

# Building Systems and Maintenance

## Building Envelope Energy Saving Opportunities

- Install insulation to poorly insulated attics/roofs, ceiling, walls, floor (R20 in walls, R40 in ceilings).
- Install triple glazed, low emissivity window units with warm edge spacers when repairing frames.
- Install storm windows (either permanent ones, or only during the cold season for those windows opened regularly for ventilation during the summer).
- Reduce glass area (wall up/close off windows that are not efficient or effective).
- Install solar shading, such as blinds or curtains.
- Install reflective film on windows (contact window manufacturer/supplier first).
- Replace clear glass with reflective glass.
- Install airlocks, door vestibules.
- Wall up/close off unneeded openings such as unused doors.
- Reduce infiltration around doors, windows and through walls by caulking around doors, windows and exterior joints, and repair cracks in walls. Most buildings have cracks and leaks that are equal to a 2' x 2' open window. For large cracks without moving parts, such as in walls, floors or foundations, apply eco-friendly spray foam insulation.
- Add/repair the weather stripping around doors and windows; install plastic film over the interior of windows, especially those facing north and west;
- Use rotating doors. If there is a choice in your building, use rotating doors instead of standard hinged or sliding doors. They allow less heat to escape.
- Install air curtains on heavily used doors.

The amount of energy needed to heat and cool a building depends on two major factors:

1. The building envelope — roof, walls, windows and doors and the lowest floor of the building.
2. The installation and operation of the mechanical and electrical equipment.

The following section explains how the building envelope affects energy consumption.

## Components and Systems

The building envelope includes all the components that make up the shell of the building: the roof, walls, floors, windows and doors including basement walls, and seals and joints between different components. A central function of any building is to provide heated or cooled space away from the wind and the weather. The building envelope is what separates you from the external elements.

Each part of the building envelope has at least four basic systems. These are the systems that can be improved to reduce energy consumption. The four systems are as follows:

- air barrier system
- insulation
- cladding for walls and water management for roofs
- vapour retarder.

In many religious buildings it can be difficult or expensive to make improvements to the air barrier or insulation, particularly if you have to remove the interior finish or open an exterior wall to do it. If you have a bare concrete or poorly-insulated concrete block wall, adding insulation from the inside and a new interior finish can be cost effective and reduce energy consumption.

You should deal mainly with the first three systems to reduce energy consumption, although you will probably find it is easy to incorporate a vapour retarder, as we point out later in this section.

It is especially important to control air leakage because it affects the performance of the building in many different ways. For example, if you install extra insulation without first stopping all leaks, you will probably start or increase a problem of moisture accumulation in the walls and ceiling.

Adding insulation to a poorly insulated attic is usually cost effective but adding insulation to a flat roof should only be considered when it is time to replace or rebuild the roof.

### Air Barrier Systems

Uncontrolled air leakage through the building envelope is typically responsible for up to a third, or even more, of the total heat loss of smaller buildings such as detached houses.

Air leakage out of the building is called exfiltration and air leakage into the building is called infiltration, but the common term to describe both is simply infiltration. Air leakage can affect moisture accumulation in the walls and ceiling, and temperature control, which affects energy consumption, in the building.

Finding air leaks can be done yourself by noting the movement of the smoke trail of a lit incense stick on a windy day. Or it can be done by a professional energy auditor who will use a calibrated blower door test using a powerful fan mounted in a sealed doorway to reduce air pressure within the building.

Your building should have an air barrier system to reduce uncontrolled air leakage.

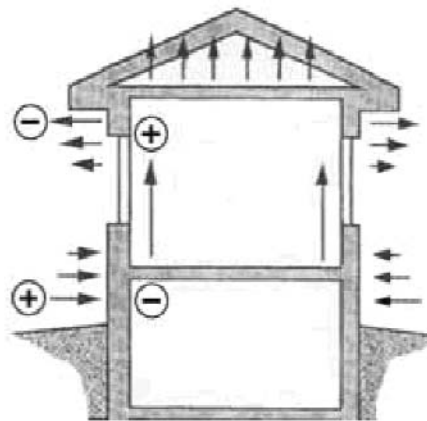
The air barrier system is a very important part of the building envelope, because heat loss due to air leakage is a high percentage of your energy dollars and moisture accumulation can lead to premature building failure. You should retrofit and maintain what you can of your air barrier system before tackling anything else.

### Materials to Use

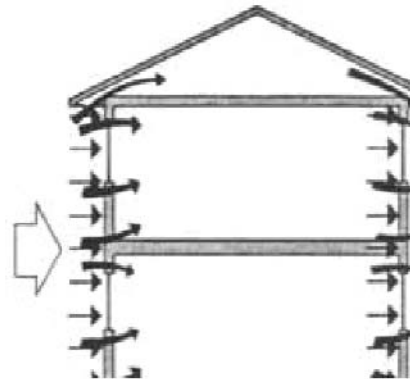
Strictly speaking, an “air barrier” is not something you can simply buy from a store and apply to a building. You have to build up an air barrier system during the construction or renovation of a building.

Many different materials in a building can be converted to become part of the air barrier system, as long as the materials are reasonably impermeable to air leakage. Drywall, plywood, concrete, and many common construction materials are relatively impermeable to air leakage.

Leaks can be sealed with tapes, caulking or gaskets, for instance, gaskets placed around electrical switches and outlets. You can now buy many different types of caulking that are suitable for a variety of purposes and types of building materials. Remember to ask if



Leakage in a building caused by the stack effect. Air is drawn into the bottom half of a building to replace air leaving through upper half.



Leakage through a building under the effect of wind. Leak develop at joints between components, through cracks in materials, and through openings such as electrical boxes.

the caulking will set up like rubber or a compressible gasket. You don't want to have the caulking still "liquid" when it's supposed to stay in place for a long time.

Materials like acoustic sealants are NOT good for this purpose because they don't set up and are very messy. Materials like Mono, silicones, polysulphide, and urethanes are better suited. Another question that should be asked is how the caulking stands up to cold and moisture. Do not use caulking that will quickly become brittle and crack or shrink, as it will lose its effectiveness. Make sure to use non-toxic sealants in sensitive areas such as kitchens.

### **Where to Seal**

Leaks occur at joints between components, cracks in materials, and openings such as electrical boxes. When you find a leak in a wall or ceiling you will probably find there are several layers of construction. At best only one of them will be completely sealed. This is the layer where you will have to seal the leak.

If you seal the wrong layer of construction you won't stop air leakage but only direct it through some other crack or opening. For example, if you find a leak at an electrical box in a building that was sealed using polyethylene, it may not do you any good to seal the drywall. Air will still leak through the poly and past another crack through the drywall, at the floor for instance. For some penetrations, the fixture penetrating the wall or ceiling may move in relation to the wall.

To fix a leak then, the first thing to do is figure out where the leak is best sealed. What else is making up the air barrier? What should you use to build up the air barrier?

Leakage through a building is affected by the wind. Leakage in a building can also be caused by the stack effect. Air is drawn into the bottom half of a building to replace air leaving

through the upper half. Unlike the wind, the stack effect is constant, slow and steady.

It may be possible to convert the building's interior finish to an air barrier that can easily be caulked and repaired. Pay special attention to the details of the building, such as corners and joints with the ceiling and floor or partitions, to make sure there are no leaks.

No matter what type of air barrier system you use, consider the following four important points before you start. The air barrier:

- should be continuous throughout the whole building
- must be fastened to the structure so it can resist high inward and outward wind loads. Deflection of poly between studs must be kept to a minimum to avoid tearing.
- should be in contact or sandwiched between solid materials on both faces to prevent movement and possible tearing. Poly located between drywall or sheathings and insulating batts or sheets may not be adequately protected.
- must have the same life expectancy as the building, or else you have to be able to maintain or repair it.

### **Mistakes to Avoid**

In recent years people have focused on "sealing the vapour barrier" when they really meant to "stop all leaks." This has worked for many cases, particularly wood frame buildings, but there are many situations where the vapour barrier has not remained sealed. The vapour barrier, or to give it its proper name the vapour retarder, may not be the best material to seal. It may not be strong enough to remain sealed after a wind storm, or it may not be possible to seal it around structural braces or metal ties in metal buildings.

Polyethylene, a common vapour retarder, can be used in wood frame buildings where it can be stapled and held between the interior and the insulation and studs.

For other types of construction it is best to use materials such as wallboard, plywood, metal liner panels, or reinforced membranes. There are now special membranes such as PermaBarrier by Grace, TFM by Tremco, and other manufacturer's products, which can be used to make a vapour barrier system for many types of buildings.

Other areas where air sealing should be considered:

- Outlets: electrical gaskets and taping can prevent heat loss through outlets.
- Ducts: in commercial buildings, it is estimated that up to 40 percent of energy used in a heating system is lost to duct leakage and fan problems. The payback for sealing ducts is 2 to 5 years. Apart from energy consumption, leaky ducts can compromise comfort, safety and indoor air quality. Sealing can improve these by improving air flow rate, preventing dust, fumes, odours and humidity from entering the ducts and preventing back drafting of gases such as carbon monoxide.

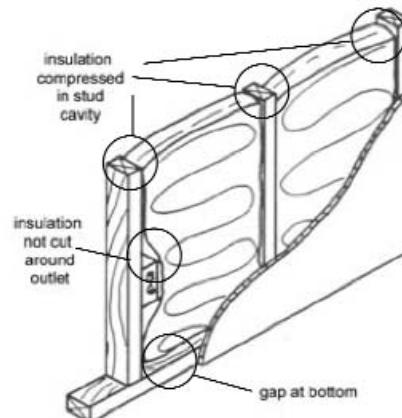
Materials for sealing; although the name 'duct tape' sounds very fitting, regular duct tape is actually quite a poor substitute for other materials. Metal reinforced tapes and mastic approved by Underwriters Laboratories are the preferred standard. Mastic is a dense goo reinforced with fibre, which is applied with a brush. Large holes in ducts can be patched with metal and sealed with mastic. For hard to reach areas, a new technology of aerosol sealant can be blown through the ducts. The substance is then lodged into the holes to seal them. The commercial name is Aeroseal. Franchises exist to deliver this duct sealant and to do a comprehensive diagnostic of the ducts, safety check, repair, sealing and reporting. A cost-benefit analysis should be done to compare this method with conventional duct sealing. An online calculator tool is available at: [www.bchydro.com/business/investigate/investigate10337.html](http://www.bchydro.com/business/investigate/investigate10337.html).

- Windows: window insulation shrink film is useful in the winter as an interim solution before replacing leaky windows or adding storm windows. Shrink film or polyethylene sheets can easily be applied over windows. The film of sheets come in kits that include double-sided tape. Like plastic wrap over a bowl, the interior side of the window would be covered by the film to act as a barrier to keep outdoor air from entering through air leaks in the window or through thin glass. The kits are typically inexpensive, ranging between \$11-\$23 per kit.

For more information on caulking and weather-stripping and recommended applications, see the City of Edmonton's "Carbon Dioxide Reduction Edmonton" publications (see "Caulking and Weather-stripping"): [www.co2re.ca/publications/default.htm](http://www.co2re.ca/publications/default.htm)

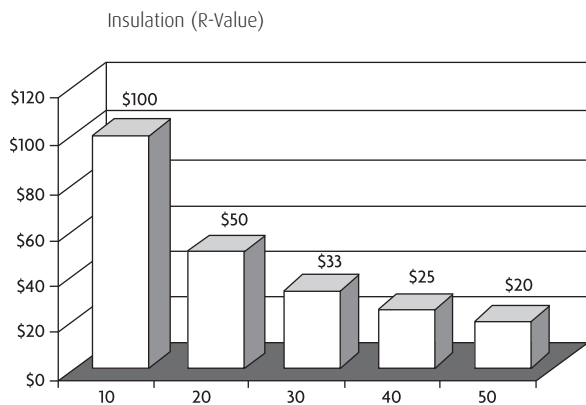
## Insulation

A building is kept warm and dry when it is well sealed, well ventilated and well insulated. Insulation acts like a teapot cozy, which adds another layer for heat to penetrate before it can escape. This insulation buffer still needs an air barrier on the exterior to keep the rain and wind out; as well, it needs a vapour barrier on the warm interior side to keep moisture from escaping and condensing when it reaches a cold outer surface (causing moisture damage or mould growth). Be sure to address moisture entry problems before insulating.



Insulation is installed to control “heat conduction” or heat passage through the building envelope. It is rated according to its resistance to conduction. This is commonly called its R-value (RSI in metric units). If two different types of insulation have the same R-value, they will control heat to the same extent. There may be differences in the requirements for installation or protection. One type of insulation may be more susceptible to moisture or some other hazard. But there will be no difference in thermal performance if each is installed and protected according to the manufacturer’s instructions.

An example to show the economics of adding more insulation



Example of heat loss in dollars, as a function of insulation level.

Other factors, such as durability and cost, should be used to determine preferences for insulation purchases. There are different types of insulation materials for different jobs: certain building areas use only particular types of insulation.

The four main types of insulation are: Batts or Blankets, Loose-Fill insulation, Rigid or Semi-Rigid Board and Spray-Foam insulation.

### Batts or Blankets

Fibreglass and mineral wool are the most common materials in batt or blanket form.

They usually come packaged in plastic as a bale. Batts and blanket insulation is easy to install in accessible places such as unfinished walls and some attics. The bales can be cut to fit the area and can conform to some uneven surfaces. Safety equipment and protective clothing are required for installation.

### Loose-fill Insulation

Loose fill materials include fiberglass, mineral fibre or cellulose fibre. They are blown in or poured in. (Poured insulation requires more material to achieve the same RSI-value as blown in insulation). Since it does not have a shape, the particles that make up this material can fill irregular or inaccessible spaces such as attics and small enclosed spaces around roof or ceiling joists. For buildings with hollow walled construction, disturbance can be minimized by having the material blown in via small holes drilled in the walls. The material does not suit below-grade areas such as basements. Loose-fill is good for topping up existing insulation in attics and filling in cracks and uneven spaces. An experienced professional is typically needed to install loose-fill. In any case, installation requires following the manufacturer’s instructions.

### Rigid or Semi-Rigid Board Insulation

This type of insulation includes a variety of different possible materials including glass fibre, foam plastic and mineral fibre. These boards are lightweight and easy to cut, though they can be tricky to fit into irregular spaces. Some materials use refrigerant gases (fluorocarbons) such as extruded polystyrene or polyisocyanurate.

Board stock is good for the exterior face of new construction and for the exterior of basement walls. For new construction, the insulation reduces thermal bridging (areas that span the warm side to the cold side of the wall giving heat an easy escape route). For basement exteriors, insulating the outside of basement walls works well with damp proofing and foundation drainage: rigid

fiberglass or mineral wool acts as a drainage layer to keep water away from the foundation.

### **Spray-foam Insulation**

This type of insulation can fill cavities very well as they are sprayed directly onto the building surface or poured into enclosed cavities using a spray gun with a pump. The foam expands and sets immediately. A specialized contractor should be hired for the application; they would also mix the materials on the job site. Typical materials include cellulose, polyisocyanurate and polyurethane.

For more information on the above types of insulation see Natural Resource Canada's publication "Keeping the Heat In" under the 'Materials' chapter: [oee.nrcan.gc.ca/keep\\_heat\\_in/index.cfm](http://oee.nrcan.gc.ca/keep_heat_in/index.cfm), or check out Canada Mortgage and Housing Corporation's document "About Your House — Insulating Your House": [www.cmhc-schl.gc.ca/en/co/maho/enefcosa/enefcosa\\_002.cfm](http://www.cmhc-schl.gc.ca/en/co/maho/enefcosa/enefcosa_002.cfm)

### **How Much Insulation Is Enough?**

Energy loss is inversely proportional to the R-value of the wall, roof or floor. The higher the R-value, the lower the heat loss. This has important implications when determining how much insulation is sufficient in a building, as the following example shows.

Suppose a wall has been built with an insulation level of R-10. You can reduce heat loss by 50 percent by adding an additional R-10, for a total of R-20. Upgrading the insulation from R-20 to R-30 reduces heat loss by another 16.7 percent; from R 30 to R-40 by another 8.3 per cent and from R-40 to R-50 by another 5 percent. Each addition of insulation costs the same (disregarding the extra space that would likely be required). However, clearly the value of each addition is not the same. Some judgment or calculation has to be made to get the most economic level of insulation.

### **Insulation Installation**

Insulation must be held in place in walls and ceilings so that it is not dislodged by wind or shifted by other pressures. If you are using fiberglass or other types of batt insulation, be careful not to compress the batts. The insulation value of a given material is closely tied to the thickness of the material, so compressing the batt will lower the insulation value. Compression may also allow air to circulate in the wall or ceiling cavity and short-circuit the insulation.

All types of insulation must be carefully cut and closely fitted around protrusions like electrical boxes or structural supports. Insulation should always be placed tight against the air barrier system, as outlined in the previous section.

### **Cladding**

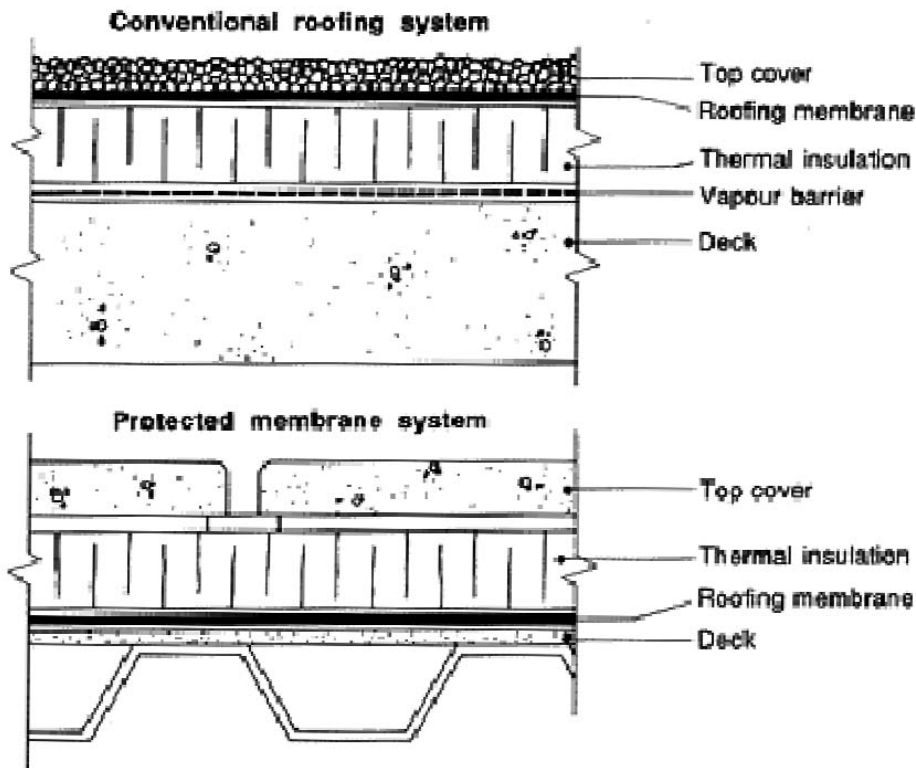
The cladding of the building protects interior elements from weathering and exposure to sun and rain. Normally this requires protection against wind gusts, sometimes with a type of building paper.

The cladding itself need not be sealed. In fact it is best to leave it unsealed so that any water trapped inside the wall can drain or vent to the exterior. This is exactly what happens with hardboard, vinyl, or metal siding. Some cladding systems, like brick, have weep holes purposely drilled through the exterior to allow moisture to drain. These must not be sealed.

### **Roofing**

Many roofing systems actually shed water, while some can be described technically as waterproofing. Whatever the system, water management is vital. Water should always be directed down and away from the building.

Shingles are typically used on pitched roofs and membrane systems are commonly used on flat roofs, but strictly speaking, you should



Conventional built-up and inverted "flat" roof systems.

not allow a roof to be built totally flat. The more slope the less chance there is for ponding of water on the roof, which can eventually lead to leaks and further damage.

Membrane systems installed in the conventional manner, over the top of the insulation, are subject to deterioration due to maintenance traffic, extremes of temperature and solar radiation. If you have this system, generally referred to as a built-up roof or BUR, and must use the roof for equipment maintenance, consider installing a walkway to protect the roof.

A more recent innovation is the inverted roof system, also called protected membrane system, which places the roof membrane under the insulation. Many insulation companies and roofing suppliers can provide one of these systems. A ballast of gravel or paving stones is often used to hold the insulation in place. Some roof insulation

products have a concrete layer bonded to the top to hold it in place.

### Vapour Retarders

Vapour retarders or, as they are still commonly called vapour barriers, are sometimes thought to be the only defense against air leaks. This is because polyethylene is often used in housing to provide air tightness, but it is not true that poly is the only defense or even the best defense against air leaks. However, a vapour retarder is still needed on the warm side of the insulation. This can be poly or even two or three coats of an oil-based paint (not latex) or other airtight, waterproof materials.

Note that if the building uses drywall, plywood, or some other system to stop all air leakage, it is not absolutely necessary to seal the vapour retarder. Vapour moves by diffusion through material directly so a small hole in the vapour retarder doesn't degrade

the rest of the vapour retarder. (see section on air barrier systems). Air, on the other hand, moves and will carry moisture with it, so it is very important that an air barrier be well sealed and continuous.

### **Moisture Problems**

If buildings have an enemy it can be defined in one word: moisture. Moisture affects the thermal performance of the building envelope by reducing the resistance of insulation. Only a small amount of moisture in the insulation cuts the R-value by far more than anyone thought just a few years ago. This costs extra heating and cooling dollars. Moisture problems are often very difficult to discover in the first place, and may be even harder to track down and stop.

### **Deterioration**

Moisture that accumulates in the building envelope can lead to a variety of very serious performance problems not directly related to energy consumption. This is especially true if the moisture attacks the building's structural integrity, such as when it rots structural members. Moisture corrodes metal components in the wall. This may become an unsightly nuisance or lead to failure of some part of the building structure.

Frost and ice can also accumulate in spaces within the walls and ceiling of a building. Ice build-up can cause deformation and deterioration of interior and exterior finishes. Icicles hanging from the outside of the building may be a hazard to occupants below. When the ice and frost melt in spring, some of the melt water may run back inside where it is a nuisance and further hazard.

Masonry and brick buildings can suffer additional problems with moisture. Efflorescence is the white marking that often appears on these buildings. Caused by salt that makes up part of the bricks, it is deposited on the surface by moisture. Surface staining by other materials may also occur. Moisture

can cause cracking of the walls in brick and masonry buildings, and also in stucco and wood veneer buildings.

### **How Moisture Accumulates in Buildings**

Moisture can get into the materials and assemblies of the building from the outside and from the inside. Outside is rain or snow and inside is humidity, which can condense in the walls and ceiling spaces. Moisture condensation occurs due to air leakage, for the most part, but also due to vapour diffusion, which is handled by the vapour retarder.

Contrary to popular opinion, it is not absolutely necessary to seal the vapour retarder because this will allow an increased amount of diffusion (a slow process) only over a small area. It is far more important to control air leakage, which may or may not be possible with the vapour retarder.

### **Handling Moisture**

The most effective strategy is to prevent moisture from accumulating in the first place. However, almost all buildings have some form of moisture deposition or accumulation, and it is impossible to achieve a 100 percent perfect building. As a result, there has to be some consideration for handling the moisture.

A number of approaches are used to minimize condensation in buildings. In retrofit situations these basically involve reducing the amount of airflow through cracks and openings, reducing the humidity level of indoor air, or warming condensation surfaces to reduce or eliminate the condensation.

To reduce the indoor humidity levels, try using ventilation fans to exhaust moist air from the building and bring in cold dry air. Heat recovery could be part of the ventilation to reduce energy costs.

Another strategy is passive ventilation that uses the wind to induce air flow through ducts and planned openings, or increasing

natural ventilation through a chimney by increasing its size. Controlling moisture also helps prevent deterioration of buildings.

### **Condensation in Chimneys**

A higher efficiency furnace may lead to excess moisture accumulating in the chimney since these furnaces need smaller chimneys than has been the standard for many years. The combustion of oil or natural gas can result in flue gases condensing in a cold chimney stack. Humid indoor air drawn into the chimney can also contribute to the problem. According to Natural Resources Canada, moisture can leave its mark with:

- a white, efflorescent powder on the outside of the chimney
- brick or mortar joints crumbling
- wet patches on inside walls behind the chimney
- tile pieces at the bottom of the chimney
- water seeping out of the clean-out door or around the base of the chimney behind the furnace.

This moisture problem can be remedied in a couple of different ways. A double-walled stainless steel flue pipe extending from the furnace to the chimney can keep flue gas temperature high to prevent condensation in the chimney. Alternatively, a stainless steel chimney liner surrounded by insulation can help temperatures from falling in the chimney.