



## WEATHERIZATION TIPS FOR YOUR HOME

Here's some information on how to evaluate and improve the ability of your home to keep you comfortable.

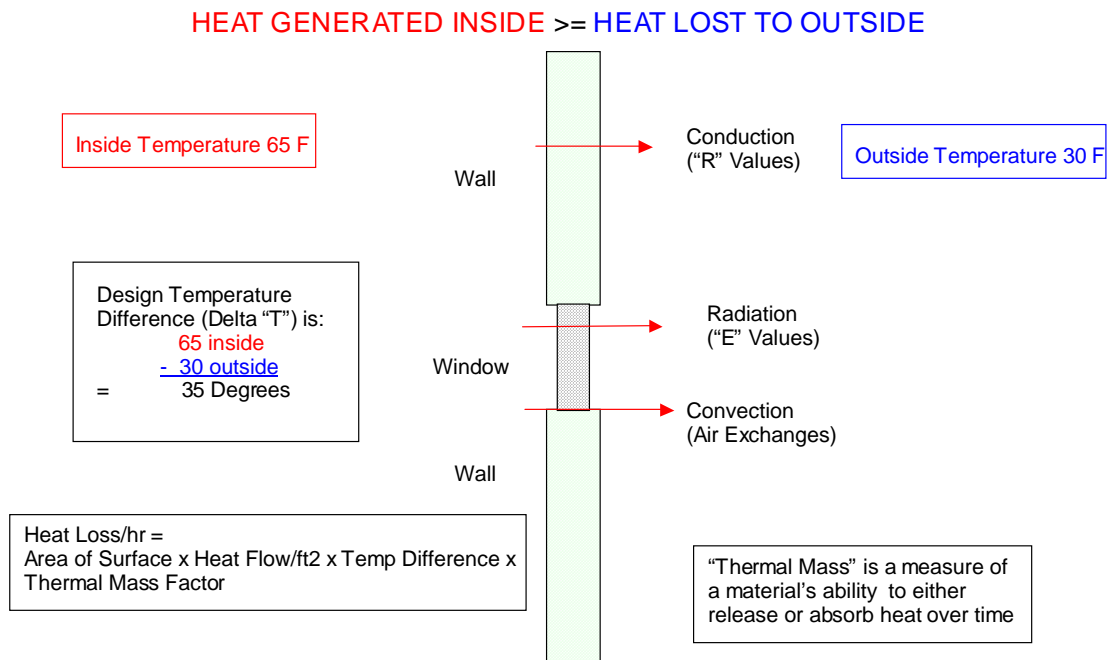
### I. BACKGROUND

In the Winter, the capacity of your heating system has to be at least equal to the heat lost outside in order to maintain a comfortable temperature. In the Summer, the cooling capacity of your air conditioning system has to likewise be equal to the heat gain.

Also, to maintain a comfortable interior temperature, your heating/cooling system has to be sized for the worst-case heat loss/gain.

The most accurate method of determining heat loss/gain is by a detailed calculation (don't worry, we have computers to do this for us). Basically, this involves defining the heat flow through each surface, adding up the total of each surface (building envelope) and then factor in the design temperature difference. In this climate, *heat loss* is more significant than *heat gain*, so most of our discussion will focus on *heat loss*.

Here's a diagram that breaks down heat loss for a typical house:



## II. DEFINITIONS:

### DESIGN TEMPERATURE (DELTA T, “ΔT”)

This is the difference between the interior and the exterior temperature and is one of the key factors in calculating heat loss. The maximum capacity of the heating system is designed for a “worst case” temperature difference for your climate. In Brainerd, this is typically minus 30F, while the interior temperature is typically 65F (which is the temperature at which an “ordinary” house needs supplemental heat). This results in a 95 degree design temperature. As you will learn later, while you can’t control Mother Nature, interior temperatures can be adjusted to reduce design temperatures.

### THERMAL MASS (THERMAL INERTIA)

Different materials can store different amounts of heat. As an example, a rock can hold a good deal of heat and release it slowly over time, while paper cannot. Thermal mass is used to describe this property and is used in most heat loss calculations. It is also important in understanding set-back thermostats (see later section).

### HEATING CALCULATIONS

Typical heat loss calculations use “Heating Degree Days”, allowing us to calculate seasonal heat loads and compare heating costs from year to year. It is figured by subtracting the *average* temperature for the day from 65F (when an ordinary house needs supplemental heating). As an example, assume today’s average temperature is 30F:

$$\begin{aligned} & \mathbf{65F \text{ (base temp)}} \\ & - \mathbf{30F \text{ (actual average temp)}} \\ & \mathbf{\underline{\times 1 \text{ day}}} \\ & \mathbf{= 35 \text{ Heating Degree Days}} \end{aligned}$$

For a measure of severity for heating seasons (typically October through May), you could add-up all the heating degree days. Here are the totals from the last years in Brainerd:

<u>Heating Season</u>	<u>Total Heating Degree Days</u>	<u>%Difference</u>
'99 – '00	7504	
'00 – '01	8850	+18%
'01 – '02	8209	-7%
'02 – '03	9071	+10%
'03 – '04	8713	-4%
'04 – '05	8479	-3%
'05 – '06	7943	-6%
<b>'06 – '07</b>	<b>8335</b>	<b>+5%</b>
8 yr average	8388	
<b>20 yr Average</b>	<b>9163</b>	<b>+9%</b>

Here’s an example how to use these numbers; if you noted that your heating costs last winter ('06-'07) were about 5% higher than the previous year, this would be exactly proportional to the increase in heating degree days from '05-'06 (8335 vs 7973). Our 8 year average is 9% warmer than the 20 year figure; we are uncertain what that really means.

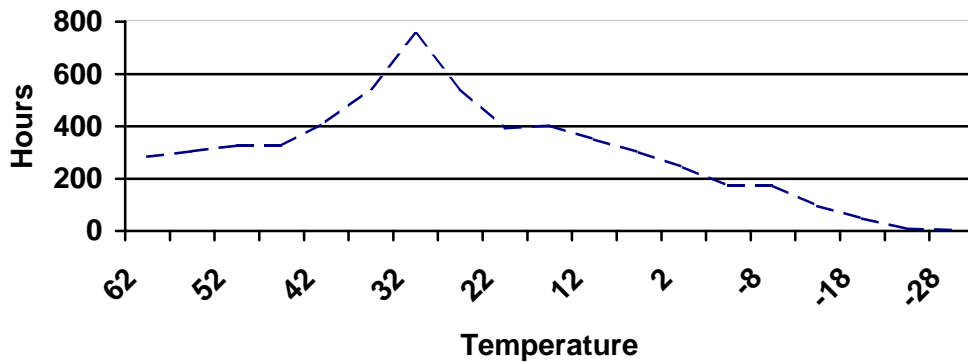
Heat loss calculations are usually done with computer software. Crow Wing Power uses a computer template developed by the utility industry and is customized to the climate in Brainerd, MN. With it, we can assist electric customers in their heat loss calculations. Heating contractors and architects can also do heat loss calculations for you.

Some computer models utilize “BIN Hours”. This breaks down the entire heating season into the hours for each temperature, organized into groups or “bins”. Since heat loss is dependant upon both temperatures difference and time, these models may be more precise than those using average heating degree days. However, it requires lengthy calculations, and is found only in more sophisticated computer programs.

BIN Hour Heating Hours, Central Minnesota				
House with 50,000 BTU max heat loss, 5,689 total BIN hrs				
MedianTemp	BIN Hrs	BTU Required	BTU-HR	% of Total
62.5	284	2,642	750,328	0.65%
57.5	305	5,273	1,608,265	1.39%
52.5	326	7,904	2,576,704	2.23%
47.5	326	10,535	3,434,410	2.97%
42.5	417	13,166	5,490,222	4.75%
37.5	544	15,797	8,593,568	7.44%
32.5	754	18,428	13,894,712	12.03%
27.5	543	21,059	11,435,037	9.90%
22.5	393	23,690	9,310,170	8.06%
17.5	403	26,321	10,607,363	9.18%
12.5	350	28,952	10,133,200	8.77%
7.5	301	31,583	9,506,483	8.23%
2.5	244	34,214	8,348,216	7.23%
-2.5	172	36,845	6,337,340	5.48%
-7.5	172	39,476	6,789,872	5.88%
-12.5	95	42,107	4,000,165	3.46%
-17.5	48	44,738	2,147,424	1.86%
-22.5	8	47,369	378,952	0.33%
-27.5	4	50,000	200,000	0.17%
TOTALS	5,689		115,542,431	100.00%

This generally looks like:

### BIN HRS CENTRAL MN



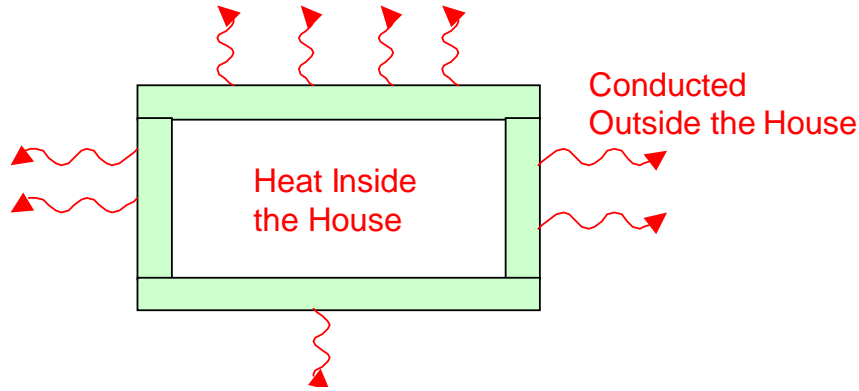
There is a web-site run by the Department of Energy that can help the do-it-yourselfer with heating calculations for their own home: [www. Homeenergysaver.lbl.gov](http://www.Homeenergysaver.lbl.gov).

### III. MANAGING THE HEAT REQUIRED BY YOUR HOUSE

The heat required by your house is based on the difference between the inside and the outside temperatures, and how the construction of your house resists the movement of heat from high to low. Here's a closer look at how this heat moves:

**CONDUCTION** (*accounts for about 38% of heat lost in a typical house*)

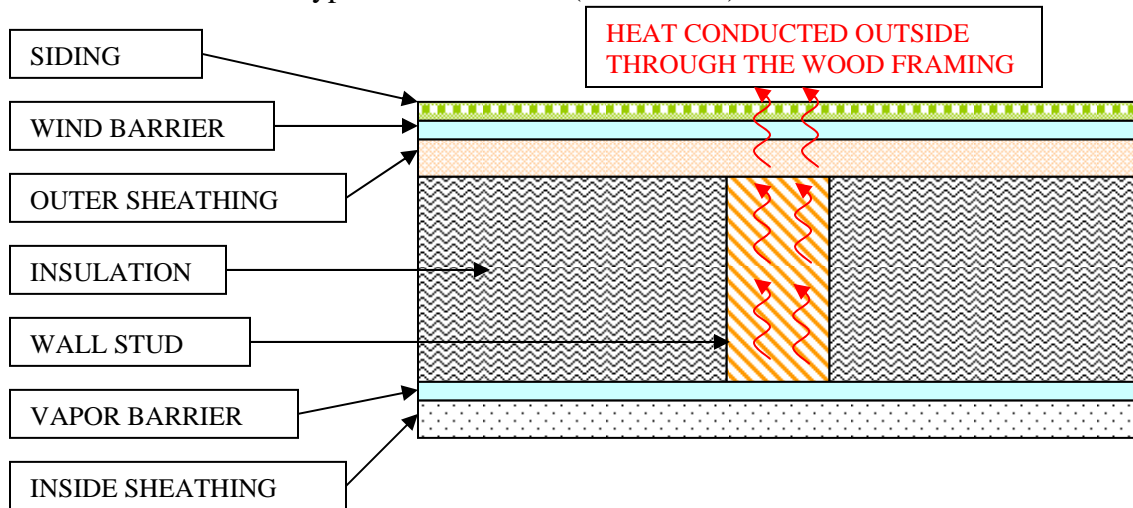
This is a process of heat moving through a solid surface, such as the structure of your house. Heat has a tendency to flow from high to low temperatures. To slow down this flow, you add insulation. "R" values give you the relative effectiveness of insulation; an "R 6" allows heat to move half as fast as an "R 3".



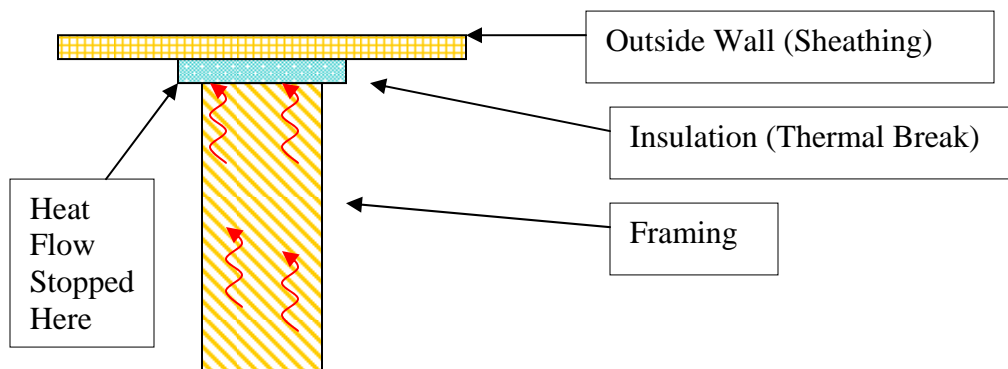
#### "R" Values of various materials

<u>Item</u>	<u>"R" Value</u>
Solid Wood 1"	1
Hollow Concrete Block	2.05
w/1" styro	7.05
w/2" styro	12.05
w/3" styro	17.05
2x4 wall w/fiberglass batt	12
2x6 wall w/fiberglass batt	19
2x8 wall w/fiberglass batt	27
Attic w/10" fiberglass batt	30
Attic w/8.5" cellulose	30
Attic w/12.5" fiberglass batt	38
Attic w/10.5" cellulose	38
Attic w/16" fiberglass batt	49
Attic w/13.5" cellulose	49
Single Pane Window	0.88
Double Pane Window	1.72
Triple Pane Low E, Inert Gas Window	4.35
Solid Wood Door	1.61
W/metal storm door	2.63
Metal Urethane Insulated Door w/ breaks	13.5

Here's the structure of a typical outside wall: (not to scale)



Wood has an average “R” value of 1 per inch, while fiberglass insulation is about 6 times greater. In a typical wall, 15-18% of its volume is solid wood, not insulation. There is also additional framing around windows and doors, adding more solid wood in these areas. To cut down on the heat conducting through this solid framework, a modern home incorporates “thermal breaks”. This is usually a part of the outer sheathing or can be insulation added between the framing and the outer wall.



While heat “conducts” evenly in all directions, more insulation is typically added to the ceiling, followed by the walls, and lastly, the floor. This recognizes the fact that “convection” tends to move heat upwards via “convection” (see next section) and that maximum temperature differences occur in above-ground surfaces exposed to air as opposed to the ground.

Insulation values can be determined by inspection if the areas are accessible (i.e. attic) or by an infrared camera that “sees” heat (infrared energy) leaking through. You want to have at least R30 in your attic and more is better. Visual clues can also tell you how well the insulation is doing. As an example, look at your roof on a frosty morning. It should be uniformly coated with frost. Any warm spots will melt off quickly; these should be noted for further investigation. Late in the season as snow builds up, these warm spots can

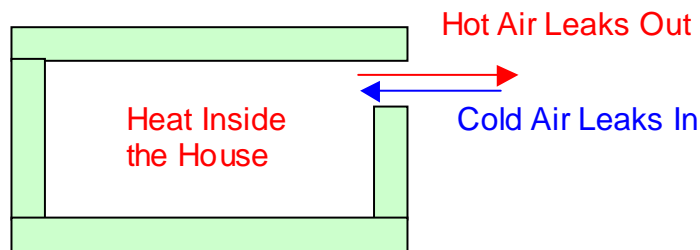
cause “ice dams”. Warm spots can also be caused by air leakage, which is discussed in the “Convection” section.

Inside the house, if parts of the wall are exposed, you can look at these directly to determine if insulation is sufficient. A common area that could be lacking insulation is the rim joist or the basement wall. You can feel along walls and ceilings with a bare hand to find cold spots. Occasionally warm up your hand to keep it sensitive. Frosted areas and resulting mold build-up on walls or ceilings may indicate a lack of insulation.

Exposed areas such as basement walls, rim joists, and attics can be insulated more easily. Finished areas, such as exterior walls and vaulted ceilings, are more expensive and difficult to add insulation. In most cases, upgrading insulation can be very expensive, but can result in significant savings to your heating bills.

**CONVECTION** (*accounts for about 55% of heat lost in a typical house*)

This is a process of moving heat by a fluid. For a typical house, the “fluid” is cold air leaking in and warm air leaking out. Reducing air leakage can be the easiest and most cost-effective means of reducing heat loss in your home.



In the winter, outside air contains less moisture than inside air, so a good indicator of air leakage is the indoor humidity level. On an average, if your house cannot naturally maintain sufficient humidity in the winter, your house probably leaks in too much cold, dry air. A humidity gauge is a good investment to help you to measure moisture levels.

**Recommended Humidity Levels**

Outdoor Temperature	Maximum Indoor Relative Humidity
-20 or below	15 percent
-20 to -10	20 percent
-10 to 0	25 percent
0 to 10	30 percent
10 to 20	35 percent
20 to 30	40 percent

A professional can measure air leakage by a device called a “Blower Door”. It allows you to pressurize or depressurize your house, precisely measure air leakage by gauges, and pinpoint these leaks with a smoke generator so repairs can be made.

You can also find air leaks on your own. On a windy day, just feel along the wall, windows, doors and other likely penetrations towards the direction of the wind. Drafts indicate air leakage. You can also use a source of smoke (i.e. incense, match) to see where the air is coming in. Mark these spots for repairs later.

You can also check for air leaks on a calm day. Block OFF as many obvious air intake sources as you can, including fireplace dampers, and furnace chimneys. CAUTION: shut off gas vented appliances first! Then turn ON as many exhaust fans as you can, including the clothes dryer (on a cold temp setting) to depressurize your house. Now, dampen the back of your hand and hold it up to obvious sources of air leaks, such as doors, windows, attic hatch and penetrations such as electrical boxes. Any incoming air will quickly cool off your hand, making these leaks easy to pinpoint. Mark these spots for later correction.

As mentioned before, warm air tends to rise. This can leak into the attic, melting the snow on the roof and causing ice dams. During the winter, the freeze/thaw cycle can force water under the shingles, ruining your roof, ceiling, and even the walls of your house. You'll want to find the source of warm air and fix it as soon as you can. Attic hatches can be a common source of air leakage in the ceiling so proper insulation and weather stripping is critical around it.

You should also examine any vents or dampers for proper operation. A clothes dryer vent can easily plug up with lint, preventing the damper from closing and allowing precious warm air to leak out (and critters to come in). Don't forget the vents for exhaust fans, too.

You can find an excellent selection of products designed to reduce air leakage at your favorite home improvement store. These include caulking, window film, weather stripping and gaskets. Under \$10 worth of products could save an average house \$25 - \$50 in heat. Stopping up air leaks is the most cost effective energy saving upgrade.

On the other hand, modern houses can be built so tight that they require mechanical ventilation to bring in sufficient fresh air, and to exhaust moisture and other indoor pollutants. Humidity levels over 40%, frost on the windows and a noticeable musty odor when entering from the outside may indicate your newer house needs more fresh air.

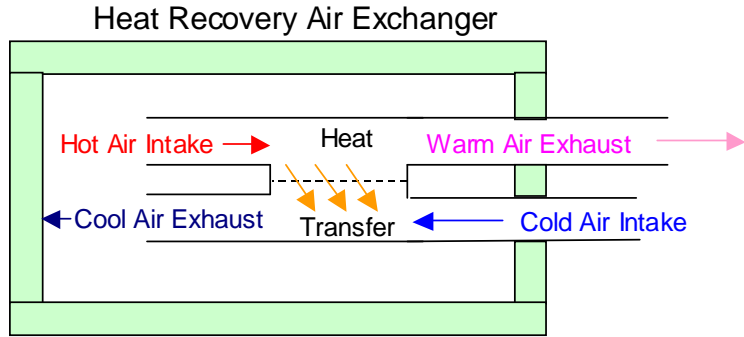
#### **ASHRAE standards for Residential Ventilation**

Minimum of .35 air changes /hour

-and-

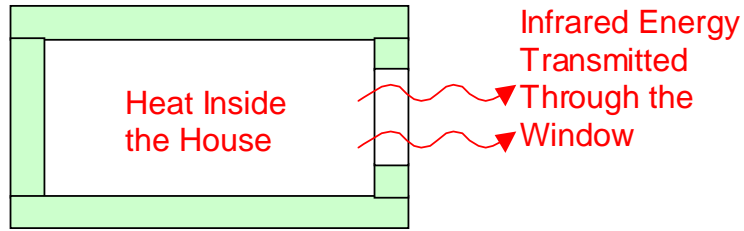
At least 15 CFM (cubic feet per minute) for each person

A heat-recovery ventilator is a typical solution to poor ventilation. It is designed to bring in fresh, outside air, while exhausting stale, inside air. During this process, heat is extracted from the exhausted air, saving some of the energy needed to condition the incoming air. This process also works in warmer weather, recovering energy from the cooler, conditioned air inside your house.

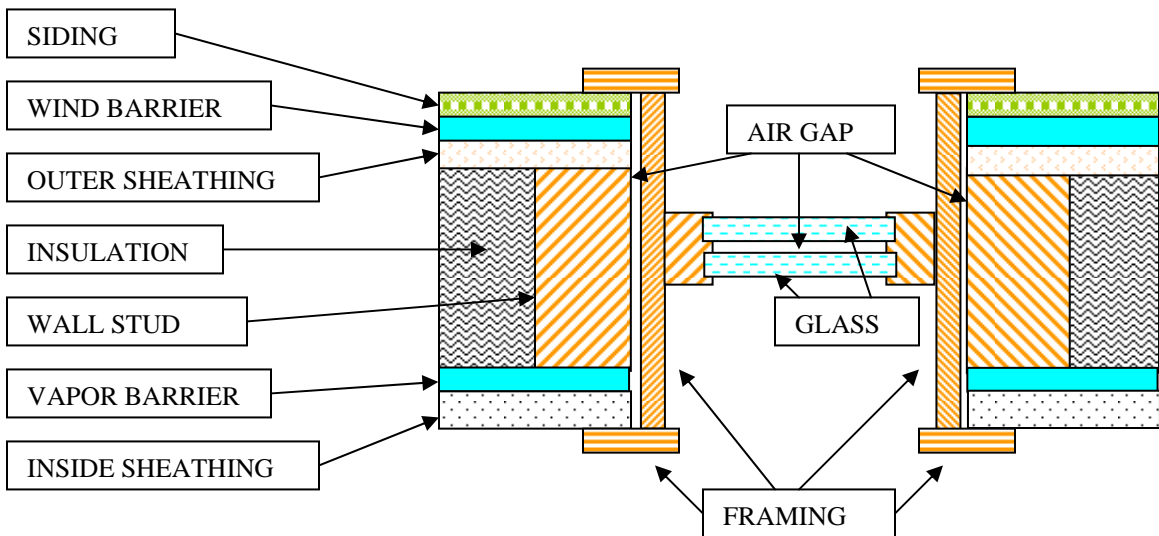


**RADIATION** (accounts for about 7% of heat lost in a typical house)

This is heat (infrared) energy transmitted in straight lines through space. Here's a common example: When you sit by a campfire, the side of your body towards the fire gets warm, while your other side does not. Likewise, if you are sitting close to a window on a cold night, you may feel the side towards the window getting cold, while your other side is still comfortable.



Windows can be a significant source of radiated energy losses. You can reduce these losses by window coverings, installing low "E" (emissive) windows or eliminating the window altogether. Here's a diagram of a typical window (not to scale):



Heat moves through windows by conduction, convection and radiation. Just like a solid wall, heat will conduct through the glass and the framing surrounding a window. Air will leak around the gaps between the framing, which can be a significant part of the entire air leakage of the house. Finally, radiation losses through the glass can be sizable if there is a lot of glass area.

### “R” Values of various windows

<u>Item</u>	<u>“R” Value</u>
Single Pane Window	0.88
Double Pane Window	1.72
Triple Pane Low E, Inert Gas Window	4.35

But, Windows are not all bad and can add a lot of value of your home. They let in a view of the outdoors, add natural light and warmth during the day, and can be a major design element for your home. A more energy efficient window may cost more up-front, but will payback this difference many times during its lifespan in reduced energy costs.

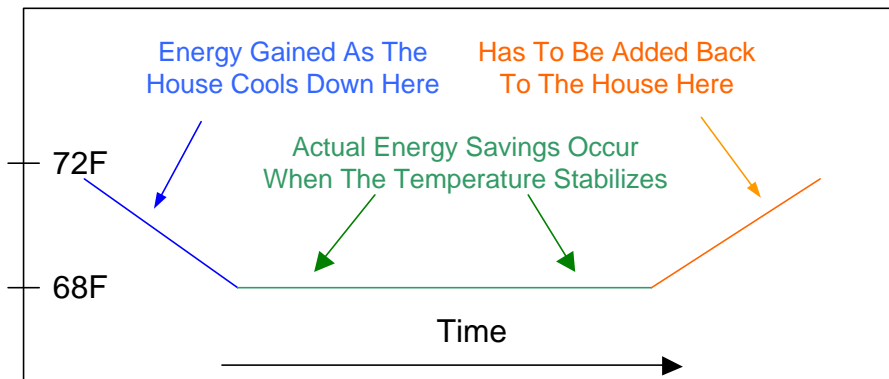
## IV. OTHER STRATEGIES TO REDUCE HEAT LOSS IN YOUR HOUSE

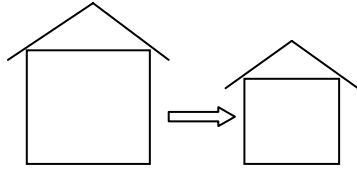
### Control Inside Temperatures

Heat flow is directly proportional to the difference in temperature between the inside and outside. While you can't control the *outside* temperature, you can control what happens *inside*. By setting your thermostat at a lower temperature, you can reduce heat loss, resulting in significant energy savings. U.S. Department of Energy estimates an average 1% energy savings for every degree you can lower your thermostat.

Rather than maintaining a constant, lower temperature all the time, you can also lower the temperature only when you leave home or at night when sleeping, and bring it back up as needed. Programmable Setback Thermostats are designed to adjust these temperatures for you automatically.

The best energy savings come from setbacks that are at least 8 hrs or more. Here's why: It could take 1 or more hours for house to cool down and a similar time for it to fully warm back up. The heat you “gain” during the cool-down time will have to be “added back” when you raise the temperature later that day. Energy savings only occur when the house stabilizes at a lower temperature. This graph shows how this works:





### **Heat A Smaller House.**

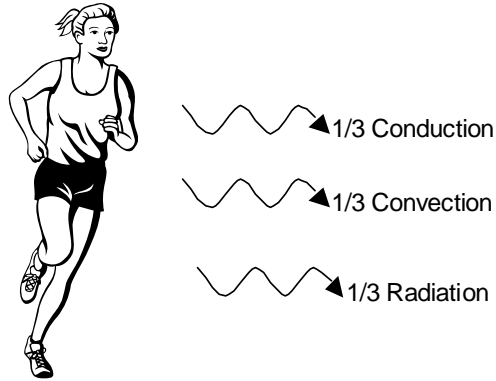
With everything else being equal, a small house will require less heat than a larger house. You probably won't be remodeling your existing house to decrease its size, nor will you likely be moving into a smaller house anytime soon. However, you may be able to effectively change the size of the heated space of your house by closing off areas that are not used in colder temps. Be sure to close off heating runs into these areas and block off airflow around doors and other openings. If heating runs go through these spaces to other parts of your house, you should insulate them; otherwise they'll still lose some heat to the space. If there is plumbing pipes in these areas, be careful they don't freeze.

**CAUTION:** If you block off too many air vents, this could interfere with the operation of your forced air furnace. A heating technician should be able to help you with this.

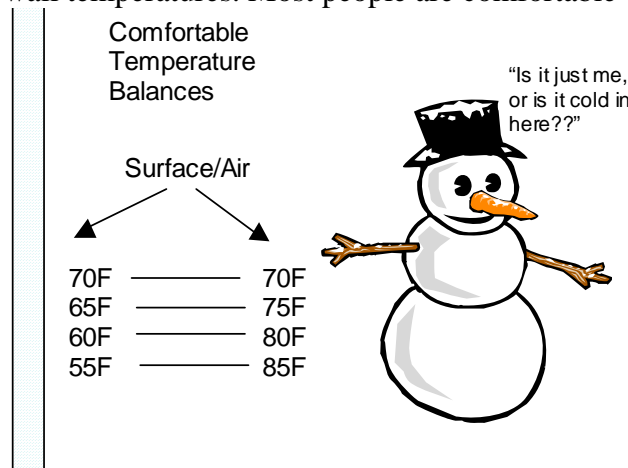
## V. "HUMAN FACTORS"

Up to now, we have been considering heating/cooling requirements of your home assuming it is an empty box. However, your house and its heating/cooling systems exist to serve the needs of its occupants. Humans have their particular quirks in respect to these needs.

- Here's how heat flows from a typical human body:



- This differs from how "measured" heat typically moves out of the house, namely 38% conduction, 55% convection, and 7% radiation. The body "feels" radiated heat loss is as significant as convection, which is contrary to our measurements.
- Knowing how heat flows from a human body is important in understanding "Temperature Balance". This is the ratio between air temperature and the surrounding wall temperatures. Most people are comfortable with these ratios:



- In other words, if the surrounding surfaces are colder, the air temperature has to be higher to compensate. Here's an example; in a basement with a 55 degree wall surface temperature, the air temperature would have to be set at 85 degrees to "feel" as comfortable as a balanced 70/70 degree room upstairs. This points out the importance of adequate wall insulation to both reduce heat loss and to allow for a lower temperature setting.
- Here's some average values where most people are comfortable:
  - ✓ Humidity range from 40-50%
  - ✓ Temperature range from 68-72F
  - ✓ Air movement below 10 mph

- Each person is a little different
  - ✓ Some people may be comfortable outside these ranges
  - ✓ This can be a source of friction with other occupants
- Dress for the season
  - ✓ The human body can tolerate a wide range of conditions with appropriate equipment (clothing)
  - ✓ In the winter, it is normal to wear more clothing to retain body heat. This allows for lower room temperatures.
  - ✓ Summertime clothing allows a higher room temperature with acceptable comfort.
  - ✓ If people don't dress appropriate for the season (i.e. wear sweaters in the summer), then heating/cooling requirements in the house may have to be adjusted. This can waste a great deal of energy.
- People add moisture and heat
  - ✓ In an office setting, each person adds about 550 BTU's/hr. Different sized people and different activity levels will affect this (i.e. dance hall).
  - ✓ Occupants also add moisture through their breath and skin.
  - ✓ If the relative humidity of the air is too low (less than 40%), then excessive moisture can be lost through the skin, creating a cooling effect. Interior temperatures may have to be higher to maintain comfort.
- "Windchill"
  - ✓ Air movement past the skin will help to strip away heat and moisture. This is useful in warm temperatures to cool you down. In the winter, noticeable air movement creates a cooler feeling, even if the air temperature is at normal levels.
- Habits
  - ✓ We can affect comfort and energy usage by how we use our home and its systems. Examples would include:
    - Sleeping with a window open for "fresh air" even during extremes in temperature.
    - Frequent fiddling with the thermostat, causing wide temperature swings and wasting energy
    - Excessive use of a dehumidifier, even when humidity levels are already low or are being controlled by the air conditioner

## VI. SUMMARY

Managing the heat loss and gain in your home is dependant upon these factors:

1. Size of the Building
2. Difference Between Interior and Exterior Temperatures
3. How the Building is Constructed
  - Insulation (conduction)
  - Air Leakage (convection)
  - Windows (radiation)
4. The Needs of the Occupants

## VI. HEATING TERMS

BTU (British Thermal Unit) = heat to raise 1lb water 1 degree F, 8.4 lb/gallon water

Electricity 1,000 watts = 3,412 Btu's

Natural Gas 1 therm = 100,000 Btu's

Propane 1 gallon = 95,000 Btu's

Fuel Oil (#2) 1 gallon = 138,000 Btu's

Wood (air dried seasoned) Btu's/cord

Rock Elm 32,000,000

White Oak 30,600,000

Sugar Maple 29,000,000

Yellow Birch 26,200,000

White Ash 25,000,000

White Spruce 16,200,000

Corn #2 Yellow 7,000 Btu's/lb @ 15% moisture, 56 lb/bushel

An Average Person adds 550 Btu/hr to interior space (office setting)

### Electricity:

Volts x amps = watts (also) watts/volts = amps

1000 watts = 1 kilowatt

1000 watts used in 1 hour = 1 kilowatt hour (kWh)

To fuse heating circuits, usually derate by 80% from calculated load.

1500 watt electric heater / 120 volts = 12.5 amps / 80% = 15.6 amp fuse

### Information Sources:

MN Dept of Public Service at: <http://www.state.mn.us/cgi-bin/portal/mn/jsp/content.do?subchannel=-536881511&id=-536881350&agency=Commerce>

Department of Energy at: [www.energy.gov/house/index.html](http://www.energy.gov/house/index.html)

Minnesota State Board of Electricity at: [www.electricity.state.mn.us/](http://www.electricity.state.mn.us/)

Builders Association of Minnesota at : <http://www.bamn.org/>

### Financing:

Many banks offer energy efficient mortgages, with reduced financing rates for houses meeting certain efficiency standards. Homes built to meet or exceed Minnesota's current energy code may qualify. Your lending agency will have details on this program.

Sometimes 3<sup>rd</sup> party certification is required. You can get more information at:

[www.natresnet.org](http://www.natresnet.org) Residential Energy Services Network

[www.fanniemae.com](http://www.fanniemae.com) Fannie Mae @ 1-800-732-6643

[www.hud.gov](http://www.hud.gov) Department of Housing and Urban Development

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