lighting fixtures, sensors and timers that control lighting, before undertaking more invasive treatments that may negatively impact the historic building." (Grimmer, et al. 2011, 2)
  - Retrofitting historic lighting fixtures with appropriate new energy efficient lamps should be considered a priority when considering energy efficiency upgrades to an historic building/structure. (Alderson 2009, 2-4).
  - When upgrading fixtures, the following aspects should be considered (Alderson 2009, 2-4):
    - Changing the lamp should not affect the appearance of the fixture
    - Energy efficient light sources should match the warm to white color range of incandescent light and day light as closely as possible

Color Temperature is the color appearance of a lamp when lit. Higher the temperature (above 4000K) the cooler or more blue the light appears. Lower the temperature the warmer or more orange the light appears. Keep in mind that historic lamps and candles appeared warmer than what current lamps do.

COLOR TEMPERATURE DIAGRAM OF LAMPS

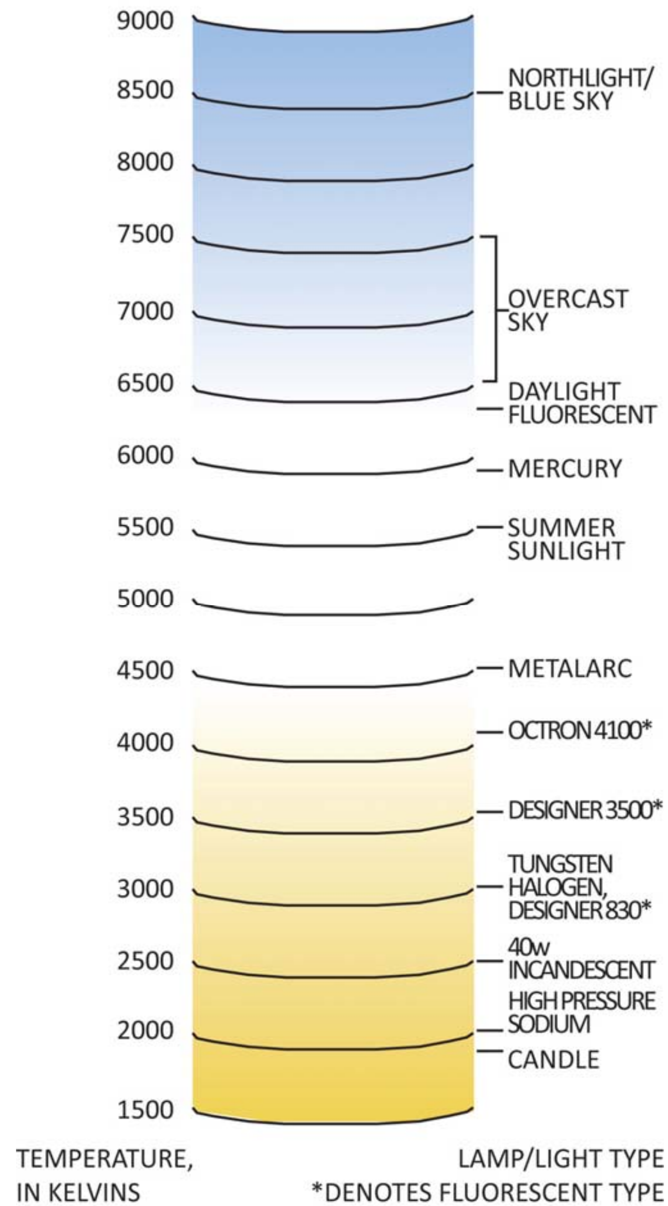


Chart 26 51-2

CONSIDERATIONS continued:

- **Energy Savings Potential and Cost Considerations:**
  - First, determine the Energy cost for Existing lamps, repeat for each type of lamp:
    - Determine number of lamps (light bulbs) ______________
    - Determine wattage (printed on lamp) ______________
    - Determine hours / day used ______________
    - Determine time period 1 month, 30 days
    - Determine cost per kWh? (from utility bill/company) ______________
      - Example uses EIA, US Energy Information Administration for rates.
  - Second, determine the Energy cost for New lamps, repeat for each type of lamp:
    - Determine number of lamps (light bulbs) ______________
    - Determine wattage (printed on lamp) ______________
    - Determine hours/day used ______________
    - Determine time period 1 month, 30 days
    - Determine cost per kWh? (from utility bill/company) ______________
      - Example uses EIA, US Energy Information Administration for rates.
  - CFL use approximately 25% of the energy that an Incandescent uses
  - LED use approximately 13% of the energy that an Incandescent uses

Energy Savings Potential and Cost Consideration Example:

First, determine existing lamp cost (10 -60w Incandescent lamps)

1. *Determine number of lamps = 10*
2. *Determine wattage = 60w*
3. *Determine hours/day used = 10*
4. *Determine time period = 30 days*
5. *Determine cost per kWh = $0.10*
6. *Determine kWh used: 10 x 60 x 10 x 30* ***= 180 kWh***
7. *Determine cost: 180 x .10* ***= $18.00/mon.***

Second, determine new (CFL) lamp cost

8. *Determine number of lamps = 10*
9. *Determine wattage = 15w*
10. *Determine hours/day used = 10*
11. *Determine time period = 30 days*
12. *Determine cost per kWh = $0.10*
13. *Determine kWh used: 10 x 15 x 10 x 30* ***= 45 kWh***
14. *Determine cost: 45 x .10* ***= $4.50/mon.***

Third, repeat for LED lamp cost (10– 8w lamps)

15. *Determine kWh used: 10 x 8 x 10 x 30* ***= 24 kWh***
16. *Determine cost: 24 x .10* ***= $2.40/mon.***

CONSIDERATIONS continued:

- **Energy Savings Potential and Cost Considerations continued:**

Cost Comparison between Incandescent, CFL and LED Lamps

Lamps	Watts	Lumens	Lumens/Watts	Price/ lamps	Lamp Lifespan	Lamps needed for 50K hrs	50k hours lamp expense
Incandescent	60	800	13.3	$1.25	1,200 hrs	42	$52.50
CFL	15	900	60	$3.95	10,000 hrs	5	$19.75
LED	8	800	100	$35.95	50,000 hrs	1	$35.95

Lamps	50k hours lamp expense	50k hours Energy expense	Total Cost per for 50k hr
Incandescent	$52.50	$298.80	$351.30
CFL	$19.75	$74.70	$94.45
LED	$35.95	$39.84	$75.79

Chart 26 51-3

Notes:

1. Lamp costs are the average cost of lamps in the Albuquerque, NM area 2012
2. 50k of Energy expense is based on LED lamp life
3. Typically, color is the first consideration in lighting design, followed by availability.

CONSIDERATIONS FOR UPGRADING INTERIOR HISTORIC FIXTURES:

- **Approach:**
  - Removal of existing historic lighting fixtures for Restoration
    - Determine the type of lamps to be used: LED's or CFL's
    - Replacement of old yellow lens
    - Replacement of reflectors
    - Rewire fixtures
  - Retrofitting existing fixtures with new lamps to meet current performance /energy goals
    - **Light Emitting Diodes (LED's)**
      - Benefits:
        - Average Lamp life of 50,000 hours
        - Lamp temperature range
        - Low energy usage
        - Easy to retrofit in fixtures
      - Disadvantage: Initial cost is higher compared to CFL's and incandescent lamps
    - **Compact Fluorescents lamps(CFL's)**
      - Benefits
        - Longer lamp life than the incandescent lamp
        - Low energy usage then an incandescent lamp
      - Disadvantages
        - Initial cost is higher compared to incandescent lamps
        - Provides a whiter light, not suitable for high lighting art and/or objects
        - Higher energy usage then a LED
    - **Electronic ballast**
      - Benefits: Lower energy usage and longer life than magnetic ballast.
      - Disadvantage: Initial cost is higher than a magnetic ballast
    - **Dimming ballast**
      - Benefits: Lower energy usage and longer life than magnetic ballast.
        - Can control the lighting levels in CFL's lamps
        - Will reduce energy usage by reducing the lighting levels
      - Disadvantage: Initial cost is higher than a standard electronic ballast

Figure 26 51-1 CFL's come in various shapes and sizes

Figure 26 51-2 LED's also come in various shapes and sizes to fit the lighting need.

CONSIDERATIONS FOR UPGRADING INTERIOR HISTORIC FIXTURES:

- **Approach continued:**
  - Identify locations where historic fixtures have been removed that should be replaced
  - Replacement or relocation of historic fixture.
    - Take historic fixtures from back room areas and relocate them to public areas
  - Consider having historic fixtures recreated
    - Would provide new technology lamps and ballast in an historic looking fixture
    - UL labeling or the equivalent testing of can be provided by testing labs
    - Provide with remote ballast as needed
    - Cost consideration
  - Determine Lamp controllability required / desired: well controlled lighting systems reduce energy use, since the possibility of leaving lights on when they are not used is reduced.
    - Time Clocks
    - Photo Cells
    - Motion Sensors
    - Replace wiring between fixtures and switches
    - Extend new wiring to branch circuit panel
  - Coordinate with Daylighting strategies (08 02 Natural Lighting)
  - Determine required / desired Lighting Levels
    - Recalculate the foot candle levels in all area
    - Levels shall be based on new energy code and IES standards
    - This may allow for the distribution of historic fixtures to other locations within the facility without effecting new lighting level standards

Figure 26 51-3 Old Terminal, Albuquerque, New Mexico The historic fixtures were found in local museum but were not reinstalled because obtaining the UL rating was time consuming and prohibitively expensive. Therefore, the historic fixtures were replicated and can be seen in the above photograph.

Figure 26 51-4
Before Renovation

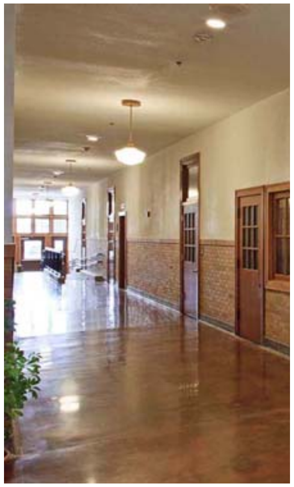


Figure 26 51-5
After Renovation

The Renovation restored lighting back to similar levels and type fixtures. Coronado School, Albuquerque, NM

CONSIDERATIONS FOR UPGRADING EXTERIOR HISTORIC FIXTURES:

- **Approach:**
  - Restoration of existing fixtures
    - Provide with new technology lamps (see page 150 for more information on the LED and CFL lamp types listed below)
      - Light Emitting Diodes (LED's)
      - Compact Fluorescents lamps (CFL's)
      - High Intensity discharged lamps (HID)
        - Benefits
          - Long lamp life
          - Can provide higher lumen output than LED's and CFL's.
          - Requires fewer fixtures than LED's or CFL's to provide the same levels.
          - Good for indirect lighting needs
        - Disadvantages
          - **High Energy use, but few fixtures might still make this feasible**
          - High lamp and ballast cost
      - Rewire fixtures
  - Identify locations where historic fixtures have been removed and should be replaced
  - Replacement or relocation of historic fixture.
    - Take historic fixtures from back of buildings or from areas not normally seen by the public and relocate them to public areas
  - Use of new fixtures to supplement existing historic lighting fixtures.
    - Install new lighting in non-intrusive areas to highlight features of a building
    - Use accent lighting on architectural features
    - Landscape lighting
  - Have historic fixture recreated to match existing fixtures
    - Provide with new technology lamps.
    - Provide with remote ballast as needed
  - Lamp controllability: especially on the exterior, more control equals less energy use
    - Time Clocks
    - Photo Cells

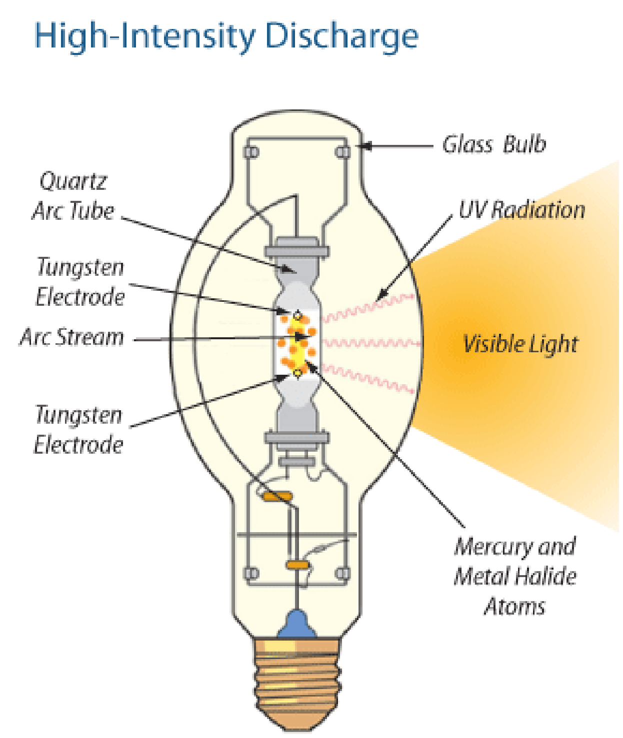


Figure 26 51-6
Graphic courtesy of the US Department of Energy

CONSIDERATIONS FOR SUPPLEMENTAL LIGHTING:

- **Approach:**
  - Supplemental lighting (U.S. General Services Administration 2012)
    - Is to provide increasing lighting levels in areas where the historic lighting fixtures cannot provide sufficient lighting levels
    - Should avoid competing visually with historic lighting
    - Free standing torchieres, task lighting and discrete accent lighting are recommended for increasing lighting levels.
    - Special care should be taken in ceremonial spaces containing ornamental ceiling and historic chandeliers.
  - Discretely placed new lighting fixtures to avoid competing with historic lighting.
    - Cove Lighting
    - Indirect Lighting
    - Cornice Lighting
    - Additional Task Lighting
  - Lamp controllability
    - Dimmable lamps
    - Day light sensors to control lamp intensity
    - Motion sensors
  - Conduit routing
    - Keep conduit exposure to a minimum
    - Do not run conduit or wiring exposed in public areas
    - Conceal with conduit system along baseboard or behind millwork
    - Do not drill into existing ornamental finishes. If unavoidable, drill in corners to minimize impact.
    - Channel walls to provide minimal damage to existing walls
    - Avoid altering decorated character-defining features

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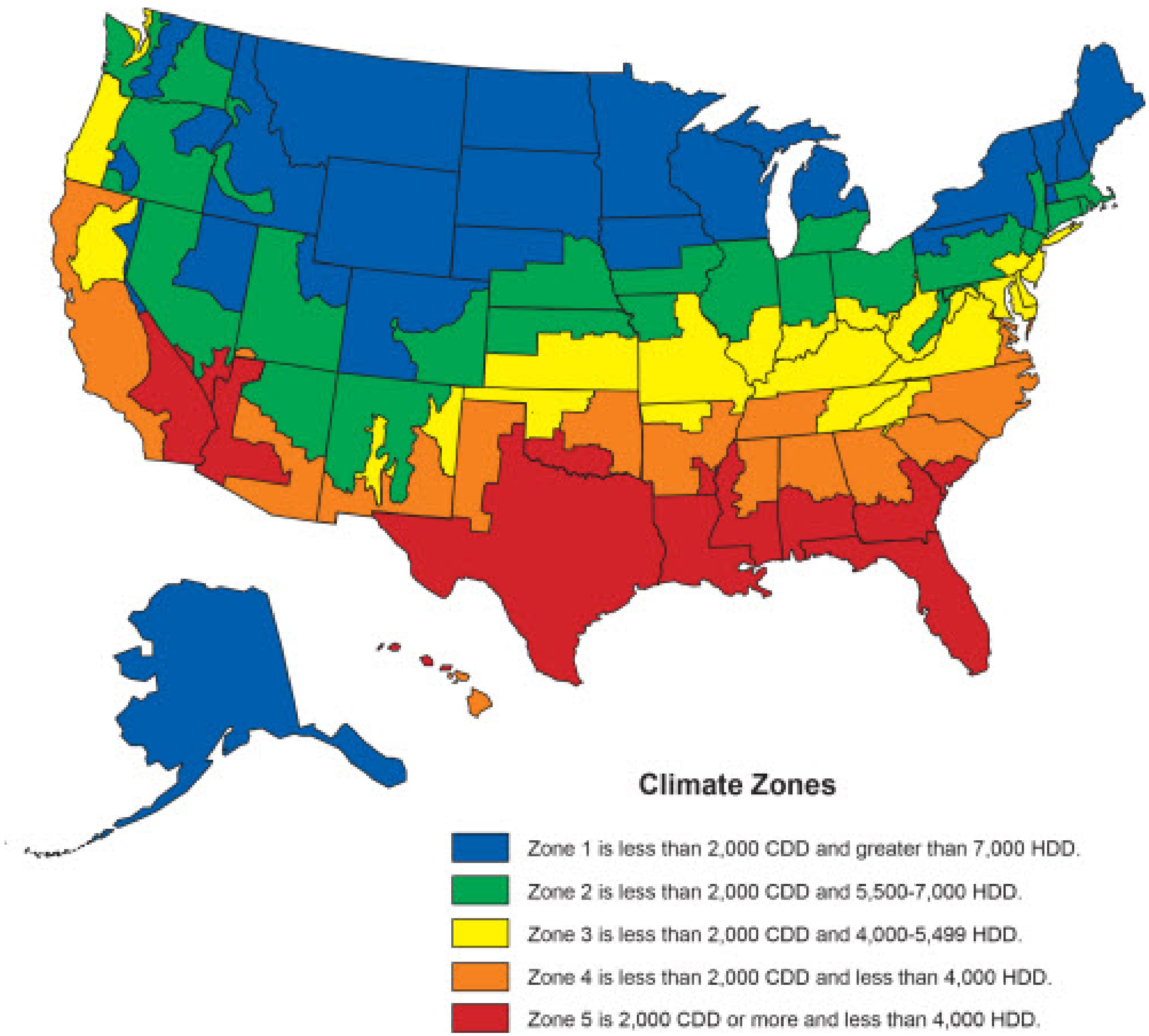
APPENDIX D: CONVERSION FACTORS

- **Kwh to BTU:**
  - 1 Kwh = 3412.2 BTU
  - 1 BTU = 0.0000293 Kwh
- **Therm to BTU:**
  - 1 Therm = 100,000 BTU
- **Gallons of fuel oil to BTU:** This value changes depending on the type of fuel used, quality of fuel, and in some cases, the pressure (www.generatorjoe.net/html/energy.html).
  - Propane: 1 gallon = 91,500 BTU
  - Gasoline: 1 gallon = 125,000 BTU
  - Kerosene: 1 gallon = 135,000 BTU
  - #2 Oil: 1 gallon = 138,500 BTU
  - Diesel: 1 gallon = 139,200 BTU
  - #6 Oil: 1 gallon = 153,200 BTU

U.S Climate Zones for 2003 CBECS (updated with corrections February 2012)

http://www.eia.gov/emeu/cbecs/climate_zones.html



DETAILS of the U.S. Climate Zones Map

The CBECS climate zones are groups of climate divisions, as defined by the National Oceanic and Atmospheric Administration (NOAA), which are regions within a state that are as climatically homogeneous as possible. Each NOAA climate division is placed into one of five CBECS climate zones based on its 30-year average heating degree-days (HDD) and cooling degree-days (CDD) for the period 1971 through 2000.

There are 359 NOAA climate divisions within the 50 U.S. states. Boundaries of these divisions generally coincide with county boundaries, except in the western U.S., where they are based largely on drainage basins. For a map of all the NOAA climate divisions in the U.S., see http://www.esrl.noaa.gov/psd/data/usclimdivs/data/map.html. For individual state maps that show the NOAA climate divisions by county, see http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/CLIM_DIVS/states_counties_climate-divisions.shtml.

Each building in the CBECS is assigned a CBECS climate zone based on the 30-year average (1971-2000) HDD and CDD (base 65 degrees Fahrenheit) for the NOAA climate division in which the weather station closest to the sampled building is located.

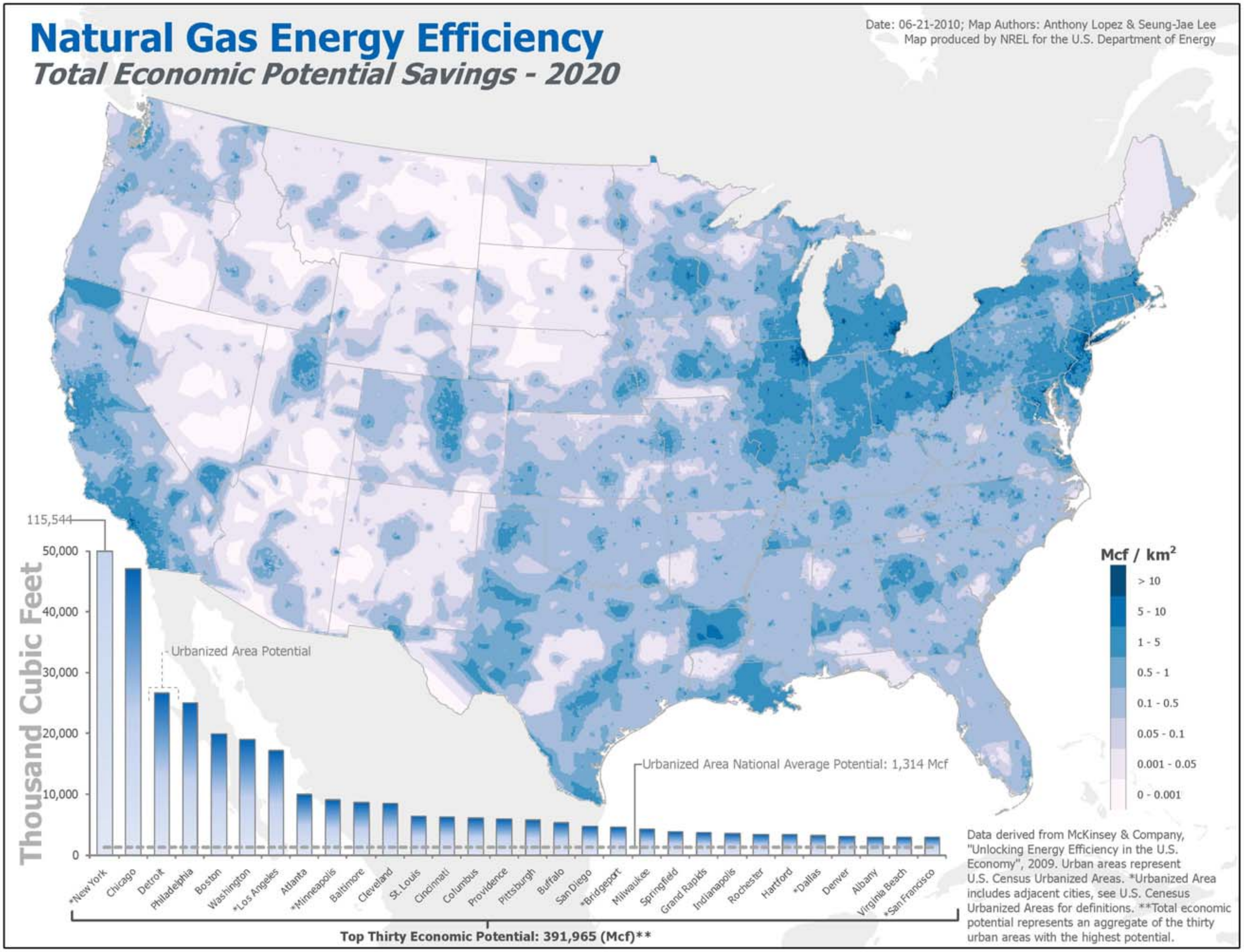
Specific questions on this product may be directed to:

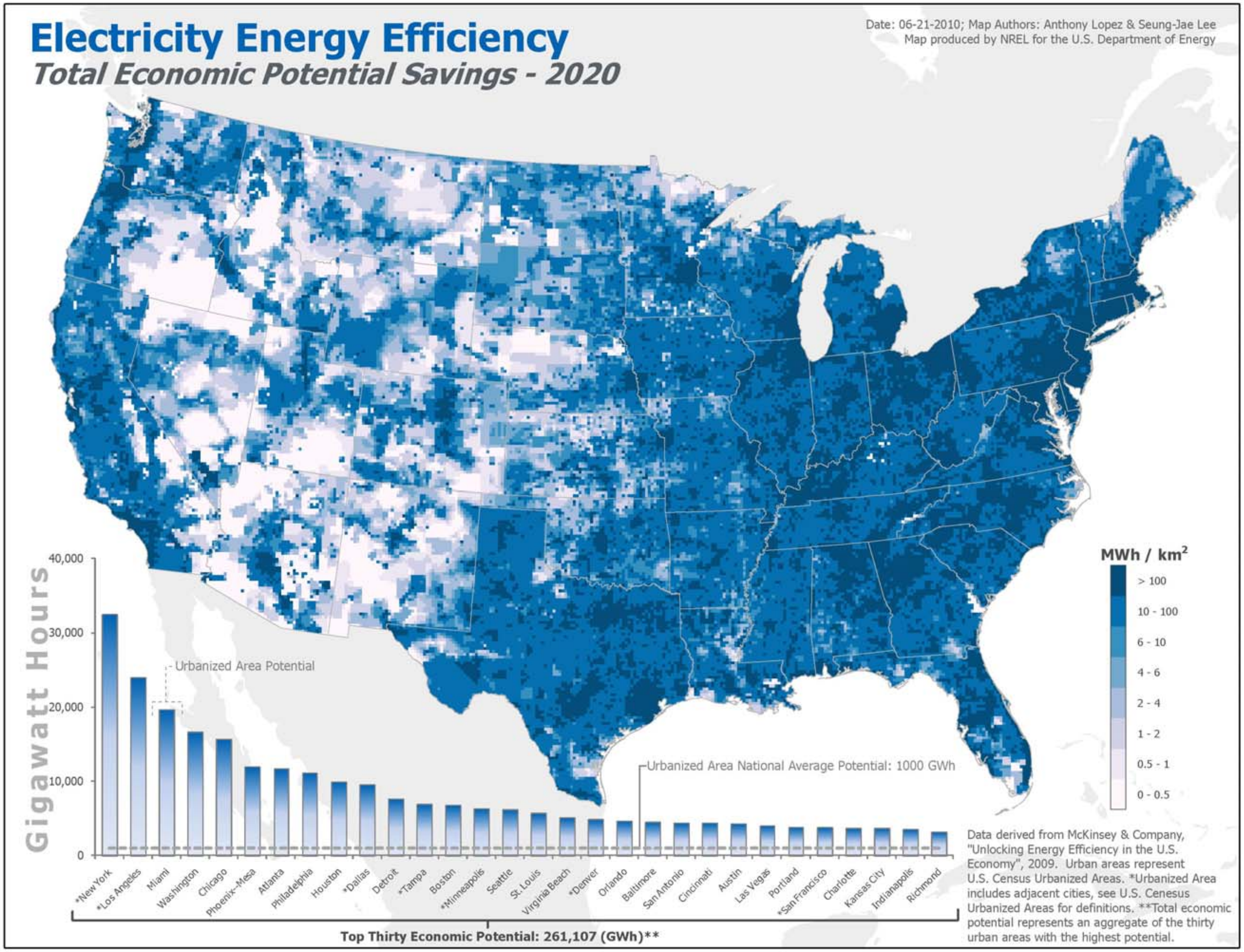
Joelle Michaels
joelle.michaels@eia.doe.gov
CBECS Manager

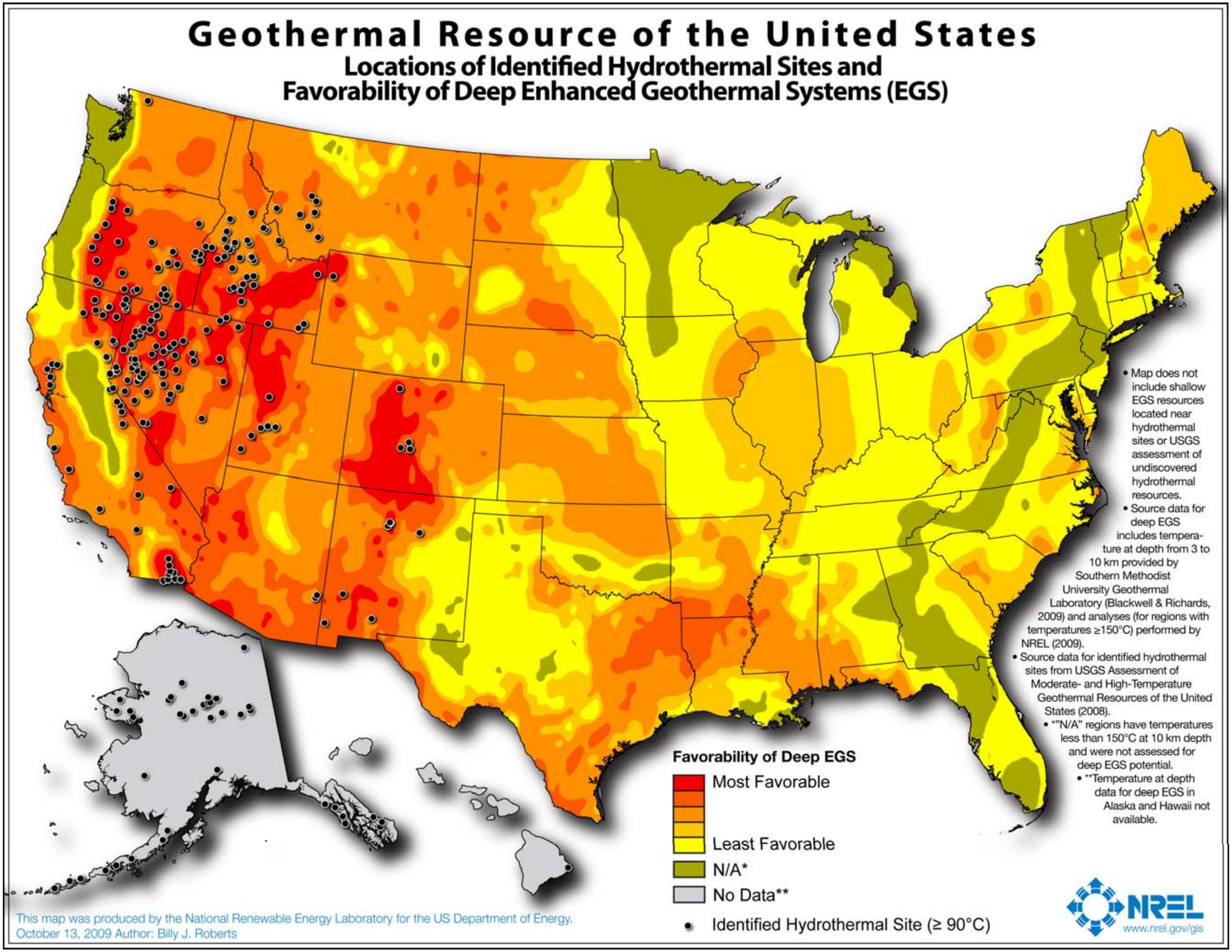
APPENDIX F: EXPANDED RIGID INSULATION TABLE

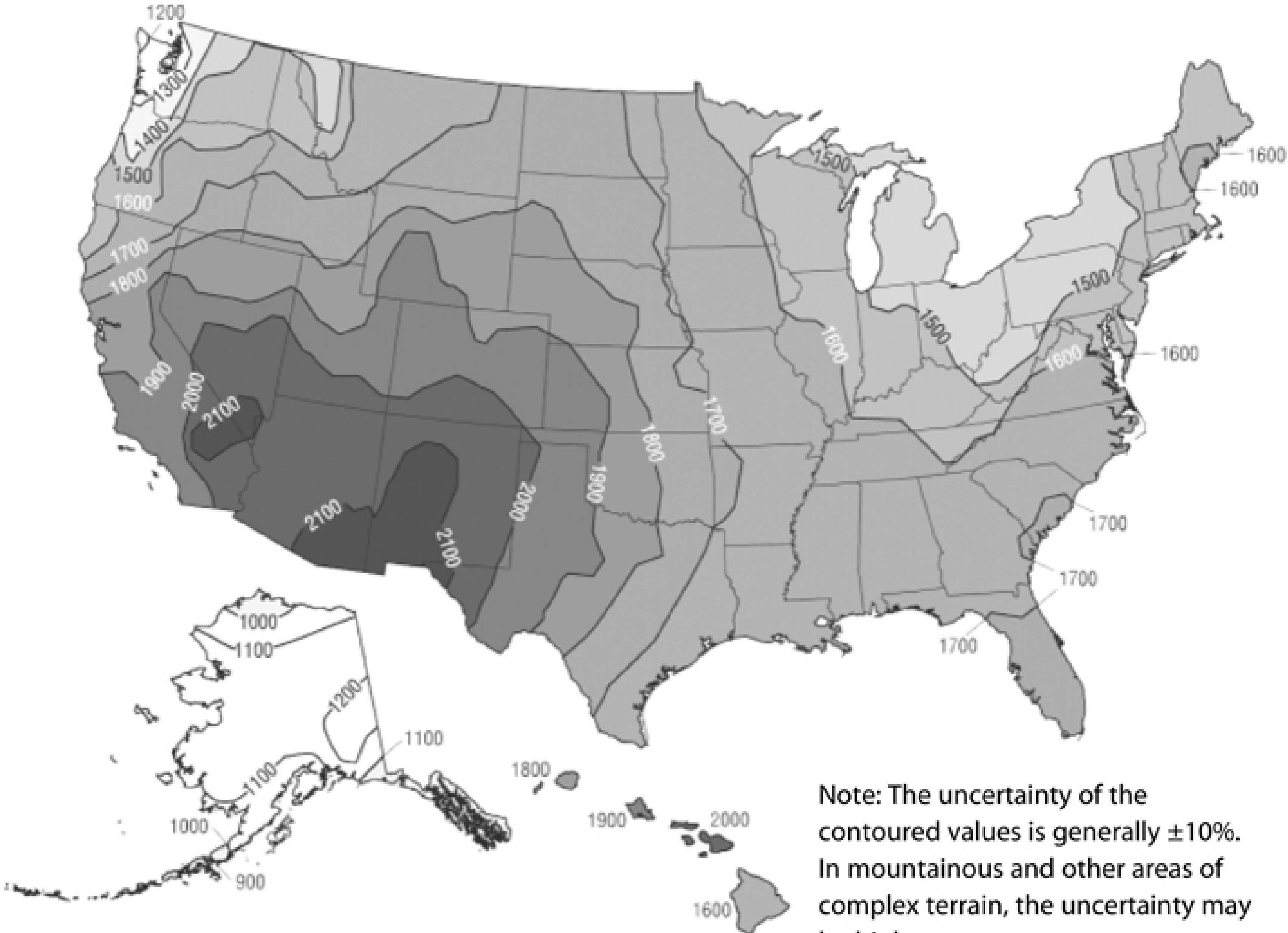
Expanded Rigid Insulation Table showing how the inputs are derived. This table will also appear in Part 1, Introduction, Item 3 with blank inputs for individual use. Values cannot be factored until the inputs are set. If viewing as a Word document, double click inside the table and add the input values.

DESCRIPTION	CALCULATION	INPUTS	UNITS
Initial R-value			(hr x sf x degF)/BTU
Final R-value			(hr x sf x degF)/BTU
HDD			days x degF/yr
CDD			days x degF/yr
Heating Efficiency			% gas heating efficiency
Cooling Efficiency			COP
Cost of Gas		$ -	$/therm
Cost of Electricity		$ -	$/kWh
Area of Insulation			sf
Inverse of initial R-value	=1/(Initial R-value)	#DIV/0!	BTU/(hr x sf x degF)
Constant	=hours in a day	24	hours/day
Initial Heating Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x HDD	#DIV/0!	BTU/yr
Convert to Therms	=(Initial Heating Energy)/(100,000 x Heating Efficiency)	#DIV/0!	therms/yr
Initial Heating Energy Cost	=Therms/yr x $/therm	#DIV/0!	$ heating/year
Initial Cooling Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x CDD	#DIV/0!	BTU/yr
Convert to kWh	=Initial Cooling Energy / 3,412	#DIV/0!	kWh
Initial Cooling Energy Cost	=kWh/COP x $/kWh	#DIV/0!	$/year
Initial Total Cost Calculation	=Initial Heating Energy Cost + Initial Cooling Energy Cost	#DIV/0!	$/year
Inverse of final R-value	=1/(Final R-value)	#DIV/0!	BTU/(hr x sf x degF)
Final Heating Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x HDD	#DIV/0!	BTU/yr
Convert to Therms	=(Final Heating Energy)/(100,000 x Heating Efficiency)	#DIV/0!	therms/yr
Final Heating Energy Cost	=Therms/yr x $/therm	#DIV/0!	$ heating/year
Final Cooling Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x CDD	#DIV/0!	BTU/yr
Convert to kWh	=Final Cooling Energy / 3,412	#DIV/0!	kWh
Final Cooling Energy Cost	=kWh/COP x $/kWh	#DIV/0!	$/year
Final Total Cost Calculation	=Final Heating Energy Cost + Final Cooling Energy Cost	#DIV/0!	$/year
Total Cost Savings	=Difference of Final Energy Cost and Initial Energy Cost	#DIV/0!	$/year

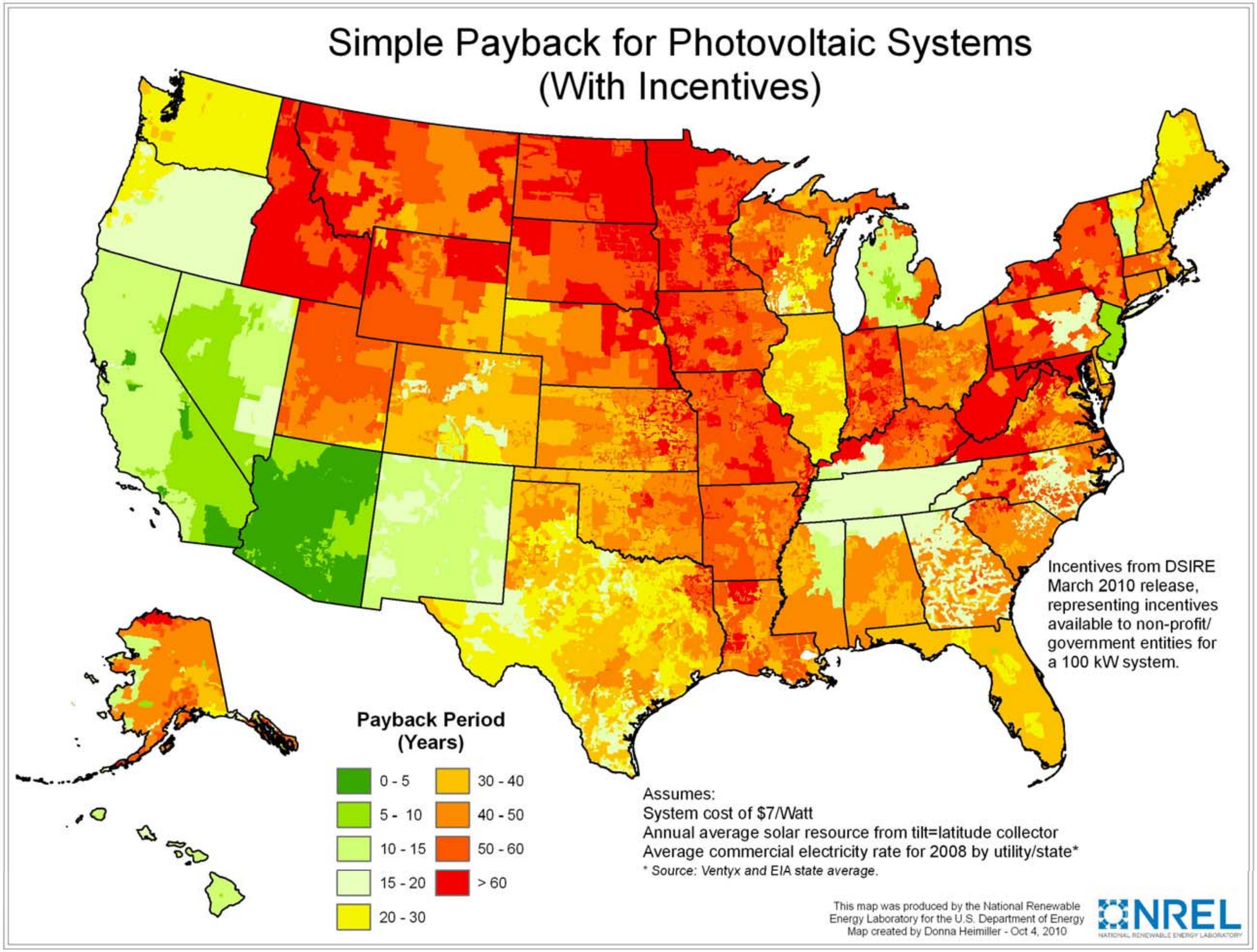

Natural Gas Energy Efficiency
Total Economic Potential Savings - 2020
Date: 06-21-2010; Map Authors: Anthony Lopez & Seung-Jae Lee
Map produced by NREL for the U.S. Department of Energy
Thousand Cubic Feet
115,544
50,000
40,000
30,000
20,000
10,000
0
Urbanized Area Potential
Urbanized Area National Average Potential: 1,314 Mcf
*New York
Chicago
Detroit
Philadelphia
Boston
Washington
*Los Angeles
Atlanta
*Minneapolis
Baltimore
Cleveland
St. Louis
Cincinnati
Columbus
Providence
Pittsburgh
Buffalo
San Diego
*Bridgeport
Milwaukee
Springfield
Grand Rapids
Indianapolis
Rochester
Hartford
*Dallas
Denver
Albany
Virginia Beach
*San Francisco
Top Thirty Economic Potential: 391,965 (Mcf)**
Mcf / km²
> 10
5 - 10
1 - 5
0.5 - 1
0.1 - 0.5
0.05 - 0.1
0.001 - 0.05
0 - 0.001
Data derived from McKinsey & Company, "Unlocking Energy Efficiency in the U.S. Economy", 2009. Urban areas represent U.S. Census Urbanized Areas. *Urbanized Area includes adjacent cities, see U.S. Cenesus Urbanized Areas for definitions. **Total economic potential represents an aggregate of the thirty urban areas with the highest potential.

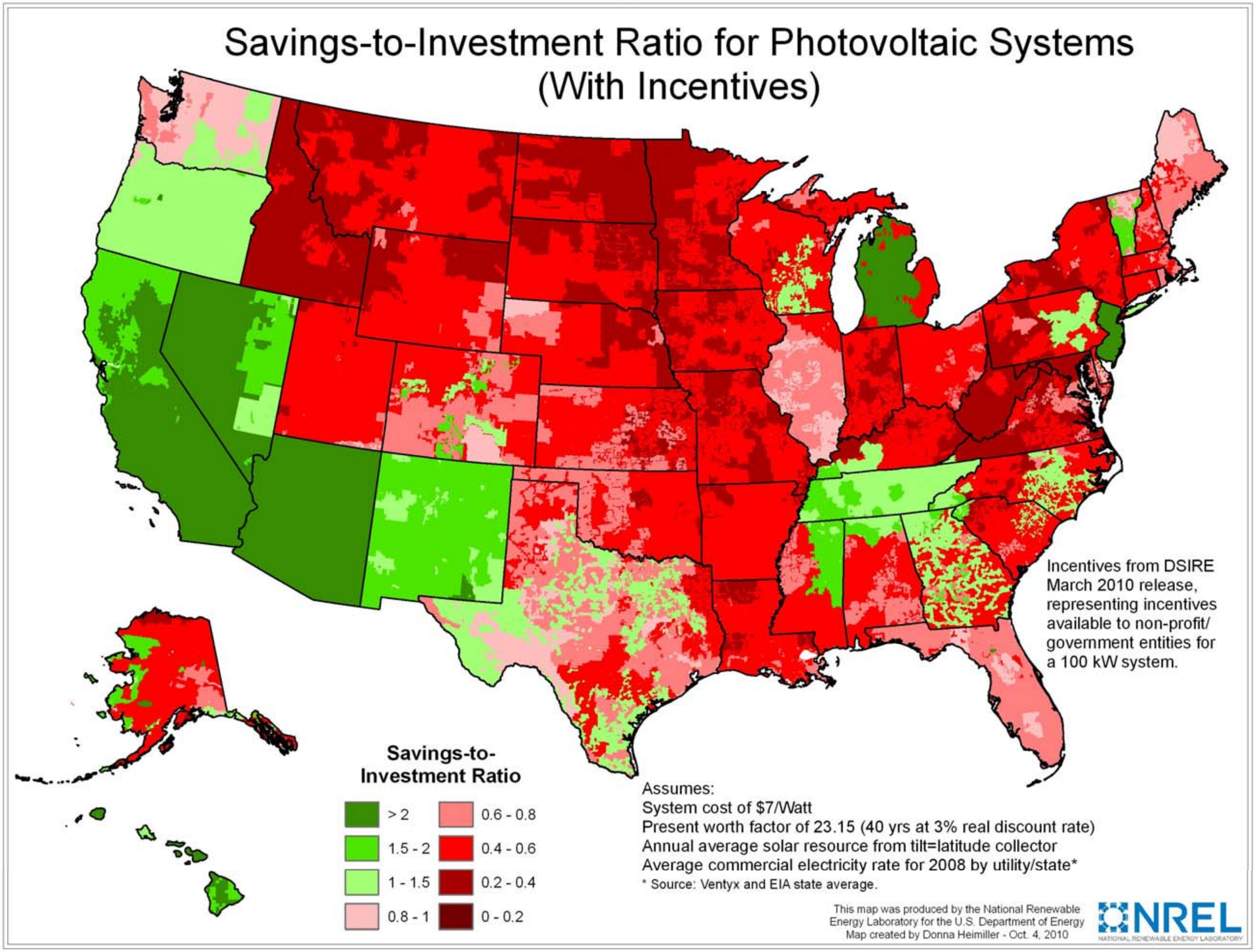

Electricity Energy Efficiency
Total Economic Potential Savings - 2020
Date: 06-21-2010; Map Authors: Anthony Lopez & Seung-Jae Lee
Map produced by NREL for the U.S. Department of Energy
MWh / km²
> 100
10 - 100
6 - 10
4 - 6
2 - 4
1 - 2
0.5 - 1
0 - 0.5
Gigawatt Hours
40,000
30,000
20,000
10,000
0
Urbanized Area Potential
Urbanized Area National Average Potential: 1000 GWh
*New York
*Los Angeles
Miami
Washington
Chicago
Phoenix-Mesa
Atlanta
Philadelphia
Houston
*Dallas
Detroit
*Tampa
Boston
*Minneapolis
Seattle
St. Louis
Virginia Beach
*Denver
Orlando
Baltimore
San Antonio
Cincinnati
Austin
Las Vegas
Portland
*San Francisco
Charlotte
Kansas City
Indianapolis
Richmond
Top Thirty Economic Potential: 261,107 (GWh)**
Data derived from McKinsey & Company, "Unlocking Energy Efficiency in the U.S. Economy", 2009. Urban areas represent U.S. Census Urbanized Areas. *Urbanized Area includes adjacent cities, see U.S. Cenesus Urbanized Areas for definitions. **Total economic potential represents an aggregate of the thirty urban areas with the highest potential.


Geothermal Resource of the United States
Locations of Identified Hydrothermal Sites and
Favorability of Deep Enhanced Geothermal Systems (EGS)
• Map does not include shallow EGS resources located near hydrothermal sites or USGS assessment of undiscovered hydrothermal resources.
• Source data for deep EGS includes temperature at depth from 3 to 10 km provided by Southern Methodist University Geothermal Laboratory (Blackwell & Richards, 2009) and analyses (for regions with temperatures ≥150°C) performed by NREL (2009).
• Source data for identified hydrothermal sites from USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the United States (2008).
• *"N/A" regions have temperatures less than 150°C at 10 km depth and were not assessed for deep EGS potential.
• **Temperature at depth data for deep EGS in Alaska and Hawaii not available.
Favorability of Deep EGS
Most Favorable
Least Favorable
N/A*
No Data**
Identified Hydrothermal Site (≥ 90°C)
This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
October 13, 2009 Author: Billy J. Roberts
NREL
www.nrel.gov/gis



Note: The uncertainty of the contoured values is generally ±10%. In mountainous and other areas of complex terrain, the uncertainty may be higher.


Simple Payback for Photovoltaic Systems
(With Incentives)
Incentives from DSIRE March 2010 release, representing incentives available to non-profit/ government entities for a 100 kW system.
Payback Period
(Years)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 50
50 - 60
> 60
Assumes:
System cost of $7/Watt
Annual average solar resource from tilt=latitude collector
Average commercial electricity rate for 2008 by utility/state*
* Source: Ventyx and EIA state average.
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct 4, 2010
NREL


Savings-to-Investment Ratio for Photovoltaic Systems
(With Incentives)
Incentives from DSIRE March 2010 release, representing incentives available to non-profit/ government entities for a 100 kW system.
Savings-to-Investment Ratio
> 2
1.5 - 2
1 - 1.5
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2
Assumes:
System cost of $7/Watt
Present worth factor of 23.15 (40 yrs at 3% real discount rate)
Annual average solar resource from tilt=latitude collector
Average commercial electricity rate for 2008 by utility/state*
* Source: Ventyx and EIA state average.
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct. 4, 2010
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Source: www.ncat.org/energy/images/**IES**%20**footcandles**.pdf (Iron and Steel Manufacturing continued on next page.)

IES Footcandle Recommendations

The following selected footcandle ranges represent the Illuminating Engineer Society's (IES) current illuminance recommendations. Indiviudal applications will determing exact foot-candle levels. Please refer to the IES Lighitng Handbook for more detailed evaluation.

Airplane Manufacturing
- Drilling, riveting, screw fastening....75
- Final assemble, hangar....100
- Inspection....50-200
- Welding....50

Assembly
- Rough easy seeing....20-50
- Rough difficult seeing....50-100
- Medium....100-200
- Fine....200-500(a)
- Extra fine....500-1000(a)

Auditoriums
- Social activities....5-10
- Assembly only....10-20
- Exhibitions....10-20

Automobile Manufacturing
- Final assembly, finishing, inspecting....200
- Body & chassis assembly....100
- Body parts manufacturing....100
- Frame assembly....50

Banks
- Lobby general....10-50
- Writing areas....20-70
- Teller stations, posting & keypunch....50-150

Garages-Motor Vehicles
- Storage....5
- Traffic Lanes
  - Parking garage....10
  - Service garage....10-20
  - Entrances....50
  - Repair area....50-100

Gymnasiums
- Assemblies....10
- General exercise & recreation....30
- Exhibitions, matches....50

Hospitals
- Rooms....10-30
- Corridors....5-30
- Emergency rooms....50-100
- Operating rooms....100-200

Hotels
- Bathrooms....20-50
- Bedrooms for reading....20-50
- Corridors, elevators and stairs....10-20
- Front desk....50-100
- Linen room
  - Sewing....100-200
  - General....10-20
- Lobby
  - General lighting....10-20
  - Reading and working areas....20-50

Iron & Steel Manufacturing
- Stock, hot top, checker cellar, calcining....10-30
- Building, slag pits, stripping yard....20

- Mail sorting....50-100
- Off-set printing and duplicating area....20-50
- Spaces with VDT's....75

Paint Shop
- Spraying, rubbing, hand art, stencil....20-50
- Fine hand painting & finishing....50-100

Paper Manufacturing
- Beaters, grinding....20-50
- Finishing, cutting....50-100
- Hand couting....50-100
- Paper manchine reel, inspection....100-200
- Rewinder....100-200

Printing
- Photo engraving, etching. blocking....20-50
- Color inspecting....100-200
- Presses....50-100
- Proofreading....100-200
- Composing room....50-100

Schools
- Reading....20-100
- Typing....20-100
- Demonstrations....100-200
- Sewing....20-100

Sheet Metal Works
- General....100
- Tin plate inspection, galvanized, scribing....100-200

Barber Shops
Beauty Parlors.....50-100

Chemical Works.....30

Clothing Manufacturer
Receiving, storing, shipping, winding, measuring.....20-50
Pattern making, trimming.....50-100
Shops, marking.....50-200
Cutting, pressing.....100-500(a)
Sewing, inspection.....200-500(a)

Electrical Equipment Manufacturing
Impregnating.....20-50
Insulating coil winding, testing.....50-100

Food Service Facilities
Dining areas
Cashier.....20-50
Cleaning.....10-20
Dining.....5-20
Food displays.....30-100
Kitchen.....50-100

Foundries
Annealing furnaces.....20-50
Cleaning.....20-50
Core making.....50-200
Inspection
Fine.....100-500
Medium.....50-100
Molding.....50-200
Pouring, sorting.....50-100

Control platforms, repairs, mixer building.....30
Rolling mills.....30-50
Shearing.....50
Tin plate.....50
Motor room, machine room.....30
Inspection.....100

Laundries
Washing.....20-50
Ironing.....20-100

Library
Ordinary reading, stacks.....20-50
Book repair and binding.....20-50
Study & notes, cataloging, card files, check desk.....20-100

Machine Shops
Rough bench.....20-50
Medium bench, rough grinding, buffing.....50-100
Fine bench and work.....200-500(a)

Materials Handling
Loading trucking.....10-20
Picking stock classifying.....20-50
Wrapping, packing, labeling.....20-50

Offices
Accounting.....50-100
Audio-visual areas.....20-50
Conference areas.....20-70
Corridors, stairways.....20(k)
Drafting.....50-200
General and private offices.....50-100
Lobbies, lounges and reception areas.....0-20

Stores
Circulation area stockroom.....10-30
Merchandising, serviced.....30-100
Merchandising, self-service.....200

Textile Mills
Cotton picking, carding, roving, spinning.....50
Beaming & slashing.....150
Drawing.....200
Others.....100

Warehousing, Storage
Inactive.....5-10
Active
Rough bulky.....10-20
Medium.....20
Fine.....20-50

Welding
General.....20-50

Woodworking
Rough sawing and bench work.....20-50
Sizing, planing, rough sanding, medium quality machine and bench work, gluing, veneering, cooperage.....20-50
Fine bench and machine work, fine sanding and finishing.....50-100

Footnotes:
(a) Obtained with a combination of general light plus specialized supplementary lighting

(k) Or not less than 1/5 the level in adjacent areas

Array: Solar panels arranged in a group to capture sun light to convert it into usable electricity.

BTU/hr: Measurement of heating and cooling. 1 BTU is the energy required to heat 1 pound of water 1 degree.

Building: Refers to one of several categories of historic properties. Buildings refer to places that primarily shelter human activity, while structures are related to purposes other than human shelter.

Character defining features: Aspects that are integral to a building or structure's historic and architectural significance and integrity. Character defining features are usually physical aspects such as the overall shape, design, materials, windows, craftsmanship, decorative features and defining features of the site layout or landscape context. The SHPO determines what features of the property have the status of "character defining features."

Code: Is the legally enforceable criteria that projects must meet. In the case of DoD properties, the Unified Facility Criteria (UFC) is the applicable code document.

Coefficient of Performance (COP): The ratio of heating or cooling provided (in watts) divided by the electrical energy consumed (in watts). Better performing equipment has a higher COP.

Cooling Degree Days (CDD): Number of days multiplied times the average temperature difference between the outside temperature and a desired average indoor temperature, typically 65 degrees (averaging desired day and night temperatures). CDD are specific to a location and a time period.

Delta T: The difference between the desired inside temperature and the outside temperature.

Eligible: Refers to the status of a structure 50 years or older that has not been placed on the National Register of Historic Places (NRHP), but is deemed by the SHPO to be eligible. A building or structure that has been declared "eligible" for the NRHP is afforded the same protections as a registered building.

Energy Efficiency Ratio (EER): The EER is similar to the Coefficient of Performance (COP), and is the ratio of output cooling (in BTU/hr) to electrical energy input (in watts).

Fenestration: The arrangement, proportioning, and design of windows and doors in a building. (www.merriam-webster.com).

Forced Air HVAC Systems: Use fans, ductwork, heating, and cooling sections to temper and distribute air.

Free Standing Photovoltaic System: Electrical system which received its power from solar panels which are independent of the utility grid. System may be used in conjunction with batteries and wind turbines.

Furrout: A means of supporting a finished surfacing material away from the structural wall or framing. Used to level uneven or damaged surfaces, or to provide a space between substrates. (Gypsum Construction Handbook, 436). A furrout can be used as a means to provide significant insulating value to an exterior wall construction.

Grid-tied: Solar panels which are connected to the facility electrical system and the utility grid with excess power being fed back to the utility.

Guidelines: When the word "Guidelines" is used to refer to the Secretary of the Interior's Standards for Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings, its use is described by the National Park Service as follows:
"The Guidelines have been prepared to assist in applying the Standards to all project work; consequently, they are not meant to give case specific advice or address exceptions or rare instances." (http://www.nps.gov/history/hps/tps/standguide/overview/using_standguide.htm).
When the word "Guidelines" is used in other contexts in this document, such as in the title of this report, it does not have the authority of the National Historic Preservation Act of 1966. These "Guidelines" are suggestions that can assist project planners and managers who need to meet the Secretary of the Interior's Standards and Guidelines while trying to reduce the energy use of historic properties.

Heating Degree Days (HDD): Number of days multiplied times the average temperature difference between the outside temperature and a desired average indoor temperature, typically 65 degrees (averaging desired day and night temperatures). HDD are specific to a location and a time period.

Historic resource or **historic property:** Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places (National Register; NRHP).

Historic district: A significant concentration, linkage, or continuity of sites, building, structures, or objects united historically or aesthetically by plan or physical development. A single building slated for remodeling or an energy upgrade might not seem eligible by itself, but might require the SHPO's review because it is in a historic district, <u>and</u> it is designated as contributing to that district.

Pertains to the movement of heat and moisture through buildings.

Hydronic Heating and Cooling Water Piping: HVAC systems can use this type of piping instead of ductwork to aid in distributing the heating/cooling air.

Individually eligible property: A single building, structure, site, or object that meets the National Register criteria for designation. If such a property is a building or a structure, it may include interior as well as exterior features. It could also include landscaping features immediately surrounding the property.

Insulation: The resistance of heat (energy) transfer. Higher insulation (higher R-values) reduce the heating or cooling requirements of spaces.

Kilowatts: A measurement of electrical energy.

MBH: A unit of measurement used for heating and cooling. 1 MBH refers to one thousand BTU per hour. 12 MBH = 1 ton.

Mullion: A slender vertical member that forms a division between units of a window, door, or screen or is used decoratively. (www.merriam-webster.com).

Muntin: A strip separating panes of glass in a sash. (www.merriam-webster.com).

Nomenclature: A system or set of terms or symbols especially in a particular science, discipline, or art. (www.merriam-webster.com).

Off-grid: See Free Standing Photovoltaic System.

R-Value: R-values represent the insulation value of materials. R-values are generally measured in hour x sf x degF/BTU for a given material, but can also be measured per inch of material thickness.

Refrigerant Piping: See Hydronic Heating and Cooling Water Piping definition.

Scupper: An opening in the wall of a building through which water can drain from a floor or flat roof. (www.merriam-webster.com).

Site: Refers to one of several categories of historic properties. Sites are locations of significant events (prehistoric or historic in time) with historical, archaeological, or cultural value regardless of whether or not there is a standing building or structure.

Soffit: The underside of a part or member of a building, such as an overhang or staircase. (www.merriam-webster.com).

Stand Alone Photovoltaic System: See Free Standing Photovoltaic System.

Standards: When capitalized, “Standards” refers to the Secretary of the Interior’s Standards for the Treatment of Historic Properties. These Standards are described in the National Park Service website as follows:
“The Standards are neither technical nor prescriptive, but are intended to promote responsible preservation practices that help protect our Nations’ irreplaceable cultural resources. For example, they cannot, in and of themselves, be used to make essential decisions about which features of the historic building should be saved and which can be changed. But once a treatment is selected, the Standards provide philosophical consistency to the work.” (http://www.nps.gov/history/hps/tps/standguide/overview/choose_treat.htm).
The Secretary of the Interior’s Standards for the Treatment of Historic Properties have the authority of the National Historic Preservation Act of 1966, as amended.

Structure: Refers to one of several categories of historic properties. Buildings refer to places that primarily shelter human activity, while structures are related to purposes other than human shelter.

Synergistically: Refers to distinct agencies which have the capacity to act in synergism – the interaction of discrete agencies, agents, or conditions such that the total effect is greater than the sum of the individual effects. (www.merriam-webster.com).

Task Lighting: Lighting which is designed to increase illumination at the level where tasks are completed, such as office desks or reading tables.

Therm: 100,000 BTUs. Typical measurement for natural gas or propane usage.

Thermal Mass: Material that is dense and weighty. Thermal mass slows heat transfer due to its depth. Concrete, brick and stone masonry, and adobe walls can act as thermal masses if they are thick enough to cause delay in heat transfer.

Ton: Measure of air conditioning output. One ton is 12,000 BTU/hr or 12 MBH.

Tracking System: For solar panels, 'track' the sun to maintain the optimal angel to the sun to provide the maximum efficiency from the solar panels.

Transom: A window above a door or other window built on and commonly hinged to a transom – a transverse piece in a structure, such as a lintel. (www.merriam-webster.com).

U-Factor: U-factors are the inverse of R-values, and measure how well heat is conducted through an assembly. Materials with lower U-factors reduce heating and cooling losses.

Undertaking: A project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency, including those carried out by or on behalf of a federal agency; those carried out with federal financial assistance; and those requiring a federal permit, license, or approval (36 CFR § 800.16(y)).

Variable Air Volume HVAC Systems: These are 'forced-air' but can operate effectively at lower airflows when conditions allow the reducing of energy usage.

Ventilation: An important factor in the comfort and safety of building occupants. Ventilation is fresh 'outside air' brought into the space.

APPENDIX L: ABBREVIATIONS

ACHP	Advisory Council on Historic Preservation
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
bd	Board (as in gypsum board)
BTU	British Thermal Units (measurement of energy)
BTU/h	British Thermal Units per hour (measurement of power)
CAV	Constant Air Volume System
CDD	Cooling Degree Days
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet Per Minute
CMU	Concrete Masonry Unit
COP	Coefficient of Performance
CRM	Cultural Resource Manager
CSI	Construction Specifications Institute
degF	Degrees Fahrenheit
DX	Direct Expansion (Refrigeration Cycle)
EER	Energy Efficiency Ratio
EGS	Enhanced Geothermal Systems

EIA	Energy Information Administration
EIFS	Exterior Insulation and Finish Systems
EIMA	EIFS Industry Members Association
EO	Executive Order
EPA	Environmental Protection Agency
ERV	Energy Recovery Ventilator
FC	Fan Coils
GIS	Geographic Information System
GISS	NASA Goddard Institute for Space Studies
GPM	Gallons Per Minute (flowrate of heating/cooling water)
HDD	Heating Degree Days
HID	High Intensity Discharge Lamps
hr	Hour
HVAC	Heating, Ventilation, and Air Conditioning
IBC	International Building Code
IECC	International Energy Conservation Code
IES	Illuminating Engineer Society
in	Inches

Insul	Insulation
kW	Kilowatts
kWh	Kilowatt Hour (measure of electricity)
LCD	Liquid Crystal Display
LCA	Life Cycle Analysis (or Assessment)
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
MAU	Makeup Air Unit
MBH	One thousand BTUs/hr
NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act of 1966
NPS	National Park Service
NREL	National Renewable Energy Laboratory
NRHP	National Register of Historic Places
PEX	Crosslinked polyethylene (type of piping)
PP	Polypropylene (type of piping)
PV	Photovoltaic
ROI	Return on Investment

RTU	Roof Top Unit
SEER	Seasonal Energy Efficiency Ratio. SEER is higher than EER for the same equipment.
sf	Square Feet
SHPO	State Historic Preservation Officer
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SOI Standards	Secretary of Interior Standards for Rehabilitation
THPO	Tribal Historic Preservation Officer
TPO	Thermoplastic Polyolefin Membrane Roof
UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
US DOE	United States Department of Energy
V	Volt
VAV	Variable Air Volume System
VRF	Variable Refrigerant Flow