Insulating to
Reduce Heating Costs

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In North Dakota,
50 percent of energy
used in homes is for
heating and air conditioning.
Properly insulating your home
not only saves money,
but also makes the home
more comfortable.

NDSU
Extension Service

Conditioned air in your home can be lost in three ways. Heat moves from a warm to a cold place by conduction, convection or radiation. Conducted heat moves through a material. Convected heat is carried by a moving fluid, such as circulating air or water. Radiated heat passes through a space (air) and warms objects it strikes. For example, the sun warms the Earth, but not the space between them. A building loses heat by conduction through construction materials, by exhausting warm air that is replaced by cold outdoor air and by radiation to or from surfaces. Simple measures can insulate walls economically and effectively to resist heat flow.

Radiant heat loss affects the comfort level. Animals or people lose heat by radiant heat transfer when they are surrounded by a surface that is lower in temperature than their body temperature. Radiant heat loss causes you to feel cool when sitting in front of a window on a cold winter day, even though the room air temperature may be 75 degrees Fahrenheit (°F).

Although all building materials have some insulation value, the term "insulation" usually refers to materials with a relatively high resistance to heat flow that are designed specifically for that purpose. R-value is a term that describes the ability of a material to resist heat flow. The higher the R-value, the better the insulation.

Where to Focus First

The major areas of heat loss in the typical home are the walls, ceiling, foundation, windows, doors and air leaks. Air leaks are areas in the home where air can pass directly from one room to another or to or from the outside without resistance. A gap around a door is an example, but homes have many more places that allow heat to escape. Depending on the construction of the home, homeowners generally should concentrate on the air leaks or infiltrations first, and then insulate areas that are below recommended levels.

Determining what areas in the home are in greatest need of energy efficiency upgrades will take a little investigation. First determine the climate zone in which you live from Figure 1 *(see page 2)*. Using the recommendations from Table 1 *(see page 2)*, check to see how much insulation you should have in each area of your home and determine where additional insulation would be most beneficial. For example: If you have double-glazed windows and 16 inches of insulation in the attic, but no insulation on your foundation, concentrating on the foundation would make more sense. For a detailed examination to determine if your house is inefficient, refer to appendix A.

Table 1. Insulation values for North Dakota. Insulation value of windows is given in both a U-factor and R-value for comparison purposes. Window ratings generally are given as U-factor, which is the inverse of R-value.

Where basement and crawl space insulation requirements have two different values: The first R-value applies to continuous insulation, the second to framing cavity insulation. Crawl space wall R-value shall apply only to unventilated crawl spaces; R-5 shall be added to the required slab edge R-values for heated slabs; and floors over outside air must meet ceiling requirements. (International Code Council, 2006)

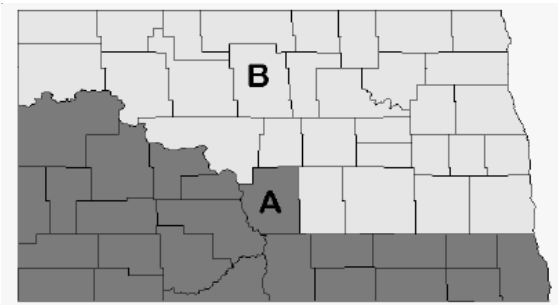| | Window U factor | Window R factor | Ceiling | Wood-framed wall | Foundation Types | | | |
					Floor over unheated space	Basement wall	Slab perimeter	Crawl space wall
Zone A	0.35	2.86	R-49	R-19	R-30	R-10/13	R-10, 4ft	R-10/13
Zone B	0.35	2.86	R-49	R-21	R-30	R-10/13	R-10, 4ft	R-10/13

Figure 1.
Climate zone map of North Dakota. Based on heating degree days (HDD). Zones identified as A and B are used in Table 1.
(**International Code Council, 2006**)

Comparing Insulation Costs

R-value is the ability of a material to prevent heat transfer. Thicker materials do not always have higher R-values. The R-value of a 6-inch rigid piece of polystyrene has an R-value of 30, while a 6-inch fiberglass blanket will have an R-value of about 21. Does that make the polystyrene a better buy? Not necessarily. The fiberglass may be less expensive or easier to install, or have better properties for the particular application. To determine a cost per R-value, simply divide the cost of the insulation by the R-value. Then figure in the cost of installation and other associated costs.

Doing it Yourself or Choosing an Insulation Contractor

After you determine if you need more insulation, the next decision to make is if you are going to hire a contractor to perform the installation or do it yourself. The overriding concern is that while some insulating jobs are done easily, others require special skills or equipment. Insulating an easily accessed attic with blankets of fiberglass or your exterior foundation may be relatively simple. Insulating the wall cavity in living spaces may be quite involved.

If you decide to have the work done commercially, you need to know two things: 1) Where to look for the contractor, and 2) How to choose a qualified and reputable contractor for the job. To find a contractor, check in the Yellow Pages under Insulation Contractors. Then consult the local chapter of the National Association of Home Builders, your local energy provider or a trusted real estate agent. Put together a list of three to four contractors for comparison. Start by asking each contractor for references. Reputable installers gladly will provide references.

Other places to research an installer are the Chamber of Commerce, Better Business Bureau and state regulatory agency. Once references are checked, ask the contractors for a detailed estimate. Never assume that specific tasks are going to be performed unless those tasks are stated in writing. Be sure to compare estimates equally; one estimate may require the homeowner to perform cleanup while another may not. Choose the contractor who best fits your needs and budget.

Types of Insulation

The material the insulation is made of refers to the type of insulation. Cellulose or wood fiber insulation is made from used newsprint, other paper feedstock or wood. Chemicals are added to provide fire resistance. Fiberglass insulation is made from glass heated and drawn out to form long fibers. While it can cause skin irritation, fiberglass is noncorrosive, has no objectionable odor and does not burn. Rock wool or slag wool is similar to fiberglass in the manufacturing process and properties.

Polystyrene insulation comes in either a molded or extruded form. Molded polystyrene, or "bead board," is less expensive, but has a lower R-value per inch. It also absorbs more moisture than extruded polystyrene. Extruded polystyrene is fine-textured and moisture-resistant. Both molded and extruded polystyrene degrade through time with exposure to sunlight, so they need a protective covering. They are also flammable and will release toxic substances while burning, so they need to be covered with gypsum board or other fire protection.

Polyurethane insulation is a cellular plastic that has a high R-value per inch. It typically is applied as a foam or rigid board. A similar type to polyurethane is polyisocyanurate. Both are flammable and release toxic substances while burning. Icynene is a newer sprayed-on, expanding foam insulation. It remains flexible and does not absorb water as easily as other insulation types.

Table 2. Typical R-value for common building materials.
Most values are from the 2005 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Foundation and will vary depending on construction.

Material	R-value	
	Per Inch	For thickness listed
Batt and blanket Fiberglass or wool	3.00 to 3.80	
Polyurethane	6.00	
Polyisocyanurate	7.04	
Icynene	3.6	
Cellulose	3.13 to 3.70	
Hay or straw, 20 inch	~1.5	30+
Extruded polystyrene boards	5.00	
Solid concrete	.08	
Plywood (⅜-inch) Plywood (½-inch)	1.25 1.25	.47 .62
Softwoods, fir and pine	1.25	
Hardwoods, maple and oak	.91	

Windows, insulating glass,
¼-inch air space
    Double pane
    Triple pane
		
		1.69
		2.56

Doors, exterior (includes air space)
    Wood, solid core, 1¾-inch
    Metal, urethane core, 1¾-inch
		
		3
		10

Forms of Insulation

The form of the insulation refers to the shape it takes as it is applied. Fiberglass and rock wool insulation generally comes in batts or blankets. A batt is a precut section of insulation generally 4 or 8 feet long, while a blanket is a much longer roll – up to 100 feet or more. Batts and blankets may be faced or unfaced. Faced batts have a paper or foil backing that should be installed toward the heated living space. The backing, a vapor retarder, limits moisture from entering the insulation and reducing its effectiveness. The vapor retarders often are referred to mistakenly as vapor barriers. While they do reduce the amount of vapor that passes through the material, they are not a complete barrier. Unfaced batts may be used with an external vapor retarder or to increase insulation levels where the retarder already exists. Thicknesses range from 1 inch to 9 inches and widths of 16 or 24 inches to match stud spacing.

Loose-fill insulation comes in bags and can be blown in with a machine or poured. Common loose-fill materials include cellulose, rock wool, vermiculite, polystyrene beads and fiberglass. While most commonly used in ceilings, loose-fill insulation applications include filling cores in concrete blocks and insulating stud wall cavities.

Rigid-board insulation may be made from cellulose fiber, fiberglass, polystyrene or polyurethanes. A common size for rigid-board

insulation is 4 feet by 8 feet, with thicknesses ranging from ¼ inch up to 4 inches. Rigid boards may be used on the inside or outside of walls and, in some cases, on exterior below-grade walls. Depending on your location, many building codes require polystyrene and polyurethane boards must be covered with a 15-minute, fire-rated thermal covering if used on the inside of a house. This type of covering will provide a thermal barrier that will keep the temperature rise of the insulation below 250°F for at least 15 minutes in case of a fire.

Some covering materials with the 15-minute rating are at least ½-inch exterior-grade plywood treated with fire retardant, ½-inch-thick portland cement plaster and fired-rated sheetrock or gypsum board. They commonly are used in remodeling construction, especially for basement walls.

Sprayed-in-place insulation is applied during construction to a stud wall cavity. Spray-on insulation contains an adhesive that sticks to the surface being insulated. The most common materials are cellulose, polyurethane, fiberglass and Icynene. Polyurethane and Icynene insulation have the ability to expand when applied, which makes them capable of getting into cracks and voids other insulations would miss, which significantly reduces air infiltration.

Both are gaining popularity in residential applications, but polyurethane has been used extensively in commercial or agricultural buildings. According to Minnesota building code, rim joist areas in new construction must be covered with spray-on insulation.

Applying Insulation

Attic

Whatever type of insulation you install, make sure you have a vapor barrier between the living space and the insulation. If you add batt or blanket insulation over pre-existing insulation, be sure to buy the insulation without paper or foil backing.

Begin in the attic by attempting to locate air infiltration areas. Sealing leaks should be accomplished before insulation is installed or added. Look for gaps around plumbing or heating penetrations. Also take note of interior walls that extend into the attic. If the tops of these walls are not sealed, warm air can enter the walls and escape from the living space. The walls act like funnels for heat loss.

Recessed lighting also presents a problem for insulating. The lights extend into the attic, creating possible areas for air infiltration, as well as reduced insulation surrounding the lights. Modern recessed lights are sealed to prevent air infiltration. Insulated boxes can be constructed to surround recessed lights. Do not forget to insulate the access area into the attic.

Run weather-stripping around access doors and cover the door with insulation. Commercial tents can be purchased that fit over attic access doors or one can be made easily with rigid insulation. Once the air leaks are sealed, begin the work of insulating.

Batt and loose-fill insulation are the most common materials used to insulate attics, depending on the construction. Some attics have a floor over the top of the ceiling joists, but most are open with exposed joists. If flooring is in place, loose-fill insulation can be blown under the floorboards. However, removing the flooring can make insulating easier and allow the homeowner to use all types of insulation. While putting loose-fill insulation over the floor might be the easiest installation method, it prevents storing anything in the attic, so most homeowners would object to this. An option is to place rigid-board insulation on top of the attic floor and cover it with plywood. If attic storage cannot be given up, concentrate the storage next to the attic door to minimize the insulation loses.

If the attic does not have any insulation, buy insulation batts or blankets wide enough to fit between the ceiling joists. If you already have insulation up to the top of the joists, you can place additional material at right angles to the joists to minimize heat loss due to seams.

If adding batts or blankets, decide what thickness should be used. This depends on a number of things: the cost of the project, the free space in the attic and the current R-value. The Department of Energy recommends houses in North Dakota have an attic insulated with an R-value of 49. This is the least amount of insulation you should strive to have in place.

The cost of more insulation may outweigh the benefits. Using the recommended R-values per inch for fiberglass insulation in Table 2, an R- value of 49 would require around 16 inches of insulation. To determine the amount or square feet to buy, multiply the length of the attic by its width. If the attic consists of several oddly shaped areas, figure each area separately and add the totals.

To prevent moisture problems in the attic, you must provide 1 square foot of air vent for each 300 square feet of attic floor. Include half at the eaves and half at or near the peak.

If working in an attic without a floor, use temporary flooring to avoid stepping between joists and possibly falling through the ceiling. A few planks or a piece of ¾-inch plywood works well.

Be sure to leave clearance between the insulation and the roof near the edge of the attic floor (Figure 2). This clearance is necessary so air from the soffit vents can enter the attic and enable moist attic air to leave. This will prevent moisture problems in the attic. If you use loose-fill insulation, you will need to prevent the material from falling down into the soffit and covering the vents. You can do this by using a baffle made of cardboard, wood or rigid insulation. Baffles also can be purchased at a building supply store.

In many homes, getting adequate insulation depths at the attic edge and still maintaining a minimum 2-inch clearance below the roof is difficult. In this case, you can cut rigid insulation into pieces to fit snugly between the rafters. Lay these pieces on top of the insulation at the edge of the attic. The rigid insulation has a higher R-value per inch than other materials, and a piece of it placed here will insulate well and still give enough clearance for ventilation.

Adding insulation to a cathedral ceiling generally requires a contractor. The contractor will add insulation over the roof, then reroof or add insulation to the inside ceiling and refinish it (Figure 3).

Walls

Insulating walls is best accomplished during renovations. If siding is to be replaced, rigid-board insulation can be applied to increase the R-value. Interior walls can be insulated after removal of wall coverings. Insulate the wall cavities by using the same methods used to insulate an attic.

If adding insulation without major renovations, loose-fill and foam insulation are the common forms. For both, a hole must be drilled into each wall cavity to add insulation. While the hole may be drilled from the inside, it most often is drilled from the outside. The holes can be hidden by removing a piece of siding, drilling the holes and then replacing the siding, which leaves no visible evidence of the work.

Applying loose-fill insulation requires drilling a hole at the top or bottom of the cavity and blowing insulation into the space. Problems exist with loose-fill insulation not completely filling the space due to obstructions, such as wiring and plumbing, or the house
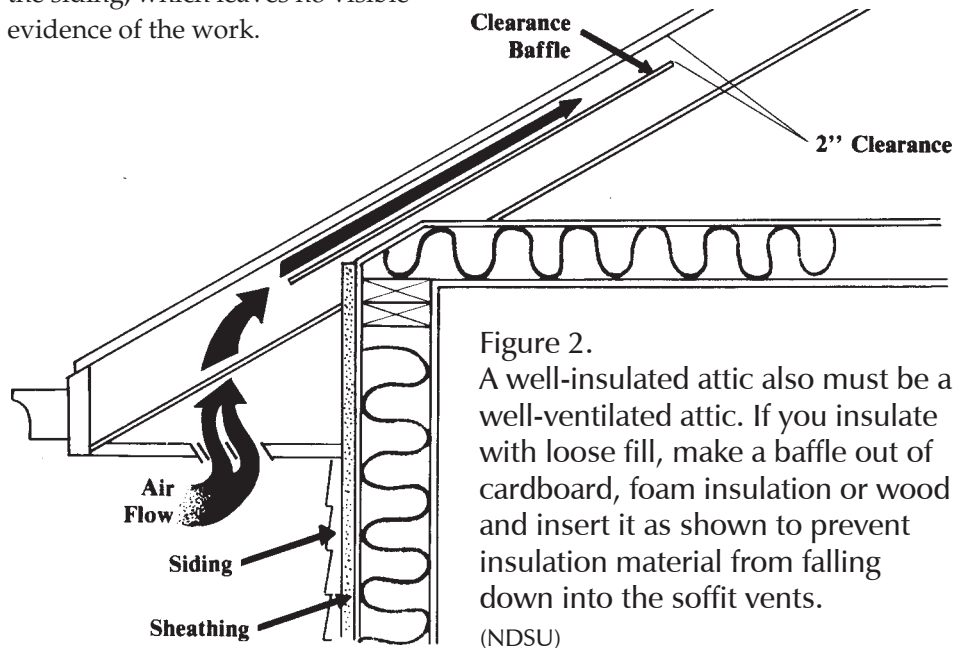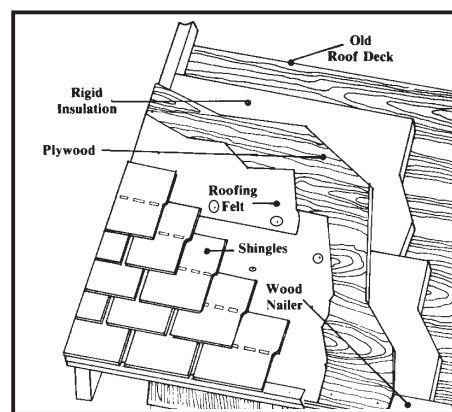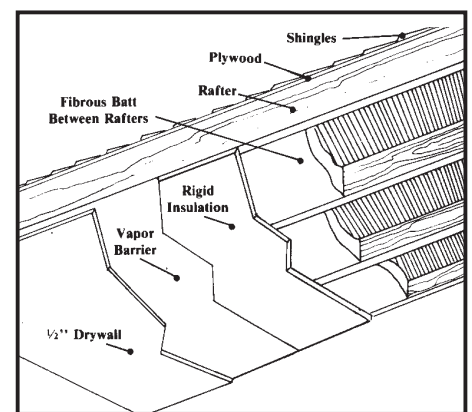

Figure 2.
A well-insulated attic also must be a well-ventilated attic. If you insulate with loose fill, make a baffle out of cardboard, foam insulation or wood and insert it as shown to prevent insulation material from falling down into the soffit vents.
(NDSU)

Insulating outside a cathedral ceiling   **Insulating inside a cathedral ceiling**

Figure 3.
Insulating cathedral ceilings. Both the exterior and the interior of a cathedral ceiling can be insulated. Exterior insulation is applied to the top of the roof and a new roof is installed over the insulation. To insulate the interior, furring strips are installed on the ceiling and the insulation is placed between the strips.
(NDSU)

settling through time. Foamed-in-place insulation requires a series of holes drilled into the wall, with spacing and sequence depending on the construction. While foam insulation costs are higher than for loose-fill insulation, foam insulation will not settle. Due to the difficulty insulating behind existing walls, this is generally best left to the professionals.
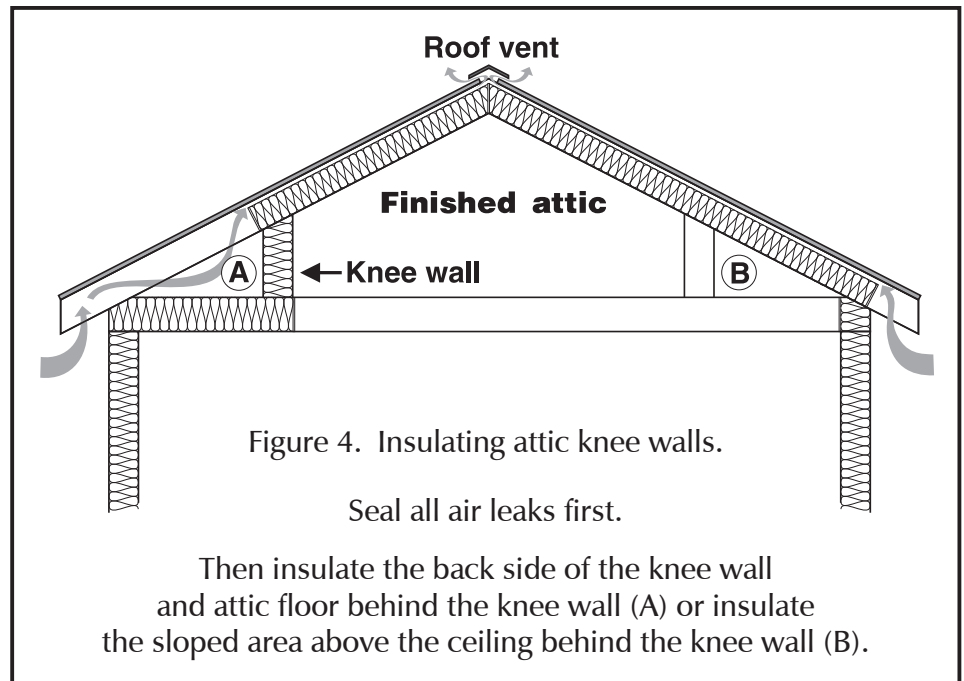
Knee Walls

Knee walls are found in houses with finished attics. The knee wall is the short wall that reaches from the sloped ceiling to the floor, Figure 4. Not only are air leaks common in these areas, but they are frequently not insulated properly. The knee walls generally have exposed studs behind them and can be insulated with batts or blankets. Make sure the vapor retarder backing insulation is next to the living space. If the studs are covered on the backside, you can insulate the knee wall by drilling a hole in the covering near the top of the wall and filling the cavity with blown insulation.

The sloped area above the ceiling is a more difficult to insulate. Block the rafter cavity at the bottom and fill it with a loose-fill insulation poured from the attic over the ceiling. You can insulate the floor behind the knee wall and the attic above it the same way you would a regular attic.

Crawl Spaces

Batts or blankets are about the only practical way to insulate a floor over a crawl space or unheated basement. While rigid insulation will work, it generally will cost more per R-value in this application. The insulation fits between the floor joists and is held in place with wire netting across the bottom of the joists. Use a 6-mil polyethylene vapor barrier on top

Figure 4. Insulating attic knee walls.

Seal all air leaks first.

Then insulate the back side of the knee wall and attic floor behind the knee wall (A) or insulate the sloped area above the ceiling behind the knee wall (B).

of any bare soil to prevent moisture from getting into the crawl space. If the crawl space contains air ducts or water pipes, insulating the wall and allowing the space to achieve a stable temperature to prevent pipes from freezing would be better. Frequently, these crawl spaces are being treated as mini-basements to minimize moisture problems.

Basement

Either the outside or inside of a heated basement can be insulated. If finishing the basement, insulating the interior wall surfaces is the easiest. If the basement already is finished, or if plans are not to finish it, insulate the exterior wall surface. A basement insulated on the outside of the walls has more heat storage than those insulated on the inside. The concrete stays warmer and will release heat to the house if the home heating system temporarily fails. Insulating the outside of the walls also keeps the footing warm, limiting the potential for soil movement due to freezing.

The first step to insulate the inside of the foundation wall is attaching vertical furring strips or 2-inch by 4-inch framing, Figure 5. Put batt, blanket or rigid insulation between the strips. Batt or blanket insulation with vapor retarders can be installed by stapling the edges of the retarder to the front of the furring strips. Be sure a vapor retarder exists. Batt and blanket insulation is becoming less common in basement insulation due to moisture problems. Moisture can enter the insulation from either side, reducing its R-value and creating the potential for mold growth. Rigid insulation is becoming the insulation of choice for basements.

Polystyrene rigid insulation is the most common basement wall insulation due to its higher R-value and better moisture resistance. Simply glue rigid insulation to the wall and finish the wall with a 15-minute fire-rated thermal covering. Rigid insulation is used to insulate the outside of a basement wall both above and below the ground level.

Figure 5.
Insulating a basement wall from the inside.
(NDSU)
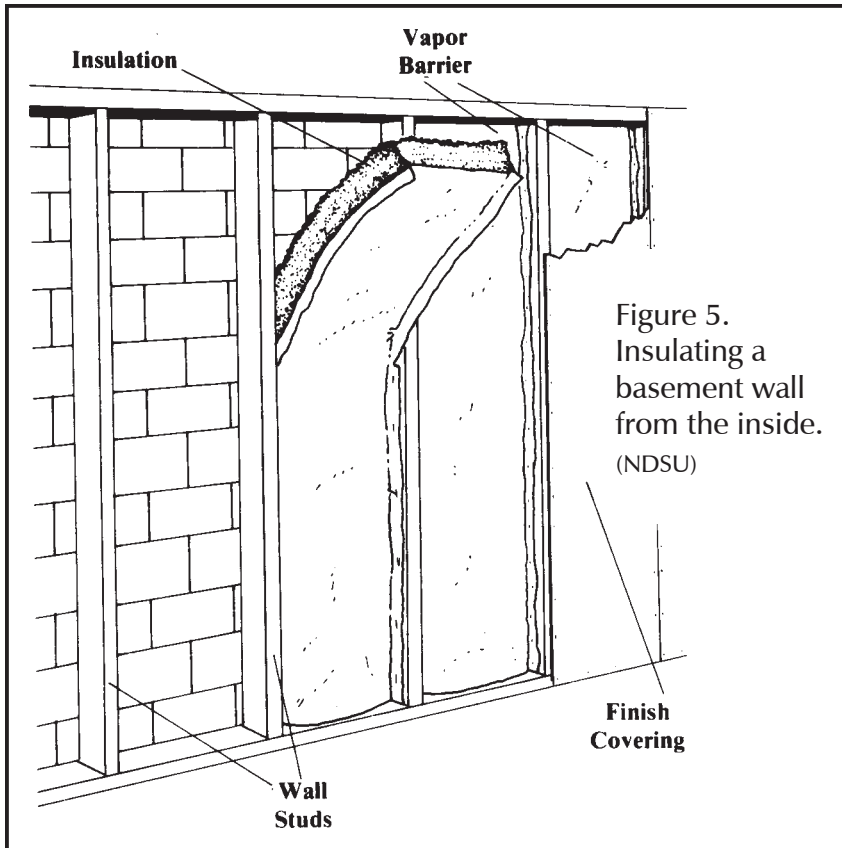
Remove the soil from the outside foundation wall to a depth of 4 feet and glue the rigid insulation to the foundation with construction adhesive. Make sure to cover any exposed above-ground insulation to prevent degradation by the sun and other elements, Figure 6.

An often overlooked area for air infiltration and poor insulation is the rim joist. This is the area where the wall framing meets the foundation. Cut rigid insulation to fit these areas and caulk the seams to ensure the least amount of air infiltration possible. (see Figure 7, page 8.) Cover the insulation with a 15-minute fire barrier. Fiberglass insulation also can be used in the rim joists, but a vapor retarder must be installed to reduce moisture problems. Make sure to check local and state building codes to determine what is required in your area.
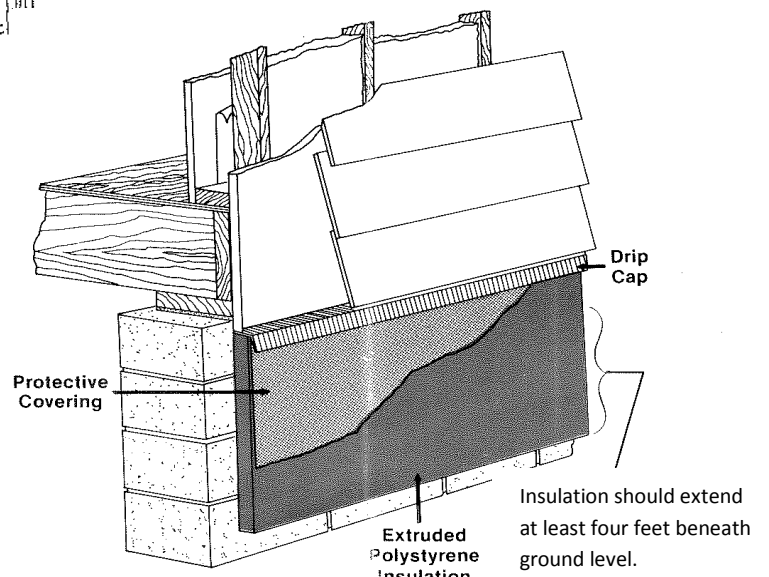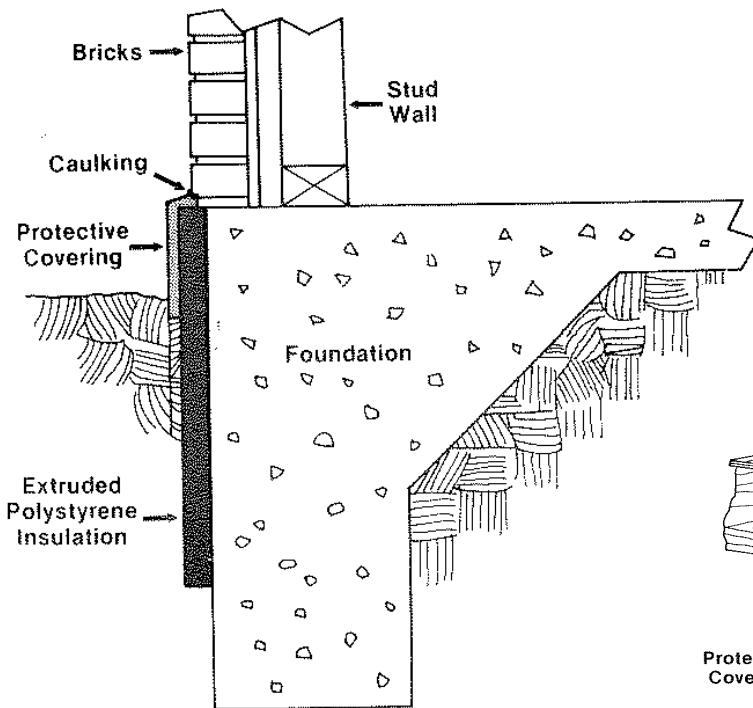
Figure 6.
Applying insulation to an exterior foundation wall.
(NDSU)

Figure 7.
Insulating the rim joist and sealing air leaks with rigid insulation. Insulation needs to be covered with a 15-minute fire barrier.

Photo courtesy of the Family Handyman Magazine.
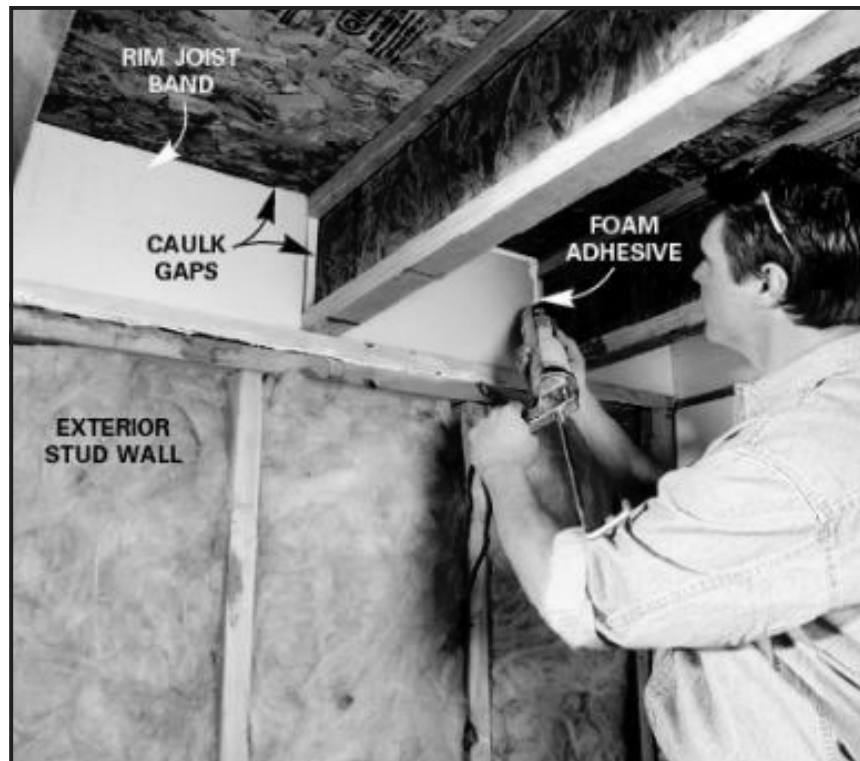
Applying Insulation

Here are some general insulation installation tips:

- Use a utility knife or large shears to cut batts or blankets to fit snugly between joist and sills.

- Use insulated boxes around recessed light fixtures.
  Check local building codes for other restrictions and regulations.

- When using batts and blankets, place long runs first.
  Use the remaining pieces to fill in the smaller areas.

- Adhesives, vapor retarders and some insulation are flammable.
  Be sure to keep open flames away.

- Repair any roof leaks or damage before insulating.

- Make sure the attic has adequate ventilation to prevent the buildup of moisture. Often moisture freezes during the winter, then drips into the living space at the first thaw.

- Attach a piece of rigid or batt insulation to attic access doors and make sure the door is weather-stripped.

- Wear a dust mask, long-sleeved shirt and gloves when handling insulation. Fibers and chemicals can be transferred to clothing, so wash the clothing separately.

Appendix A
Calculate Home Energy Heating Efficiency

The heating energy index shows how efficiently energy is used in a home.

The index allows a comparison as improvements are made or between houses.
It takes into account the average winter conditions, types of heating fuels and house construction.

Consisting of two steps, the first involves calculating the overall index for the heated spaces.

Knowing this value, you can make a decision to determine where the
largest heat transfer occurs by calculating heating coefficients.

Heating Energy Index Calculations

STEP 1. Determine heating energy use.

The first step calculates the amount of energy the house requires in an average heating season. Enter the fuel type and quantity of fuel used from October to April for each energy type.

Table 1. Energy usage.

Type of Energy	_____	Type of Energy	_____
Month		**Month**	
October	_____	October	_____
November	_____	November	_____
December	_____	December	_____
January	_____	January	_____
February	_____	February	_____
March	_____	March	_____
April	_____	April	_____
Total	_____	**Total**	_____

STEP 2. Convert fuel use to BTUs.

To determine the amount of energy required to heat the home, enter the amounts from Table 1 above into the appropriate blank below, then multiply it by the number given. This converts energy use to British thermal units (BTU).

Electricity _____ kilowatt-hours (kwh) X 3,413 = _____ BTU

Natural gas _____ hundreds of cubic feet (CCF) X 100,000 = _____ BTU

Natural gas _____ dekatherms X 1,000,000 = _____ BTU

Fuel oil _____ gallons X 140,000 = _____ BTU

LP gas _____ gallons X 95,000 = _____ BTU

STEP 3. Find the degree days.

Using the map at right, get the best estimate for the heating degree days (HDD) for your area. An HDD is calculated by subtracting the daily average temperature from 65 °F. So if the outside air temperature is 45 °F on a particular day, the HDD would be 20 (65 °F minus 45 °F). The HDD for the entire year is the sum of the daily HDDs.

City	Heating Degree Days
Bismarck	8,802
Bottineau	10,288
Bowman	8,682
Cavalier	10,195
Devils Lake	9,424
Dickinson	8,558
Ellendale	8,441
Fargo	9,092
Grand Forks	9,489
Jamestown	8,999
Minot	8,990
Williston	9,044

Climatography of the U.S. No. 81. 1971-2000

Heating Degree Days (HDD) _____
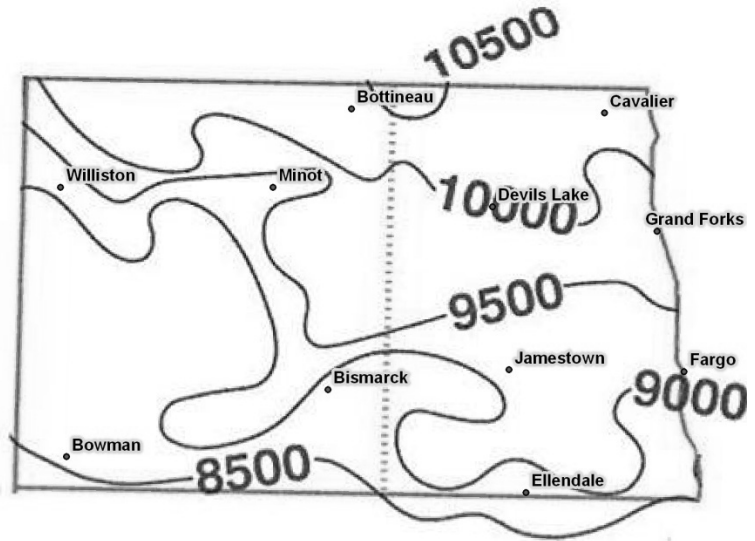
Climatography of the U.S. No. 81 – Supplement 3
Maps of Annual 1961-1990 Normal Temperature, Precipitation and Degree Days

(James Owenby, Richard Heim Jr., Michael Burgin, Devoyd Ezell)

STEP 4. Find the area (square feet) of heated space.

To determine the area of heated space, multiply the length of the house by the width.
If the house has unheated space, subtract this from the total. Do not include unheated basements.

Square Feet (FT²) _____

STEP 5. Calculate the Heating Energy index.

Use this number to compare the house with other houses. Once upgrades are completed, also use this number to see how efficiently the house uses energy.

A. Begin by dividing the total BTU by the degree days. This will give the BTU used for each degree day.

$$\frac{BTU}{DEGREE\ DAYS} = \underline{\hspace{2cm}}\ BTU/HDD$$

B. Next, divide the result of BTU/HDD in step A by the area of your house (STEP 4).
This will give you the heating energy index.

$$\frac{BTU/HDD}{FT^2} = \underline{\hspace{3cm}}\ heating\ energy\ index$$

C. Now compare this heating energy index with the values from the thermometer on page 11 to see how efficiently your home uses energy.

Example Calculation

This example is included to enable you to understand how to calculate your home's heating energy index. The example home uses natural gas as a fuel for a central heating system, clothes dryer and water heater. The basement contains an electrically heated heated room. The electricity used by the electrical appliances and lights are also included in this analysis, since the heat they produce helps to heat the house.

STEP 1.

Because the example home uses two types of fuel for heating. Step 1A would be done like this:

Type of Energy	Natural Gas		Type of Energy	Electricity
Units	CCF		Units	KWH
MONTH			**MONTH**	
October	154		October	303
November	289		November	376
December	439		December	354
January	257		January	412
February	278		February	461
March	185		March	363
April	104		April	325
TOTAL	1706		TOTAL	2594

STEP 2.

In converting the example home's heating use to BTUs (British Thermal Units), we get:

Electricity ___2594___ KWH X 3,413 = ___8853322___

Natural Gas ___1706___ CCF X 100,000 = ___170600000___

Total = ___179453322___

STEP 3.

If the example home is in Minot, its degree days will be approximately:

Heating Degree Days (D.D.) ___9000___

STEP 4.

Find the square footage of the heated parts of the home. In our example, we must remember to add the square feet of the electrically heated room in the basement.

Square Feet (FT^2) ___1600___

STEP 5.

Find the Energy Index for the example home. The calculations would be done like this:

A. $\dfrac{179,453,322}{9,000 \text{ D.D.}}$ = 19,939 BTU/D.D.

B. $\dfrac{19,939}{1,600 \text{ FT}^2}$ = 12.5 Heating Energy Index
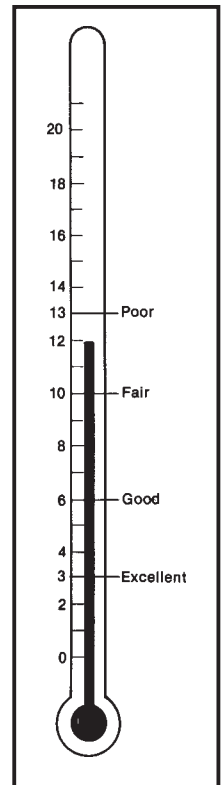
In the example used, the house has an index of 12.5. It could use some improvements to lower the heating costs.

Visit us on the web at:
www.ndsu.edu/energy

Additional Resources

ASHRAE 2005.
ASHRAE Handbook – Fundamentals.
American Society of Heating Refrigeration and
Air-Conditioning Engineers Inc. Atlanta, Ga.

ICC 2006.
International Energy Conservation Code.
International Code Council Inc. Falls Church, Va.

USDOE 2005.
Your Home: *Knee Wall Insulation and Air Sealing*.
U.S. Department of Energy, Energy Efficiency and Renewable Energy.
Available at *www.eere.energy.gov*.
Accessed April 10, 2008.

This publication is an update, revision and compilation of various Extension publications.

North Dakota
DEPARTMENT OF COMMERCE
Office of Renewable Energy
& Energy Efficiency

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