



Energy Efficiency: Building Insulation - Design and Installation

An Online Continuing Education Course for Engineers

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Energy Efficiency: Building Insulation – Design and Installation

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Introduction

This is the second course in a two-part series on building insulation. Volume I looked at how insulation works and the characteristics of each of the major types of residential insulation. In this course, we will look at the economics of insulation, how to install insulation in the various areas of a residential structure, and briefly discuss techniques to control moisture in a structure. As discussed in Volume I, the efficiency of a building envelope, which includes anything that encloses a building such as walls, ceilings, windows, foundations, is a key to improving the energy efficiency of structures. Basically, the envelope is anything that separates the inside of a building from the outside environment. A good energy efficiency program begins with having a building envelope that efficiently minimizes heat loss.

Heating and cooling accounts for 50 to 70% of the energy used in an average home. Inadequate insulation and air leakage are leading causes of energy waste in most residential homes. The benefits of a good building envelope include:

- Saves money,
- Makes the home more comfortable by helping to maintain a uniform temperature throughout the house, and
- Makes walls, ceilings, and floors warmer in the winter and cooler in the summer.

The amount of energy efficiency improvements depend on several factors: local climate; the size, shape, and construction of the house; the living habits; the type and efficiency of the heating and cooling systems; and the fuel used.

This course will help you to understand where to apply insulation, how to install insulation, and how much insulation makes sense for a given climate. We'll start with the cost/benefits of adding insulation.

Chapter 1: Cost Considerations

Because insulation is such an important component in an efficient building envelope it is often the first item that is considered in an energy efficiency improvement plan. Adding insulation can be expensive, but it often yields the quickest payback of any energy conservation method. It is easy to determine the potential cost savings that can be achieved with the addition of insulation by using a payback calculation.

The payback calculation takes into consideration the installed cost of the new insulation, the efficiency of the heating source, the marginal cost of energy used to heat the structure, and the outside temperature where the building is located. Actually the temperature data is based on Heating Degree Day data for the building location. The payback calculation is,

$$\text{Payback} = \frac{(\text{Cost}_{\text{Ins}} * \text{R}_{\text{Existing}} * \text{R}_{\text{New}} * \text{EFF})}{(\text{Energy Cost} * (\text{R}_{\text{New}} - \text{R}_{\text{Existing}}) * \text{HDD} * 24)}$$

Where,

Payback = Expected payback, years.

Cost_{Ins} = Installed cost of the insulation, \$/ft².

$\text{R}_{\text{Existing}}$ = Areas existing R-Value.

R_{New} = New R-Value of area.

Eff = Efficiency of the heating system.

Energy Cost = Energy cost, \$/BTU.

HDD = Heating Degree Days.

Note: The efficiency factor for natural gas, propane, and fuel oil systems is based on the Annual Fuel Utilization Efficiency (AFUE) factor. Typical values are 0.88 for propane systems and 0.92 for natural gas systems. For heat pumps, the Coefficient of Performance (COP) is used and typical values are 2.4 for air source systems and 3.5 for geothermal systems.

The term Heating Degree Day (HDD) refers to a calculation that measures the likely need for heating during a given period. Heating degree days are calculated by recording the mean temperature during a given day and subtracting from 65 degrees Fahrenheit. For instance, if the mean temperature on January 2nd was 38F, then the Heating Degree Days for January 2nd would be 65-38 = 27. This calculation is repeated for each day in the year and the values are summed to find the total number of Heating Degree Days for a location. If the mean temperature for any day is above 65F, then the value is used to determine the Cooling Degree Days (CDD). Both Heating Degree Days and Cooling Degree Days are useful in analyzing energy consumption.

The following chart has recent Heating Degree Day information for several locations in the United States.

Table 1 Heating Degree Day Data (Base = 65F)	
Location	HDD
Alabama	2,840
Connecticut	6,068
Florida	694
Minnesota	8,754
Alaska	11,525

From this chart you can see that Connecticut has slightly more than twice the heating requirement than Alabama.

Since the payback calculation requires the energy cost in \$/BTU some conversion may be necessary since electricity is typically sold in \$/kWh, natural gas is sold in \$/CCF or \$/Therm, and fuel oil and propane are sold in \$/Gallon. Since the BTU content of each fuel type is readily known we can convert the cost into \$/BTU easily. See the following chart,

Table 2 Energy Conversion to \$/BTU			
Energy Source	BTU Content	Cost per Unit	\$/BTU
Electricity	3,412 Btu/Kwh	\$0.011 / kWh	\$0.0000322
Natural Gas	103,000 Btu/CCF	\$2.58 / CCF	\$0.0000250
Natural Gas	100,000 Btu/Therm	\$2.50 / Therm	\$0.0000250
Fuel Oil	138,500 Btu/Gal	\$5.00 / Gal	\$0.0000361
Propane	91,000 Btu/Gal	\$3.00 / Gal	\$0.0000329

With this information, consider an example where the existing insulation in the walls of a building located in Connecticut are R-3.5 and the owner desires to improve the insulation to R-13. The installed cost of the insulation will be \$0.29 per square foot. The heating system is an electric heat pump with a COP of 2.5 and the energy cost is 11.0 cents per kWh. What is the estimated payback of the insulation?

For Connecticut we see from Chart 1 that the HDD is 6,068. From Chart 2 we see that the energy cost in \$/BTU for electricity is \$0.0000322 /Btu. The payback is,

$$\text{Payback} = (0.29 * 3.5 * 11 * 2.5) / (0.0000322 * (11 - 3.5) * 6,068 * 24)$$

Payback = 0.79 years.

In this example the payback for upgrading from an R-Value of 3.5 to an R-Value of 13 is slightly less than one year. In Alabama, the payback for the same energy costs, but in Alabama?

From Chart 1 we see that the HDD is 5,000. The calculation is then, payback

$$\text{Payback} = (0.29 * 3.5 * 11 * 2.5) / (0.0000322 * (11 - 3.5) * 5,000 * 24)$$

Payback = 1.70 years.

Because Alabama does not have a heating season, the payback for adding insulation is approximately 1.7 years. This assumes a uniform space with uniform insulation. Cooling costs are not considered in this calculation. heating costs.

