Energy Efficiency

INTRODUCTION TO ENERGY CONSERVATION

In recent years, some dramatic changes have occurred in the areas of construction pertaining to the “energy performance” of the home. Home builders have responded to energy cost increases and unpredictable sources of energy by building homes that consume less energy than their standard predecessors.

Housing constructed without regard to energy efficiency will subject their owners not only to current high energy costs but to possible supply problems and even greater prices increases well into the next century. The construction of houses that consume less energy makes good long-term sense.

Energy efficient houses make up an increasing portion of new housing starts. The construction industry has developed the R-2000 standard for energy efficient housing. That standard, in general terms, dictates that an energy efficient house has high levels of insulation and incorporates airtight construction methods. It has controlled ventilation and an efficient heating system. The house is designed to optimize passive solar gain by relocating windows wherever possible to a southern exposure. An energy efficient house should probably use between 40 and 80 per cent less energy for space heating than a house built prior to 1980.

A house uses and loses energy in different ways, therefore, no single item will, by itself, save a lot of energy (such as a heavily insulated attic).

An energy efficient home can be very unforgiving....when certain principles are not followed, problems are likely to result. A common misconception is that the various energy conservation features available can be treated as a list of options where one or more can be picked out and incorporated into the home. In most cases, this is a hit and miss situation. Sometimes the selection proves suitable; in another situation the energy performance of the home may not come close to expectations; and in some cases unforeseen problems can arise.

A designer must select features that work together. The home needs to be treated as a system where each conservation feature has its own subtle interaction with all others....some sort of balance between these features must be sought. A careful design combined with careful construction and high quality workmanship is essential for an energy efficient home to perform properly.

With an understanding and proper use of this system approach, you are sure to obtain maximum benefit from the conservation measures used.

BENEFITS OF ENERGY EFFICIENT CONSTRUCTION

A question you might want to ask yourself is....should I consider an energy efficient home?

An energy efficient house offers many advantages. Drafts are eliminated, heat distribution throughout the house is more even, and it will feel warmer at lower thermostat settings. In the winter, humidity levels can be controlled, which allows for more comfort. Noise levels from external sources are considerably reduced and the house will be less dusty than a standard house. The house will also be cooler in the summer. Of course, fuel consumption will be much lower and the house is likely to maintain a good resale value.

The major drawback is that an energy efficient home is going to cost more initially. Usually the extra cost is in the range of an added 5% to 15% in construction costs. Savings in energy costs may eventually pay for that extra initial expenditure. The period of time that it takes to recover your extra costs through fuel savings is called the payback period. The payback period will be different for every house that is built. Home owner energy habits, the price (or rising price) of energy, the climate, the extra initial costs, the quality of the design, and the quality of construction all have an effect on the length of the payback period.

The extra cost in new construction to achieve energy efficiency is normally much less than the cost of upgrading a house years after its construction. It may be sensible to avoid additional extra expense by building an efficient house in the first place.

It is anyone's guess at this time as to what future energy costs are going to be. Whether the price goes up or not, the fact remains that if you use less energy, it is going to cost you less to heat your home.

HEAT LOSS AND HEAT GAIN

When dealing with the energy requirements of a home there are two major areas of concern - heat loss and heat gain.

HEAT LOSS

This is heat that is lost through the building envelope. Total heat loss has to be counteracted by an equal amount of heat gain in order to maintain the desired interior temperature. This heat loss can be attributed to three things: conduction, convection, and radiation.

Conduction is the process of the heat being transferred directly through a substance from a warm region to a cooler one. This process occurs through all areas of the building envelope (walls, ceiling, basement, doors, and windows) as long as there is a temperature differential between the outdoor and indoor environments.

Convection is the transfer of heat from one region to another by air circulation. Heat loss through air leakage can occur wherever there is a path that air can follow through the building envelope. Convection will cause warm air to be exhausted from the home (air exfiltration) and replaced with cold outdoor air drawn into the home (air infiltration).

Radiation is the transfer of heat in the same way that the sun radiates heat. In an uninsulated wall space, a warm inside wall would radiate heat across the uninsulated space to the cold outer wall.

HEAT GAIN

This is the heat that is introduced to the interior of the home. This heat gain can be classified as either incidental heat gain or intentional heat gain.

Incidental heat gain is a heat by-product from sources not primarily intended to supply heat, such as electrical appliances and fixtures (lights, stove, oven, etc.), the occupants of the home, and by sunlight (passive solar).

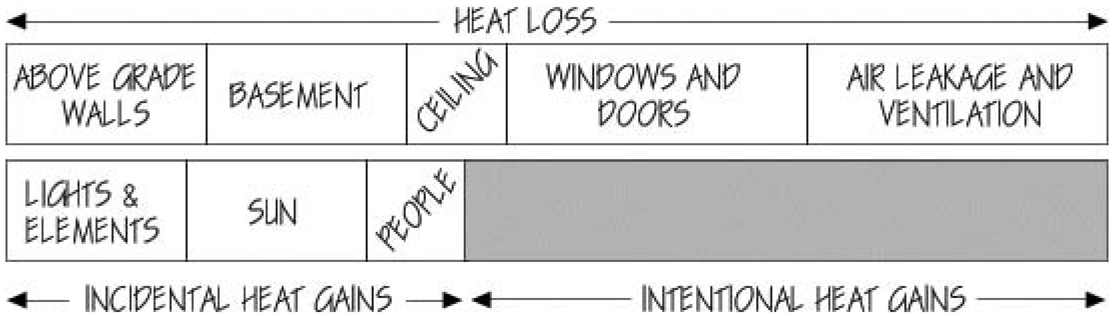
Intentional heat gain is the heat added by some type of system designed specifically for the purpose of heating the home. This heating system must have the capacity to make up the difference between the sum of the heat loss and what the incidental gains supply.

OBJECTIVE OF ENERGY EFFICIENCY

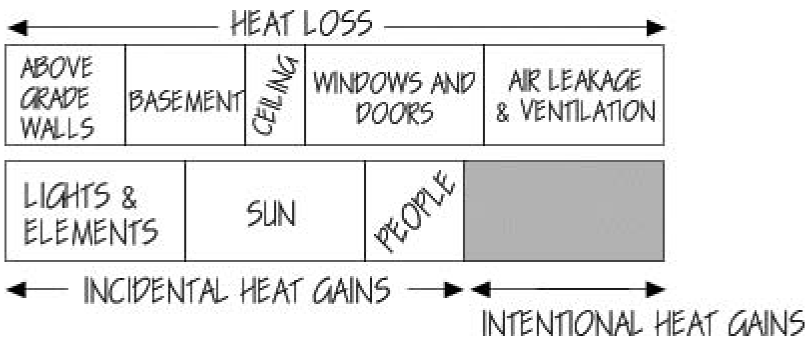
The overall objective of energy efficiency is to minimize the areas of heat loss in order to obtain the maximum benefit of the incidental (free) heat gains.

Heat loss can be reduced to such a low level that most of the heating requirements will be satisfied by incidental heat gain. This means that the demand for intentional heat gain, (that supplied by the heating system) will be very small. For this reason, the main focus in energy efficient construction is on the “loss” side of the energy equation, while modest efforts are made on the “gain” side, mainly through passive solar gain.

Conventional Home



Energy Efficient Home



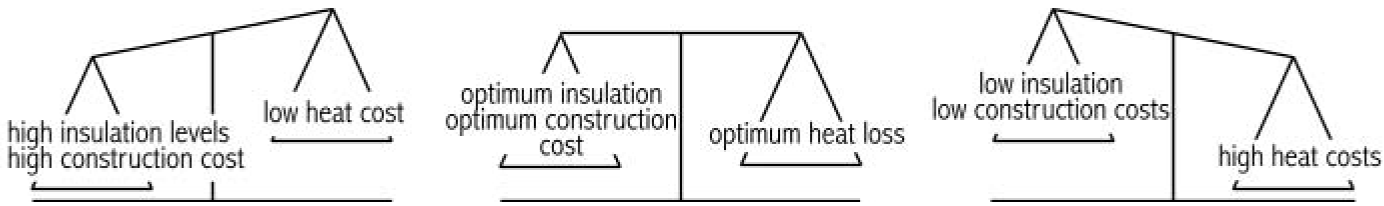
PRINCIPLES OF ENERGY EFFICIENCY

There are a number of basic principles included in the concept of Energy Efficiency. Each of these principles deals with either minimizing the heat loss of the home or maximizing its heat gain. In order to obtain full benefits when applying these principles, a high standard of workmanship and quality materials are necessary.

INSULATION LEVELS

The first thing that pops into most people's minds when the term energy efficiency arises is insulation, insulation, and more insulation. Insulation is an important principle of energy efficiency, however, it is only one of a number of interrelated principles, none of which stand alone.

Insulation retards the flow of heat. No amount of insulation can completely stop the transfer of heat, so the point in question is...what is the optimum insulation level required to get the best return from your investment? If you don't use enough, it will allow too much heat loss and your heating bills will be a monthly reminder of this fact. If you use large quantities, your construction and labour costs will be greatly inflated and you may never recover your investment through energy savings. The optimum level of insulation is achieved by finding the best balance between the cost of providing for a certain level of insulation and the energy savings you can expect to realize as a result.



A material's effectiveness as insulation can be determined by its R-value. R-value is the degree of resistance to heat loss. As an insulation's R-value increases so does its resistance to heat loss and effectiveness as an insulation. The metric equivalent to the R-value is the RSI value. For conversion purposes R-1 is equal to RSI .1761.

Before trying to determine your optimum level of insulation it is important to understand the "law of diminishing returns": as you add greater and greater quantities of insulation, the difference of the increase in energy savings becomes less and less.

An example of a hypothetical situation should serve to illustrate this law.

Problem: - existing attic which has R-l insulation
- current heat loss is through the ceiling is $500 per year
- each additional R-l costs $20

Insulation Level	Heat Loss per Year	Cost of Adding Insulation	Savings per Year	Payback Years
R-1	$500.00	--	--	--
R-1 to R-2	$250.00	$20	$250.00	.08
R-2 to R-4	$125.00	$40	$125.00	.32
R-4 to R-8	$62.50	$80	$62.50	1.28
R-8 to R-16	$31.25	$160	$31.25	5.12
R-16 to R-32	$15.62	$320	$15.62	20.50
R-32 to R-64	$7.81	$640	$7.81	81.90
R-64 to R-128	$3.90	$1280	$3.90	328.00
R-1 to R-128	$3.90	$2560	$496.10	5.16
R-1 to R-32	$15.62	$620	$484.38	1.28
R-32 to R-128	$3.90	$1920	$11.72	164.00

From this example we can learn a number of things. First, we can see that "pay-back" means the period of time it takes to recover your investment through energy savings. Dividing the cost of upgrading by the yearly savings determines the payback time in years.

For example, we see from this exercise that when upgrading from R-2 to R-4 it costs $40 to save $125 per year.

$$\frac{\text{Cost of Upgrade}}{\text{Savings Per Year}} = \text{Payback Years}$$

$$\frac{\$40}{\$125 \text{ per year}} = .32 \text{ years}$$

In this case it would take approximately four months (.32 years) to recover your investment through energy savings. This method is what is called "simple pay-back" and doesn't take into account the effects of projected fuel increases or earned interest on money saved or invested.

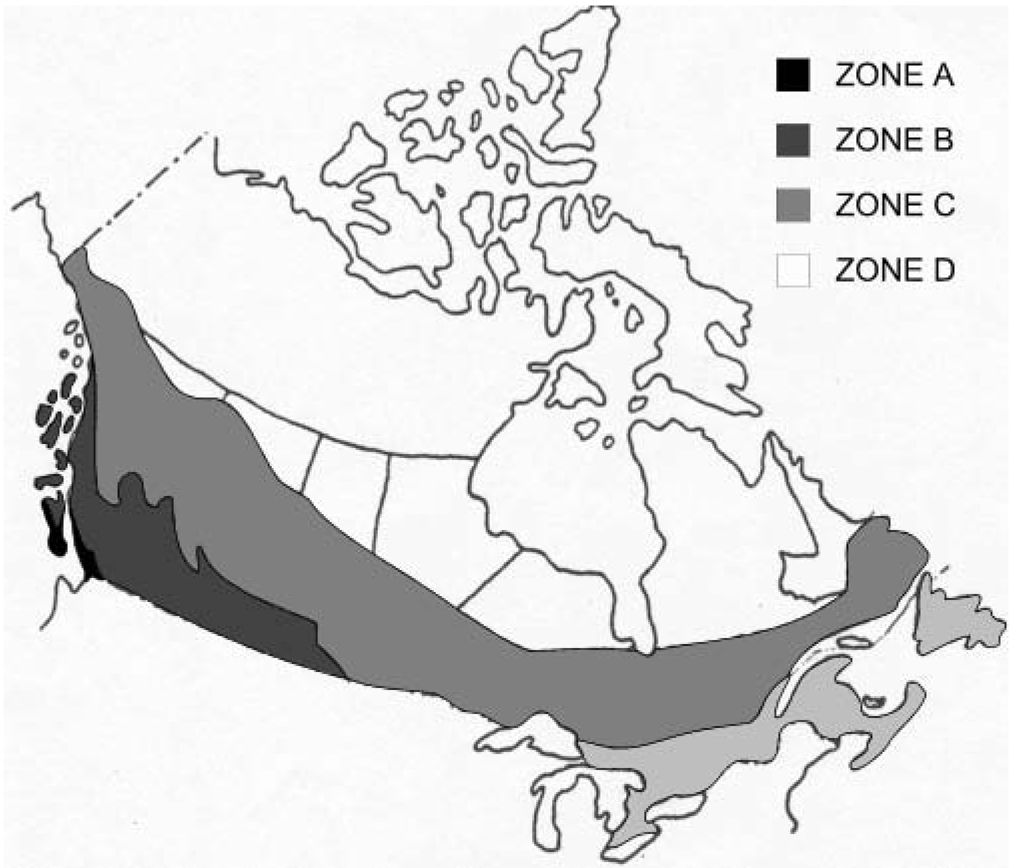
Another trend that can be observed from this problem is that as you continue to increase the level of insulation, the cost of adding that insulation escalates quite rapidly, as does the payback period. The reason for this is that as optimum insulation levels are reached, a high percentage of the heat loss has already been eliminated and any efforts at adding more insulation will make even smaller differences in the yearly savings. This is what is meant by "the law of diminishing returns".

There are too many variables to determine exactly what the optimum levels of insulation are. Even if they could be determined they would change whenever the cost of heating fuel changes.

The "Recommended Minimum Levels of Insulation"* are often used to gauge how much insulation to use. It should be emphasized that these are minimum recommended levels and will rise as heating costs increase, so whenever possible try to exceed these minimum recommended levels.

*From "Keeping the Heat In", Energy, Mines, and Resources, Canada, April, 1983 Edition

Zone A - up to 3, 500 C degree days.
Zone B - up to 5, 000 C degree days.
Zone C - up to 6, 500 C degree days.
Zone D - up to 8, 000 C degree days and over.



Note: Each zone on the map represents an area which experiences a similar number of degree days. This is simply a relative measure of how cold an area is. Degree days are calculated by subtracting the average temperature each day of the year from a base temperature (65(F or 18(C).

Recommended Minimum Insulation Levels (in R-Values)

	ZONE			
Part of House	**A**	B	**C**	D
Walls	**R-14**	R-17	**R-20**	R-21
Basements	**R-12**	R-12	**R-12**	R-12
Roof or Ceiling	**R-30**	R-32	**R-36**	R-40
Floor (over	**R-28**	R-28	**R-28**	R-28

It is also important to maintain the insulation levels you choose throughout all areas of the building envelope whenever possible. In conventional construction, certain areas in particular are often neglected or dealt with inadequately. Some of these problem areas are the floor joist perimeter, headers over windows, cantilevers overhangs and roof/wall connections.

There are also other factors which can reduce the rated R-value of the system:

- compression of insulation
- thermal transmission through framing members
- loose fitting insulation
- damp insulation
- air currents through the insulation

To maintain your optimum insulation level, these problem areas and R-value reducing factors need to be dealt with or compensated for. The means of doing so will be dealt with later on in the building envelope section.

AIRTIGHTNESS

Airtightness is one of the most important features of an energy efficient house. An airtight house keeps the warm air inside and the cold air outside. Airtightness is usually achieved by installing a continuous air-vapour barrier on the warm side of the insulation. A continuous air-vapour barrier ideally should have all joints and penetrations sealed in order to provide a completely airtight “balloon”. TYVEK is the most common brand of exterior wrap.

Recently, products to wrap the exterior of the structure have been developed which stop airflow while allowing trapped water vapour to escape from wall cavities. These products can be used with good effect along with the interior air-vapour barrier, to produce an airtight, draft free dwelling.

Airtightness of the home is important for three reasons:

a) **Protection from moisture damage for the insulation and the structure**

When moist warm inside air passes through an outside wall it leaves much of the moisture it contains within the wall cavity in the form of condensation or frost. This reduces the effectiveness of the insulation and can lead to wood rot. A continuous air-vapour barrier prevents moist indoor air from entering the wall cavity and keeps both insulation and structural members dry.

b) Lower heating costs

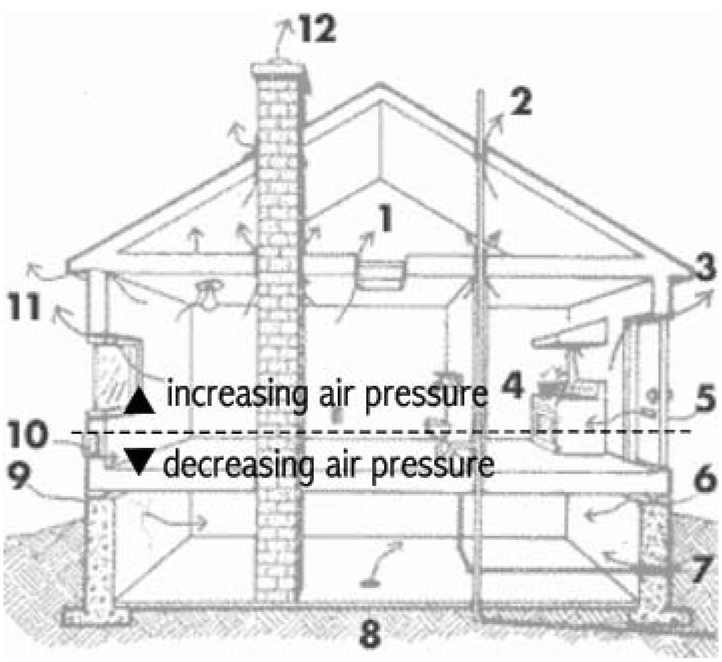
Air leakage can account for up to 40% of the heat loss in a conventional home. A continuous air-vapour barrier of some type will greatly reduce the heat lost through air infiltration and air exfiltration.

c) Comfort

Drafts are eliminated in airtight homes.

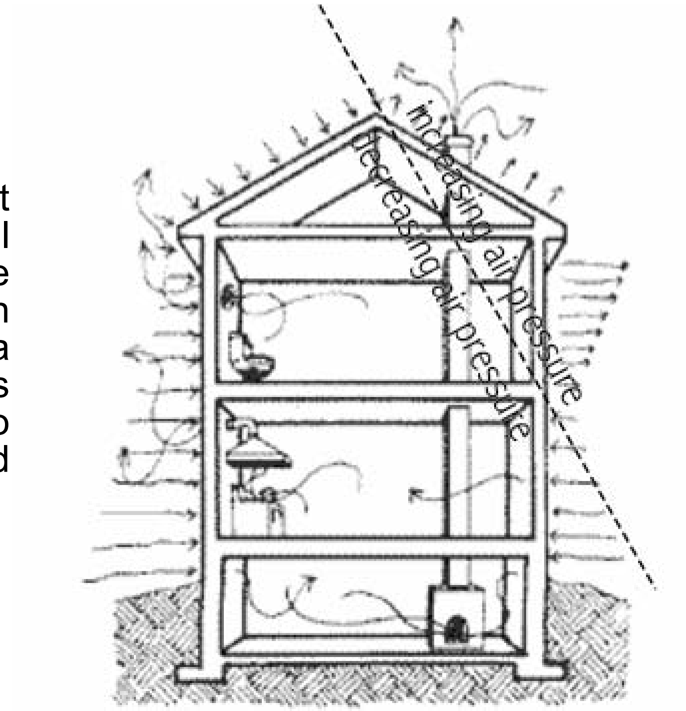
There are many potential air leakage points in the home, but with the proper construction techniques and the proper application of a continuous air-vapour barrier these leaks can he eliminated or greatly reduced.

Air leakage occurs when there is different pressure between the inside and the outside of the home. This differential is usually caused by a combination of wind and what is called the stack effect. The stack effect is caused by warm air rising in the interior of the home, creating a positive pressure in the upper portion of the home and a negative pressure in the lower portion. This tends to force the air out of the home above the neutral pressure plane and draw the air in below the neutral pressure plane.



1) attic hatch
2) ceiling penetrations into attic
3) doors
4) exhaust vents
5) mail slot
6) sill and header
7) service entries
8) floor drain
9) foundation cracks
10) electrical outlets
11) windows
12) chimney

When wind strikes a wall of a home it creates a positive pressure on that wall and a negative pressure on the opposite wall. Cold air will seek a path in through one wall and warm interior air will seek a path out the opposite wall. In effect this will cause the neutral pressure plane to tilt in order to compensate for the wind pressure.



Airtight Construction

There are a variety of techniques that may be used to achieve an airtight home. They all begin with a high quality of workmanship and include carefully chosen materials combined with proper construction details. The main objective is to provide the greatest degree of airtightness possible. These techniques will be dealt with in the building envelope section. (See Section 7)

CONTROLLED AIR MANAGEMENT

In older houses, more than enough fresh air and ventilation is supplied by uncontrolled infiltration and exfiltration of air through the building envelope. In an airtight house, the correct amount of air needed to maintain a pleasant, healthy indoor environment must be supplied by controlled ventilation. The airtightness is what allows the ventilation to be controlled. Although even a small airtight house contains enough oxygen for several days of occupancy, humidity levels and other contaminants build up and must be removed and replaced by fresh air. Fresh air is required for combustion equipment such as gas or oil furnaces, fireplaces, clothes dryers, and wood stoves.

The amount of air that must be supplied to the house depends on the tightness of the house, its size, the type of appliances it contains and on the lifestyle and individual preferences of the occupants.

Problems that can occur in a home that is too airtight are:

a) Excess Humidity

In an airtight house, the water vapour produced by showers, cooking, people, animals, and plants cannot escape. When the humidity levels are high, condensation forms on the coldest surface available, normally the window glass. If left uncorrected, the combination of condensation and humidity will result in the growth of mildew and wood rot, usually first seen around the window.

b) Odours

Without ventilation, an airtight house becomes stuffy and odours linger.

c) Indoor Contaminants

Carbon dioxide from people and combustion equipment, formaldehyde from building materials, gasses from aerosols, waxes, polishes, cleaners, paint, radon from subsoils, and nitrogen dioxide from smokers and gas ranges build up in an unventilated house.

The simple solution to these problems is to provide a sufficient amount of ventilation to remove these pollutants to the outdoors.

It is generally accepted that an air change rate of .5 air changes per hour (ACH) is the minimum level of ventilation that should be supplied to provide sufficient ventilation. The air change rate is simply the number of times per hour that the volume of indoor air is replaced by incoming outdoor air. Most conventional homes have an ACH ranging from 2 ACH to 5 ACH which is more than sufficient for ventilation: it is also a significant source of heat loss. Many energy efficient homes being built today can have air change rates, in the area of .10 ACH, much less than the recommended minimum. With homes this “airtight” some provision for supplementary ventilation must be provided.

There are three possible methods of providing this ventilation

a) Operable Windows

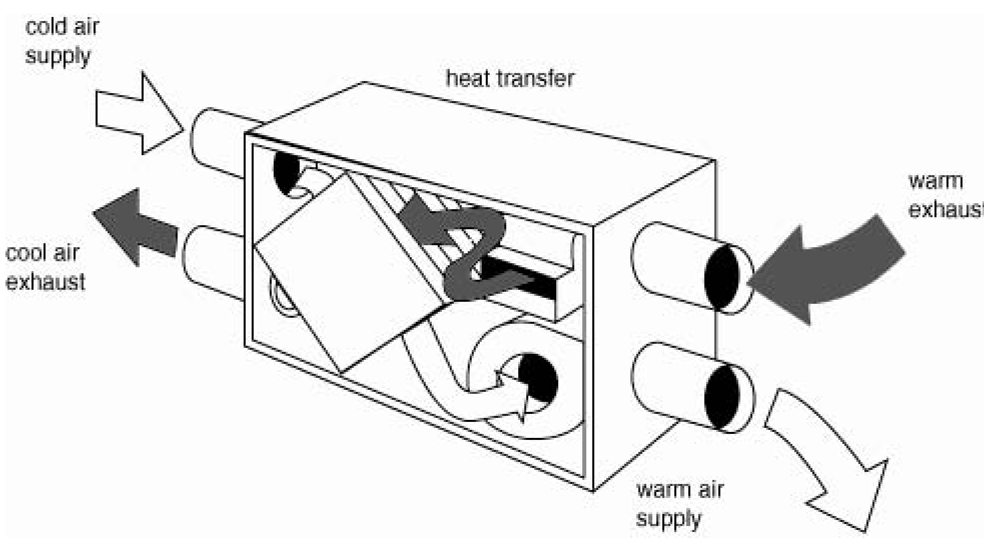
This is the simplest and, in the summer months, the most important method of providing ventilation and fresh air. Although windows will be used occasionally for ventilation during the heating season, their use is restricted by comfort and energy considerations. Because windows are manually operated, they do not provide automatic control of fresh air and certainly should not be used to provide the continuous supply of fresh air required by an airtight house during the winter months. Also, the rate of ventilation cannot be properly regulated with just the use of operable windows.

b) Direct Mechanical Ventilation

Direct mechanical ventilation involves some type of an exhaust system to remove indoor air and an intake to bring in outdoor air. This can be accomplished by using standard bathroom and kitchen fans for exhaust in conjunction with a supply of air from the outside. Similarly, a central exhaust may be used to remove air from the bathroom and kitchen and to vent it outside through a single exhaust, with a fresh-air fan supplying air to the living space. Though direct ventilation is adequate for supplying a home's ventilation it is difficult to regulate and is no more energy efficient than opening a window.

c) Heat Recovery Ventilator

The most popular system today is the use of a heat recovery ventilator (HRV). This equipment is normally used in conjunction with a central ventilation system. It reclaims most of the heat exhausted from kitchens and bathrooms and uses it to heat the incoming fresh air. Most HRVs are automatically controlled by a humidistat.



DO YOU NEED AN HRV?

You may wish to determine the exact rate of air leakage by means of a depressurization test. Air is drawn out of the home with an exhaust fan and, by measuring the pressure difference between the interior and the exterior, the air change rate is determined. This “forced air change rate” is divided by 10 to give an approximate “actual air change rate”.

In most cases it shouldn’t be necessary to perform a depressurization test to determine if ventilation requirements are met as only the most tightly built homes are likely to require supplementary ventilation.

There are also some factors which make it difficult to predetermine whether or not supplementary ventilation will be required, such as size of the home, number of occupants, lifestyle, type of heating system, etc.

You may wish to do the rough-in and live in the home for a period of time to see if your situation requires supplementary ventilation.

PASSIVE SOLAR

The previous principles we have dealt with are concerned with minimizing heat loss. Passive solar deals with maximizing a heat gain .

Passive solar is the non-mechanical collection of solar energy accomplished with standard building elements, windows, walls, etc., as opposed to active solar, which is accomplished with specialized collectors in conjunction with pumps, blowers, and heat transfer fluids.

Passive solar heating is based on three main concepts:

a) Maximum admission of solar radiation during the winter months and exclusion during summer months.

b) Minimum heat loss during the winter.

c) Thermal mass for heat storage during the day and its release at night .

Passive solar can be incorporated into virtually any home design to some degree or another. Some of the features most commonly used to supplement passive solar heating are:

a) minimize exposed north wall and window areas; maximize exposed south wall and window areas

b) adjustable blinds or shutters to admit the sun during the day and reduce heat loss at night

c) overhangs that permit the winter sun to enter but block out summer sun .

HEATING SYSTEMS

As home heating fuel becomes increasingly more expensive, the efficient performance of your heating system is more important than ever before. To try and keep pace with rising fuel costs, technology is developing heating systems that burn fuel more efficiently. The purpose of a heating system is to convert fuel into usable heat. How effectively it does this is how efficient it is.

Steady state efficiency is the performance of a heating system that has been running long enough to allow all the furnace components to reach normal operating temperatures.

Seasonal efficiency is the measure of the performance of the heating system throughout all of the on and off cycles that take place during the heating season.

There are a number of factors you should consider when selecting your heating system:

a) Evaluate the House

Look at the other components in the home. An extremely heavily insulated, airtight home will likely have a very small demand for heating. If that is the case buying a highly efficient furnace may not be a good investment. The payback period would be quite lengthy because the furnace would not be used as often as it would in a less energy efficient home.

b) Proper Sizing

Heating systems in most homes today are vastly oversized. This can reduce the efficiency of a system considerably, as an oversized furnace will go through many more on and off cycles than a properly sized one. Most furnaces take up to eight minutes to warm up to their peak operating efficiency. The objective in sizing your furnace should be to size it as closely as possible to the heat loss of the home.

A properly sized furnace should run almost continuously on the coldest day of the year. Some new furnace designs actually run very efficiently under a light heating load. When building in areas where extremely low temperatures are encountered from time to time, these designs should be considered.

c) Compare Products and Prices

Heating system components are available in a wide range of prices, qualities and efficiencies. Try to determine what degree of quality or efficiency is right for you.

d) Compare Fuel Costs

Cost and availability of fuel can be a decisive factor in some locations. A comparison of local fuel costs may indicate which type of fuel you should consider using, and consequently, the type of heating equipment you install.

HOT WATER HEATERS

Older hot water heaters are very inefficient just by the nature of their design and use. Large quantities of water are kept hot continuously just for the few times during the day that some hot water is needed.

To obtain maximum efficiency, a modern, well insulated tank should be used. As well, an insulated heat trap on the hot water line leaving the water heater will prevent convection currents from hot water rising within the pipes. Unchecked, these currents allow constant cooling of the water.

Research has been done to improve efficiency of hot water heaters. Energy efficient condensing hot water heaters are now available. There are also in-line temperature boosters and instant water heaters available although they may not yet be cost effective.

ALTERNATE HEATING SYSTEMS

There are many alternate or supplemental heating systems available that have advantages in some situations.

Fireplaces are not efficient as a heating source but still may be chosen for their aesthetic value. Units which use outside air for combustion and have a tight fitting glass door over the fire box are the most efficient.

Woodstoves are much more efficient than fireplaces. There are many different types and models on the market and care should be used to select the one most suited to your needs. Proper sizing is critical, otherwise creosote build-up and chimney cleaning becomes a major concern.

Combination furnaces are furnaces that can use two or more sources of fuel. For example, one type is a wood-electric combination where an electric heat back-up may be used when wood is not available or during times of minimal heat requirements. These can be two in one furnace combinations or two separate units ducted together.

Active solar is available with the use of specialized collectors, pumps, fans and storage facilities. However, it has not yet reached the stage where it is cost effective, especially in Northern areas.

LIFESTYLE AND USER HABITS

The lifestyle and user habits of the occupants can have a considerable impact on the energy requirements of the home. It is quite conceivable that you could have two identical homes, side by side, with considerably differing heating requirements for no other reason than the differences in the lifestyles and habits of the occupants.

There are a number of lifestyle factors that can make a difference in a home's energy requirements.

- The size of the family can have a bearing on energy consumption. On the plus side, more occupants will add additional incidental heat gains, but on the negative side, exterior doors will open and close more often and more hot water heating is required for additional washing, bathing, etc. (The extra initial cost for an energy efficient water heater may be money well spent if you have a large family.)

- Temperature settings on thermostats and hot water tanks have a noticeable effect on energy consumption depending on how high or how low they are maintained. A good practise is to turn down the thermostat at night and when the home is not going to be occupied.

- Lack of proper maintenance to water heaters and furnaces will reduce their efficiency. Families who follow the regular maintenance, cleaning and filter replacement requirements will realize the maximum efficiencies.

- A family's habits can make a difference. Some people may like to have a window open continuously, run kitchen or bathroom exhaust fans for long periods of time, or take hour long hot showers. Each of these will add to a home's energy requirements.

THE HOUSE AS A SYSTEM

The main point to remember when planning an energy efficient home is “the system” approach. The principles we have covered are not options where one or two can be picked and the others can be ignored. Each principle needs to be taken into consideration and planned for as to how it will affect the other principles.

Only by the realization that all of these principles are interrelated and that a change to one will have an effect on all others can the full benefits of the house as a system be realized.