ENERGY EFFICIENT HOUSING

Reference Guide

CEATI INTERNATIONAL

This guide was prepared by Ivor F. da Cunha P.Eng. of LeapFrog Energy Technologies Inc. for the CEATI International Customer Energy Solutions Interest Group (CESIG) with the sponsorship of the following utility consortium participants:

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1 INTRODUCTION

This Guide is aimed at new construction and renovation projects alike. It outlines key technologies, methods and systems to make the house more energy efficient. As considerable time can pass between major home renovation projects, not implementing an energy efficiency measure can represent a lost opportunity.

This Guide is a combined, updated, and refreshed publication that was based on two handbooks developed by Ontario Hydro in the late 1980's:

- Energy Efficiency Housing – Reference Guide
- Home Renovations – Reference Guide

What this Guidebook Is and Is Not

- This Guide was written to help you to become aware of issues and technologies associated with energy efficiency considerations for houses.

- This Guide addresses the typical energy efficiency technologies associated with construction techniques and non-chattel energy consuming equipment in a typical household in Canada, with emphasis on the Province of Ontario.

- The Guide does not address discretionary use of energy such as consumer electronics, appliances or lighting in a household. The Guide does not address behavioural usage of energy in a household (e.g. temperature settings).

- The Guide is intended to help the reader think about the fundamentals of the main energy equipment or material used in a house. It is intended to be used for both new construction and home renovation projects.

- This Guide is general in nature and does not address each and every possible problem and solution that is associated with energy efficiency in houses. It is not a design guide for new or renovated homes. This guidebook does not and is not intended to replace equipment manuals, maintenance procedures, or applicable Codes and Standards.

Readers are cautioned to use proper health and safety procedures, and to follow equipment operating and maintenance manuals before, during, and after any modifications, work, or testing related to any equipment or material discussed in this Guide. Failure to follow proper and safe procedures and applicable Codes could result in serious injury, loss of life, property damage, production upsets, and other risks.

2 WHOLE HOUSE ENERGY PERFORMANCE

Residential Energy Use in Canada

According to Natural Resources Canada (NRCan), in 2006, the residential sector consumed about 1350 PJ of energy. This represents roughly 16% of energy (i.e. electricity, natural gas, heating oil, propane and firewood) used by all sectors in Canada. Space heating and water heating were the largest energy consumption activities for the average household in Canada, as illustrated in Figure 1.

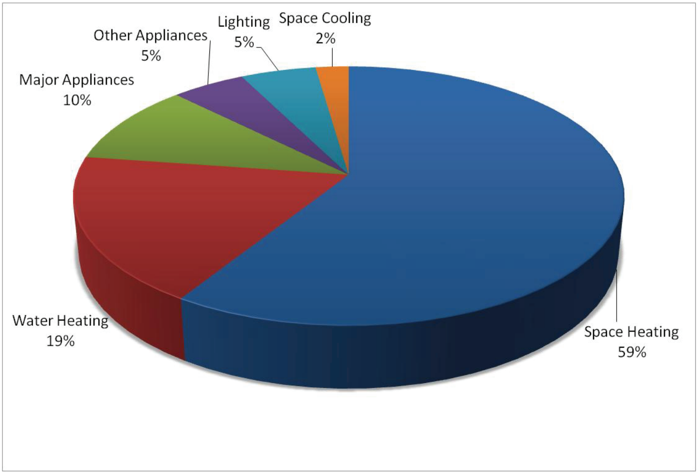

Figure 1 Residential Energy Use in Canada in 2006 (Source: NRCan)

The benefits of improved energy efficiency are at the forefront for many Canadians.

Energy consumption in most households represents an ongoing cost to homeowners. Moreover, the use of energy in houses causes primary or secondary emissions of greenhouse gas.

Studies have shown that energy efficiency features in new and existing homes can actually improve property value.

Houses are like systems. They are made of many materials and components. All the components need to work together in order to achieve peak energy performance. Simply improving one aspect may be detrimental to another part of the system. It is important to keep in mind the tradeoffs between making decisions among multiple choices.

a. The House is a System

Key external factors that affect house performance include:

- Structural loading,
- Wind and precipitation,
- Moisture flows,
- External temperature, and
- Exposure to sunlight.

External forces can be kept at bay by introducing barriers to contain heat, moisture, and airflow. However, any given barrier or system can indirectly affect the effectiveness or performance of other barriers or components. Being able to understand the interaction and interrelationship between physical barriers and mechanical equipment is the key to overall house system optimization.

As an example, although air barriers can reduce drafts and undesired heat escape, they can also introduce problems with indoor moisture build-up and humidity.

b. The Building Envelope

Given that almost 60% of the average household energy bill is used for heating, the building envelope is a critical aspect of the house's energy performance.

Moreover, as it may be between 10-30 years for a substantial building upgrade to be made, the building envelope needs to be specified and built as efficiently as practical during a new construction or a building renovation project. Not addressing the building envelope is a "lost opportunity" for energy efficiency.

In essence, the building envelope is the shell of the house that protects from external elements. Key components include:

- Above-grade walls,
- Attic and roof,
- Basement walls and floor, and
- Windows and doors.

In addition to providing protection from external elements, the building envelope must also:

- Provide structural support for the walls and roof,
- Permit natural lighting,
- Allow occupants to enter and exit the building,
- Separate the interior conditioned environment from exterior ambient conditions, and

- Contain or manage air, heat, and moisture between the interior and exterior of the house.

c. National Codes and Standards

Over the years, there have been many codes and standards developed regarding the construction and safety features for houses. Specific codes are aimed at fire, accessibility, and egress aspects for houses. In addition, there are codes for installation procedures, construction methods, material specifications, and more recently for energy performance.

The National Building Code of Canada 2005 applies to the construction of buildings, including extensions and substantial alterations. It also applies to buildings undergoing a change of occupancy, and to buildings being upgraded to remove an unacceptable hazard. The provinces and municipalities have jurisdiction with regards to adopting codes.

Caution: This Guide contains references to national and representative provincial codes. This Guide is not a substitute for prevailing codes and standards. It is therefore imperative that readers verify and follow the applicable Codes and Standards for specific new construction and building renovation projects for their jurisdiction.

The National Fire Code of Canada 2005 contains technical requirements designed to provide an acceptable level of fire safety within a community.

The Model National Energy Code of Canada for Houses 1997 (MNECH) contains cost-effective minimum requirements for energy efficiency in **new housing**. The MNECH applies to single family houses of three floors or less, and to additions of more than 10 m^2. It specifies minimum RSI insulation levels for building envelope components which are based on the type of heating fuel (oil, natural gas, electricity, wood, or propane) for different regions of Canada. These levels were determined using regional construction and heating energy costs in a life-cycle cost analysis. The MNECH also stipulates the minimum energy ratings (ER) for windows, it references energy-efficient equipment standards, and it describes when the installation of a heat recovery ventilator is required.

To allow flexibility in attaining a minimum level of energy performance, the MNECH code offers three compliance approaches:

- Prescriptive Path – specific measures, equipment, or materials must meet or exceed the level specified.
- Trade-off Path – one or more measures or equipment can be below the prescribed level so long as the other components make up for the deficiency.
- Performance Path - using a building simulation software model or verification by an independent energy assessment service, components can be selected so as to achieve a minimum performance index value.

d. Ontario Building Code 2006

The Ontario Building Code 2006 specifies a set of minimum provisions respecting the safety of buildings with reference to public health, fire protection, and structural sufficiency. It is divided into 12 Parts:

- Part 1: Scope and Definitions
- Part 2: General Requirements

- Part 3: Use and Occupancy
- Part 4: Structural Design
- Part 5: Wind, Water and Vapour Protection
- Part 6: Heating, Ventilating and Air-Conditioning
- Part 7: Plumbing
- Part 8: Sewage Systems
- Part 9: Housing and Small Buildings
- Part 10: Change of Use
- Part 11: Renovation
- Part 12: Transition, Revocation and Commencement

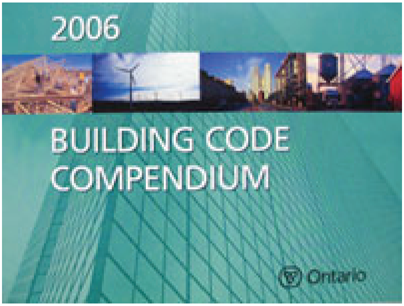

Figure 2 Ontario Building Code 2006

The Ontario Building Code 2006 was written in an objective-based format to promote innovation and flexibility in design and construction. The objective-based Code contains prescriptive requirements known as “acceptable solutions” that serve as benchmarks for evaluation. It included over 700 technical changes, including increases in the energy efficiency requirements.

Energy Efficiency in Ontario's Building Code

The 2006 Building Code is expected to enhance Ontario's energy-efficiency requirements for buildings through the introduction of higher requirements than the 1997 Building Code and previous codes. The Ministry of Municipal Affairs and Housing (MAH) anticipated that a typical new house built in 2007 under the new Building Code would be over 21 per cent more energy efficient than one built under the previous Building Code[1]. MAH expected the improvements to be derived from:

- High-efficiency gas and propane-fired furnaces (efficiency rating of 90 percent);
- Higher insulation levels (ceilings are being increased by 29 per cent, walls by 12 per cent and foundation walls by 50 percent) ; and
- More energy efficient windows (67 percent increase in energy efficiency).

Further Building Code changes related to energy efficiency are being phased in:

- All new houses built under permits applied for in 2009 require near-full-height basement insulation.
- New houses built under permits applied for in 2012 will be required to meet standards substantially in accordance with the national guideline, EnerGuide 80.

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[1] http://www.mah.gov.on.ca/Page681.aspx

Estimated Increased Capital Costs, Energy Savings and Payback Periods for Houses

Effective December 31, 2008, the Code required that new houses were to be constructed with near-full-height basement insulation. In addition, effective December 31, 2011, the Building Code will require new houses to meet standards that are substantially in accordance with EnerGuide 80 and also require that new non-residential and larger residential buildings meet standards that are substantially in accordance with energy efficiency levels that are 25% higher than the Model National Energy Code for Buildings.

Ontario has issued a Best Practices Guide for the Installation of Near-full Height Basement Insulation in conjunction with the Ontario Home Builders Association, Ontario Building Officials Association, NAIMA Canada and others in the building sector.

When compared to the 1997 Ontario Building Code, for a typical 2000 ft^2 natural gas heated home in the Greater Toronto Area, MAH expected energy savings, incremental costs, and simple payback to occur as shown in Table 1.

Table 1 Cost and Benefit for Ontario's 2006 Building Code Residential Energy Efficiency Features (Source MAH)

Effective Date	Incremental Cost	Estimated Energy Savings (%)	Simple Payback Periods (years)
December 31, 2006	$1,600	21.5%	3.0
December 31,	$2,700	28%	4.4

2008			
December 31, 2011	$5,900 - 6,600	35%	6.9 - 7.9

Note: At the time of updating this Guide (October 2009), Ontario was in a consultative process for updates to the Building Code.

Ontario's 2006 Building Code Highlights

The 2006 changes introduced a new Part 12 into Division B of the Building Code specifically aimed at energy and water efficiency. The 2006 Building Code includes "enabling" provisions to promote the use of green technologies such as:

- Solar photovoltaic systems;
- Gas fired emergency generators that can contribute to the power grid;
- Active solar hot water systems;
- Wastewater heat recovery systems;
- Rooftop storm water retention;
- Storm water and grey water re-use; and
- Motion sensors for room and minimum lighting.

It introduced significant changes related to the energy efficiency of Part 9 residential buildings with measures like:

- More energy efficient windows/sliding doors;
- Higher insulation levels for ceilings, walls & foundations;
- Limitations on thermal bridging;
- High-efficiency gas and propane-fired furnaces (90%);
- Higher standards for electrically heated houses; and
- EnerGuide 80 as a compliance option.

The EnerGuide 80 rating is a performance based rating and requires that buildings achieve at least 80% of a theoretical energy performance rating that ranges from 0 to 100%.

The code now requires near full-height basement insulation for Part 9 residential buildings as of December 31, 2008. It stipulates higher insulation levels for foundation walls by extending the R-12.0 insulation coverage from 600 mm below grade to near full height of the basement. A 380 mm gap is permitted between the basement floor level and the insulation.

Specific measures in Part 12 are aimed at Resource Conservation:

- 12.2 – Energy Efficiency Design
- 12.3 – Energy Efficiency of Part 9 Buildings
- 12.3.2 – Residential Buildings: Thermal Insulation
- 12.3.3 – Residential Buildings: Thermal Design
- 12.3.4 – Non-Residential Buildings: Prescriptive Solutions
- 12.4 – Water Efficiency
- 12.3.2 - Thermal Insulation

The 2006 Ontario Building Code stipulates minimum thermal insulation requirements depending on the location of the building within the Province. The required insulation levels for electrically heated homes are more stringent, as shown in Table 2.

Table 2 Minimum Insulation Levels Stipulated in 2006 Ontario Building Code

2006 to 2011 only	Ontario South – In force	Ontario North – in force

Primary Heating Source	Gas/Oil Heating	Electrical Heating	Gas/Oil Heating	Electrical Heating
Wall	R19	R29	R24	R29
Ceiling	R40	R50	R40	R50
Basement	R12	R19	R12	R19

EnerGuide 80

EnerGuide 80 is an energy efficiency performance level intended for houses. The EnerGuide Rating System is a performance based method and rating tool initially intended for incentive programs. In order to meet the rating, houses need to be verified in accordance with NRCan procedures, which include:

- Plan review and inspections;
- Computer simulation using HOT2000 - Version 9.34c;
- Air tightness test - maximum 2.5 Air Changes per Hour (ACH); and
- The involvement of a third party (NRCan trained personnel).

Compliance Options and Timelines

Prior to January 1, 2012, Section 12.2 - Energy Efficiency allows for three acceptable compliance methods for Part 9 residential buildings:

1. Comply with the thermal insulation levels in Subsection 12.3.2 – Residential Buildings: Thermal Insulation.
2. Comply with the design requirements of Subsection 12.3.3 – Residential Buildings: Thermal Design.

3. Attain EnerGuide 80 level.

After December 31, 2011, Section 12.2 - Energy Efficiency will only have one acceptable compliance method for Part 9 residential buildings:

1. Attain EnerGuide 80 level.

e. ENERGY STAR for New Homes

The ENERGY STAR for New Homes designation is available (October 2009) in Ontario and Saskatchewan. The program is managed by Natural Resources Canada and by regional service organizations.

The ENERGY STAR for New Homes initiative is intended to result in new homes being built to be approximately 30% more energy efficient than those built to minimum provincial building codes.

ENERGY STAR for New Homes features include:

- Heating and cooling systems – All furnaces, heat pumps, thermostats and fireplaces must be ENERGY STAR qualified.
- Ducts – Duct trunk lines and take offs must be sealed to reduce air leakage, and ducts must be channelled to provide heating and cooling to designated areas of the house only.
- Windows, patio doors, and skylights – All windows, glass doors and skylights comply with Canada's requirements for ENERGY STAR qualified windows.

- Walls and ceilings – An ENERGY STAR qualified home generally uses more insulation in the ceilings and walls than what is required by building codes.
- Ventilation and air leakage – ENERGY STAR qualified new homes must meet rigorous air tightness targets and include a heat recovery ventilation system (HRV).

To be awarded the ENERGY STAR label, the house must:

- Be built by a licensed ENERGY STAR for New Homes builder;
- Incorporate energy efficient features to meet or exceed the ENERGY STAR technical specifications; and
- Be assessed by an independent ENERGY STAR for New Homes evaluator.

After verification, Natural Resources Canada issues an ENERGY STAR for New Homes label and certificate to the homeowner. The ENERGY STAR for New Homes label (Figure 3) is normally affixed to the home's furnace or electrical box.

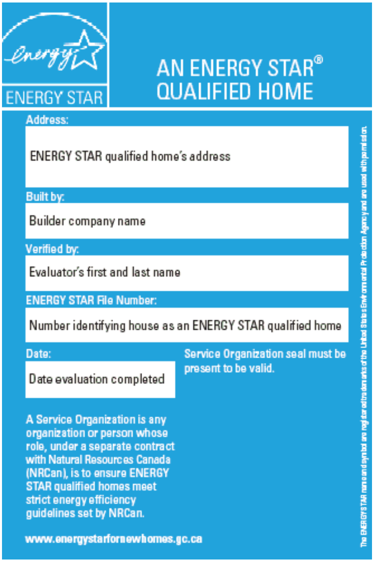


Figure 3 ENERGY STAR for New Homes Label

3 HEATING

a. Heat Loss and Transmission

About 60% of typical Canadian residential house energy consumption is used for space heating. Heat losses from the building or ineffective distribution within the building can result in actual or perceived discomfort to the occupants, together with higher than required energy bills. Heat can move into or from a house in one, two or three ways, as summarized in Table 3.

Table 3 Methods of Heat Transmission in Houses

Heat Transport Mechanism	Interpretation
Conduction	• Direct transfer from one part of an object to another part by the particles contacting one another. • Insulation works to limit the heat flow usually through pockets of trapped air, which are relatively poor conductors of heat.
Convection	• The unrestricted flow of air can pick up heat from one object and circulate it to another part of the room, where heat is discharged to a cold object. • Convection can also occur when hot and cold airstreams mix.
Radiation	• Infrared heat can be emitted from “warm” objects to the surroundings.

b. Heating Systems

There are a variety of heating systems used in Canadian homes, including:

- Furnace,
- Electric resistance baseboards,
- Hydronic boilers,
- Electric Thermal Storage, and
- Heat pumps (ground source and air source).

Heat pumps are discussed in the Space Cooling chapter.

By far, the majority of homes use furnaces for their heating needs. There are a wide range of furnace models, fuel types, and efficiencies available in Canada. Conventional efficiency gas furnaces can no longer be sold in Canada.

- Electric – electric furnaces work using electric resistance heating. The full 100% of the electric energy consumed goes towards the heating of the house. However, even before the electricity reaches the house, there can be significant energy conversion losses. For electricity produced from fossil energy, about 60-70% of the input energy can be lost. An additional 2-10% of the electricity can be lost during transmission and distribution.

- Oil - Oil furnaces can attain efficiencies of over 80% due to technology advances like flame retention head burners and high static pressure burners.

- Natural Gas – Newer gas furnaces in Canada can either be mid-efficiency (78 – 82%) or high efficiency condensing furnaces (89 – 97%). High efficiency furnaces use a plastic vent, usually situated through a side wall of the house. Mid efficiency furnaces typically use a metal chimney approved for gas appliances or a stainless steel liner inside an existing chimney.

- Propane – Similar to natural gas furnaces, propane furnaces are essentially modified natural gas units.

c. Natural Gas Heating

Since the mid-1980s, a new generation of natural gas furnaces and boilers with high efficiency factors has come to market. The salient feature of these devices is the manner in which they are vented, eliminating dilution air. In previous generations of furnace technology, combustion by-products would include water vapour and carbon dioxide. These by-products would remain hot and be vented through a chimney, taking along significant amounts of energy from the combustion and conditioned air from within the home.

Heat can also be lost up the chimney when the furnace is off.

Newer furnace designs have incorporated features to reduce the amount of heated air that can escape during the on and off cycles.

Newer designs are also capable of extracting more of the heat contained in the combustion by-products before they are vented.

Conventional Gas Furnaces

- There are thousands of conventional gas-fired forced air heating systems installed in Canada.

- Conventional gas furnaces have a seasonal efficiency of about 60% percent, which no longer meets the seasonal efficiency standards required by the regulations of Canada's Energy Efficiency Act.
- These units may no longer be sold or installed due to their low efficiency factors.

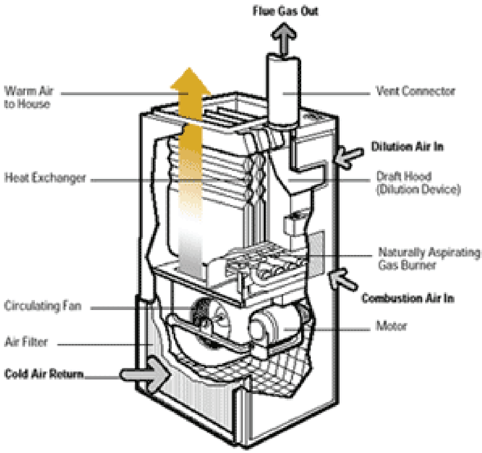


Figure 4 Conventional Gas-fired Furnace (Courtesy NRCan)

- These systems typically use a pilot light.
- Combustion gases flow through the furnace, where they pass heat via a heat exchanger, and are then exhausted, still hot, to the outside through a flue pipe and vent.
- A circulating fan passes cool house air from the return ducts over the furnace heat exchanger, where the air is warmed and passed through ductwork to the house.

Mid-Efficiency Gas Furnaces

- Mid-efficiency natural gas furnaces have a seasonal efficiency of at least 78% - some as high as 82%.
- They use naturally aspirating burners and do not have a continuously lit pilot light.
- These units generally have electric ignition systems, which over a calendar year can use 3-5% less energy than a furnace with a conventional standing pilot light.

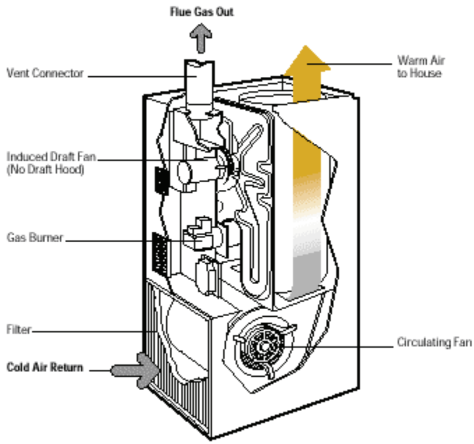


Figure 5 Standard-efficiency gas furnace with induced draft fan (Courtesy NRCan)

- A built-in induced draft fan and powered exhaust is common for most mid-efficiency furnaces.
- Seasonal efficiency is considerably higher for mid-efficiency furnaces than for furnaces with pilot lights.
- Energy savings are typically between 23 and 28 percent compared to a conventional furnace.

- These units can be vented via a chimney or out the side wall of the house using high-grade stainless steel.
- Problems have been associated with the use of high-temperature plastic vents with mid-efficiency furnaces.
- Certain types of vent materials are forbidden in some areas, so it is important to check with a qualified service provider to determine local standards and requirements.
- Installation codes sometimes require supplying combustion air to the furnace from outdoors.

High-Efficiency Condensing Gas Furnaces

- Condensing gas furnaces have the highest energy efficiency factors for available furnaces, with 90-97% seasonal efficiency.
- Depending on the design, condensing furnaces can use up to 38% less natural gas or propane than older gas furnaces equipped with pilot lights.
- The burners are similar to those on mid-efficiency furnaces, and draft is provided by an induced draft fan. This style of furnace has additional corrosion-resistant heat exchanger surfaces to recover heat from the combustion by-products ahead of the exhaust pipe.
- This condensing heat exchange section cools the combustion gases to a point at which the water vapour condenses, thereby releasing additional heat to the home.
- Extracted condensate is channelled to a floor drain.
- Homeowners can also benefit from lower installation costs as a chimney is not required.

- Moreover, flue gas temperatures are relatively low enough to be vented through PVC or ABS plastic pipes through a side wall of the house.
- Some models employ a pulse combustion technology which ignites small amounts of gas at frequent intervals.

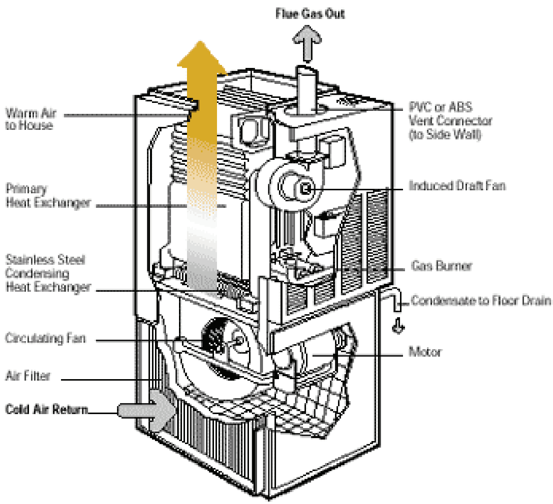


Figure 6 High-Efficiency Natural Gas Condensing Furnace (Courtesy NRCan)

Sealed Combustion Systems

- The key benefit of sealed combustion is that outside air is piped directly to the sealed combustion chamber, and the furnace does not consume conditioned house air.

- Almost all new high-efficiency furnaces have design sealed combustion features and are well suited to the tight construction of a modern energy-efficient house.
- Tight construction of energy-efficient houses, in combination with exhaust fan operation and clothes dryers can result in back drafting. Sealed combustion units prevent this potential safety problem.

d. Electric Heating

Although an increasing number of homeowners with electric heating have switched to other energy sources, electric heating is still popular as a primary or supplementary source of heat.

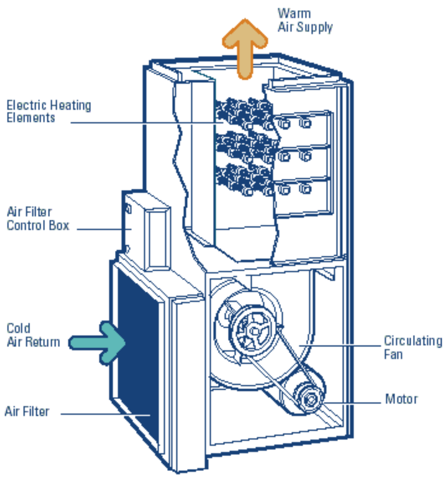


Figure 7 Forced Air Electric Furnace (Courtesy NRCan)

There are 3 types of electric heating systems widely available in Canada, including:

- Forced-air systems,
- Hydronic or hot water systems, and
- Electric radiant systems (i.e. baseboard / unit heaters).

Electric forced-air systems are commercially available in a 10 to 50 kW range of capacities. When conversions to electric furnaces occur, unused chimney flues can be sealed.

Electricity can be the primary heating source, or be used in combination with other sources (e.g. ground source heat pump) in a home heating system.

Caution: As with all projects involving electrically operated equipment, any alterations to an existing furnace involving installation of an electric plenum heater must be done by a qualified contractor. In addition, the retrofit furnace must be inspected, usually by the local electric utility authority.

e. Electric Thermal Storage

- Electric thermal storage (ETS) takes advantage of time of use rates, where available, by drawing electricity during off peak hours, offsetting peak hours energy consumption.
- Although the technology is proven and safe, it is only seen in limited capacity in North America.
- Most ETS systems can provide 16 hours of on-peak heat from as little as eight hours of off-peak charge.
- Energy is typically stored as heat in ceramic bricks, crushed rock, water, or paraffin wax during off peak

hours. When required, a fan or blower circulates cool air over the storage material to extract the heat.

- Room storage units are smaller versions of central ETS furnaces and come in sizes of 2-7 kW.
- This technology is modular in nature, and capacity can be expanded as required (electricity service permitting).

Figure 8 Electric Thermal Storage Heater (Courtesy Nova Scotia Power)

f. Programmable Thermostats

Regardless of the fuel source, one of the most effective ways to save heating dollars is to lower the house temperature setting.

- For every 1°C the thermostat is reduced, about 2% is saved on the heating bill.
- When used correctly, programmable thermostats can save 10-15% of a heating bill.

- Programmable thermostats adjust the home's temperature automatically based on a predefined setting entered by the homeowner.
- As a rule of thumb, the temperature can be set to 17°C when sleeping or not home and to 20°C otherwise.

Figure 9 Programmable Thermostat (Courtesy Ontario Power Authority)

g. Other Energy Efficiency Technologies

Zone control

Energy requirements for heating can also be lowered by using zone control.

- Zone control enables the temperature of individual rooms to be regulated.
- This usually involves using dampers and multiple thermostats placed strategically throughout the house.
- Zone control systems are available for forced air and hydronic (hot water) heating systems.

High-Efficiency Variable-Speed Blower Motors

Many homeowners across Canada have the practice of running the furnace fan continuously through a heating season and/or a cooling season.

- Consequently, the constant operation of the fan increases annual energy consumption significantly.
- Standard alternating current (AC) motors are used in most forced air furnaces. The four speed permanent split capacitor (PSC) motor is not especially energy efficient, especially at low speed operation.
- Newer furnaces are now equipped with high efficiency brushless direct current (DC) electronically commutated motors (ECM) that are capable of operating at variable speeds. Under continuous operation, compared to traditional motors operating at fixed speed, these devices use about 2/3 less electricity over a given year.

4 WALLS

Exterior walls are subject to many requirements which must be considered in the overall wall system design. These include:

- Control of rain penetration,
- Controlled admittance of natural light (windows),
- Structural strength, considering wind loads,
- Fire protection,
- Outdoor noise control,
- Durability and low maintenance,
- Control of heat loss,
- Control of water vapour diffusion,
- Control of air penetration, and
- Economy.

The last four requirements are directly responsible for the thermal performance of the wall system. Optimum thermal performance must be considered along with the entire wall analysis. It is not just the addition of insulation, but how it is applied.

Insulation Of Above Grade Walls

Above grade renovations are frequently undertaken to improve the aesthetics or usability of the living space, or to make the house exterior more attractive.

The addition of insulation and improvement of envelope air-tightness should be considered for inclusion in the project. The results can include:

- Increased comfort;

- Increased building durability;
- Increased property value; and
- Significantly reduced energy costs.

a. Super Insulated Walls

As well as meeting the fundamental wall requirements, a super insulated wall must also incorporate enhanced thermal performance. The following factors are the major design concerns for super insulated wall systems.

Table 4 Super Insulated Wall Considerations

Feature	Consideration
Thermal Resistance	• These wall systems should easily and effectively produce a thermal resistance of at least RSI 3.6 (R-20) to RSI 5.3 (R-30). This consideration will increase with new Building Code requirements.
Thermal Bridging	• The wall system should, to some extent, contain a continuous blanket of insulation with no thermal bridging.
Air tightness	• The system should incorporate an effective air barrier and vapour barrier. This can be done in all wall systems; however, some are simpler than others and are less likely to cause installation problems.
Cost	• Ideally, the incremental costs for super insulated wall systems would only include the added insulation costs. • Realistically, additional costs due to design changes, training, and labour difficulties must also be considered. • Overall constructed costs are therefore not easy to assess.
Ease of Construction	• The variance in complexity of different

wall systems is considerable. Also, acceptance of new concepts or techniques in the home building industry has historically been very slow and difficult.

The Air/Vapour Barrier

In the context of this reference guide, all super insulated construction requires effective air and vapour barriers. The air barrier may be located anywhere within the wall system, provided:

- It is continuous,
- It is supported and can withstand air pressure differentials,
- It is resistant to air flow, and
- It is durable and protected.

The vapour barrier has only two major requirements:

- It must impede water vapour diffusion, and
- It must be located on the warm side of the wall so that its temperature never drops below the dew point (which would result in condensation problems).

The general rule of thumb for vapour barrier positioning is the one-third/two-third rule. At least two-thirds of the thermal resistance of the wall must be on the outside of the vapour barrier.

The wall system must have an effective air barrier in order for the vapour barrier to work. In many wall systems, the air barrier and vapour barrier are combined. In this situation, it must be positioned as a vapour barrier and meet all the other requirements. The most common air/vapour barrier material is a 0.10-0.15mm polyethylene sheet. This material is readily available and inexpensive. It also provides for an adequate vapour barrier.

Polyethylene sheeting must be used on the warm side of the wall because of its vapour barrier properties. This makes it more difficult to ensure a continuous air barrier. One major disadvantage of this material has been strength. If left uncovered on the job site for several days or weeks, it will degrade in the sunlight and become brittle and weak.

All polyethylene sheeting to be used for air barriers has been chemically modified for better solar degradation resistance and carries Canadian Mortgage and Housing Corporation (CMHC) approvals. Any polyethylene sheet not carrying CMHC approval should not be used as an air barrier.

Additional exterior air barriers are being included in many super insulated wall systems.

Exterior Air Barriers (House Wrap)

A new type of exterior air barrier was introduced in 1982 by DuPont. At the time, Tyvek® House wrap was a one-of-a-kind product. Older houses used a variety of less effective building papers as a house wrap, or no wrap at all.

These new house wraps are probably one of the breakthrough energy saving building products introduced to the construction industry. The main property of an exterior air barrier is that it prevents air infiltration but allows vapour diffusion. This allows it to be used on the exterior wall surface (cold side), usually over sheathing material, without the fear of condensation problems.

Essentially, common polyethylene, an olefin, is spun into short threads which are then matted and bonded together. The result is an extremely strong and durable material which is porous to water vapour but tight enough to act as a good air barrier.

There are now several competing products on the market.

Advantages:

- It is an effective air barrier which is easy to install with continuity.
- One-sided air intrusion results in air currents moving through the insulation, causing thermal performance to decrease due to convective losses. An exterior air barrier will prevent this.
- Strong and is less likely to be damaged during installation. This is a major problem with common polyethylene sheet air barriers.

Disadvantages:

- A proper warm-side vapour barrier is still required for super insulated wall systems.

b. Types of Super Insulated Walls

There are six common types of super insulated wall systems:

- Strapped wall,
- Double-framed wall,
- Wall with exterior foam sheathing,
- Sandwich panel walls,
- Non-structural trusses, and
- Spray-in-place foam.

The walls (Figure 10) are referred to as systems because the individual parts work together to ensure that the entire assembly satisfactorily meets all requirements.

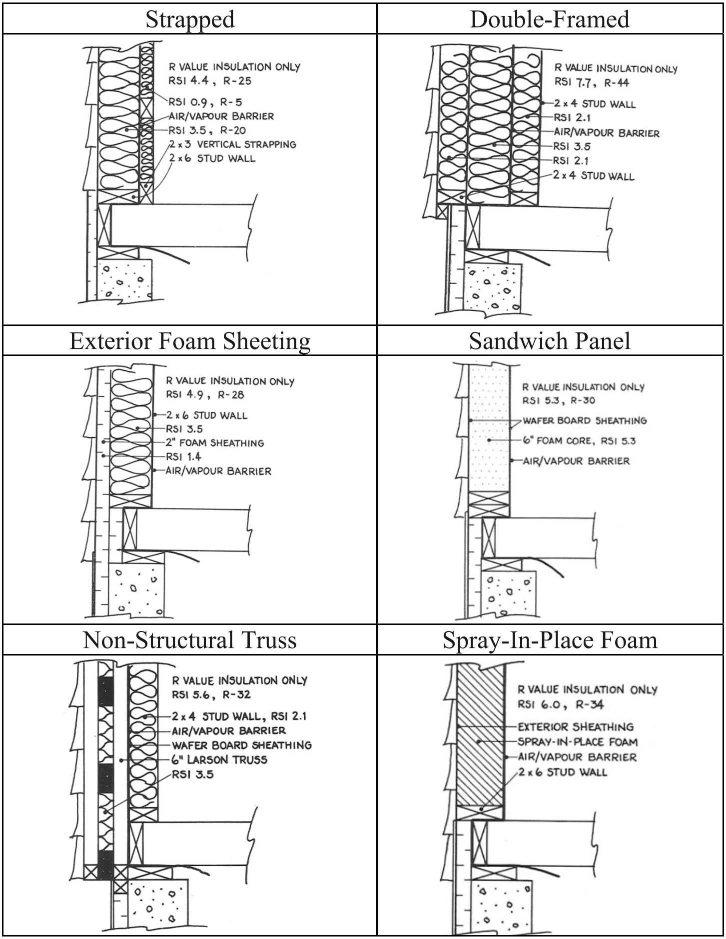


Figure 10 Types of Super Insulated Walls

The Strapped Wall

This is the most popular of super insulated wall system designs. Basically, 2"x 3"s are horizontally strapped to the existing 2"x 4" or 2"x 6" vertical stud wall. This increases the overall wall thickness with a minimal amount of thermal bridging.

Advantages:

- The air/vapour barrier can be installed deep in the wall for protection.
- Plumbing and wiring can be located in the strapped cavity; therefore no penetrations through the air-vapour barrier are required.
- Inexpensive batt insulation is used.
- Easier and less expensive to air seal than the equivalent 2"x 8" stud wall.
- Thermal bridging is significantly reduced compared to a 2"x 8" stud wall.

Disadvantages:

- Walls can become excessively thick, depending on the insulation levels required and the exterior cladding and interior finishes, e.g.:
    - 2"x 6" stud;
    - 2"x3" strap (vertical);
    - Drywall;
    - Brick cladding;
    - Fiberglass insulation;
    - Approximate thickness 28-30cm (11"- 12"); or
    - Approximate thermal resistance RSI 4.6 (R-26).

The Double-Framed Wall

Sometimes referred to as the “Canadian Double Wall”, with this construction method, two identical frame walls are attached together with top and bottom plates (plywood). The gap between the walls can be made any size to accommodate various insulating materials and thicknesses. The most common construction consists of two 2"x 4" walls with a 5.5" centre gap. The inner wall is structural. Fiberglass batts are then used to insulate the cavities. The air/vapour barrier is placed on the outside of the inner wall.

Advantages:

- The air/vapour barrier can be installed deep in the wall for protection.
- Plumbing and wiring can be located in the inner wall cavity; therefore, no penetrations through the air/vapour barrier are required.
- Inexpensive fiberglass batts can be used to attain very high R-values.
- Thermal bridging is basically eliminated.

Disadvantages:

- These walls are very thick; brick cladding is seldom if ever used - common double-frame wall thickness not including exterior cladding: 33cm (13").
- Quality control at site important.
- Details including corners, footing, floors and roofs are not common to most trades; training is required.

Exterior Foam Sheathing

Exterior rigid foam sheathing can be used on most stud frame wall types. This type of super insulation is becoming very popular among quality home builders. Insulation manufacturers now offer a wide variety of foam sheathing products. These products are usually sold as systems having special fastening techniques. Above ground, various materials are used such as urethane, isocyanurate, moulded and extruded polystyrene and rigid fiberglass. The rigid sheathing is fastened to the outside of the stud wall. The stud wall is insulated as usual, and an effective air/vapour barrier is installed. Most standard outside finishes and veneers can be applied. Depending on the particular sheathing material, R-values can vary between RSI 0.70 (R-4.0) to RSI 1.15 (R-6.5) per 25 mm (1"); 25 to 50 mm of sheathing is commonly used.

Advantages:

- Can be used with most common wall designs.
- Thermal bridging is reduced since the sheathing is continuous; all stud and joist surfaces are covered.
- Sill plate insulation is easily taken care of, especially when exterior foundation insulation is also used.
- Sheathing installation is already fairly common practice; foam sheathing installation requires very little extra training.
- Very little extra thickness is added to the wall system; R-value to thickness ratio is very high.

Disadvantages:

- Rigid insulations are generally more expensive than batts of equivalent R-value.

- Since rigid insulation acts as an exterior vapour barrier, condensation problems could exist if the warm side vapour barrier is not effective.

Super-Thick Sheathing:

- Commonly referred to as the "Styro House".
- Very high R-values (RSI 6.5 plus), using 10cm (4") or more of foam sheathing on standard stud walls.

Sandwich Panel Walls

Basically, rigid foam insulation is sandwiched between two layers of sheathing. Various sheathing materials may be used, depending on the application. These include:

- Plywoods and wafer boards,
- Finished panels,
- Plastics, and
- Metals.

The insulating material is typically polystyrene or urethane foam. Structural panels which need no support framing are gaining in popularity.

Advantages:

- These are factory-manufactured component wall systems, and are therefore built with a higher degree of quality control.
- Very high R-value to thickness ratios are possible.
- Thermal barrier continuity is simplified – often, the air barrier is incorporated into the component; however, separate vapour barriers are generally required.

- Installation is simplified and minimum on-site labour is required.

Disadvantages:

- On-site modification is restricted.
- Material costs are higher; however, installed costs are usually similar to other super insulated wall systems.
- Insect infestation has warranted some concern. This problem is presently being addressed by the industry.
- There are few major manufacturers; new local manufacturers are constantly coming and going.
- Although it is a proven and worthwhile technology, much of the industry is not established.

Non-Structural Trusses

This non-structural truss is made of 2"x 2"s held apart by plywood webs. Prebuilt lengths of 10'-16' and 8" depth are available from some lumber distributors. Site-built trusses of various lengths and depths can also be constructed. The trusses are applied vertically to the outside of a 2"x 4" stud wall. Some basic modification of the 2"x 4" wall may be necessary to attach the truss. Sheathing and an air/vapour barrier is installed to the outside of the 2"x 4" wall before attaching the truss. The wall and truss cavities are then filled using inexpensive batt insulation. Most exterior finishes can be used with the truss system except standard brick.

Advantages:

- The air/vapour barrier is installed deep in the wall for protection.

- Plumbing and wiring can be located in the inner wall cavity; therefore no penetrations through the air/vapour barrier are required.
- Inexpensive fiberglass batt insulation can be used to attain high R-values.
- Thermal bridging is reduced.
- Standard 2"x 4" structural wall frames are used.
- Very little special instruction required.

Disadvantages:

- Very new system, relatively untested.
- Wall thickness is substantially increased.
- Standard brick claddings cannot be used.
- Roof detail requires some changes.

Spray in Place Foam

Using carbon dioxide as a foaming agent, polyurethane or polyisocyanurates are sprayed into open cavities in an uncured liquid form. The foam structure is created by a gaseous foaming agent who is produced as part of the curing reaction, or added independently.

Advantages:

- High R-value - typically R-4 to R-7 per inch.
- Can also serve as an effective air barrier.
- Very effective on irregular surfaces.

Disadvantages:

- Should be protected from water.
- Takes several minutes to set and cure.

- Requires surface preparation.
- Can be messy to apply.
- Should be applied by insulating contractors.
- Generally more expensive than other types of insulation.

c. Where to Insulate?

Insulation may generally be added in three locations:

- Within the existing wall cavity,
- Outside of the existing wall, or
- Inside of the existing wall.

Use Table 5 to help decide which location is most appropriate:

Table 5 Insulation Location Decision Table

Conditions	Cavity	Inside	Outside
Siding is being replaced	X		X
Interior finish being replaced	X	X	
Siding and Interior finish will not be replaced	X		

d. Adding Insulation Within an Existing Wall

Adding insulation within an existing wall is appropriate if there is:

- Sufficient space available in the wall cavity,
- Access to the wall cavities is available (for at least foam in place or blown insulation hoses), and

- Moderate insulation resistance values are acceptable.

Advantages:

- New framing is not required.
- Wall thickness remains unchanged.

Disadvantages:

- Amount of insulation is limited by the space available.
- The uniformity of the insulation is uncertain when the cavity is not exposed.
- Some wall cavities are difficult to access.
- Some interior refinishing may be needed.

Techniques

There are three main techniques for adding insulation to the existing wall cavity:

Plaster/Dry wall Removal; Exposing the Cavity

- The wall cavity is filled with batt or other insulation.
- A polyethylene air/vapour barrier is installed.
- Drywall is installed and finished.

Pouring insulation into the cavity (single storey or balloon framing without fire stops)

- Wall top plates are drilled from the attic.
- Each stud space is filled with pouring insulation.
- Window casing/sill removal permits drilled hole access to otherwise blocked stud spaces.
- Holes are plugged and window sills restored.

- Cracks are carefully sealed around windows, at the floor/wall joint.
- Oil based paint is applied to the walls as the vapour barrier.

Spraying Insulation into the Cavity

- Access holes are drilled through the wall top plates, bottom plates, under window casing and baseboard locations into all stud space cavities (Figure 6.A).
- Spray-in-place foam is used to insulate and seal joist header spaces.
- Access holes are plugged, casing and baseboard reinstalled and minor drywall damage repaired.

e. Adding Insulation to the Inside of the Wall

Adding insulation to the inside of a wall is appropriate if:

- There is sufficient interior space to allow for thicker walls;
- Interior refinishing of envelope walls is acceptable; and
- There is insufficient space for insulation within the wall.

Advantages:

- Exterior facade is unchanged.
- High insulation values are possible.
- Work can be performed in any weather.

Disadvantages:

- Added wall thickness reduces useful floor area.
- Major disruption inside house.
- Many interior obstacles.

Techniques

There are three main techniques for adding insulation to the inside surface of an existing wall.

Strapping and Insulating

- Strapping is nailed to the existing wall.
- This space is filled with insulation.
- Electrical boxes are extended or relocated.
- A polyethylene air/vapour barrier is installed.
- The wall is dry walled and finished.

Direct Application of Rigid Board

- Window and door openings are extended.
- Electrical boxes are extended to the new surface.
- Rigid board insulation is fastened directly to the wall.
- A polyethylene air/vapour barrier is installed.
- The wall is dry walled and finished.

Framing and Insulating

- A new wall is framed and nailed in place inside of the existing wall.
- The stud spaces and space between old and new walls are filled with insulation.
- Electrical boxes, are extended or relocated.
- A polyethylene air/vapour barrier is installed.
- The wall is dry walled and finished.

f. Adding Insulation to the Outside of the Wall

Insulation added to the outside of a wall can be appropriate if:

- Building exterior resurfacing (siding, stucco) is planned;
- Roof overhang will allow for adequate soffit ventilation with a thicker wall;
- There is sufficient space to allow for thicker walls; and
- There is insufficient space for adding insulation within the wall.

Advantages:

- Interior features remain intact.
- High insulation values are possible.
- Minimal disruption inside house.
- High degree of air tightness is easily achieved.

Disadvantages:

- Work requires reasonably good weather.
- Service entrances require extension.

Techniques

There are two main techniques for adding insulation to the outside surface of the existing wall.

Insulating Sheathing

- Siding is removed and remaining sharp edges are covered with building paper.
- The wall is covered with a polyethylene air/vapour barrier.
- Board insulation is applied directly to the wall.
- Strapping and siding are applied.

Strapping/Framing and Insulating

- Siding is removed and/or any sharp edges are covered with building paper.
- Wall is covered with a polyethylene air/vapour barrier.
- Strapping or new framing is securely fixed to the outside of the existing wall.
- New frame is filled with insulation and covered with sheathing and house wrap.
- Wall is re-sided.

Insulated Siding

One other possibility for adding insulation to the outside wall is the use of insulated siding. Various products are often seen in the marketplace that claim to provide a simple means of adding modestly to the overall resistance value of the wall when a new facade is required.

g. Factory Prefabricated Housing

As builders and owners indicate a desire to reduce construction time and increase quality, factory construction becomes more popular. Popular in Europe and Japan, factory built components and on-site house factories have grown in popularity throughout North America.

While factory-built homes are not a new phenomenon in North America, they offer many advantages:

- Construction scheduling is not dependent on weather.
- Construction workers work in a controlled environment.
- Quality control is easier to implement.
- Construction can occur around the clock.

Regardless of "whole house" construction, there have been more and more factory prefabricated components being used in housing: trusses, wall panels, and stairs.

Modular houses are entirely factory built, including interior and exterior finishes, into modules or sizes suitable for shipping to a permanent site. The quality is extremely high since very little work is done on the site.

Figure 11 Mattamy Homes' Stelumar Advanced Manufacturing Plant (Photo: Toronto Star)

Advantages:

- Materials will not be exposed to site and weather conditions, since they are stored inside.
- Jigs and heavy machinery can be used to ensure good tolerances and fits.
- Insulation, air barriers and vapour barriers are generally easy to install.
- Since most of the work is done indoors, it can go on year round and workers have a safer, climate-controlled work environment - which should result in better quality workmanship.
- Costs are similar to most high quality custom home construction.

Insulation End Note

Ensuring the quality of insulating walls in both new and retrofit housing applications is very dependent on the particular product and its proper application.

5 ROOFS AND CEILINGS

a. Insulation of Roof and Ceilings

Roofs and ceilings are important in an energy efficient house as they make up a large part of the above grade building envelope. Light coloured roofs typically absorb less solar heat than dark coloured roofs, thereby requiring less energy for space cooling of the house. Insulation levels in ceilings are usually higher than for walls. The main reason for this is that ceilings are usually less expensive and easier to insulate than walls.

Requirements for high performance include:

- High insulation levels,
- Low air leakage from the heated space, and
- Adequate attic ventilation to prevent moisture build up.

These needs can often be met easily since:

- Attics usually provide good access above ceilings,
- In many cases there are no finishing concerns,
- Insulation space does not take away living space, and
- In many retrofit applications, disruption is minimal.

b. Requirements for the Super Insulated Roof

Adding extra roof and ceiling insulation is an accepted method of thermally upgrading existing residential construction. In new construction, super insulated roofs have three main requirements:

- At least RSI 7.0 (R-40), (as with walls this is constantly being increased by Building Codes),
- Full insulation over the wall plates, and
- An effective air/vapour barrier is necessary; ceiling penetrations must be dealt with properly.

c. Attics

Attics are the most common residential roof design. They are relatively easy to design for super insulation. Special care must be taken to ensure continuation of the insulation over the wall plates.

Attic Ventilation

The purpose of attic ventilation is to remove excess moisture and heat from the attic in summer. Although this function is generally less important in super insulated construction, it is still beneficial and required by code. Conventional site-built rafters do not allow for space to adequately insulate over the wall plates.

Trusses

Trusses are now used in the majority of new home construction. The advantages of trusses from the insulation standpoint are that designs can be easily modified to allow for better insulation

The most common of the trusses is the raised-heel truss or “Energy Truss”. These allow for extra height over the wall plates.

Cathedral Ceilings

Cathedral ceilings are generally more difficult to insulate because of the limited space between ceiling and roof skin. Special trusses with batts, blown-in insulation or bonded panels using rigid insulation are good options for cathedral ceilings. Ventilation baffles and insulation stops ensure sufficient ventilation.

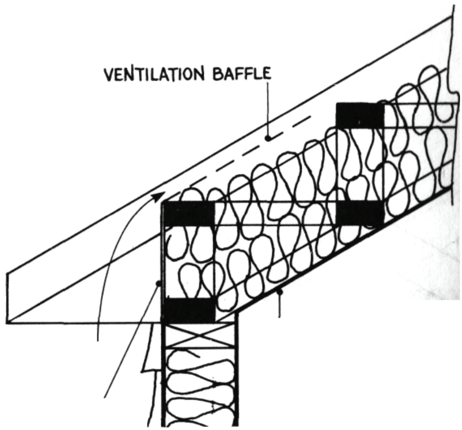


Figure 12 Cathedral Ceilings Using Trusses

Retrofitting Conventional Ceiling Insulation

The two approaches to adding insulation to ceilings are:

- Insulating in the attic, and
- Insulating the underside of the ceiling.

d. Attic Insulation

When the attic provides access to exposed ceilings it is the preferred place to add insulation.

Advantages:

- Minimum disruption.
- Continuous air/vapour barrier most easily installed.
- No finishing required.
- When the attic does not provide access, ceilings may be insulated on the interior.

Disadvantages:

- Major disruption of occupants.
- Difficulty in achieving continuous air/vapour barrier.
- Cramped work space for interior insulation.
- New drywall required.

Attic Insulation Technique

An existing air/vapour barrier may be upgraded to produce a continuous membrane if it is sealed:

- To itself at all joints;
- Around plumbing stacks and chimneys;
- Over electrical boxes and around wiring penetrations; or
- To the wall air/vapour barriers at the top plates.

Alternately, a new air barrier can be installed above the existing ceiling, rafters, and insulation and sealed.

Interior Insulation Technique

When access above a ceiling is not possible, such as is the case for some flat roofs and cathedral ceilings, it is possible to add insulation on the interior surface of the ceiling. The techniques used are similar as those for adding insulation on the interior surface of walls.

6 FOUNDATIONS

a. Types of Foundation Construction

Foundations and basements are often not insulated, and as a result can account for up to 30% of the home heating bill. The type of construction and level of insulation can play a significant role in curtailing heat loss. In addition, basement renovations including insulation are a popular means of adding finished living space.

Basement refinishing can:

- Provide a warm, dry living space,
- Eliminate existing moisture problems,
- Increase foundation life,
- Increase property value, and
- Significantly reduce energy costs.

Insulation of basement walls is worthwhile if:

- There is little or no insulation in place, or
- Existing insulation levels are well below Code.

Many older foundations are made of rubble, brick, or stone and vary in depth and thicknesses are often uneven. When originally built, these foundations were rarely damp-proofed. Generally, they have a have high mortar content, which tend to absorb water. Many can have a legacy of moisture problems. Considerations regarding moisture and moisture problems should be taken.

The full foundation basement is the most common in Canada. Most homes were built without the basement being finished or considered to be living space.

Many houses are built with a partial depth foundation that creates a crawl space below the house. In some cases, this space is open to the outside.

Some houses are built on a slab-on-grade where there is no basement or crawl space at all.

b. Heat Loss from Foundations

In cold climates such as Ontario, the ground temperature is generally cooler than room temperature. The temperature of deep ground (3 m to 6 m below grade) is approximately equal to the average annual outdoor air temperature.

Table 6 Approximate Deep Ground Temperature for Select Ontario Cities

City	Average January Air Temperature °C	Average Annual Outdoor Air Temperature °C
Toronto	-6.7	7.3
Ottawa	-10.9	5.7
Windsor	-4.4	9.3
Thunder Bay	-15.4	2.3

Down to 3m below grade, the ground temperature generally fluctuates with the daily outdoor temperature, with a time lag of days to weeks, depending on the depth.

Heat loss from foundations occurs in two directions: upward to the surface and downward into the ground. **The upward heat loss is more significant than the downward heat loss.**

For high-efficiency houses, the level of insulation for foundations should be comparable to that of above-grade walls.

Foundation Structural Materials

There are three basic structural materials used in newer foundation construction:

- Poured concrete,
- Concrete blocks, and
- All-weather wood.

It is the insulation system which is designed around these structural components which determines the effectiveness of thermal performance. Concrete is a poor insulator. Concrete blocks are only slightly better.

Table 7 Thermal Resistance of Poured Concrete and Concrete Block Walls for Typical eight-inch wall section

Material	R	RSI
Poured Concrete	0.6 - 0.8	0.11 - 0.14
Concrete Block	0.6 - 2.0	0.11 - 0.35

Note that in comparison, a single pane of glass 3mm thick typically has an R-value of R-1.0.

Thermal Bridge

A thermal bridge results when there is a discontinuity in the insulating system, which allows direct conduction of heat from the indoor to outdoor environments via a high-conductivity material. Thermal bridging is a major concern with concrete walls because of their extremely low thermal resistance.

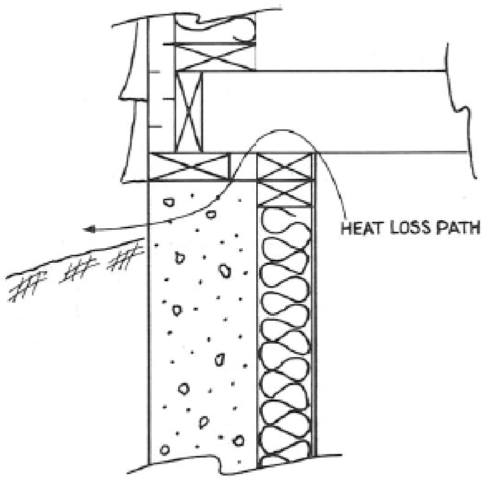


Figure 13 Thermal Bridging Through a Concrete Foundation Wall

Concrete block cores can be filled with water-resistant insulating material, such as vermiculite, to prevent the heat loss that occurs when convection cells form in hollow concrete blocks. It is important to note that core insulation in concrete block walls does not significantly increase the thermal resistance of the wall. Additional insulation is necessary for a super insulated foundation.

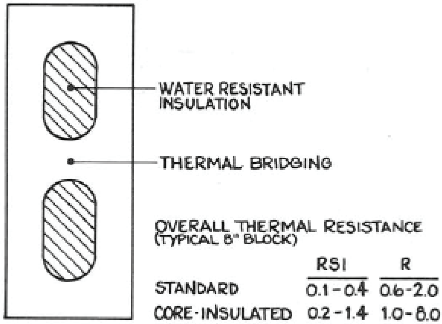


Figure 14 Core-Insulated Concrete Block

Wood, from a thermal performance standpoint, offers the better alternative to standard poured concrete or concrete block foundations. There are two basic advantages to wood frame foundation systems:

- The thermal resistance of wood is approximately RSI 0.22 per 25 mm (R-1.25 per inch); and
- A hollow frame wall can be easily filled with a suitable insulation material.

c. Insulating Foundation Types

Foundations are subdivided into three basic types:

- Slab on grade,
- Crawl space, and
- Basement.

With proper insulation systems, all three can be incorporated into a super insulated house. When designing the insulating system, the following performance considerations must be made:

- Moisture control,
- Air barrier continuity, and
- Location of thermal boundary.

d. Slab on Grade

It is important to insulate the floor slab for two specific reasons:

- To prevent heat loss down into the earth. Since the slab is on the grade surface, this heat loss is not due to deep ground temperature, but to surface temperature and can therefore be significant.
- To prevent that uncomfortable cold-floor feeling associated with the slab - this is especially important since this is the primary living area floor.

The recommended method of insulating requires a minimum of 5 cm (2") of rigid foam on the outside of the foundation wall and below the floor slab.

Many contractors have reservations about pouring the slab over the insulation and possibly damaging it. However, research has shown that pouring the slab over well supported rigid foam should not damage or deteriorate the insulation.

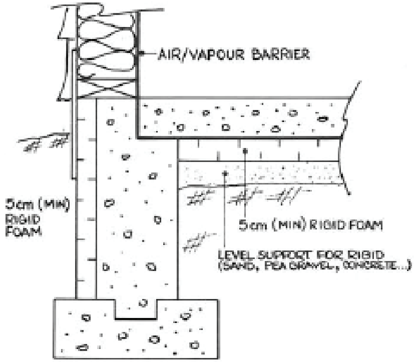


Figure 15 Slab on Grade Insulation

Some texts suggest placing the foundation insulation on the inside surface. Such systems can be effective; however, the following difficulties can arise and prove costly:

- Breach of continuity of the air/vapour barrier at floor/wall junction.
- Construction of a sub floor required to support insulation and flooring.

Advantages of the recommended method include:

- It increases the thermal mass of the floor.
- It protects the slab from thermal stress-induced cracking.
- It eases incorporation of the moisture barrier.

Finally, be sure to use rigid insulation designed or recommended for use in moist environments. Installation details may vary slightly with different manufacturers' instructions.

A third option for adding insulation to these foundations is insulating the edge of the slab.

Advantages:

- Minimum occupant disruption.
- Isolates slab from large temperature swings.

Disadvantages:

- Floor is not as warm.
- Requires excavation around foundation.

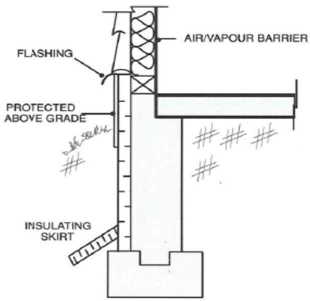


Figure 16 Slab on Grade - Slab Edge Insulation

e. Crawl Spaces

There are two insulation systems for crawl space foundations:

- Insulating underneath the living area floor, leaving an unheated crawl space; and
- Insulating on top of the crawl space floor, creating a heated crawl space.

The heated crawl space option offers several major advantages:

- Since the crawl space is within the thermal envelope, heat ducts and plumbing pipes do not have to be protected from excessive heat loss or freezing.
- Floor penetrations for pipes, ducting and wiring need not penetrate the air/vapour barrier.

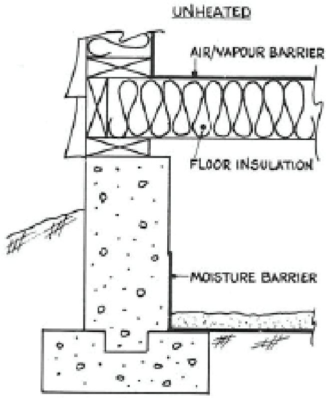


Figure 17 Unheated Crawl Space Insulation Systems

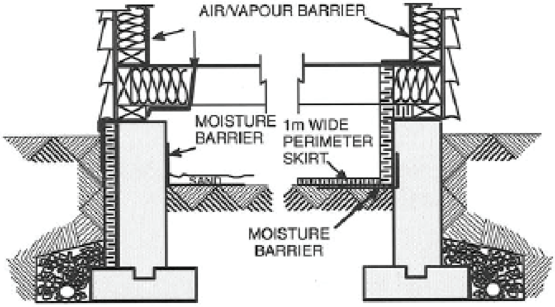


Figure 18 Heated Crawl Spaces

Techniques for Insulating the Crawl Space

Crawl space walls may be insulated on the interior or the exterior using basement wall insulation techniques:

- An air/vapour barrier is installed.
- Batt Insulation can be used to fill the joist spaces.
- Insulation is supported and protected.
- Heating ducts and water pipes in the crawl space may need to be insulated (Note: This alone does not provide freeze protection).
- Alternately, spray-in-place foam insulation can be used to replace the air/vapour barrier, the insulation and its support system.

f. Basements

Basements are the most common type of foundation. Insulation systems can be applied to either the interior or the exterior of basement walls.

Exterior Basement Walls Insulation

A major cause for concern with exterior insulation is potential damage from frost heave. To avoid this, the soil around the foundation walls must have good drainage.

Advantages:

- The concrete wall is on the warm side and therefore not subjected to thermal stress which might cause damage.
- The insulation can be continued up to the above-grade wall, thereby reducing thermal bridging at the sill plate.
- The concrete wall adds to the building thermal mass.
- Some special exterior rigid insulation assists drainage.

Disadvantages:

- Insulation material is generally more expensive.
- Care must be taken during backfilling.

Shallow Horizontal Insulation

Designers choose this type of external basement wall insulation in order to thermally couple the basement wall to the deep ground.

- Such systems may offer some cooling benefit in the summer.
- The same rigid insulation is used for outside systems.
- Selectively used when there are special considerations.

- In general, it is more expensive due to increased labour and care.

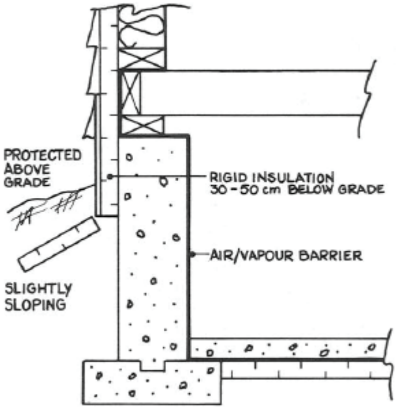


Figure 19 Shallow Horizontal Insulation

Interior Basement Wall Insulation

The most common way to insulate basement walls is from the inside.

Necessary conditions for interior basement wall insulation:

- No serious foundation problems, and
- Dry foundation walls (good damp proofing and drainage).

Advantages:

- The insulation is protected; therefore, all types of residential insulations may be used.
- Can be installed after the house construction is complete, either by the builder or self-contracted.

Disadvantages:

- A frame wall is necessary to support the insulation; the most common form is 2"x 4" or 2"x 6" studs slightly offset from the wall, which results in less interior living space.
- Moisture problems can occur due to the increased difficulties in properly installing the air/vapour barriers.

Techniques

Frame Wall and Batt Insulation

- Accommodates irregularities in the foundation wall.
- A polyethylene moisture barrier installed on the wall from grade down onto the floor (suggested).
- A stud wall is framed and installed slightly out from the wall with the bottom plate resting on the polyethylene.
- The space between the wall and the studs is filled with batt insulation installed horizontally.
- The stud spaces are filled with batt insulation.
- The header spaces are insulated and covered with a sealed air/vapour barrier.
- An air/vapour barrier is installed over the insulation and the wall is covered with drywall.

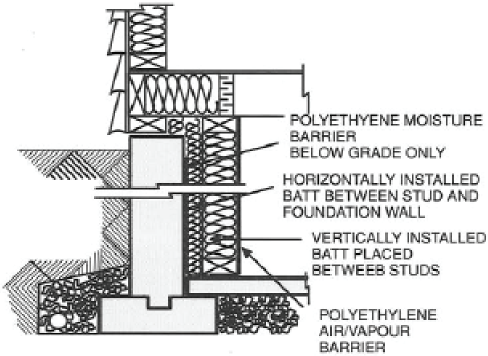


Figure 20 Frame Wall and Batt Insulation

Nailing Strips and Rigid Board Insulation

- Only suitable for flat wall surfaces.
- A polyethylene moisture barrier is installed on the wall from grade down to the floor (may be omitted if board insulation is a moisture-resistant grade).
- Rigid board insulation is mechanically fastened directly to the wall using mechanical fastening options.
- The header spaces are insulated and covered with a sealed air/vapour barrier.
- An air/vapour barrier is installed over the insulation and the wall is covered with drywall.

Spray in place foam techniques are also appropriate.

Insulating the Basement Floor Slab

Basements are not considered primary living space, and the energy loss from the slab to the deep ground is generally not sufficient to justify the additional cost. Approaches to basement floor slab insulation were discussed earlier in this chapter in the "Slab on Grade" section. As with all insulation techniques, multiple systems and solutions are available on the market that may be more suitable to a particular situation.

Insulated Foundation Block Systems

In new construction, Insulating Concrete Block systems are sometimes used as a method for insulating foundation walls. There are basically two types of insulating concrete block systems:

- Homogenous Composition Blocks, and
- Laminated Blocks.

These blocks are made of a homogenous mix of materials - usually cement, sand and stone, plus an insulating material such as expanded polystyrene beads. The insulating value of such blocks varies depending on the percentage of insulating material.

Increasing the insulating value of the block usually decreases the structural properties. Most of these blocks are sold as entire systems. This includes adhesives, mortars, coatings and finishes.

Laminated insulating block systems use blocks with vertical layers of concrete and insulation. These blocks are designed to be installed so that the insulation layers remain continuous to avoid thermal bridging problems. The insulating value depends mainly on the total thickness of the insulating layers and the insulation material itself.

Advantages:

- One-trade installation.
- May eliminate need for air/vapour barrier.
- Warm wall system increases thermal mass.
- Thermal bridging problems reduced.

Disadvantages:

- Requires specialty training.
- Design details require rethinking.

Laminated blocks are either factory-finished products which are delivered to the site and then assembled, or partially finished systems in which the rigid insulation is used as a form for a poured concrete foundation.

Foundations End Note

Ensuring the quality of insulating foundations in both new and retrofit housing applications is very dependent on the particular product and its proper application.

7 WINDOWS, DOORS & SKYLIGHTS

a. Introduction/Fundamentals

Windows are unique building envelope components. Their uniqueness stems from the multiple roles they must play:

- Control of daylight entering the building;
- Allow for natural ventilation;
- Be aesthetically pleasing;
- Provide an emergency exit; and
- Allow for communication with the outdoors.

However, like other components, windows must provide a high degree of control over the energy and mass flows into and out of a building. Consequently, windows must also meet the same basic performance criteria as walls, ceilings and doors. The important performance criteria are:

- Prevent unwanted heat flow into and out of the home,
- Maintain vapour barrier integrity, and
- Maintain air barrier, when required.

Windows traditionally have been the weak link in the thermal performance of the building envelope. On average, a single pane of glass will allow 15-20 times more heat to escape than a wall.

b. Components in a Window

A window consists of three major components:

- The glazing unit(s),
- Frames, and
- Spacers.

Figure 21 shows the basic components of a window.

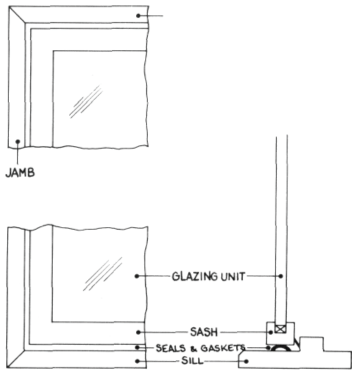


Figure 21 Window (Casement)

The glazing is the transparent part of the window. The frame holds the glazing unit and is the interface between the glazings and the wall.

The spacer is found only in sealed glazings; it holds adjacent panes of glass apart to create a gap. It is important to recognize the difference between the various components, especially when discussing performance.

The major difference between windows and other building components, such as walls and roofs, is that windows are transparent. This allows heat transfer by radiation to be much more important than it is in opaque components such as walls.

c. Energy Performance of Windows

Three major types of energy flow that occurs through windows are:

- no solar heat losses and gains in the form of conduction, convection, and radiation;
- solar heat gains in the form of radiation; and
- airflow, both intentional (ventilation) and unintentional (infiltration).

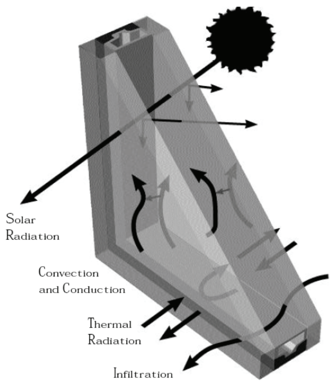


Figure 22 Energy Flow Through Windows (Courtesy US DOE)

There are several parameters used to describe the energy performance of windows as outlined in Table 8.

Table 8 Window Performance Parameters

Term	Definition
U-Value	The inverse of the R-value (the thermal resistance).
Transmittance	Usually refers to visible light passing

	through a window. The closer to "1", the clearer the window will appear.
Shading Coefficient	The amount of solar energy passing through a window compared to a 3 mm double-strength window. Important in calculating solar heat gain.
Emissivity	The ability of a surface to radiate energy (discussed later in detail).
Air Infiltration and Exfiltration	Refers to the unwanted movement of air, either into or out of the house, through the seams and cracks of a window.

These parameters are used to describe and typify the performance of various window technologies. The most important parameters for the homeowner are:

- R-Value, or U-Value,
- Shading coefficient, and
- Air infiltration/exfiltration.

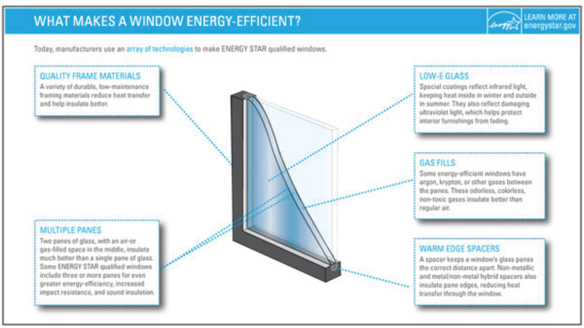


Figure 23 Features of an Energy Efficient Window (Courtesy US EPA)

d. Window Glazings

Single-Glazed Windows

Single-glazed windows are not recommended for any Canadian locations. The R-value of a single glazed window is almost entirely due to the thin films of air on the inside and outside of the window. The glass itself adds practically no thermal resistance to the window as a whole. A building with existing single-glazed windows should be retrofitted with more energy-efficient windows immediately.

Double-Glazed

Double-glazed windows can be either sealed or unsealed. A sealed unit, also called insulating glass, has two panels of glass enclosing a dead air space, and is bonded together at the edges and mounted in a sash. Insulating glass units are recommended for energy-efficient applications.

Thermally, a double-glazed sealed unit consists of:

- Two thin air films (also called boundary layers),
- Two panes of glass,
- A dead air space, and
- A spacer.

The addition of a second pane, and the creation of an air gap between the panes, reduces the conduction and convection of heat through the glazing unit.

The spacer determines the gap width between the panes of glass.

- Too wide a gap increases convective heat loss.
- Too thin a gap increases conductive heat loss.

The spacer has a much higher thermal conductance than the air gap. Hence it will reduce the thermal resistance near the edge of the glazing. This loss of glazing performance is often referred to as “edge effect”. When combined with the thermal conductance of the frame, edge effects can severely reduce overall performance.

Double-glazed units have until recently been the most widely used and economic window, in terms of cost versus energy savings. The R-value is twice that of single glazings and the additional window thickness is not a problem for builders or architects.

Table 9 Thermal Performance (R-Value) of Common Glazing Configurations

Window Frame Type	Single	Double	Triple
	R	R	R
Glass only	0.9	2.0	3.2
Wood frame	1.0- 1.1	2.0 - 2.3	3.2 - 3.4
Metal frame	0.8 - 0.9	1.6- 1.7	2.2 - 2.5
Thermally broken metal frame	0.9 - 1.0	1.8-2.2	2.6 - 3.2

Standard 3 mm glass panes (with 12.5 mm air spaces).

Multiple Glazings

A simple strategy to improve glazing performance is to add additional panes of glass and air spaces. As a rule of thumb, each additional glazing increases the unit's thermal resistance by R-1. This rule shows a diminishing return on increasing the number of glazings. For example:

- Single to double - 50% reduction in energy loss
- Double to triple - 33% reduction in energy loss
- Triple to quadruple - 25% reduction in energy loss

The reason for the diminishing reduction of energy loss is that radiation heat loss dominates when more than two panes of glass are used. Multiple glazings are only effective in reducing convection and conduction.

Multiple glazings are used when:

- There is a condensation problem in high humidity areas; or
- To improve noise insulation (i.e., homes near airports).

Advantages:

- R-values as high as R-5.

Disadvantages:

- Expensive.
- Bulky.
- Loss of light transmission.

e. Low-Emissivity Glazings

Radiation heat loss can be reduced by changing the surface properties of the glazings; the most important of which is the emissivity of the glass Low-Emissivity (Low-E) coatings that are very thin transparent films of semiconductor material applied to the surface of a glazing.

The coatings are usually made of the following materials:

- Tin oxide, and
- Silvery tin metals.

Emissivity is the ability of a surface to radiate heat. An example of a good radiator (i.e., high emissivity) is a black electric stove element. Conversely, shiny metal surfaces, such as the aluminium foil used to insulate hot food, have a low emissivity. Low-E coatings reduce the emissivity of the glass surface, which in turn reduces the radiative heat flow.

These coatings and glazings improve the thermal performance of the window, without any perceptible loss of transmission of light.

Types of Low-E Coatings

The tin oxide coating can be applied at the same time as the glass is manufactured, and is referred to as a "pyrolitic coating". The other method of applying the coating is to deposit it on the glass surface, in a vacuum, after the glass has been cut into large sheets. This process results in a sputtered or "soft coating". Table 10 shows a comparison of each type.

Table 10 Comparison of Low-E Coatings

Type of Low E Coating	Features
Sputtered or Soft	• Very low emissivity. • E= 0.10-0.20. • Must be used with sealed glazings for protection. • Gives higher optical performance. • Better thermal performance.
Pyrolitic or Hard	• Durable. • E = 0.35. • Can be exposed to the weather. • Widely available.

Shading Coefficient

A low-E coating reduces the shading coefficient from .85 to .66. This indicates less solar energy is entering a building through the window. Low-E windows should be used with caution in passive solar homes which use solar gain for space heating.

f. The Double-Glazed Low-E Window

Low-E coatings are almost always used in sealed double glazings. The coating goes on one of the surfaces inside the dead air space. For climates in which heating, rather than cooling, is the major requirement, the coating is generally placed on the outside surface of the inside pane of glass. Figure 24 shows a typical low-E double-glazed unit and the heat transfer in summer and winter.

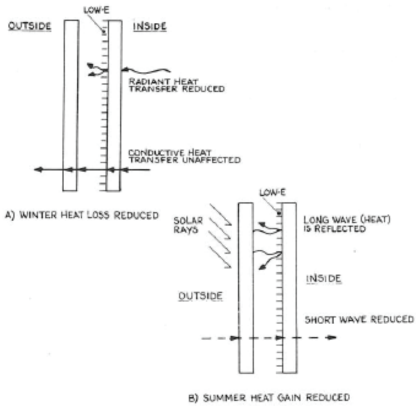


Figure 24 Summer and Winter Benefits for Low-E Double Glazed Windows

A double-glazing with a low-E coating has a thermal resistance of R-2.6 to R-2.8. This is almost equivalent to a triple glazing. The biggest difference between low-E and triple glazing is the shading coefficient. Triple-pane glazings let in more solar energy, which can be very efficient in the wintertime (though inefficient in the summertime).

Advantages:

- Thermal performance is better than double-glazing.
- Reduced heat loss in winter.
- Reduced heat gain in summer.
- Reduced condensation at higher indoor humidity levels.
- Little reduction in light transmission.
- Screens out ultraviolet rays - less fading of furniture.
- Less expensive than triple glazed.

Disadvantages:

- Reduced solar heat gain in winter.
- Slight colouration of glass.
- More expensive than double-glazed.

Gas-Filled Windows

Air, compared to other gases is a good conductor of heat. By replacing the air in the gap space with a heavier gas having lower thermally conductivity, conductive heat loss is reduced. The most common are: Argon, and Carbon dioxide.

Gas fills are used with low-E coatings in double or multiple glazed units. Typical thermal resistance for a double-glazed, low-E, gas-filled windows is R-3.5 to R-5.0.

Interpane Films

An alternative to multiple glazings is to place a thin plastic film between two standard panes of glass. The film is usually a thin sheet of polyester coated with a low-E coating. The film creates two air cavities, similar to a triple-glazed unit, but also includes a low-E coating.

Advantages:

- Same weight and thickness as double-glazed.
- High thermal resistance - R-3.5 to R-5.0.

Disadvantages:

- Less durable than glass.
- Shorter life expectancy.

g. Window Frames

The second major component of a window is the frame. The frame performs the following functions:

- Holds the window in place,
- Allows glazings to open and close, and
- Interfaces the glazings with the wall.

The important selection criteria for window frames are:

- Thermal integrity,
- Infiltration rate,
- Aesthetics, and
- Cost.

h. Frame Types

There are six major operable window types, as shown in Figure 25. One other major type of frame is the fixed frame, generally found in large picture windows. Operable windows are one of the most complex of all building components and are consequently expensive.

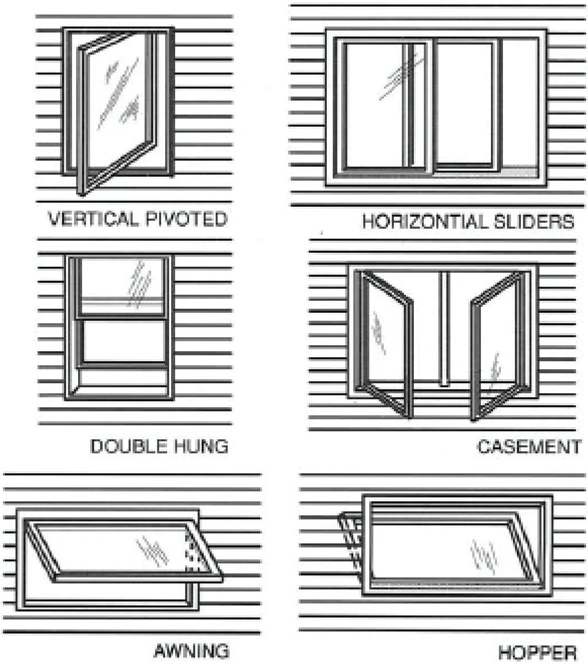


Figure 25 Window Frame Types

The choice of a frame is of course a personal one, depending on the homeowner's aesthetics and the amount s/he is willing to pay. However, in terms of performance, particularly for infiltration and overall R-value, fixed, awning, and casement tend to be better choices than either double-hung or slider types.

i. Thermal Integrity

The R-value of a frame has a large impact on the overall window R-value. The frame and the associated edge effect can decrease the window R-value by as much as 20% from the glazing R-value. The two important considerations in choosing a frame with good thermal properties are:

- Material used, and
- Design used.

Most frames are made of wood, aluminium or vinyl. Wood has a thermal resistance higher than most glazing units. Aluminium has a very low R-value, but if a thermal break is used, it will give adequate thermal performance. A thermal break is a discontinuity in the metal frame, which is replaced by a better insulating material, such as plastic. The interruption in the metal frame reduces conductive heat losses. Metal frames without a thermal break are not suitable in energy-efficient construction.

Vinyl window frames are similar to well designed aluminium frames with thermal breaks. However, vinyl-clad aluminium window frames are not significantly better than standard aluminium frames, and should therefore incorporate a thermal break in the design.

Table 11 Thermal Conductivity of Frame Materials

Frame Material	Thermal Conductivity
Aluminium	221.0 Watts/meter °C
Wood	0.11-0.20
Steel	45.0

Multiply R-value of glazing unit by a correction factor from Table 12 below to obtain approximate R-value of entire window.

Table 12 Correction Factors for Various Window Configurations and Frame Materials

Frame Material	Single Unit (R)	Sealed Double or Low-E Double Unit (R)	Triple Unit (R)
Wood	1.1 to 1.2	1.0 to 1.1	1.0 to 1.1
Metal	0.9 to 1.0	0.7 to 0.8	0.6 to 0.8
Thermally Broken Metal	1.0 to 1.1	0.9 to 1.1	0.8 to 1.0

Air Infiltration and Exfiltration

Window frames are important in reducing unwanted infiltration of air. Air leakage through a window is a direct result of cracks or seams between the frame and wall, and sash and frame. The air leakage can be both into and out of the house, depending on pressure differential, wind direction and the operation of heating and cooling equipment.

Infiltration is the second highest energy loss mechanism in window assemblies, and is responsible for approximately 25% of all the energy loss related to windows. In the case of operable windows, the critical seal is between the window sash and the frame. There are many variations on obtaining a good seal. However, most use gaskets or weather-stripping to prevent air movement.

Table 13 Air Leakage Rates of Selected Windows (0.1 litre/second/meter of seam)

Window Type	High	Average	Low
Aluminium, Horizontal Sliding	7.59	4.27	0.82
Aluminium, Casement	3.36	2.06	0.77
Aluminium, Double-Hung	4.48	3.55	3.55

Wood, Horizontal Sliding	4.0	1.90	0.40
Wood, Casement	5.33	1.45	0.16
Wood, Double-Hung	-	2.35	—
Vinyl, Horizontal Sliding	-	3.82	—
Vinyl, Casement	0.46	0.27	0.37
Vinyl, Vertical Sliding	3.58	-	1.24

Window Spacers

All sealed insulating glass units have some type of spacer that maintains the separation between the two (or more) panes of glass. The spacer material must:

- Be strong enough to hold the window apart, and
- Have a high thermal resistance.

Common spacer materials are aluminium and vinyl. The aluminium is drawn into rectangular sections, having a very thin cross-section. The thin cross-section reduces heat loss.

The spacer is usually filled with a desiccant to absorb any moisture trapped in the unit. This prevents unsightly condensation on the inside surfaces of the glass panes during cold weather.

New spacers use a variety of materials:

- Rigid foam;
- Butyl tape with aluminium strip;
- Fiberglass extrusions; or
- Wood.

All these materials have better R-values than metal spacers and will significantly reduce thermal losses at the edge of the sealed unit. Note that these spacer systems tend to be more expensive than the aluminium and are in some cases not readily available from all window manufacturers.

Installation of Windows

The proper installation of windows requires the detailing of the window/wall interface. The following questions must be answered when planning a window installation:

- What is the wall air barrier?
- Where is the airtight seal of window relative to the wall?
- How large should the wall/window gap be, and what should be used to fill it?

New Construction

The same procedures described under the following Retrofit section can be used in new construction. In general, window installation is easier for new construction; hence good performance should always be achieved.

Retrofit

Windows in homes are, on average, replaced every 14 years, though most windows have a much longer life. All types of glazings and window frames are suitable for retrofit into existing buildings. Window manufacturers will build a made-to-measure window to fit into the existing space from which the old window came.

Windows should be replaced when:

- Condensation is noticed between the panes of a sealed glazed unit;

- Panes are loose, or rattle in the sash or frame;
- Visible rot of wood components is observed;
- Existing window is single-glazed; or
- Frame is metal with no thermal break.

The best frames for retrofit applications are the same as for new installation.

Casement, awning, and fixed windows have the best infiltration and thermal performance. Metal frame sliders without thermal breaks should be avoided, as they will not provide good comfort levels or energy savings.

The installation of a new window should be done with care. It is essential that the wall and the window frame provide a continuous air and thermal barrier. Drafts are a major problem with window installations.

Batt insulation is insufficient to stop air movement. The most common method of sealing the joint between the window frame and the rough opening is caulking. The recommended caulking compound is silicone for gaps below 17 mm and polyurethane for larger gaps. Also effective is acoustic expanding foam. Care should be taken not to overfill the joint - this may stress the window frame, causing deformation and binding.

Other retrofit options, other than replacing the entire window, are to upgrade the glazing unit (especially important if the glazing seal has failed), the installation of weather-stripping, storm windows, and the upgrading of the window/wall interface.

Weather-Stripping Windows

Weather-stripping can be applied to all types of windows. There are four major types of weather-stripping.

- Felt/foam adhesive;
- Multi-filament polypropylene;
- Hollow or filled tubes; and
- Pressure.

The foam and filament types, while easy to install and inexpensive, lose their thickness and elasticity after prolonged compression and high temperatures (i.e. summertime). The loss of elasticity allows more air to pass through the joint.

The tube type weather-stripping, which is more temperature and pressure resistant, tends not to degrade as much. This type of weather-stripping is used on the sash side of double hung and on awning and casement windows.

The pressure type weather-stripping is used on hinge windows, such as awning and casement. The seal is made by the force of the window closing against the weather-stripping. The elasticity of the weather-stripping material maintains constant contact with the window.

j. Storm Windows

Adding storm windows is another easy retrofit option, which gives good thermal performance and is relatively inexpensive. There are five types of storm windows available for upgrading of existing windows.

Polyethylene

- Installed on inside of window.
- Blocks air leakage, creates airspace.
- Inexpensive, easy to install, effective.
- Easily damaged.
- Cannot be reused.

Shrink Wrap

- Installed on inside of window.
- Is taped to window frame, using double-sided tape.
- A heat source (i.e. hand-held hair dryer) shrinks it tight.
- Good visibility, blocks air leakage, creates dead air space.
- More expensive than polypropylene.
- Easy to install, inexpensive, effective.
- Easily damaged, replace every year.

Plexiglas

- Consists of a frame and rigid plastic sheets.
- Frame is permanently installed on outside of window.
- Inexpensive, easy to install.
- Easily damaged (scratches), limited life (yellows in sunlight).

Removable

- Consists of a single pane of glass in a frame.
- Window is installed and removed each year.
- To avoid condensation, space between windows must be ventilated.
- Are less expensive than permanent storms.
- Long life, durable, requires some maintenance.

Permanent

- Consist of a metal frame, with glass and screening in the same unit.
- Need only be installed once.
- Must be made especially for each window.
- More expensive than removable.

k. Skylights

Skylights provide a popular means of admitting natural light to otherwise dark areas.

- Skylights are very much like windows that are installed in a roof.
- A variation on the skylight called the roof window allows the glass and frame to pivot inward for cleaning

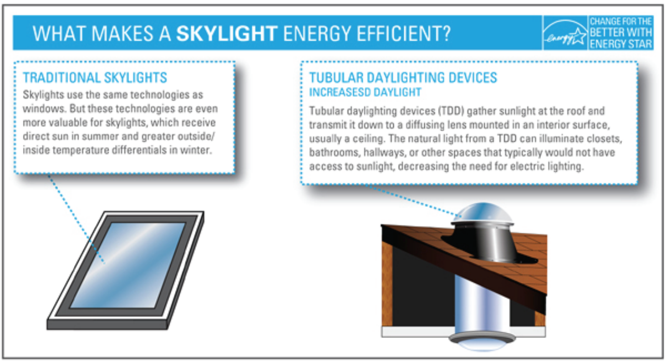


Figure 26 Features of an Energy Efficient Skylight (Courtesy US EPA)

Good skylights

- Limit heat loss;
- Prevent air exchange with the outside;
- Do not allow any water leakage; and
- Do not allow condensation to drip into the living space.

Skylights permit ventilation by opening the glazing or a separate vent. Built-in shading systems are frequently available. Skylights are available with the following energy-efficiency features:

- Multiple glazing,
- low emissivity coatings,
- gas filled glazing units, and
- insulated curbs.

Advantages:

- Admits natural light.
- Improves the aesthetics of the living space.
- Can increase natural ventilation.

Disadvantages:

- Have higher heat losses than insulated roofs or ceilings.
- Results in more envelope area if a light shaft is used.
- Penetrates the roofing system.

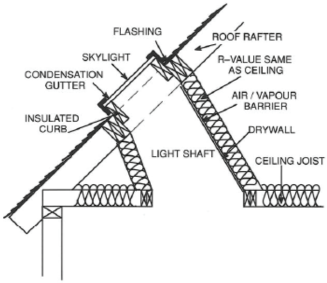


Figure 27 Installed Skylight

I. Doors

Good performance from a door implies:

- Ease of operation,
- Durability,
- Low air leakage, and
- Low heat transmission.

Upgrading existing doors or replacing them with better units can:

- Improve comfort,
- Reduce maintenance, and
- Improve energy efficiency.

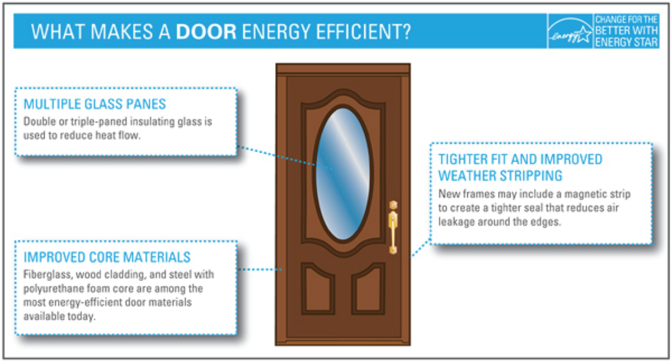


Figure 28 Features of an Energy Efficient Door (Courtesy US EPA)

Options

The options available for upgrading door performance are:

- Addition or replacement of weather stripping between door and frame;
- Sealing the door frame to the envelope air/vapour barrier;
- Addition of a storm door;
- Replacement of existing door with an insulated metal or wood unit; or
- Replacement with insulated door and a storm.

Caution: The last option should not be used on unshaded southern or western exposures, as heat build-up between the doors can result in damage.

Air Sealing

- Significant reductions in draughts and air leakage can be achieved by sealing the door frame to the air barrier.
- Batt insulation without an air vapour barrier is insufficient to stop air movement through the door frame/rough-opening.
- Caulking is recommended for gaps up to 17 mm and polyurethane foam for larger spaces.
- Care must be taken to avoid overfilling the joint and distorting the door.
- A slight distortion of the door or frame can cause a large gap over the 2 meter height of a door.

Weather Stripping

- Data to assist in the selection of weather stripping is provided in Table 10.B.

Patio doors tend to be very inefficient because of:

- The large glass area,
- The full length opening, and
- Heat conduction through the frame.

An insulated metal door containing a double glazing installed next to a fixed sealed-unit window offers a lower air-leakage alternative to a patio door. Patio doors should include the following features:

- High performance air seals;
- At least double glazed with 12 mm air space; and
- Wood or thermally broken metal or PVC frames.

Table 14 Selection of Weather-stripping for Doors

Around Doors	Application Method	Advantages
	Nails between door and jamb. Spring metal strip presses against edge of door when closed. Easiest to install if sold with predrilled holes. Bronze, aluminium, stainless steel.	Doesn't show when door is closed. Good control of drafts. Long life. Difficult to readjust. Easily tampered with.
	Nails or screws into stop. Screws take longer to install but are easier to adjust than nails. Position to make gentle contact or door will be too hard to close. Aluminium, plain or anodized, with vinyl inserts.	Can be adjusted if holes are slotted. Good durability. Keep out drafts, water, noise, light, dust, humidity. Stripping is visible alongside door.
	Nails into stop. Aluminium with wool, hair or cotton, felt, vinyl.	Keeps out drafts, noise, light, dust. Visible alongside door or window. Not as durable as rigid metal-backed sealer. Not easily adjusted once sealer loses contact with door or window.

Around Doors	Application Method	Advantages
	Flexible magnetic seal similar to those used on refrigerators. Usually supplied; already installed in frame with pre-hung door.	Very good seal and is flexible enough to accommodate seasonal movement of steel doors. Quite inconspicuous. Only works with steel doors.
	Adhesive-backed strips of foam simply stick to jamb or stop; vinyl-covered foam strips nail on.	Installs in minutes. Doesn't show. Keeps out drafts, noise, light, dust, and humidity. Temporary; foam soon flattens, breaks down.
Threshold	Fits under door; door bottom should have about 1/s-inch bevel to seal against vinyl bubble. Available in different heights. Metal cap with built-in angle available to fit over bottom of doors; offers smooth surface. Aluminium plain or anodized and vinyl.	Works as combined threshold and weather strip; useful where there's no threshold or wood is worn out. Provides good weather seal. With wear, vinyl bubble will flatten out, tear, and lose effectiveness. (Replacement bubbles sold.)
Under Doors	Screws into interior side of in-swinging door. Aluminium, stainless steel with sponge, vinyl.	Adjustable. Effective. Exposed to view. May drag across rugs.

Around Doors	Application Method	Advantages
	Screws onto outside of in-swinging door. Door opens, sweep retracts. Door closes, striker plate causes sweep to lower. Aluminium, plain or anodized, with vinyl, neoprene, or felt drop.	Useful where threshold is flat or there is no threshold. Good durability. Sweep may not retract quickly enough to pass over edge of threshold or carpet up against door.
	Fits over door bottom, screws into face. Shoe with slotted screw holes allows adjusting for seal with some margin for error. Aluminium, vinyl inserts.	Effective, durable seal. May be used with wood threshold that's not worn down in middle. Usually sold with drip cap that sheds rain. Vinyl insert replaceable. Before installation, bottom of door may require trimming or door threshold may have to be replaced.

m. Structural Ratings for Windows

All windows and sliding glass doors need to be rated in terms of their structural integrity when they are installed in new homes or buildings.

There are national, provincial, and local building codes which specify minimum ratings, depending on the climatic conditions. Table 15 indicates the different structural performance ratings and their ranges.

Table 15 Air Tightness Factors for Windows and Sliding Doors (Source: NRCan)

Type	Least airtight	Most airtight
Most operable windows	A1	A3
Single-hung windows*	A1/fixed	A3/fixed
Single sliding windows*	A1/fixed	A3/fixed
Non-operable (fixed) casement windows	A1	A3
Picture windows	Fixed (pass/fail rating)	
Sliding glass doors	A1	A3

* The operable and non-operable sashes may be tested and rated separately for single-hung and single sliding windows.

Energy Performance Certification

All windows sold in Canada must be tested and certified for energy performance by independent accredited laboratories which include:

- CSA International;
- Intertek Testing Services;
- Quality Auditing Institute Ltd.; and
- The National Fenestration Rating Council (United States).

n. ENERGY STAR® Window Selection Tips

Windows, doors, and skylights are eligible to be certified for the ENERGY STAR rating. This simplifies the purchase decision for the consumer or builder. There are essentially three steps to purchase ENERGY STAR windows, doors, and skylights.

The four climate zones in Canada are based on a 30 year averaged annual temperature indicator, heating degree days (HDD).

- Zone A: 3500 HDDs or less.
- Zone B: 3501 – 5500 HDDs.
- Zone C: 5501 – 8000 HDDs.
- Zone D: 8000 HDDs or more.

The higher HDD value, the colder the location and the longer the heating season. Zone A is the warmest region and Zone D is the coldest region in Canada.

Step 1 - Look for the ENERGY STAR symbol on the display models or product literature.

Figure 29 Sample Energy Star Label for Windows in Canada

Step 2 - Using the climate map (Figure 30), find the zone where the product will be installed.

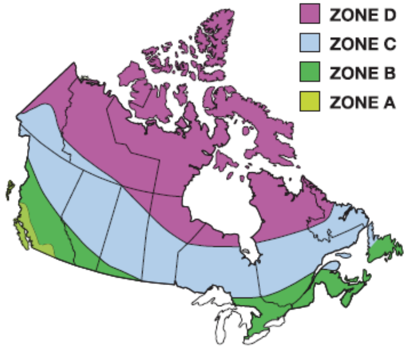


Figure 30 Heating Degree Day Climate Zones (Source: NRCan)

Step 3 – Ensure that the window product model being purchased is qualified for that zone (Figure 31).

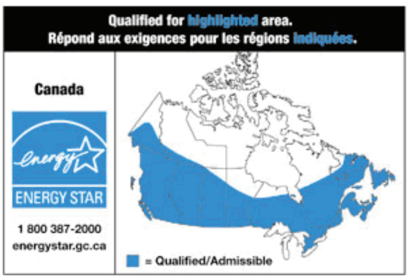


Figure 31 ENERGY STAR Window Qualified Zone Label

Tips:

- To save even more energy, use a window that is specified for a colder zone than where it will be installed.

- For installations at substantially higher elevations than sea level, purchase windows rated for at least one higher climate zone.

On-Line Window Rating Tool

Natural Resources Canada has a free on-line product database for the majority of windows available in Canada. It can be accessed at:

http://www.oee.nrcan.gc.ca/residential/business/manufacturers/search/windows-search.cfm?attr=4

8 SPACE COOLING

a. The Refrigeration Cycle

Regardless of the type of air conditioning technology, the underlying method of cooling is vapour compression refrigeration cycle (Figure 32).

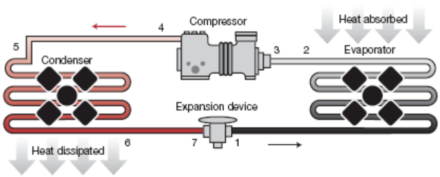


Figure 32 Simplified Refrigeration Cycle (Courtesy UK Carbon Trust)

The cycle involves multiple steps:

- The refrigerant is a substance that circulates through the air conditioner and transports heat from one section to another.
- Through phase change from liquid to gas and vice versa, the refrigerant absorbs and releases heat.
- Heat transfer occurs within a coil or heat exchanger with fins.
- In the evaporator section, the refrigerant absorbs heat from its surroundings, causing the refrigerant to boil and become a low-temperature vapour.
- An electrically powered compressor compresses the refrigerant gas molecules together, which increases both the temperature and pressure of the refrigerant.

- The condenser coil allows the refrigerant gas to give off heat to its surroundings and to change phase from gas to liquid.
- The expander device releases the pressure created by the compressor and results in a temperature drop and phase change to a low-temperature vapour/liquid mixture.

b. Air Conditioners

In the residential sector, there are three types of commercially available air conditioners in widespread use:

- Central air conditioners,
- Room air conditioners, and
- Heat pumps.

Room and central air conditioners are single purpose, in that they only provide cooling. Heat pumps are dual-purpose in that they can also provide heat during winter months.

- Central air conditioners and heat pumps are used to cool an entire living area.

- Room air conditioners can effectively cool up to three rooms and have the advantage of low installation cost.

c. Central Air Conditioner Types

Central air conditioners are intended to cool the entire house. A large compressor and outdoor coil are located outdoors and are connected by refrigerant lines to an indoor coil mounted in the furnace (Figure 33).

In most houses, the same duct system is used for both heating and cooling the air distribution.

Energy performance improves as the Seasonal Energy Efficiency Rating (SEER) increases. The SEER is the ratio of heat removed (in Btu) per electrical energy used (in Wh). Most commercially available central air conditioning units have SEER ratings that range from a minimum of 10.0 to a maximum of about 17.0.

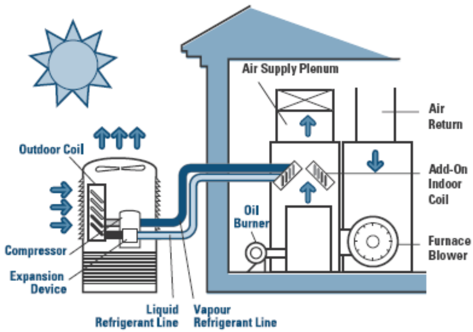


Figure 33 Central Air Conditioner (Courtesy NRCan)

Split-system unit

Almost all central air conditioning units are split-systems. They consist of separate indoor and outdoor sections. The indoor section has a heat exchanger coil, and is typically installed above the house furnace. The remaining components are installed outdoors and a refrigerant line joins the two sections.

Mini-split and multi-split ductless units

Some central units use “mini-split” and “multi-split” units. These units contain one or more indoor coil connected to one outdoor unit. Ductwork is not required, and these units are ideal for new additions to homes. The indoor section mounts on a suitable spot on an inside wall, ceiling, or floor. Both outdoor and indoor units generally have a very slim profile compared to conventional split-systems.

Small-duct high-velocity units

For retrofit situations where the house does not have ductwork (i.e. electric or hydronic baseboard heating), small-duct high-velocity units can be used. These central air conditioners use plastic pipes in partitioned walls to outlets and inlets for air distribution.

d. Room Air Conditioner Types

Room air conditioners are fully contained air units and are not “split” like central air conditioners. They are intended to cool only a small area, which is usually up to 3 rooms in a small contiguous area.

The two major categories of room air conditioners are:

- Window Mounted - units with louvered sides for installation in window openings; and
- Through the Wall units - without louvered sides for through-the-wall installation.

The most common type is the unit with louvered sides. Powered by electricity, the room air conditioner extracts heat from the living space and conveys it directly to the outdoors.

Ductwork is normally not required, and all components are contained in a single package that is mounted in a window opening or through the wall (Figure 34).

Some room air conditioner units are portable, and they have movable and flexible ducts for air exchange.

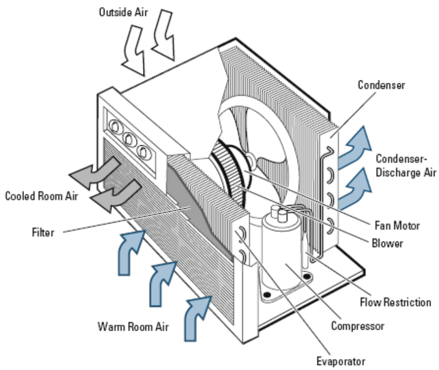


Figure 34 Room Air Conditioner Components (Courtesy NRCan)

Through-the-wall (TTW) Air Conditioning Units

- Through the wall air conditioners tend to be less efficient than regular window units.
- They are designed to fit through the wall and are constructed this way as the wall framing would interfere with the airflow through the sidewalls of the air conditioner.

- They must also meet minimum efficiency regulations.
- Although not common in colder climates, some TTW room air conditioners are built to provide some heating, either with electric resistance heating, or by what is called a reverse cycle.
- With the reverse cycle, the room air conditioner can act like a heat pump and heat the room.

Window-mounted units

Most room air conditioners are the window-mounted, louvered type. They are available for installation in a variety of window ports including:

- Single- and double-hung windows,
- Horizontal sliding windows, and
- Casement windows.

They are mounted into an open window and plugged in. For larger units, a dedicated 240-volt circuit may need to be installed.

Portable units

Portable room air conditioners have a flexible duct that is used to exhaust heat to the outside. They can easily be moved from room to room. Water condensed from the cooled air has to be removed and drained away through temporary ducting to the outdoors. Currently, there is no CSA Standard or energy efficiency rating for this product.

e. Heat Pumps

A heat pump uses the vapour compression refrigeration cycle described in 7a, but is capable of reversing the refrigerant flow using a device called a reversing valve. In effect, the heat pump is able to extract heat from a source and move it into the home while operating in heating mode. In Canada, heat pumps are typically air source or ground source.

Heat pumps are rated by a coefficient of performance (COP) or the heating energy output divided by the energy input. COP can also be expressed as the (heating capacity in Btu/hour) / (energy input in Watts × 3.413 Btu/Watt hour)

The higher the COP, the higher the energy efficiency.

Air source heat pumps use the outdoor air as a heat source during heating mode and the outdoor air as a heat sink during cooling mode. Air source heat pumps were popular in the early 1990's. Since that time, technological and quality installation advances have made ground source and water source heat pumps more popular.

This Guide provides a cursory overview of heat pumps. A more detailed review of heat pump technology can be found in the ***CEATI Energy Efficiency Reference Guide on Heat Pumps***.

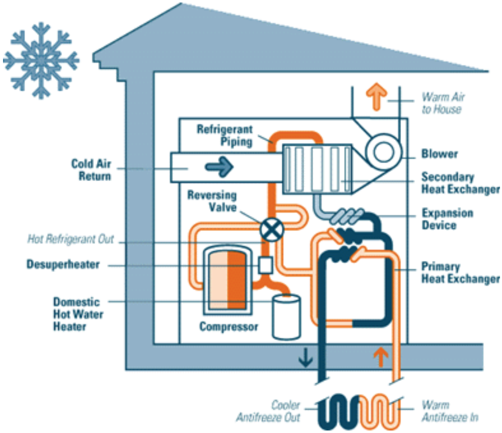


Figure 35 Ground Source Heat Pump (Courtesy NRCan)

Ground Source Heat Pump Basics

Ground Source Heat Pump (GSHP, geothermal or "GeoExchange") technology transfers heat between the stable temperature of the earth and a building to maintain the building space conditions.

For most parts of Canada, at a few meters below the ground surface, the temperature remains at approximately 15°C throughout the year.

- This stable temperature provides a resource for heat in the winter and a means to reject excess heat in the summer. In a GeoExchange system, a fluid is circulated between the building and the ground loop piping buried in the ground.
- In the summer, the fluid picks up heat from the building and moves it to the ground. In the winter, the

fluid picks up heat from the ground and moves it to the building.

- Heat exchangers exchange thermal energy between a building and the ground. When the building needs heating, the system extracts energy from the ground and pumps it into the building where it is concentrated by the heat pump.

- Conversely, when the building needs cooling, the heat from the building is concentrated by the heat pumps, and the system removes heat from the building and pumps it to the ground.

Ground Source Heat Pump Configurations

For houses with large yards or access to lakes or rivers, a horizontal loop may be appropriate (Figure 36). With this configuration, loops of plastic coils containing a water-ethanol mixture circulate at meters below the ground surface.

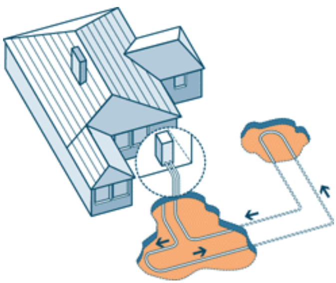


Figure 36 Horizontal Loop Configuration (Courtesy NRCan)

For smaller lot sizes, vertical configurations may be appropriate. Bore holes are drilled to a level of approximately

30 – 100 m below the surface (Figure 37) and contain the plastic piping for the transfer fluid for heat exchange.

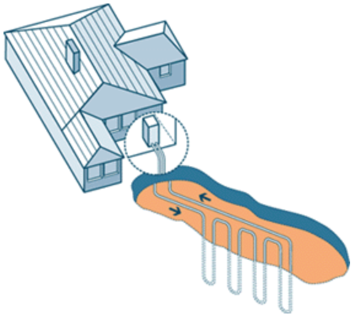


Figure 37 Vertical Loop Configuration (Courtesy NRCan)

Heat Pump Energy Performance

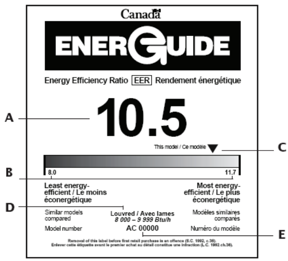
Heat pumps work in a similar manner as central air conditioning units. Their Seasonal Energy Efficiency Ratings (SEER) are competitive with central air conditioners, and heat pumps have a competitive advantage of reducing heating costs during the winter.

Unlike air conditioners, which need to discharge heat to a highly variable outdoor temperature, heat pumps mostly discharge against an almost constant year-round temperature. Consequently, the ground source heat pump can be more energy efficient.

On an annual basis, ground source heat pump savings can range from about 20% (for gas heated homes) to 60% (for electrically heated homes).

f. Energy Guide Labelling

Both room air conditioners and central air conditioners are covered under Canada's Energy Efficiency Regulations, which came into effect February 3, 1995. Figure 38 shows a sample label used in Canada for Air Conditioning units.



Sample room air conditioner EnerGuide label

Note: The EnerGuide label for room air conditioners always compares models of the same type and with similar cooling capacities.

- A This number shows the energy efficiency ratio – EER – of the room air conditioner model. The EER is based on a Canadian Standards Association (CSA) test procedure that manufacturers must follow.
- B The numbers shown on the left and right of this line indicate the range of EERs available for similar models (same type and similar cooling capacity) during one year.

  The number on the right is the most energy-efficient model produced or available in a given year, as listed with EnerGuide. The number on the left of this line is the EER of the least efficient model produced or available in a given year, as listed with EnerGuide.

  The numbers on this scale are provided by EnerGuide to all manufacturers and dealers, and are updated every year to reflect new models introduced in Canada.
- C This triangle places the EER of the model on the label in comparison with the least and most efficient EERs (numbers on the left and right) of models of the same type and with similar cooling capacities.
- D This is the type and cooling capacity category. Types are either louvred or non-louvred. Cooling capacity category is in Btu/h.
- E This is the actual model number of the unit on which the label should be placed.

Figure 38 Illustrative EnerGuide label use for Air Conditioning Equipment

g. Room Air Conditioner Efficiency Ratings

The Energy Efficiency Regulations specify that room air conditioners must carry an EnerGuide label, which provides consistent and reliable information about the relative energy efficiency of room air conditioners on the market.

- The large bold number found on the EnerGuide label for room air conditioners is known as the Energy Efficiency Ratio EER of the unit, and the higher the EER, the more efficient the room air conditioner. EER is a unit of heat moved (in Btu/h) per unit of electrical power input (in Watts).

- The inverted triangle and the graduated bar can be used to compare the performance of a particular model with others of the same class.

- Class refers to the type (louvered or non-louvered) and cooling capacity category, which are indicated near the bottom of the label.

- The further the triangle is to the left of the scale, the less efficient it is. The further the triangle is to the right of the scale, the more efficient it is.

Commencing in 2004, the ENERGY STAR symbol (see Figure 39) appeared on top tier energy efficient air conditioning units.

Figure 39 Energy Star Symbol

To qualify for the ENERGY STAR symbol, a room air conditioner must meet a standard of premium energy efficiency and exceed NRCan's minimum efficiency threshold by at least 10 percent, as shown in Figure 40.

TYPE	WINDOW-MOUNTED (LOUVRED SIDES)	THROUGH-THE-WALL (WITHOUT LOUVRED SIDES)
Cooling Capacity (Btu/h) Standard	Minimum EER to be ENERGY STAR qualified	
Less than 6 000	10.7	9.9
6 000 to 7 999	10.7	9.9
8 000 to 13 999	10.8	9.4
14 000 to 19 999	10.7	9.4
20 000 and over	9.4	9.4
Casement-only – all	9.6	
Casement-slider – all	10.5	

Figure 40 Energy Star performance levels for thorough-the-wall and casement units (Source NRCan)

Certification

The room air conditioner EER and cooling capacity are determined in accordance with the Canadian Standards Association (CSA) Standard C368.1-M90, which specifies methods of testing, test conditions, and tolerances.

h. Central Air Conditioner and Heat Pump Efficiency Ratings

All central air conditioners must meet minimum efficiency standards of performance under Canada's Energy Efficiency Regulations. Natural Resources Canada and the Heating, Refrigerating and Air Conditioning Institute of Canada (HRAI) have established an industry-managed energy efficiency rating system for furnaces, central air conditioners, and heat pumps.

The central air conditioner SEER and cooling capacity are determined in accordance with CSA Standard C273.3-M91: Performance Standard for Split-System Central Air Conditioners and Heat Pumps. The standard specifies the tests and calculation procedures to be used to determine SEER and capacity ratings. The standard also specifies the minimum efficiency requirements.

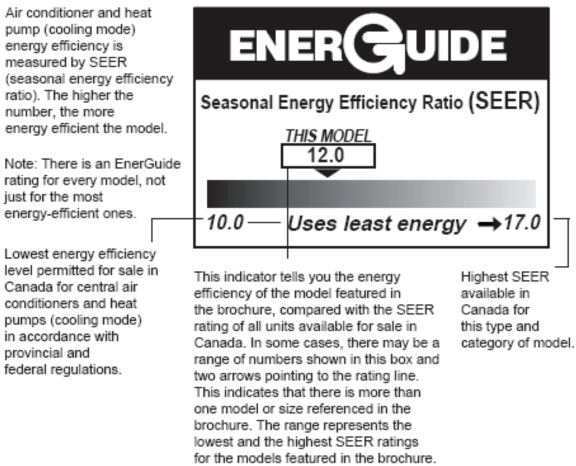


Figure 41 Energy Efficiency Rating for Central Air Conditioners and Heat Pumps

9 VENTILATION

Adequate ventilation is essential for good indoor air quality and occupant health. Leaky houses tend to have too much ventilation when the weather is cold and windy, and too little when it is calm and mild.

Tight houses require mechanical ventilation systems to provide a reliable supply of fresh air. Mechanical systems may be controlled to provide the desired amount of fresh air.

a. Increased Air tightness

During renovations, it is recommended that measures are to be taken to tighten the envelope. Some consequences of these actions are:

- Improved comfort,
- Reduced heating/cooling costs, and
- The opportunity and the need to use controlled mechanical ventilation.

Advantages of using controlled mechanical ventilation:

- The supply of fresh air is independent of weather conditions;
- The amount of ventilation is controlled to provide the required amount of fresh air - continuously; and
- Central ventilation systems provide the opportunity to recover waste energy in the exhaust air with a heat recovery ventilator.

b. Types of Ventilation Systems

A number of different types of ventilation systems are available:

- Exhaust systems,
- Central exhaust systems,
- Local exhaust fans,
- Equipment venting systems,
- Supply Systems,
- Central supply systems,
- Local supply fans,
- Make-up air systems,
- Balanced Ventilation Systems,
- Ventilation without heat recovery, and
- Heat recovery ventilators.

Local Exhaust Fans and Unintended Ventilation

In general, there are multiple systems that exhaust air from within the home internally. In all cases, exhausted air must be made up for with outdoor air, either through mechanical ventilation or infiltration. This outdoor air must be heated or cooled, which increases the home's energy use.

Bathroom Exhaust Fans

Inexpensive models are mostly axial fan types, while centrifugal types are more expensive and higher capacity. It is recommended to install a unit in every bathroom, whether with or without a window, to remove odour and moisture. Fans must be ducted to the outside of the house, not to the attic, which may cause dry rot.

- Ducting through the attic must be insulated to avoid condensation from the exhausted moist air. Control by separate wall switch, or by light switch.
- Size properly and select a quiet unit.
- Remember that people sometimes don't use exhaust fans because they are noisy, or in order to save energy.
- An alternative to exhaust fans is the use of bathroom exhaust intakes and ductwork as part of a central ventilation system.
- Some units come with heat lamps, and lights.
- Capacities: 20 to 50 L/s (40 to 100 cfm).

Kitchen Range Hoods

- Range hoods are driven by either axial or centrifugal fans. Newer models are integrated with microwave ovens.
- Usually has a two-speed switch, or a variable speed control.
- Range hoods need to operate only when the range is used.
- Fans come with a removable, washable grease filter.
- Ducted or non-ducted (recirculating) units are available.
- Non-ducted units may come with a removable charcoal filter.
- Commercial units are available which can be installed either as ducted or as non-ducted (with knockout for either application).
- A non-ducted unit can remove only some of the grease and fails to remove odours, moisture, and smoke.
- It is recommended to install a quiet ducted unit with proper duct size and minimum duct fittings.

- Ducts must exhaust directly to the outside and can't be connected to a heat recovery system, because grease may block the heat recovery core.
- Wall, window, or ceiling exhaust fans have been used as less effective alternatives to kitchen range hoods.
- Capacities: 50 to 210 L/s (100 to 420 cfm).

Window/Wall Exhaust Fan

Axial type

- Filter available on some models for grease and lint removal.
- Non-ducted.
- Telescoping sleeves fit most wall thicknesses.
- Switch-operated or pull chain.
- Some models have exterior dampers, which may be opened automatically by the fan switch or by the pull chain.

Central Vacuum Systems (if Externally Exhausted)

- Range of air flow rate: 45 to 65 L/s (90 to 130 cfm).

Clothes Dryer

- Range of air flow rate: 40 to 55 L/s (80 to 110 cfm).

Chimneys

- Chimneys are structures of brick, stone, concrete, metal, or other non-combustible material, providing a housing for one or more flues, which carry off products of combustion.

- The flue is the vertical shaft through which smoke and hot gases are carried from the fireplace or combustion equipment to the outside.
- A single flue may serve one or more appliances – for example, the furnace and a water heater.
- Gases in a chimney have a higher temperature than household or outside air - so they are lighter and flow upwards.
- The flow of gases creates a draft of air through the fireplace, stove, or furnace. At start-up, the temperature of the combustion gases in the chimney is relatively low - creating a small draft and maybe some spillage of combustion products.
- A chimney is part of a natural exhaust system, i.e., natural venting equipment exhausts through the chimney.

Fireplaces – Wood Burning

- Fireplaces are generally inefficient heating systems and also may create back drafting problems.
- Back drafting, or down drafting, means that the air flow in a chimney flue reverses, bringing combustion products into the house.
- Typical flow of a fireplace fire is 110 L/s (220 cfm).

Fireplaces – Natural Gas

Venting is required to remove combustion gases from the firebox to the outdoors. Three options are available:

- Natural draft venting,
- Power venting, and
- Direct venting.

Natural draft fireplaces typically use a B-vent or, in an existing chimney, an approved metal liner that includes a B-vent or a flexible metal liner. Power vented fireplaces have an electrical fan to assists the venting process.

To be installed in an energy-efficient home, a gas fireplace should be either direct-vented (sealed) or power-vented.

c. Supply Systems General Description

There are three basic types - central supply systems, local supply fans, and make-up air systems.

- A central supply system uses a fan to supply air to individual rooms in the house.
- Local supply fans are used for local supply in individual rooms (living room, bedrooms).
- Make-up air systems are intentional openings which supply outdoor air to the house, to balance the negative pressure caused by exhaust fans or systems.
- Supply systems cause a positive pressure in the house, especially if there are no intentional air outlets or exhausts.
- The positive pressure causes air exfiltration which may lead to condensation of moisture in the walls or in the attic.
- A supply and an exhaust system should form a balanced system.

Central Supply for Forced Air Systems

- For a house with a central forced-air system, a thermally insulated duct can be run from the outside to the return air plenum.

- The furnace blower draws air from the outside and the return air duct, and supplies the mixed air throughout the house.
- The adjustable damper in the supply air duct regulates the quantity of outside air.
- The cost of a damper, 4 meters of insulated flexible duct, and an intake air hood is about $100.

Balanced Ventilation Systems General Description

- A balanced ventilation system uses a supply fan to draw outdoor air into the house, and an exhaust fan or fans to exhaust indoor air to the outside.
- The exhaust and supply flows are adjusted to bring about a balance.
- This system keeps a neutral pressure in the house.
- Potential problems related to positive and negative house pressures are avoided.
- Exhaust air is drawn from rooms with high levels of moisture or pollutants.

Outdoor air is distributed to individual rooms

There are two basic types:

- Systems with no heat recovery, and
- Heat recovery ventilators.

Ventilation with No Heat Recovery

- A house with a central forced air system can have balanced ventilation with a central supply and an exhaust system.

- A separate exhaust system is needed.
- A central exhaust system may be used.
- With this arrangement, there is no heat recovery.
- For houses with no forced-air system, a balanced ventilator unit could be used.
- However, a heat recovery ventilator would be preferable.

d. Heat Recovery Ventilator (HRV)

A heat recovery ventilator (HRV) is a mechanical ventilation device that not only brings in clean air from the outdoors, but also recovers heat from the stale air exiting the house.

- By continuously exchanging heat between outgoing stale air and incoming fresh air, the HRV device conserves energy.
- HRV systems also have the capability to filter incoming outdoor air for particles and allergens.

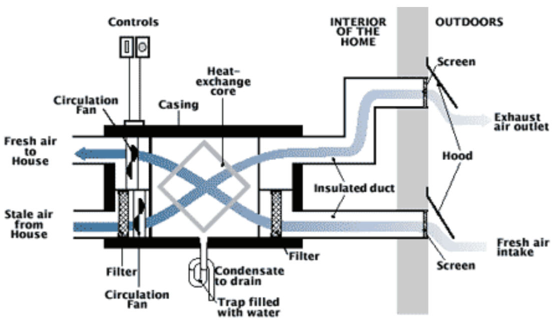


Figure 42 Components of a Heat Recovery Ventilator (Courtesy NRCan)

Heat Recovery Ventilators General Description

A heat recovery ventilator (HRV) consists of two fans, a heat exchanger, necessary controls, and filters, all in one unit.

Heat recovery ventilators are balanced ventilation systems with heat recovery. Supply and exhaust air flow rates are balanced (equal). The exhaust air warms up the intake air during winter, and cools down the intake air during summer. HRV units are designed for continuous ventilation. A two-speed control provides continuous and additional ventilation. Flow rates range from 50 to 100 L/s (100 to 200 cfm).

There is a variety of different HRV types commercially available, including:

- Flat plate,
- Rotary wheel,
- Concentric tube,
- Heat pipe,
- Capillary blower, and
- Heat pump.

The most common HRV used in Canadian homes is the flat plate type. Heat exchangers are made of many layers of thin metal sheets such as aluminium, or plastic (polypropylene) material. Exhaust air flows in the same direction between alternate layers, while fresh air flows in between the other layers. In the counter flow flat plate core, the fresh air and exhaust air flow in opposite directions. In the cross flow flat plate core, the fresh air and exhaust air flow in a perpendicular direction. Since the plates are thin, heat is transferred easily across from the warm air to the cold air.

Speed Control

The HRV runs continuously all year, at low speed, to satisfy the basic ventilation requirements. A manual switch on the HRV provides either high and low speed control, or variable speed control. Some units are hardwired to be continuously on (at low speed). Manual switches or timers, in bathrooms and kitchens can be used to switch HRV to high speed. A humidistat can switch HRV to high speed when humidity rises above a preset level.

Some units have a built-in humidistat to monitor exhaust air humidity, and switch to high speed at high humidity.

Defrost Control

If the incoming fresh air is very cold, it may cool the exhaust air below its freezing point and cause condensation and freezing in the heat exchange core. An automatic defrost cycle prevents ice build-up in the heat exchange core. The defrost cycle is activated by a preset fresh air temperature (-5 to -15 ° C) and will come on for a preset duration (2 to 5 minutes), every hour. The four automatic defrost cycles are:

- Supply shut off, exhaust melts ice - Fresh air fan stops and exhaust fan continues to discharge stale air to the outside or inside of the house;
- Supply shut off, exhaust shut off - Exhaust fan stops, and a damper blocks off fresh air, but allows house air to pass through the fresh air side of the HRV;
- Exhaust recirculates - Exhaust air downstream of the HRV is ducted to pass through its fresh air side; and
- Supply preheat - Duct heater warms fresh air before it enters the HRV.

Energy recovery ventilators (ERV) are also available, which recover latent heat (i.e. enthalpy) in addition to sensible heat.

HRV-installed House with Forced-Air System

The heat recovery ventilator discharges fresh air to the return air register of the forced-air system closest to the furnace. The fresh air cannot be ducted directly to the return air duct without written permission from the HRV manufacturer. The furnace blower should run continuously, and it can run at low speed (if available) to distribute fresh air throughout the house. Dedicated ductwork is normally needed to exhaust air from bathrooms, kitchen, laundry room, and rooms with high pollution sources. Fresh-air ductwork should supply fresh air to bedrooms, living rooms, dining rooms, basement, and rooms without exhaust.

10 WATER HEATERS

Domestic water heating accounts for about 20% of the energy consumed in homes.

Water-heating energy costs can be managed by:

- Using energy efficient fixtures, like low flow showerheads;
- Switching to cold water for cleaning and washing;
- Installing energy efficient water heating equipment and accessories (e.g. heater blankets, pipe wrap);
- Selecting the appropriate fuel and water heater type;
- Installing heat recovery equipment in drain pipes; and
- Using renewable energy sources for water heating (e.g. heat pump or solar).

a. Types of Water Heaters

A water heater uses a heating source to increase the temperature of incoming cold water from a municipal supply or well. The heated water is either produced on demand or is stored in a tank and distributed as required. The most common types of residential hot water heaters include:

- Storage tank water heaters,
- Instantaneous or Tankless heaters,
- Heat Pump,
- Combination Space and Water Systems, and
- Solar water heaters.

Storage tank water heaters are the most common domestic hot water (DHW) heating system in use today. They range in size from 20-80 US gallons, and operate using electricity, natural gas, propane, or other fossil fuels. Standby energy losses are higher than with instantaneous water heaters.

Instantaneous or Tankless water heaters heat water directly on demand, without use of a storage tank. They produce a limited amount of water and may not be suitable when multiple simultaneous uses occur. Most can produce a 50°C temperature rise at a flow rate of about 20 litres per minute. They are best suited for low demand applications.

Heat pump water heaters are electric storage water heaters that are 2-3 times more efficient than conventional electric resistance units. They draw heat from the surrounding air, and are most effective in warm climates.

Combination space and water heating systems provide space heating and domestic hot water. There have separate water heaters and forced-air or hydronic systems which may be combined. Combination heaters are especially beneficial in very well insulated smaller houses.

Solar water heaters use solar energy to preheat or heat domestic hot water. Capital costs are considerably higher than conventional systems, but operating costs are very low. Most solar water heaters in Canada can only preheat or produce 40-50% of the hot water requirements for a typical house.

b. Storage Tank Water Heaters

Storage tank water heaters are the most popular type used in Canada. These devices heat and store water in a tank using fuels like electricity, natural gas, propane, or oil. They provide a reservoir of hot water that is available at any time of the day or night.

Hot water is drawn from the top of the tank, and is replenished by cold water entering from the bottom.

Since the mid 1980's, advances to water heaters have resulted in systems that are up to 40% more energy efficient than their predecessors. Energy efficient water heater models usually have one or more of the following features:

- Extra tank insulation for improved heat retention and less "standby loss" (loss of heat through the walls of the tank);
- Factory-installed heat traps, which prevent unwanted flow of hot water out of the tank; and
- Sturdier heat exchanger, capable of transferring more heat from the energy source to the water.

Gas Storage Tank Water Heaters

Gas fired storage tank water heaters may include advanced design features, like:

- Better control of the flue baffle and flue damper, which reduces heat loss through the flue vent;
- Blower operated exhaust;
- Condensing heat exchangers, which boost the overall efficiency; and
- Electronic ignition, which eliminates the need for using pilot lights.

Conventional Storage Gas Water Heaters

Natural gas or propane fuelled residential water heaters are available in 115, 150 and 190 litre capacity sizes (30, 40 and 50 US gallon respectively). Essentially, they are made from a steel cylinder and are coated with 2.5 - 5.0 cm between the tank lining and the outer jacket (Figure 43). Other components include cold water supply inlet, hot water outlet pipe, draft hood, and flue.

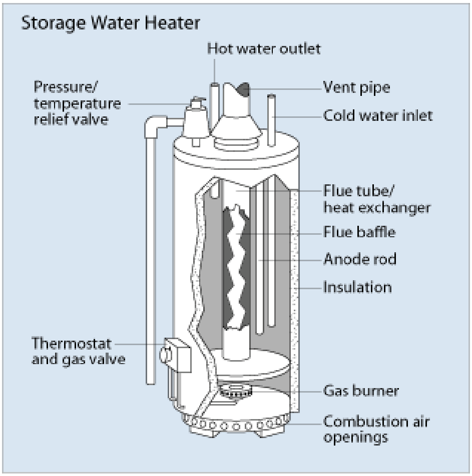


Figure 43 Conventional Gas Water Heater (Courtesy US DOE)

Hot water temperature and gas flow are controlled by a combination thermostat and gas valve. A combustion chamber at the bottom of the storage tank houses a gas burner. Air for combustion is brought in through air openings located at the bottom of the combustion chamber. Most units have a continuously burning pilot light that ignites the main burner when required. Overall seasonal efficiencies are around 55 to 60 percent.

Energy Efficient Gas Water Heaters

There are several types of energy efficient gas water heaters, including power vented, direct vent, and high efficiency condensing gas water heaters.

Power Vented Gas Water Heaters use induced draft fans to push the exhaust gases either up the chimney vent or out the side wall of the house, resulting in a marginal energy efficiency improvement.

Direct Vent Gas Water Heaters draw combustion air from outside the building and use a blower to exhaust combustion gases and are about 20% more efficient than conventional gas water heaters.

High Efficiency Condensing Gas Water Heaters use a heat exchanger to preheat the incoming cold water and cool the outgoing flue gases, and can attain 90% efficiency.

Natural Resources Canada provides an on-line tool to assist in the selection of natural gas and propane hot water heaters.

http://oee.nrcan.gc.ca/residential/business/manufacturers/search/gas-water-heaters-search.cfm?attr=0

Electric Storage Tank Water Heaters

An electric water heater (Figure 44) has several main parts, including a tank, thermostats, two submerged electric resistance elements, a cold water inlet pipe, and a hot water outlet pipe.

Tanks are generally shielded with foam insulation, and lined on the inside with a ceramic glass layer for corrosion protection.

As hot water is withdrawn from the tank, it is replenished with cold water. When the water temperature falls below a set point, the elements are energized, thereby reheating the water to the correct temperature.

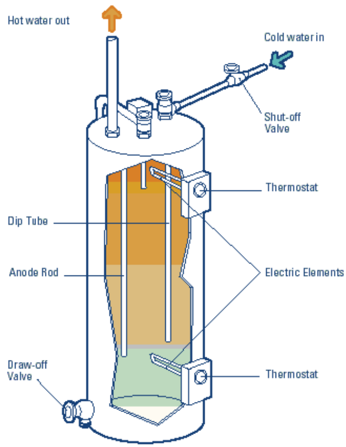


Figure 44 Electric Hot Water Heater (Courtesy NRCan)

The two submerged electric resistance heating elements in water heaters are very efficient, providing almost 100% of the available heat to the surrounding water. The elements can be operated separately or concurrently, and draw up to 4500 W of power.

Older water heaters are prone to lose heat as a result of standby losses.

Natural Resources Canada provides an on-line tool to assist in the selection of electrical hot water heaters.

http://oee.nrcan.gc.ca/residential/business/manufacturers/search/electric-water-heaters-search.cfm?attr=4

Tankless Water Heaters

Also known as demand or instantaneous water heaters, these devices do not have storage tanks. They reduce the penalty of standby heat loss by only heating water on demand. Most units are fuelled by natural gas, although some models are powered electrically. For gas operated units, separate ventilation is required. They are usually installed close to the point of end use, and some houses may have multiple units. Maximum flow is typically 20 litres per minute, and unlike storage tanks, only appliance or use (e.g. shower) can occur within this capacity.

Combination Space/Water Heating Systems

Combination space/water heating systems integrate the household heating and hot water requirements.

The technology uses a single boiler which requires only one combustion burner and one vent.

Sometimes the technology takes advantage of a secondary insulated external storage tank with a high-efficiency low-mass boiler.

Using a fan coil radiator, the hot water can release heat to air that is blown.

Most combination systems are sized to produce heat on the coldest winter day. This results in the system being oversized during the summer months when only the hot water is used.

Solar Water Heaters

Solar water heaters use the sun's energy to heat water. The heated water is generally used for domestic hot water or for swimming pool heating. For regions in Canada, solar systems typically supply 40-50% of the required hot water.

In addition to the solar collector, one or more storage tanks need to be installed inside the house.

Some systems require for the water temperature to be boosted or supplemented by a conventional electric or fossil fuelled water heater. Figure 45 outlines some of the features of the three most common types of solar hot water heaters.

Solar Thermal Collector Style	Features
Batch Collectors or Integrated Collector-Storage (ICS) 	• Heats water in dark tanks or tubes contained within an insulated box. • Heated water can remain in the collector for long periods when demand is low. • Typically not appropriate for cold climates. • Water is stored until drawn. • Generally has a tempering valve to prevent scalding.
Flat-Plate Collectors	• Assembly is housed inside an insulated box, and covered with tempered glass. • Common configuration is a series of

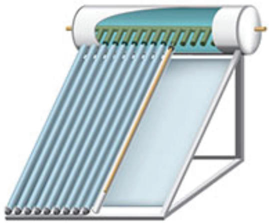
	parallel tubes. • Sized for about 150 litres of water. • Typically made from copper tubes fitted inside flat absorber plates.
Evacuated Tube Collector 	• Uses a thermos vacuum principle. • Can operate in overcast conditions or when temperatures fall to as low as -40°C. • Generally 2 times the price per ft^2 as flat plate collectors. • Glass or metal tube containing the water or heat transfer fluid is surrounded by a larger glass tube under vacuum. • Individual tubes can be replaced as needed. • Most efficient collectors available.

Figure 45 Solar Water Heaters
(Illustrations Courtesy US EPA)

c. Reducing Water Heater Energy Losses

The vast majority of direct heat loss from water heaters is comprised of:

- Standby Losses - losses by heat conducted through the tank walls and base; and
- Pipe Losses - losses by hot water convection through the hot and cold water feed pipes.

The operating efficiency of a hot water system can be enhanced significantly by designing the system carefully, and selecting equipment that generates hot water more efficiently and reduces stack and standby losses.

To Reduce Stack and Standby Loss

- Cover the tank with a certified insulating blanket. Caution: Be sure not to insulate over any controls or obstruct the vent connections or combustion air openings, and prevent the insulation from coming in contact with the vent connector.
- Install a heat trap above the water heater.
- Insulate accessible hot water pipes with pipe wrap (at least 0.35 (R-4) value.
- Install the water heater over a layer of rigid thermal insulation to reduce heat loss through the bottom of the tank.
- Purchase tanks with bottom inlet of cold water.

Water Temperature

- When the water tank temperature falls below 60°C, there is a greater chance of attaining conditions ideal for legionella bacteria to breed.
- When water temperate is above 50°C, there is a greater chance of children and others being scalded.

NRCan and other agencies recommend that to minimize legionella and minimize the potential for scalding, the water tank temperature should be set at 55°C[2], and that anti-scalding valves or protection devices be used in the house.

d. Water Usage and System Sizing

Peak hot water demand usually occurs during showering. As a rule of thumb, there should still be some hot water left in the storage tank after three people have showered (over a 40-minute period).

With a low flow showerhead, most hot water requirements can be met by a water heater with a first hour rating (FHR) of 270 litres (60 gallons).

Selecting a smaller water heater tank with a high FHR generally results in an optimally performing system, while minimizing cycling and standby losses when hot water is not in high demand. Table 16 indicates guidelines for tank size selection based on household and lifestyle factors.

Table 16 Typical Water Consumption and Household Size (Source NRCan)

Hot Water Use	Family Size (people)	Electric Tank Size	Gas Tank Size	Oil Tank Size
Vacation Cottage – no dishwasher – no clothes washer	Up to 2	135 litres (30 gallons)	90 litres (20 gallons)	90 litres (20 gallons)

[2] http://oee.nrcan.gc.ca/residential/personal/new-homes/water-conservation.cfm?attr=4

Small/Medium Family Home – 1 bathroom – no dishwasher – clothes washer	2	180 litres (40 gallons)	135 litres (30 gallons)	135 litres (30 gallons)
Medium Family Home – 1.5 bathrooms – dishwasher – clothes washer	3	225 litres (50 gallons)	180 litres (40 gallons)	135 litres (30 gallons)
Medium/Large Family Home – 2 bathrooms – dishwasher – heavy-duty clothes washer	4	290 litres (65 gallons)	180 litres (40 gallons)	180 litres (40 gallons)
Large Family Home – 2 or more bathrooms – heavy-duty dishwasher – heavy-duty clothes washer	5	360 litres (80 gallons)	225 litres (50 gallons)	225 litres (50 gallons)

Source: Natural Resources Canada

e. Water Heaters Efficiency Standards

ENERGY STAR qualified water heaters consume at least 5% less energy than conventional models. The energy efficiency performance for water heaters is measured by the Energy Factor (EF).

The higher the EF, the more efficient the water heater.

Storage water heaters are also rated for “First-Hour Rating” (FHR).

This is a measure of the quantity of hot water (litres) that can be supplied in one hour starting with a full tank.

Tankless water heaters are also rated in litres per minute (LPM), where LPM represents the quantity of hot water over a 42.8 Celsius degree rise. The following types of water heaters must meet or exceed the following EF levels in order to qualify as ENERGY STAR:

Table 17 ENERGY STAR Water Heater Energy Factor Levels

Product Category	Minimum Efficiency Rating	First – Hour Rating
Gas storage water heater Until August 31, 2010	EF $\geq$ 0.62	FHR $\geq$ 254 litres per hour
Gas storage water heater As of September 1, 2010	EF $\geq$ 0.67	FHR $\geq$ 254 litres per hour
Gas tankless water heater	EF $\geq$ 0.82	LPM $\geq$ 9.5 over 42.8°C rise
Condensing gas storage water heater	EF $\geq$ 0.80	FHR $\geq$ 254 litres per hour
Heat pump water heater	EF $\geq$ 2.0	FHR $\geq$ 190 litres per hour

Source: Natural Resources Canada effective January 1, 2009

f. Hot Water Conservation

There are several low cost or no cost actions that can be done to reduce hot water consumption.

- Fix Leaks - A one drop per second leak wastes about 9000 litres of water per year, or the equivalent taking a 10 hour shower. Leaks are relatively easy to spot and can be fixed at a low cost.

- Use Low Flow Showerheads – Low Flow shower heads conserve energy and water without changing water pressure. Low flow shower heads can (10-12 lpm) use up to 60% less water than standard fixtures. Newer low flow shower heads can provide a better shower experience compared to many existing regular shower fixtures.

- Consider a Shut off Button on Showerhead – water flow can be temporarily shut off or reduced significantly while lathering or shampooing.

- Use Flow Restrictors – Flow restrictors on taps can reduce water use from 15-20 lpm to between 4-10 lpm.

- Use Cold Water for Laundry – up to 93% less energy can be saved by using cold water for the washing and rinse cycle for clothes washers.

- Take Quick Showers instead of Baths - A five-minute shower, for instance, uses less than 38 litres of hot water, compared with 57 to 95 litres for a bath.

g. Drain Water Heat Recovery

All hot water that ends up going down the drain carries away energy. Drain water heat recovery (DWHR) systems recover some of this energy by preheating the cold water entering the water heater or other fixtures that use cold water.

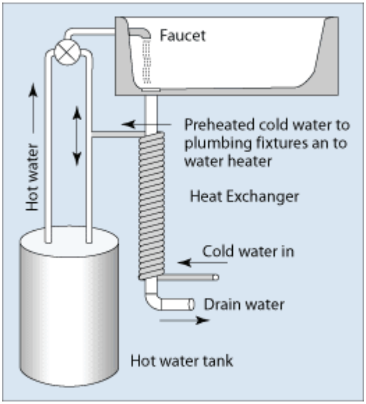


Figure 46 Drain Water Heat Recovery (Courtesy US DOE)

The most common system is used for shower drains. The DHWR unit is a drain pipe (Figure 46) with a copper coil wrapped around it. As the hot water flows down the drain, it forms a thin film on the inner layer of the pipe.

Cold water, which does not mix with the drain water, picks up the heat as it flows in copper tubes that are wrapped around the drain pipe. The "warmed" cold water can then flow either to the cold water inlet of the hot water tank or for the cold water tap to the shower.

DWHR is effective when there is a simultaneous flow of both hot and cold water, for example a shower. It is not as effective for batch discharge of hot water when cold water is not being used, for example emptying a bathtub.

DHWR technology can be used for all types of hot water systems, including electric, natural gas, and solar.

11 INSULATION

a. The Proper Choice of Insulation

The proper selection of insulation material and quantity depends on its intended end use. Good resistance to heat flow is one of the most important factors to consider; however, based on the end use and economic evaluation, other factors need to be accounted for, which include:

- Ability to resist moisture flow,
- Ease of installation,
- First cost and life cycle cost,
- Fire-rated protection,
- Health and safety to occupants,
- Removal, treatment and disposal,
- Resistance to air movement, and
- Resistance to high temperatures.

b. Insulation Levels

Canada's Model National Energy Code for Houses has divided the country into 4 distinct degree day (DD) zones:

- Zone A: up to 3500 DD
- Zone B: 3500 – 5000 DD
- Zone C: 5000 – 6500 DD
- Zone D: over 6500 DD

Each category represents a geographic area that experiences a similar number of degree days per year. A Degree day is a measure of heating demand based on the difference between the average daily outdoor temperature and 18°C. Cumulative degree day totals for each month or for the entire heating season are used to estimate heating energy needs. Canada's Model National Energy Code recommends minimum levels of insulation for various parts of a house structure. This is based on the corresponding geographical zone, as shown in Table 18.

Table 18 Recommended Minimum Level of Insulation (Source MNEC)

Zone		A	B	C	D
Walls	RSI	3.0	3.6	4.1	5.3
	R	17.0	20.0	23.0	30.0
Basement Walls	RSI	3.0	3.0	3.0	3.0
	R	17.0	17.0	17.0	17.0
Roof or Ceiling	RSI	4.5	5.6	6.7	9.0
	R	26.0	32.0	38.0	51.0
Floor (over unheated spaces)	RSI	4.5	4.7	6.7	9.0
	R	27.0	27.0	38.0	51.0

Most modern building insulation materials have been evolving during the past 90 years. Rapid improvements of products occurred during the 1970s in response to the energy crisis. Chronologically, the major insulation materials were developed in the following order:

- Rock or slag wools - 1920s.
- Glass fibers - 1930s.
- Perlite- 1940s.
- Plastic foams - 1940s and 1950s.
- Modern cellulose-1960s.

All insulations are designed to reduce the unwanted flow of heat into or out of a house. Resistance to heat flow depends on:

- Density of the material,
- Size and diameter of the fibers (or foam structure), and
- Thickness.

Manufacturers adjust these physical properties to obtain the best thermal performance of the material, depending on their requirements. The most important specification for any type of insulation is its R-value rating. R-value is a measure of the insulation's resistance to heat flow. The higher the value, the better that the R-value can be specified both as an overall value and on a thickness basis. The R-value only refers to the actual properties of the insulation; it does not account for any deficiencies in installation or building design. Consequently, the inappropriate use of the insulation may lead to building components having much lower R-values than the insulation.

c. Type of Insulation

Insulation can be grouped into four main areas, based on how it is packaged and installed. Table 21 lists the main physical properties of various insulations, and the advantages and disadvantages of each.

d. Batt

Most fiber-type insulation is formed into batts. The individual fibers are sprayed with a binder and felted. Rock wool and fiberglass are the two most common products. Batts are non-load bearing, and are friction fitted into open stud cavities. They are restricted to interior use, away from water.

Rock Wool

As its name implies, rock wool is made from natural rock. However, most are now made from iron, copper, and lead smelting slag. The slag or rock is fired with coke and then spun into fine fibers. The fibers are sprayed with phenolic resin, compressed, and cured into slabs. The slabs are cut to make batts of the desired size. The rock wool is non-combustible, chemically inert and rot resistant. The material is very popular in Europe, but has lost its market share to fiberglass in North America. Method of use and application are essentially identical to fiberglass. Thermal properties are also similar (see Fiberglass section).

Fiberglass

Fiberglass insulation is made of long slender fibers of glass, felted together to form batts. Two methods are used to manufacture it, one being very similar to that described under rock wool. The second method involves flowing hot glass onto a rotating, perforated disk. This method produces shorter fibers, and denser mats. The fibers are sprayed with a binder and collected into mats. The mats are formed into batts, which may also have foil or kraft paper facings. The fibers are non-combustible, chemically inert and rot proof. The binder and facing may burn and will deteriorate in humid or wet conditions.

Fiberglass batts come in several thicknesses, the most common for fitting into standard 2"x 6" and 2"x 4" stud cavities. Batt density is 1.0 Ib/cubic foot with an R-value of R-3.2 per inch. The R-value of a fiberglass batt depends on its density and thickness. In general, there is a small loss of R-value when a batt is compressed. For example, a 6.25" batt has an R-value of R-19 when uncompressed. When placed in a stud cavity and compressed to 5.5", it has an R-value of R-18. Table 19 shows the reduction in R-value due to compression of batts into stud cavities.

Table 19 Insulation R-Values when Insulated in a Confined Wall Cavity

Nominal Lumber Size	Actual Depth of Wall Cavity									
R-Values When Installed Un-compressed		38	30	22	19	13	11	8	6	3
Standard thickness (inches)		12	9 1/2	6 3/4	6 1/4	3 5/8	3 1/2	2 1/2	1 1/4	3/4
2"x12"	11 1/4	37								
2" x 10"	9 1/4	32	30							
2" x 8"	7 1/4	27	26							
2" x 6"	5 1/2		21	20	18					
2" x 4"	4			15	14					
2" x 4"	3 1/2			14	13	13				
2" x 3"	2					9.8	8.8			
2" x 2"	1 1/2					6.3	6.0	5.7		
2" x 1"	1 1/2								3.2	3.0

Batts are available with overall R-values from R-3 to R-38. By increasing the batt density from 1.0 to 6.0 Ib/cubic feet, the R-value can be increased. This high-density fiberglass insulation gives a 20% increase in overall R-value for the same thickness. Most batts will have a paper or foil back, referred to as a vapour retarder. This backing is not an effective vapour barrier, but should be maintained in an intact condition.

Fiberglass is not an effective air barrier. While the small pore structure of the batts reduces convective heat loss, air moving around the batt, rather than through it, can dramatically reduce the insulating effect. Convective heat loss within the stud cavity can reduce the effective wall R-value by up to 50%. This is not a reflection on fiberglass insulation; rather it shows the importance of proper installation and the need for an air barrier.

e. Loose Fills

Loose fill insulation will take on the form of the cavity in which it is placed. Generally, loose fills consist of milled or granular material. There are two methods used to install loose fill insulation:

1. Blown - the insulation is entrained in an air flow, via a fan, and pumped into the space; and
2. Poured - the insulation is displaced from bags onto a horizontal surface (such as an attic) under the force of gravity.

The preferred method is to blow the insulation in. This ensures complete filling and uniform density. The material can be blown into existing enclosed cavities.

This a major advantage in retrofit applications. For attics, the loose fills can be either blown or poured. The following materials are the most common loose fills:

- Cellulose,
- Fiberglass,
- Vermiculite, and
- Perlite.

Cellulose

Cellulose is manufactured from finely shredded newsprint with borax or other chemicals added to resist fire, fungal growth and rot. It is a fluffy, low-density material. Cellulose has a higher resistance to air infiltration than most other loose fill insulation. Once it is installed, air infiltration can be reduced significantly. The installed density is very important to prevent settling of the material after installation.

Obtaining the correct densities is up to the installer; there is no effective mechanism for measuring the density while blowing in the insulation. It is very important to use a reputable and experienced company to ensure proper installation. If installed correctly, cellulose has a very high R-value of R-3.6 per inch.

Glass Fiber/Rock Wool

Fiberglass loose fill is the same material as that used in batts, except that it is chopped up in a hammer mill to produce a fluffy loose material suitable for blowing. Installation is essentially the same as cellulose; glass fiber is blown into enclosed wall cavities and attics using air. Proper installed density is 1.5 to 1.7 Ib/cubic feet. The R-value of R-2.9 per inch is slightly less than batt insulation. Rock wool is comparable to fiberglass, except the proper blown density is 2.0 to 3.5 Ib/cubic feet.

Vermiculite

Vermiculite is a mica-like laminar mineral which has been heated to drive off hydrated water. During heating, the water turns to steam and expands, causing the laminate to expand (like popcorn). A light pebble material is formed that has good insulating properties. Installed densities range from 4 to 10

Ib/cubic feet. The lower-density material is used for loose fill applications. Vermiculite can be used in a high-moisture environment, such as block cavities in a foundation wall. It has a low R-value of R-2.3 per inch.

Perlite

Similar to vermiculite, perlite is used mainly in industrial/commercial buildings as roof insulation. It is also used as an additive to concrete. Low-density perlite is used as a loose fill. Installed density is 2 to 11 Ib/per cubic foot. Perlite can be used in a high-moisture environment, such as block cavities in a foundation wall. It has a good R-value of R-2.4 to R-3.7 per inch.

f. Rigid Board

The following materials are used to make rigid insulating board:

- Expanded polystyrene,
- Extruded polystyrene,
- Polyurethane,
- Phenolic foam, and
- Glass fiber.

Expanded (Moulded) Polystyrene

This is made from expandable beads filled with a small quantity of pentane. Upon heating with steam, the polystyrene softens and the pentane expands. The beads expand into hollow cells. The puffed-up beads are poured into a mould and formed into “headboard”. Expanded polystyrene is one of the most common insulation materials. It is presently manufactured by more than 175 companies in North America. It comes in standard sizes from 16" to 48" widths and from 1" to 6" thick. It has excellent thermal properties: low density R-value of R-3.7 per inch and medium density R-value of R-4.0 per inch. Moulded polystyrene is one of the most cost-effective insulations available, and can be used on either interior or exterior surfaces.

Extruded Polystyrene

Granules of polystyrene are heated into a viscous fluid and then extruded through a die. The resulting foam has a closed structure and very low permeability to both air and water. Polystyrene is commonly referred to by the familiar trade name of Styrofoam® as produced by Dow Chemical.

Extruded polystyrene has a very high R-value of R-5.0 per inch. Polystyrene is classified by method of production, density, strength and other physical properties. There are four major categories of extruded polystyrene, as shown in Table 20.

Table 20 Categories of Rigid Board

Type	I	II	III	IV
RSI per 25mm	.65	.7	.74	.86
R per inch	3.7	4.0	4.3	5.0
Density (lb/ft^3)	0.9	1.35	1.15	3.0
Compressive Strength (psi)	8	16	25	100
Flexural Strength (psi)	25	35	36	100
Water Vapour Permeability (perm-inch)	5.0	3.5	3.5	1.1
Water	4.0	3.0	3.0	0.3

Absorption (%)				
Dimensional Stability (%)	2.0	2.0	2.0	2.0
Oxygen Index	24.0	24.0	24.0	24.0

For most residential applications, Type II or III are used. Where additional strength is required, such as under foundations, Type IV insulation can be used. For example, Styrofoam SMR by Dow is a Type IV. Styrofoam is a registered trademark of Dow Chemical Company.

Polyurethane Foams

Unlike polystyrene, polyurethane foams are directly formed from a chemical reaction between two reactants. The reactants are mixed in the right quantities, and then poured onto a moving conveyor, where they combine to form a continuous slab of foam. The foam is subsequently cut into boards. This product is primarily used in commercial applications, although it is also used in residential construction. The boards are generally covered on one surface with a foil. Due to its flammable nature, polyurethane must be covered with a less combustible material, such as drywall or paneling. It has an extremely good R-value per inch of R-5.0 to R-6.0.

Phenolic Foams

This is another plastic foam board. It has been widely used in Europe, but not in North America. The product has many of the same properties as polystyrene, but tends to be brittle and easily damaged. It is suitable for exterior walls and interior foundation walls. It has an acceptable R-value of R-4.4 per inch.

Glass Fiber

Glass fibers are coated with a binder and pressed into dense sheets of varying shapes and sizes. The material resists rot, slumping and is chemically inert. However, it is not as rigid as other board products. It generally has the characteristics of other glass fiber products, but is denser and stronger. It can be used as an exterior sheathing, or as interior wall, foundation, and duct insulation. Thermal performance is typically R-4.2 per inch.

g. Wet-Sprayed

Another method of applying loose fill insulation is sprayed-on or wet-sprayed. The loose material is wetted, mixed with an adhesive and sprayed onto the surface to be insulated, using compressed air.

The insulation can be sprayed on up to six inches thick with one coat. This method can only be used on open cavities such as exposed stud walls. Consequently, this method is usually used on new homes rather than in retrofit applications. The main advantages are ease and speed of application. Wet-spraying has been widely used in the commercial/industrial market on steel buildings. It is now being adopted by some residential home builders. Materials which are suitable for spraying are:

- Cellulose,
- Fiberglass, and
- Rock wool.

Wet-spraying, while it gives good performance, is not presently competitive with blown insulation.

Spray-in-Place Foams

The most common foams, polyurethane or polyisocyanurates, are sprayed into open cavities in an uncured liquid form. This liquid then cures into a rigid foam structure within several minutes. The foam structure is created by a gaseous foaming agent, who is produced as part of the curing reaction or added independently. The foaming agent is generally released during the curing process. Carbon dioxide is the most common foaming agent. These materials must be protected from water and are for interior use only. They have a very high R-value - typically R-4 to R-7 per inch. These products are applied by insulating contractors and manufacturers. When properly applied, many may also serve as effective air barriers. Application of spray-in-place foams is messy and extra care and preparation is generally required. This insulation material is considerably more expensive; however, it is generally very effective, especially on irregular surfaces.

h. Insulation Materials

This section contains a description of commonly available or used insulation products for residential applications.

Table 21 Common Residential House Insulation Materials

Insulation Format	Insulation Material	Advantages	Disadvantages

Insulation Format	Insulation Material	Advantages	Disadvantages
Batt	Fiberglass	• Easy to install in open cavities. • Dries with little effect on RSI value. • Reasonable cost for RSI value (although generally higher than for loose fill). • Some products are non-combustible, check with the manufacturer. • Lightweight. • Non-settling	• Cannot be installed in an enclosed cavity. • Does not fit readily into uneven spaces. • Should not be exposed to high moisture sources. • Should not be installed in contact with high temperature sources (e.g., chimney, recessed light fixtures). • Can irritate the eyes, skin and respiratory system during installation. • Little resistance to air infiltration.

Insulation Format	Insulation Material	Advantages	Disadvantages
Loose Fill	Fiberglass	• Easily fills irregular horizontal spaces. • Has a light weight for its RSI value. • Dries quickly when not covered, and with negligible effect on RSI value. • Some products are non-combustible; check with the manufacturer	• Should not be exposed to high moisture areas. • Should not be installed in contact with high temperature sources (e.g., chimney, recessed light fixtures). • Low RSI value per unit thickness. • Can irritate the eyes, skin, and respiratory system during installation. • May settle after application if not installed properly.

Insulation Format	Insulation Material	Advantages	Disadvantages
	Cellulose	• Normal passage of water vapour has little effect on chemicals or RSI values. • Has a higher resistance to air infiltration than most loose fill insulation. • Can be installed in enclosed cavities through a smaller diameter hole more easily than other loose fill insulations. • The only blown-in insulation that can be installed by homeowner with rented equipment. • When properly applied, is less prone to settling in walls than other loose fill insulations.	• Should not be exposed to high moisture areas. • Should not be installed in contact with high temperature sources (e.g., chimney, recessed light fixtures). • Likely to settle in wall cavities if not blown to high density of 56 kg/m^3 (3.5 lb/ft^3).
	Vermiculite	• Highly resistant to fire. • Pours more easily into walls than other loose fill insulations.	• Absorbs moisture and dries slowly. • Comparatively low RSI value for the price.

Insulation Format	Insulation Material	Advantages	Disadvantages
RIGID BOARD	Fiberglass	• Resistant to fire. • Dries with little effect on RSI/R value. • Not affected dimensionally by changes in moisture or temperature. • Flexibility will compensate for minor exterior wall irregularities. • Easy to handle and install. • Does not act as a vapour barrier when used as exterior wall sheathing.	• More compressible than other rigid board insulations. • Care must be taken when applying finishing materials. • Skin irritant.

Insulation Format	Insulation Material	Advantages	Disadvantages
	Expanded Polystyrene Moulded	• Has the lowest cost per RSI value of all the foam board insulations. • Can be installed on foundation walls with a compatible adhesive. • Lightweight, easy to handle.	• Can be a fire hazard unless properly covered. • Must be protected from exposure to sunlight and solvents. • Damages easily. • Is not for use at high temperatures. • Shrinkage of 0.5-1% must be allowed for. • Attachment systems and adhesives can be expensive to use. • Low-density "beadboard" can be affected by excessive moisture conditions.

Insulation Format	Insulation Material	Advantages	Disadvantages
	Expanded Polystyrene Extruded	• Most moisture-resistant foam plastic; excellent for exterior or below-grade applications. • Can be installed on foundation walls with a compatible adhesive. • Lightweight, easy to handle. • Can perform as an air-vapour barrier when installed on interior side of insulated cavities if joints are sealed properly. • High RSI value per unit thickness.	• Can be a fire hazard unless properly covered. • Must be protected from exposure to sunlight or solvents. • Damages easily. • Is not for use at high temperatures.

Insulation Format	Insulation Material	Advantages	Disadvantages
RIGID BOARD	Polyurethane with Vapour Retarding Backing	• Resistant to vapour flow. • Foil-covered sheets maintain RSI value. • Easy to install and handle. • Very high RSI value per unit thickness.	• High cost per RSI value. • Ages and loses some thermal resistance unless protected from light and air. • Can be a fire hazard unless properly covered. • Is damaged by repeated freezing and thawing. • Dimensionally unstable – expands.

Insulation Format	Insulation Material	Advantages	Disadvantages
SPRAY IN PLACE	Polyurethane	• High RSI value per unit thickness. • Can be applied to irregular surfaces, such as prefabricated metal buildings. • Provides an airtight seal.	• Effectiveness highly dependent on installation techniques and conditions. • Is a fire hazard if left exposed. • Must be covered shortly after installation to prevent deterioration from sunlight. • May expand when exposed to air or moisture. • RSI value decreases somewhat with age. • Comparatively high cost per RSI value.
	Polylsocyanurate	• Lower costs than polyurethane. • Can provide airtight seal. • Can be applied to irregular surfaces.	• Effectiveness highly dependent on installation techniques and conditions. • Lower R-value than polyurethane. • Not suitable for high-moisture areas.

APPENDIX A - GLOSSARY

The following terms are related to residential heating, ventilation and cooling technologies.

Term	Definition or Context
Bel (B)	A unit of sound measurement equivalent to 10 dB (decibels). One Bel is the threshold of human audibility.
Btu/h, or British thermal unit per hour	A measure of the heat transfer rate of a heating system. One Btu is the amount of heat energy given off by a typical birthday candle.
Capacity of an air conditioner	A measure of the maximum rate at which an air conditioner can remove heat from the conditioned space. Capacity is expressed in Btu/h or refrigerant tons, and is determined under a specific set of test conditions.
Coil	System of tubing loops through which refrigerant flows and where heat transfer takes place. The tubing may have fins to increase the surface area available for heat exchange
Compressor	Device that squeezes the molecules of the refrigerant vapour together, increasing the pressure and temperature of the refrigerant.
Condenser	A coil that allows the refrigerant vapour to give off heat to its surroundings and become a liquid.
Cooling load	The maximum amount of heat, under design conditions, that builds up in a space without a cooling system operating. It is calculated to determine the capacity of air conditioner required.
Energy efficiency ratio (EER)	The higher the EER, the more efficient the unit. It is a measure of how much cooling effect is provided by the air conditioner for each unit of electrical energy that it consumes under steady-state operation. EER is measured in Btu/h per Watts.

Term	Definition or Context
Evaporator	The coil through which the refrigerant absorbs heat from its surroundings, causing the refrigerant to boil and become a low-temperature vapour.
Expansion device	It releases the pressure created by the compressor. This causes the temperature to drop and the refrigerant to become a low-temperature vapour/liquid mixture.
Heat gain	Term applied to various components of the heat load, such as appliance heat gain and solar heat gain. All of the heat gain components are summed to calculate the cooling load.
kW, or kilowatt	Equal to 1000 watts. This is the amount of power required by ten 100-watt light bulbs.
Oversizing	Practice of selecting an air conditioner with a cooling capacity greater than the cooling load.
Plenum	Air compartment that forms part of the system for distributing warmed or cooled air through the house. It is generally a large compartment immediately above the heat exchanger.
Refrigerant	Substance that circulates through the air conditioner, alternately absorbing, transporting and releasing heat.
Seasonal energy efficiency ratio (SEER	Measures the cooling efficiency of an air conditioner over an entire cooling season. It is determined by dividing the total cooling provided over the cooling season, in Btu/h, by the total energy used by the air conditioner during that time, in watts/hour. The SEER is based on a climate with an average summer temperature of 28°C.
Ton	A measure of cooling capacity. It is equivalent to 3.5 kW or 12 000 Btu/h.
Under sizing	Practice of selecting an air conditioner with a cooling capacity smaller than the cooling load.
Watt (W)	Standard unit of power; one kilowatt (kW) equals 1000 watts.

APPENDIX B - ESTIMATING ANNUAL HEATING COSTS

The following section was adapted from a methodology developed by Natural Resources Canada.

This method applies primarily for existing homes where utility bills are available for one or more annual heating cycles. Based on actual energy bills, it calculates the approximate amount of energy consumed (MJ) to heat a house. This actual value can be compared to benchmark values for different housing archetypes.

To benefit from this method it is important to:

- Calculate the unit fuel cost for heating, and
- Identify the type of heating appliance used.

In addition, the methodology can be adapted to evaluate "what if" scenarios, like:

- Upgrading heating equipment – to evaluate expected annual energy cost savings; and
- Converting from one fuel to another – to evaluate increases or decreases to annual heating costs.

Step 1: Determine the Unit Fuel Cost

From actual utility bills or by contacting the local energy utility, one can determine the unit cost of fuel:

- For example, the average cost of electricity would be the sum of the monthly electric bills for one year ($), all divided by the sum of the total energy (kWh) consumed for that same period. For most Canadian residential accounts, this value may range from $0.06 to $0.18 per kWh.

- For natural gas, it would be the sum of all monthly gas bills (including distribution and commodity) for one year ($) all divided by the total volume of natural gas (m^3) consumed for the same period.

- Tip: Be sure to subtract the cost of any rental equipment included on the utility bill, such as hot water tanks, furnace rentals, or other home improvements.

- When considering fuel substitution options, ensure that unit energy costs for the substituted fuel are also available or estimated.

- Enter the unit costs into the appropriate section of Table 22.

- Convert the unit cost value from its native unit into a cost per MJ using the conversion factor in Table 22. For example, to convert from cubic meters of natural gas to MJ, divide by 37.5.

Table 22 Energy Content and Local Price of Various Energy Sources

Energy Source	Energy Content (Metric)	Energy Content (Imperial)	Local Unit Price
Electricity	3.6 MJ/kWh	3 413 Btu/kWh	$0._____ /kWh

Oil	38.2 MJ/litre	140 000 Btu/gal (US)	$0._____ /litre
Natural Gas	37.5 MJ/m³	1 007 Btu/ft³	$0._____m³
Propane	25.3 MJ/litre	92 700 Btu/gal (US)	$0._____litre
Hardwood*	30 600 MJ/cord	28 000 000 Btu/cord	_____$/cord
Softwood*	18 700 MJ/cord	17 000 000 Btu/cord	_____$/cord
Wood Pellets	19 800 MJ/cord	20 000 000 Btu/cord	_____$/cord

Conversion: 1000 MJ= 1 Giga joule (GJ)
* The value provided for wood are for a "full" cord, measuring 1.2m x 1.2m x 2.4m (4 ft. x 4 ft. x 8 ft.).

Identify the Heating Appliance

- The next step involves selecting the type of heating equipment that is intended to be used, or selecting the "base case" versus "proposed case" that is being evaluated for use.
- A generic list of heating equipment types is shown in Table 23.
- Note the efficiency figures in the column titled Seasonal Efficiency.
- Using these values, calculate the dollar savings that can be achieved either by upgrading an older system to a newer one, or by choosing higher efficient equipment fuelled with an alternate energy source.

- If the utility bill includes energy that is used for domestic hot water heating, apply a default heating factor of 80% (or the actual factor if known).

Table 23 Typical Heating System Efficiencies

Energy Source	Technology	Seasonal Efficiency (AFUE) %
Oil	Cast-iron head burner (old furnace)	60
	Flame-retention head replacement burner	70–78
	High-static replacement burner	74–82
	New standard model	78–86
	Mid-efficiency furnace	83–89
	Integrated space/tap water (mid-efficiency)	83–89
Natural Gas	Conventional	60
	Vent damper with non-continuous pilot light	62–67
	Mid-efficiency	78–84
	High-efficiency condensing furnace	89–97
	Integrated space/tap water (condensing)	89–96
Electricity	Electric baseboards	100
	Electric furnace or boiler	100
	Air-source heat pump	1.7 COP**
	Earth-energy system (ground-source heat pump)	2.6 COP**
Propane	Conventional	62
	Vent damper with non-continuous pilot light	64–69
	Mid-efficiency	79–85
	Condensing	87–94
Wood	Central furnace	45–55
	Conventional stove (properly located)	55–70
	"High-tech" stove*** (properly located)	70–80

	Advanced combustion fireplace	50–70
	Pellet stove	55–80

** COP =Coefficient of performance, a measure of the heat delivered by a heat pump over the heating season per unit of electricity consumed.
*** CSA B415 or EPA Phase II tested.

Determining the Annual Heating Load

The following formula can be used to determine the annual heating load:

Annual Heating Load
= (Heating Bill / 100,000) × (Seasonal Efficiency / Energy Cost/Unit) × Heating Factor × Energy Content

Example - Natural Gas: The annual bill natural gas for space heating and water heating is $1374. Natural gas costs $0.44/m^3, the house has an old conventional gas furnace with a seasonal efficiency of 60 percent. The energy content of natural gas is 37.5 MJ/m^3. Assume a default heating value of 80% (i.e. 80% of the natural gas used is for space heating and 20% is for hot water heating).

Annual Heating Load = (1374 / 100,000) × (60 / 0.44) × 80% × 37.5
= 56 GJ

As a benchmarking tool, or for the purpose of new construction design estimation, values in Table 24 can be used for annual heating requirements for various locations in Canada.

Table 24 Typical Annual Heating Loads in Giga joules (GJ) for Various Housing Types in Canadian Cities (Source NRCan)

City	Pre-1990 Detached	Post-1990 Detached	Post-1990 Semi-Detached	Post-1990 Town-house
Victoria	85	60	45	30
Prince George	150	110	80	60
Calgary	120	90	65	50
Edmonton	130	95	70	55
Fort McMurray / Prince Albert	140	105	80	60
Regina/Saskatoon / Winnipeg	130	90	70	50
Whitehorse	155	115	85	60
Yellowknife	195	145	110	80
Thunder Bay	130	95	70	55
Sudbury	120	90	65	50
Ottawa	110	75	55	40
Toronto	95	65	45	35
Windsor	80	55	40	30
Montréal	110	80	60	45
Québec	115	85	65	50
Chicoutimi	125	90	70	55
Saint John	105	75	60	45
Charlottetown	110	80	60	45
Halifax	100	75	55	40
St. John's	120	85	60	45

Due to construction practices, actual house size, weatherizing, renovations, and reinsulating, and the variations from house to house, these values are only general guidelines. Hence, they should not be used as a substituted for accurate heating determination.

Assumptions used in Table 24:

- Pre-1990 detached – approximately 186 m^2 (2000 sq. ft.).
- Post-1990 detached – approximately 186 m^2 (2000 sq. ft.).
- Post-1990 semi-detached – approximately 139 m^2 (1500 sq. ft.).
- Post-1990 Townhouse – inside unit, approximately 93 m^2 (1000 sq. ft.).

APPENDIX C - ESTIMATING ANNUAL COOLING COSTS

This section is adapted from a methodology and literature developed by Natural Resources Canada.

The following formulas are intended to provide an estimate of the operating cost of a room air conditioner. The actual energy consumption can vary depending on several factors. The annual cost of operation of an air conditioner can be calculated as shown below. The method can also be used to provide an estimate of the energy-cost savings of using a more efficient (i.e. higher SEER or EER rating) air conditioner. The formula for calculating the yearly operating cost of central air conditioners:

Cost of operation
= (24 × DDC18)/ (TOD – 18) × (CAP (35°C)/SEER) × (Cost/kW/1000)

For room air conditioners, the formula for the yearly operating cost is:

Cost of operation
= (24 × DDC18)/ (TOD – 18) × (CAP (35°C)/ (0.9 × EER)) × (Cost/kW/1000)

Where:
DDC18 = number of cooling degree-days (base 18°C) from Table 25;
TOD = summer outdoor design temperature (°C) for location from Table 25;
CAP (35°C) = the capacity of the air conditioner (in Btu/h) at an entering air temperature of 35°C;

SEER = the rated seasonal energy efficiency ratio (Btu/h/W);
EER = the rated energy efficiency ratio; and
Cost per kWh = local electricity cost (in $/kWh).

Sample Cooling Calculation

A Toronto resident is considering purchasing a central air conditioner. The utility rate for electricity is $0.115/kWh.

From Table 25, Toronto has 359 cooling degree-days and a summer outdoor design temperature of 30°C. The rated capacity of the unit is 36,000 Btu/h with a rated SEER of 12.0.

Cost of operation = (24 × 359)/ (30 – 18) × (36,000)/12.0) × (0.115/1000)
= $248/year

Table 25 Cooling Degree-Days and Summer Outdoor Design for Ontario Locations (Source NRCan)

CITY	DDC18	TOD (°C)
London	236	30
North Bay	119	27
Ottawa	245	30
Sudbury	138	29
Thunder Bay	70	29
Toronto	359	30
Windsor	422	31

APPENDIX D - ESTIMATING RESIDENTIAL ELECTRICAL SERVICE SIZE

Electrical Service Size Estimator

	Number of Units	Estimated Volt Amps (VA) per unit	Extended Value (VA)	Group Subtotal (VA)	
CONNECTED LOAD					
Area of House in square feet (Conditioned space) Note: Calculation uses 3VA per ft2	1,500	3	4,500		
Number of Small Appliance Circuits	8	1,500	12,000		
Laundry machine circuit	1	1,500	1,500		
Subtotal - Connected Load			18,000		(A)
On First 3000 VA of Line (A)use 100% diversity factor		3,000	3,000		
On Remaining Connected Load VA for line (A) use 35% diversity factor		15,000	5,250		
Connected Load				**8,250**	(B)
HEATING & AIR CONDITIONING					
Number of Air Conditioning Units and Average Unit Wattage per Unit	1	6,000	6,000		(C)
Number of Baseboard Electric Heaters & Average Unit Wattage per Unit	4	3,000	12,000		(D)
Choose Larger or Air Conditioning (C) or Heating Load (E)				**12,000**	(E)
MAJOR APPLIANCES (120 volt)					
Dishwasher	1	1,250	1,250		(F)
Refrigerator	1	900	900		(G)
Other 1- Freezer	1	1,100	1,100		(H)
Other 2 - Specify	-	-	-		(I)
Other 3 - Specify	-	-	-		(J)
Major Appliances (120 volt) subtotal lines (F) to (J)			3,250		(K)
Major Appliances (120 volt)line (K) multiplied by 75% diversity factor				**2,438**	(L)
MAJOR APPLIANCES (240 volt) Typically requiring >15 amp circuits					
Clothes Dryer (100% diversity factor)	1	5,000	5,000		(M)
Stovetop Units (75% diversity factor)	4	1,500	4,500		(N)
Oven with Broiler (80% diversity factor)	2	2,000	3,200		(O)
Electric Hot Water Heater (75% diversity factor)	1	4,500	3,375		(P)
Major Appliances (240 volt) subtotal lines (M) to (P)				**16,075**	(Q)
TOTAL ESTIMATED HOUSE LOAD - Add Lines (B)+(E)+(L)+(Q)				**38,763**	(R)
Supply Voltage in Volts				240	(S)
Estimated Required Amps - Divide line (R) by (S)				**162**	(T)
Round up line (T) to next higher value of 100, 125, 200 or 400 amps to end up with Electrical Service Size Estimate (AMPS)		162	--->	200	AMPS

Appendix D – Estimating Residential Electrical Service Size

Caution: This estimator is only one approach to estimating a residential electrical service system. Readers MUST to adhere to electric service sizing procedures as specified in the Canadian Electrical Code (2009) and other applicable Codes and Standards.

APPENDIX E - HEATING DEGREE DAYS FOR VARIOUS ONTARIO LOCATIONS

Location	Heating Degree Days	Zone
Atikokan	6052	C
Big Trout Lake	7577	C
Chapleau	5989	C
Cochrane	6411	C
Cornwall	4234	B
Dryden	5912	C
Earlton	5837	C
Fort Erie	3789	B
Fort Frances	5637	C
Geraldton	6496	C
Gore Bay	4769	B
Hagersville	3800	B
Hamilton	4012	B
Kapuskasing	6372	C
Kenora	5749	C
Kingston	4289	B
Kirkland Lake	6048	C
Lansdowne House	7087	C
London	4062	B
Manitouwadge	6121	C
Moosonee	7017	C
Muskoka	4883	B
Niagara Falls	3661	B
North Bay	5295	B
Ottawa	4600	B
Petawawa	5178	B
Peterborough	4537	B
Point Pelee	3565	B

Appendix E – Heating Degree Days for Various Ontario Locations

Red Lake	6319	C
Sarnia	3882	B
Sault Ste. Marie	5052	B
St Catharines	3659	B
Stratford	4210	B
Sudbury	5344	B
Thunder Bay	5718	C
Timmins	6149	C
Toronto	4066	B
Trenton	4222	B
Wawa	5963	C
Wiarton	4442	B
Windsor	3525	B

Source: NRCan

APPENDIX F - CHECKLIST FOR ENERGY EFFICIENCY OPPORTUNITIES

The following guidelines are provided to assist the homeowner or inspector with tracking and identifying drafts and leaks.

Inside Basements and Crawl Spaces

- Around any holes or gaps where the electrical lines, gas lines or oil fill pipes go through the wall (exercise caution);
- Cracks in the foundation wall and slab;
- Floor drains;
- In and around window and door framing;
- Location where the wood-frame wall (sill plate) meets the masonry (concrete or stone) foundation, or where joists penetrate the masonry wall;
- Near holes for wiring and plumbing going into external walls; and
- Next to leaky ducting or poorly fitted hot-air registers or cold-air intakes.

Main Living Areas

- Above sliding pocket doors;
- All interior trim and baseboards;
- Around window-glass panes for tightness, and near the window sash and the window casing;
- Cracks in the wall finish or ceiling;
- Doors and hatches leading into unheated attics;
- Electrical outlets, including ones on interior walls;

- Exhaust fans and vents (these should vent to the outside and close properly when not in use);
- Fireplace dampers and fireplace bricks;
- Joints where a wood frame wall joins a masonry wall or chimney;
- Near corners where two walls meet with an imperfect seal;
- Near light fixtures in the ceiling;
- Near the door, including the threshold and around the door frame;
- Next to plumbing pipes and ductwork; and
- Under sinks and behind bathtubs.

In and Around Attics

- All attic access doors;
- All ceiling areas over bathrooms and stairwells;
- Along any shared walls;
- Around chimneys;
- Around wires or ceiling light fixtures that penetrate the attic floor;
- Near ducts that enters the attic from inside the house;
- Near the plumbing stack and any other pipes entering the attic; and
- Next to the junction of the ceiling with interior wall partitions.

For Water Heaters

- Wrap the heater in an insulating blanket. Be sure to check your user's manual and labels on the tank first.

- Note: Most new water heaters have insulation and are highly energy efficient. Adding a blanket may not make much difference.
- Always insulate hot water pipes, especially in unheated spaces.
- Ensure that combustion air openings at the bottom of natural gas tanks and draft diverters at flue ducts on the top are always kept unblocked.
- Examine your water heater – if its surface is hot or even warm, some of the energy used to heat the water is being wasted.
- Factory settings for water tanks are often 60°C (140°F). The temperature can be lowered to 55°C (130°F) to save energy. Caution: Avoid setting it any lower, as this would risk the growth of disease-carrying bacteria, such as legionella.
- Lower the water-heater thermostat to a minimum setting when away for extended periods.
- Periodically (twice a year, or monthly if located in an area with heavy mineral deposits) empty a bucket of water from your water heater. Exercise caution as the water is hot.
- Reduce the heat that is lost in long pipe runs.
- To avoid scalding at 55°C, hire a plumber to install a tempering valve.
- Use thin pipes, which have lower entrapped volume and are more energy efficient than thicker pipes.
- When installing a new hot water tank or designing a new home, try to locate it as close to the kitchen, laundry and bathrooms.

APPENDIX G - USEFUL MEASUREMENT AND CONVERSION FACTORS

Temperature
Fahrenheit Temperature = (1.8 × Celsius Temperature) + 32

Pressure
1 bar = 14.50 lbf/sq.in (psi)

Length
1 cm = 0.3937 inches
1 m = 3.28 feet

Volume
1 litre = 0.26417 gallons (US)

Energy
1 kWh = 3.6 MJ
1 kWh = 3,412 Btu

Power
1 HP = 0.746 kW
1 kW = 3,412 Btu/h
1 ton = 12,000 Btu/h

APPENDIX H - LITERATURE AND INTERNET REFERENCES

Note: All Websites shown or referenced in this section were verified in October 2009.

Reference Books and Codes

Builders' Manual, Canadian Home Builders' Association, 2008

Canadian Electrical Code (2009), Canadian Standards Association

National Building Code of Canada 2005, National Research Council of Canada

Ontario Building Code (2006), Ministry of Municipal Affairs and Housing

CSA Standards

Note: CSA Standards are available for purchase via www.shopcsa.ca

C191 Performance of Electric Storage Tank Water Heaters

C260 Rating the Performance of Residential Mechanical Ventilating Equipment

C273.5 Installation Requirements for Air-to-Air Heat Pumps

C368.1 Performance Standard for Room Air Conditioners

C370 Cooling performance of portable air conditioners

C652 Installation of Electric Storage Tank and Heat Pump Water Heaters

C656 Performance Standard for Split-System and Single-Package Central Air

C744 Standard for Packaged Terminal Air Conditioners and Heat Pumps

C745 Energy Efficiency of Electric Storage Tank Water Heaters and Heat Pump

C748 Performance of Direct-Expansion (DX) Ground-Source Heat Pumps

C749 Performance of Dehumidifiers

C814 Energy Performance of Ceiling Fans

C828 Performance Requirements for Thermostats

C13256-1 Water-Source Heat Pumps

F280 Determining the Required Capacity of Residential Space Heating

F326 Residential Mechanical Ventilation Systems

Government Agency Weblinks

Canada Mortgage and Housing Corporation

ecoENERGY Retrofit – Homes Program

Home Energy Ontario

Office of Energy Efficiency (Canada)

Ontario Ministry of Energy and Infrastructure

Ontario Power Authority – Residential Programs

Your feedback and comments are appreciated.
Please provide suggestions to:

info@ceati.com

Energy Efficiency is Good Business

- Economic Prosperity
- Environmental Performance
- Social Responsibility
- Security