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ENERGY EFFICIENCY BUILDING ENVELOPE RETROFITS FOR HOUSES

- Interior Retrofit for 1960s and 1970s One-Storey Raised Bungalow
- >75% Space Heating Energy Savings

Figure 1: One-Storey Raised Bungalow

INTERIOR RETROFIT

The building envelope can be retrofitted from either the exterior or the interior. The choice will largely depend on the house's interior and exterior finish, layout and construction, lot line setback requirements, other renovation needs and whether or not the house will be occupied during the renovation. There are several advantages to airtightening and insulating a house from the interior. An interior retrofit can be done year-round, it doesn't affect exterior cladding, it may cover cracks, holes and thermally conductive materials (called 'thermal bridges'), and it doesn't reduce distances to property lines.

RETROFIT FOR ENERGY SAVINGS

One of the best ways to reduce the energy consumption of an existing house is to add insulation to the roof, walls and basement, upgrade windows and doors, and seal cracks, leaks and holes. These improvements, called "energy efficiency building envelope retrofits", help to reduce heat losses in the winter and heat gains in the summer, and should result in lower energy bills, improved comfort and reduced outside noise intrusion.

This Fact Sheet provides guidance for interior energy efficiency building envelope retrofits to 1960s and 1970s one-storey raised bungalows that can reduce space heating energy consumption by 75 per cent or more (Figure 1). It describes the starting point (what you have now), air sealing and insulation options to achieve the targeted energy savings, technical considerations to keep in mind in the planning of the retrofit project, and general precautions.

What You Have Now

The pre-retrofit construction of a 1960s and 1970s one-storey raised bungalow will vary depending on its age, location and whether any upgrades have already been completed. The building envelope of a typical 170 m² - 200 m² (1,830 sq. ft.-2,153 sq.ft) house of this vintage with finished basement will likely be clad with masonry, siding or stucco. Figure 2 illustrates common materials, insulation RSI (R)-values, and assemblies for this type of building, subject to regional variations. Houses such as these generally have high air leakage with measured airtightness values averaging above 6.0 air changes per hour at an applied air pressure difference of 50 pascals (ACH_{50}).

Houses built in the 1960s and 1970s also tend be lightly insulated. It is common to find attics with a single layer of insulation and walls with insulating values that are half that required in new homes. Basements usually have modest levels of insulation, if any at all. Fortunately, there are many opportunities to improve the energy efficiency of the building envelope. Insulation, air sealing and window technology have evolved significantly. For example, higher RSI (R)-value insulation is now available; low-emissivity coatings, gas fills and improved seals and spacers improve the thermal performance of windows considerably; and airtightness techniques are better understood.

To achieve over 75-per-cent space heating energy savings in what may be called a 'near net-zero' retrofit, airtightening and insulation values should be increased in all of the critical areas of the building envelope: roof or attic, above-grade walls, windows and doors, below-grade walls and basement floor slab. Figure 3 shows a general approach to retrofitting the same wall shown in Figure 2 - from the attic to the basement.

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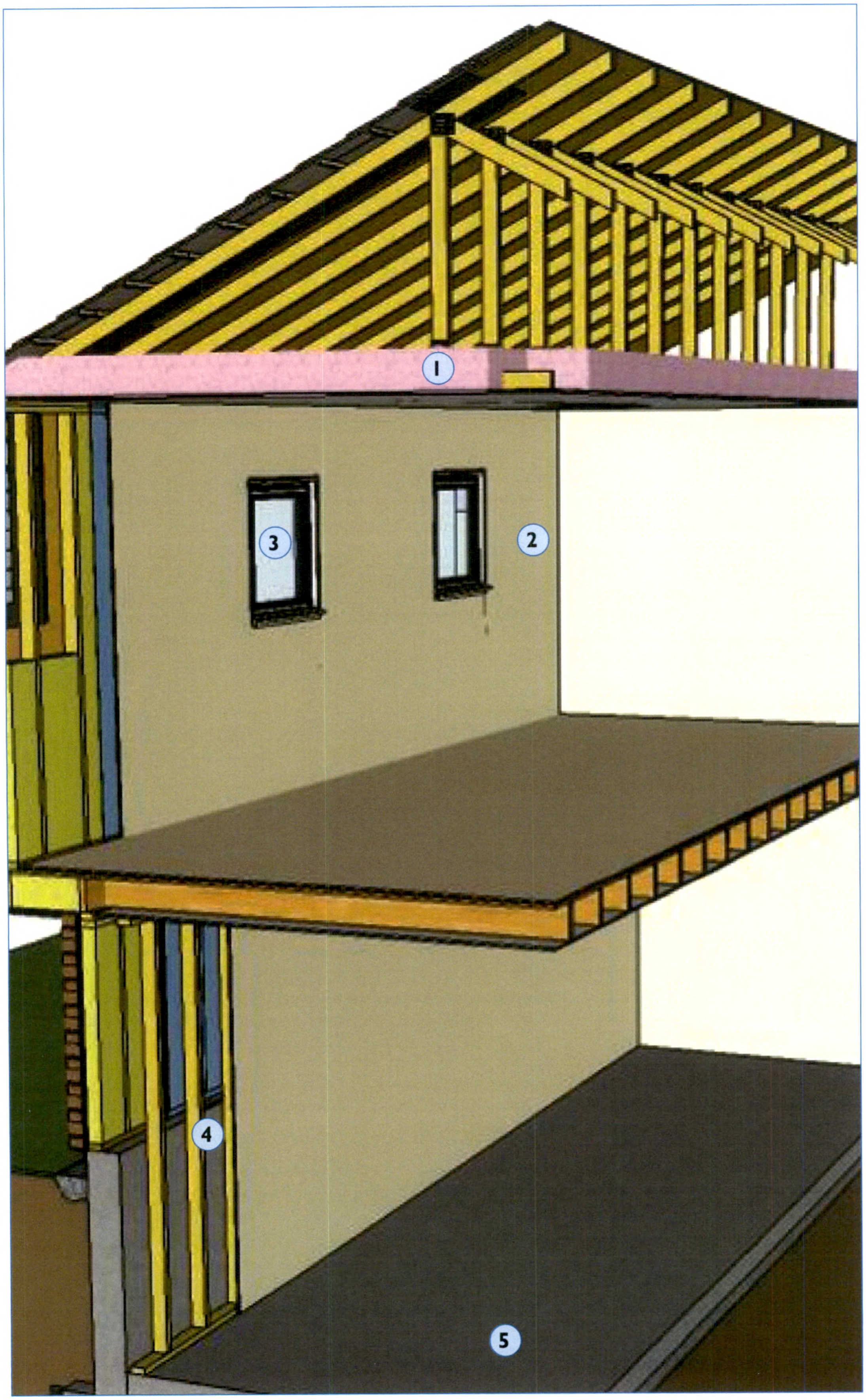


1. Roof and attic

- Fibreglass or cellulose insulation, providing a nominal RSI-4.5 – 5.5 (R-25 – 31).

2. Above-grade walls

- 38 mm x 89 mm (2" x 4") wood frame walls. The stud cavity may contain fibreglass batt insulation, providing a nominal RSI-2.0 – 2.6 (R-11 – 15).

3. Windows and doors

- Single- or double-glazed with wood or vinyl frames.

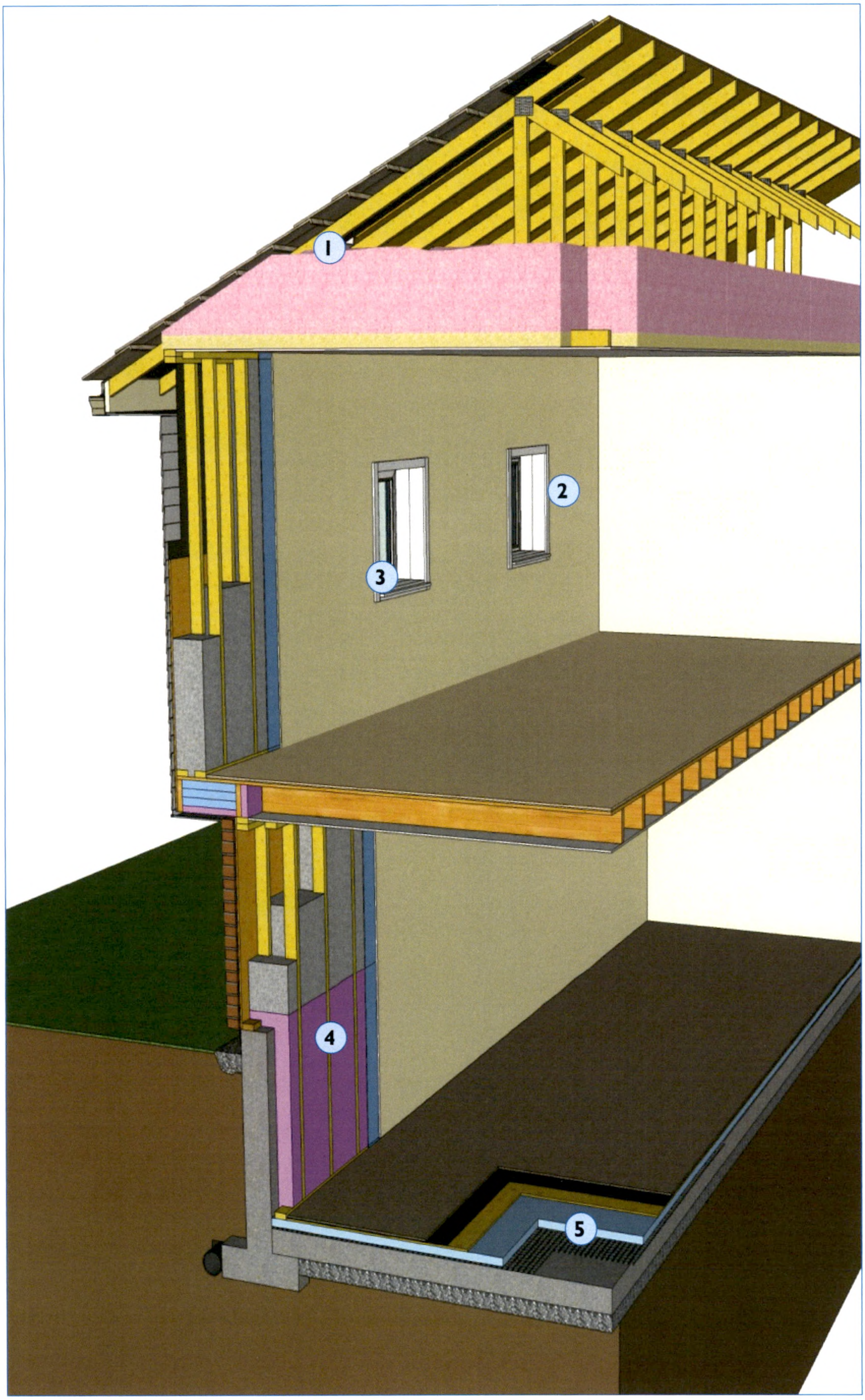
4. Below-grade walls

- Concrete or concrete block, may be uninsulated or may have wood-frame walls on inside filled with fibreglass batt insulation, providing a nominal RSI-1.1 – 2.2 (R-6 – 12).

5. Basement floor slab

- Poured concrete over gravel.

Figure 2: Pre-retrofit section through roof and ceiling, above and below grade walls, floors and basement slab of a raised bungalow



1. Roof or Attic

- Add or extend insulation guards (baffles)
- Spray foam on top of ceiling and add blown-in insulation above ceiling (or additional fibrous insulation over existing attic insulation)

2. Above Grade Walls

- Install interior insulation and wood furring
- Install polyethylene air barrier/ vapour retarder and gypsum board finish.

3. Windows and Doors

- Replace windows with triple-glazed, low-e, argon gas fill, low conductivity frames with insulated spacers
- Install insulated doors
- Install closed-cell spray foam between windows and doors, and rough openings

4. Below Grade Walls

- Install closed-cell spray foam insulation or extruded polystyrene (XPS) insulation, (or install a combination of spray foam and batt insulation)

5. Basement Floor Slab

- Install extruded polystyrene (XPS) insulation over existing floor slab
- Install new sheathing and finished floor

Figure 3: Post-retrofit section through roof and ceiling, above and below grade walls, floors and basement slab of a raised bungalow

Before planning a retrofit for a specific house, CMHC recommends that a qualified residential energy service provider undertake an EnerGuide audit of the house. The audit should measure the airtightness of the pre-retrofit house, suggest upgrades to the heating system, and locate areas where air leaks should be sealed and insulation should be added. Audits and ratings can be obtained from service organizations licensed under Natural Resources Canada's EnerGuide program. For more information on finding a qualified service organization, visit *http://oee.nrcan.gc.ca/residential/personal/16352.*

BUILDING ENVELOPE RETROFIT MEASURES FOR SPACE HEATING ENERGY SAVINGS

Taken together, the following energy efficiency retrofit measures should result in space heating energy savings of 75 per cent or more:

- Improve the airtightness to 1.0 ACH_{50} or lower.
- Add insulation in the roof or attic.
- Add insulation on the interior of below-grade (basement) walls.
- Add insulation on the interior of above-grade walls.
- Add insulation to the basement floor slab.
- Replace windows and doors with highest energy performance units.

Improving airtightness by sealing cracks, holes and gaps in the building envelope is relatively inexpensive and has a big effect on reducing energy loss, making it the most cost-effective measure. In other words, it leads to the greatest savings of heating energy per dollar spent. Moreover, an airtight house gains the full benefit of all the other retrofit measures because air leakage can reduce the thermal resistance of some types of insulation. Because of this, the retrofit includes increasing airtightness to 1.0 ACH_{50} (Table 1). Improved airtightness reduces air leakage into the house and may require improved mechanical ventilation, such as that provided by a heat recovery ventilator, to maintain acceptable indoor air quality. The measures required to achieve this level of airtightness can be determined by an energy audit.

The suggested total effective RSI (R)-values to achieve space heating energy savings of 75 per cent or more are as follows: RSI-10.6 (R-60) in the roof or attic, RSI-3.5 (R-20) in the below-grade walls, RSI-7.0 (R-40) in the above-grade walls, RSI-1.8 (R-10) in the basement floor slab, and RSI-1.0 (R-5.7) in the windows. Assuming that the pre-retrofit house has similar insulation levels to those outlined in Figure 2, the approximate total amount of insulation recommended for each of the building envelope locations is shown in Table 1.

TECHNICAL CONSIDERATIONS

Roof and attic

Insulation

Insulation can be added to the interior of the roof/attic space provided that there is sufficient space between the top of the ceiling finish and the underside of the roof. It can be cost-effective and relatively easy to achieve high levels of insulation (i.e. RSI-10.6 (R-60)) in open attic space. This may also allow trade-offs with other areas of the house that are harder to insulate (e.g. the basement floor slab) while still achieving the desired space heating energy savings. To achieve RSI-10.6 (R-60), two options may be considered:

ACH_{50} value	Retrofit Measures					Space heating energy saved (approximate)
	Add insulation in roof or attic	Add insulation to interior of below-grade walls	Add insulation to interior of above-grade walls	Add insulation to basement floor slab	Replace windows and doors with highest energy performance units	
1.0	Option A: RSI-10.6 (R-60) Option B: RSI-8.8 (R-50)	RSI-3.5 (R-20)	RSI-7.0 (R-40)	RSI-1.8 (R-10)	RSI-1.0 (R-5.7)	>75%

Table 1: Suggested ACH_{50} and total effective RSI (R)- values to achieve space heating energy savings of 75 per cent or more.

Option A: Remove any existing insulation and add about 50 mm (2 in.) of closed-cell spray foam insulation over the existing ceiling finish between the bottom chords of the roof trusses (Figure 4). Top up with additional fibreglass or cellulose batt or blown-in insulation to increase the effective insulation value to RSI 10.6 (R-60) . The 'effective' insulation value accounts for the reduced insulation value of thermally-conductive components in the assembly, such as trusses, rafters and studs, and is usually lower than the nominal value of the insulation itself.

Option B: Keep existing batt or blown-in insulation and top up with additional cellulose or fiberglass insulation above it to achieve an effective insulation value of RSI 8.8 (R-50). If this option is chosen, it is important to ensure air barrier continuity by sealing all penetrations through the ceiling to the existing air barrier, likely the polyethylene sheet above the ceiling.

When installing additional insulation in the attic space, ensure that a sufficient number of insulation baffles (also called guards) are installed along the eaves of the roof to provide the required ventilation into the attic space and ensure the baffles are not blocked.

Airtightness

The existing air barrier at the attic, if present, is likely polyethylene above the gypsum board ceiling. The spray foam insulation in Option A of this retrofit provides a continuous air barrier at all ceiling penetrations (e.g. electrical boxes for light fixtures, bathroom fans and ducts and plumbing vent stacks). Be sure to seal the attic hatch with a compressible gasket. Ensure air barrier continuity at the roof-to-wall connection by sealing the polyethylene in the roof to the wall air barrier system. This is best accomplished by spraying closed-cell foam insulation into the space between the ceiling and the insulation baffles (guards), making sure the spray foam connects the ceiling and wall air barriers (ie:- polyethylene). The spray foam acts as insulation, vapour retarder and air barrier.

Vapour Retarder

The polyethylene sheet located above the ceiling gypsum board or the closed-cell spray foam insulation can provide resistance to vapour diffusion into the attic space.

Water Penetration Control

The roof assembly sheds all exterior moisture by gravity drainage over shingled materials. The underlayment beneath the shingles provides a secondary line of protection. During the retrofit, pay careful attention to the condition of the roof sheathing (as viewed from the underside) and the attic space. If there are indications of moisture penetration (water staining, mold or wood rot), further investigation and repair will be required.

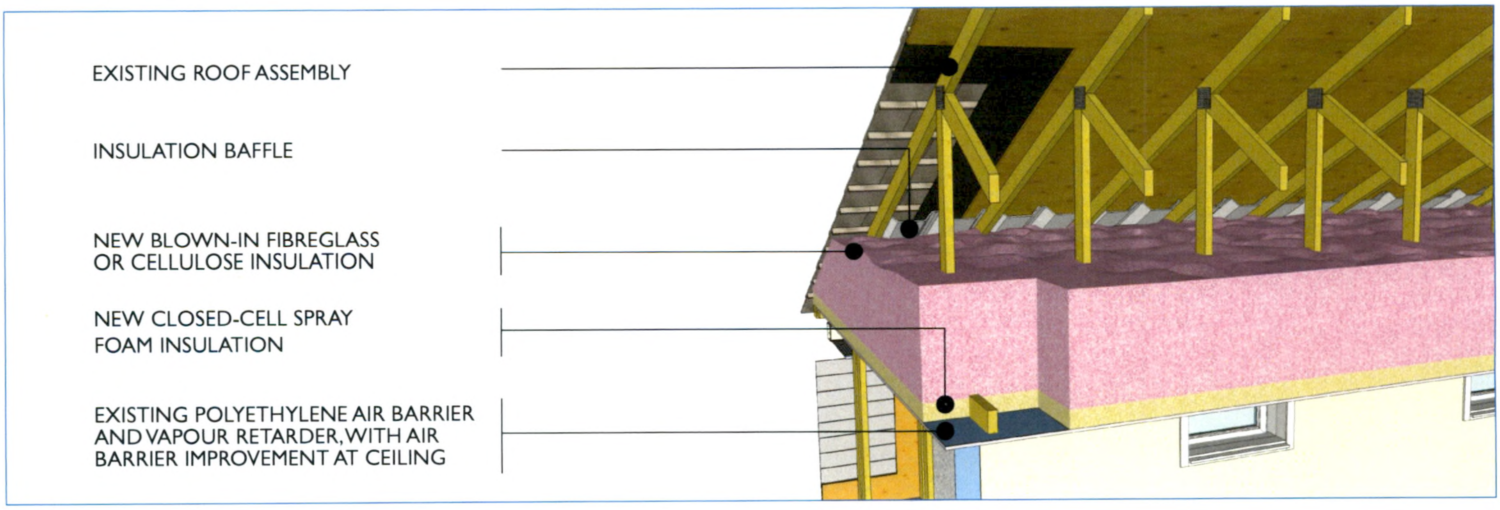


Figure 4: Section through roof and attic

Important considerations

Ensure there is adequate attic ventilation. Check that insulation baffles, which are installed between each pair of roof trusses at the building envelope, are installed properly, and vents at soffits and ridges are present and not blocked. If there are no baffles between each pair of rafters or trusses, these should be added as part of the retrofit.

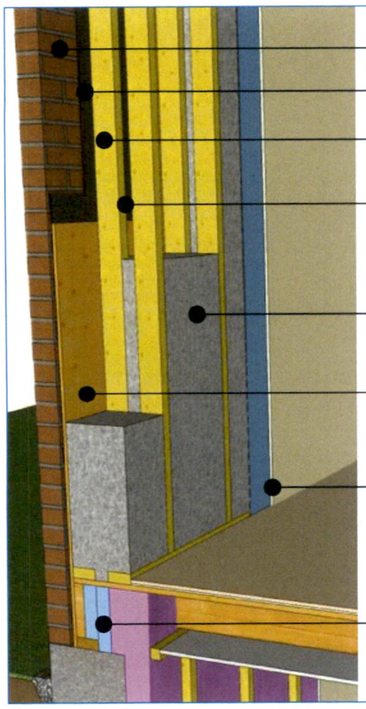
Above-Grade Walls

Insulation

To retrofit above-grade walls from the interior, a double stud wall can be built to provide space for the additional insulation necessary to attain the thermal requirements outlined in Table 1. This is done by removing the existing drywall and polyethylene, and building a second row of 38 by 89 mm (2 x 4 in.) wood stud framing with a gap between the stud walls. The total depth of the cavity must be sufficient to contain the thickness of insulation needed to achieve an effective insulation value of RSI 3.5(R-20). Fill the wall cavity with insulation and install a new polyethylene vapour retarder/ air barrier and gypsum board finish (Figure 5). Thicker walls will result in loss of interior floor space when retrofitting from the interior. The required space can be reduced by using insulation with a higher RSI (R)- value in the existing wall and in the new wall cavity.

Airtightness

Airtightness is achieved by installing an air barrier on the interior of the insulation. This can be accomplished with polyethylene that is properly sealed and detailed at connections, or taped and sealed gypsum board. Connect all components of the air barrier system at all interfaces and joints throughout the house (e.g. windows, wall to roof, wall to floor, etc.) and across interior partitions where they intersect with exterior wall assemblies or ceilings.



Vapour Retarder

Polyethylene provides the primary vapour retarder layer. Alternatively, vapour retarder paint, in combination with sealant at joints and penetrations, may provide adequate vapour control.

Water Penetration Control

The existing cladding acts as a water shedding surface. The water resistive barrier is the sheathing membrane, typically building paper in older houses. Ensure that exterior water is prevented from entering the wall. Ideally, there should be a vented air space between the cladding and wall sheathing to enable the wall to dry[1].

Pay attention to the condition of the exterior sheathing (as viewed from the inside). If there are indications of moisture penetration (water staining, mold and wood rot), further investigation and repair will be required.

Figure 5: Section through above-grade wall

[1] A drained and vented rainscreen wall with an air space between the cladding and sheathing is recommended.

Important considerations

With interior wall retrofits, the floor joists extending to the exterior of the wall assembly can create a thermal bridge where increased heat loss occurs. This can be minimized by adding two layers of 50 mm (2 in.) XPS insulation plus 50 mm (2 in.) of closed-cell spray foam insulation inboard of the rim joist, between the floor joists around the perimeter of the foundation. Alternatively, spray closed-cell foam full-depth from the rim joist to the stud wall insulation. Electrical services must be relocated to the inside face of the new wall.

Windows and doors

Insulation

Windows should be triple-pane and have low-e coating(s), argon gas fill and low conductivity insulating glass edge spacers which can be customized depending on performance needs. For instance, a low-e coating applied to the inside surface of the outside pane will reflect much of the sun's energy back to the exterior, thereby reducing helpful solar heat gains in the winter. If the coating is applied to the outside surface of the inside pane, this will allow more of the sun's energy into the house and will also help reflect internal heat back into the house to reduce the space heating requirements. Look for windows with overall thermal resistance values of RSI-1.8 (R-5.7) or better.

Replacing architecturally significant doors may not be desirable, but poorly insulated doors can cause a significant loss of energy in a well insulated house, particularly in cold climates. If replacing the doors, look for doors with insulated cores and thermal resistance values greater than RSI-1.0 (R-5.7). Consider installing storm doors outside the existing exterior doors to reduce heat loss in winter. During summer months, the storm door ventilation screen should be open if necessary to vent the airspace between the exterior door and the storm door to the exterior, thereby preventing damage to the exterior door components due to excessive solar heat build-up.

Where possible, consider exterior shading devices, such as roof overhangs and awnings, to limit solar heat gain on south, east and west-facing windows during the summer. For south facing windows as a rule of thumb the awning or overhang should extend out a distance equal to ⅓ the window height to provide shading.

Airtightness

It is important to provide an airtight interface between the windows/doors and the walls. This can be accomplished by installing a backer rod and sealant, or spray foam insulation, in the gap between the rough opening and the window or door. The backer rod may be omitted where a sill dam is installed beneath the window (Figure 6). Operable windows (e.g. awning, sliding, casement, tilt-turn, single or double-hung windows) are prone to leakage over time; gaskets, caulking, tapes, seals and weather stripping break down with continued use. Choose windows with low air-leakage characteristics and durable seals and gaskets.

Vapour Retarder

The windows and doors can act as vapour retarders provided that the connections between the windows/doors and walls are airtight and vapour tight.

Water Penetration Control

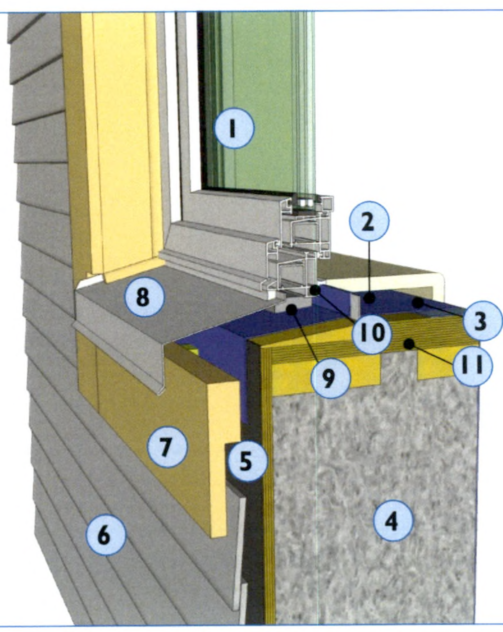
It is important to provide good sealing and water shedding where the window/door sits in the wall. Provide a waterproof "sill dam" underneath the window and slope it outwards to the exterior of the wall. Ensure the sill water barrier is effectively sealed to the window frame and the water barriers in the existing or retrofitted wall assembly.

Choose windows with appropriate water penetration resistance. This is particularly important for houses in exposed locations or climates with high wind and rain loads.

Important considerations

It is important to carefully seal the window to the wall in order to achieve a continuous air and water barrier. Many different approaches are possible depending on the window and type, the wall assembly, and the position of the window within the rough opening[2].

Interior retrofits to improve the thermal performance of the building envelope will result in a thicker wall assembly. This means the window can be installed in one of three positions: in line with the exterior surface, in line with the interior surface, or in the middle of the rough opening as shown in Figure 6. Installing the window in line with the interior wall will help to reduce the potential for condensation on the glass as it is in a warmer location but may require deep sill flashings and window trim on the exterior, especially when the house is clad with siding. This reduces window exposure to wind-driven rain but relies more on flashings to deflect water. Installing the window in the middle of the wall, as shown, requires less exterior flashing and trim, and provides space for an interior window sill.



1. TRIPLE GLAZED WINDOW WITH LOW CONDUCTIVITY FRAME
2. FOIL FACED SELF-ADHERED MEMBRANE, TAPED TO THE SILL DAM AND POLYETHYLENE FOR AIR BARRIER CONTINUITY
3. POLYETHYLENE AIR AND VAPOUR BARRIER
4. DOUBLE STUD WALL ASSEMBLY
5. EXISTING SHEATHING PAPER
6. EXISTING CLADDING (ANY TYPE)
7. TRIM
8. SILL FLASHING COMPLETE WITH END DAMS
9. WINDOW SHIMS
10. SILL DAM WITH SEALANT (OR SPRAY FOAM-NOT SHOWN) TO CONNECT WALL AIR BARRIER TO WINDOW
11. PLYWOOD BUCK FOR WINDOW ATTACHMENT

Figure 6: Exterior view of window installation at the sill

[2] Refer to CMHC's "Design, Selection and Commissioning of Window Installations".

Below Grade Walls

Insulation

The existing basement wall is usually cast-in-place concrete up to the height of the window sill, with wood framing between the foundation wall and the floor above. Insulation can be applied to the interior of both the concrete foundation wall and the above-grade wall (Figure 7).

The below-grade foundation walls can be retrofitted from the interior by spraying closed-cell foam insulation against the inside of the foundation wall in sufficient thickness to achieve an effective insulation value of RSI 3.5 (R-20). Extruded polystyrene (XPS) insulation can be used as an alternative to spray foam insulation, with joints taped to prevent interior air from reaching the concrete foundation wall. Closed-cell spray foam can also be installed at the rim joist between the floor joists to reduce thermal bridging and improve airtightness at this location. To reduce costs, 25 mm to 50 mm (1 to 2 in.) of closed-cell spray foam insulation may be applied to the foundation wall followed by 38 by 89 mm (2 x 4 in.) wood framing filled with fiberglass batt insulation or mineral wool.

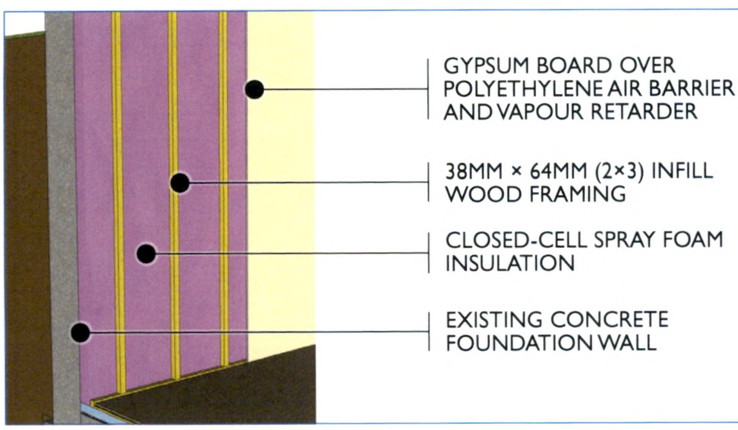
The upper portion of the basement wall may be an insulated stud frame similar to the walls on the main floor of the house. For these areas, you should implement the same insulation and airtightening strategies that were used for the above-grade walls.

Airtightness

The retrofit should improve the airtightness at the below-grade to above-grade wall connection. Closed-cell spray foam on the inside of the foundation wall provides a continuous air barrier as well as a vapour barrier. Spray foam insulation between the floor joists at the perimeter of the basement ceiling will minimize the effects of thermal bridging at this location and create a continuous air barrier from the below-grade to above-grade wall.

Important considerations

Proper detailing is required where the interior partition walls meet the exterior foundation wall. Spray foam around wood framing at these locations.



Vapour Retarder

It is important to control water vapour for the entire below-grade assembly. A vapour retarder is required at the interior of the insulation to prevent condensation from occurring on the cold foundation wall and in the wall framing. Polyethylene vapour retarder on the inside of the above- and below-grade insulation, extends down to the basement floor.

Water Penetration Control

This retrofit strategy relies on the existing foundation assembly to control and drain exterior ground water. If the existing foundation appears to have drainage or leakage problems further investigation and repairs should be completed.

Figure 7: Section through below grade wall

Basement Floor Slab

Insulation

To improve the energy efficiency in new home construction, insulation may be installed below the slab. However, in the energy retrofit of existing basement concrete slabs, one must insulate the slab from the interior. This is done by removing the interior flooring (if the basement is finished) and installing a drainage mat and XPS board insulation (in sufficient thickness to meet the thermal requirements outlined in Table 1). Tape all joints and install floor sheathing and finished flooring above the insulation (Figure 8). Insulation thickness may be limited by the amount of floor to ceiling height available in the basement. Consider using insulation with a high RSI (R)-value per unit thickness to minimize the floor-to-ceiling height reduction.

Airtightness

An air barrier is required on the interior side of the insulation to prevent warm interior air from contacting the cold concrete slab. This can be achieved by taping the joints of the XPS insulation, and by connecting the floor air barrier with the wall air barrier. A continuous and effective basement air barrier should also reduce infiltration of soil gases (moisture, radon) into the occupied spaces.

Vapour retarder

XPS insulation is an adequate vapour retarder; therefore, an additional vapour control layer is not required.

Water Penetration Control

The existing foundation and slab assembly serves as the water control layer. When undertaking this retrofit look for signs of water ingress through, or moisture problems on the existing floor slab. Any existing water ingress problems will require further investigation and repair.

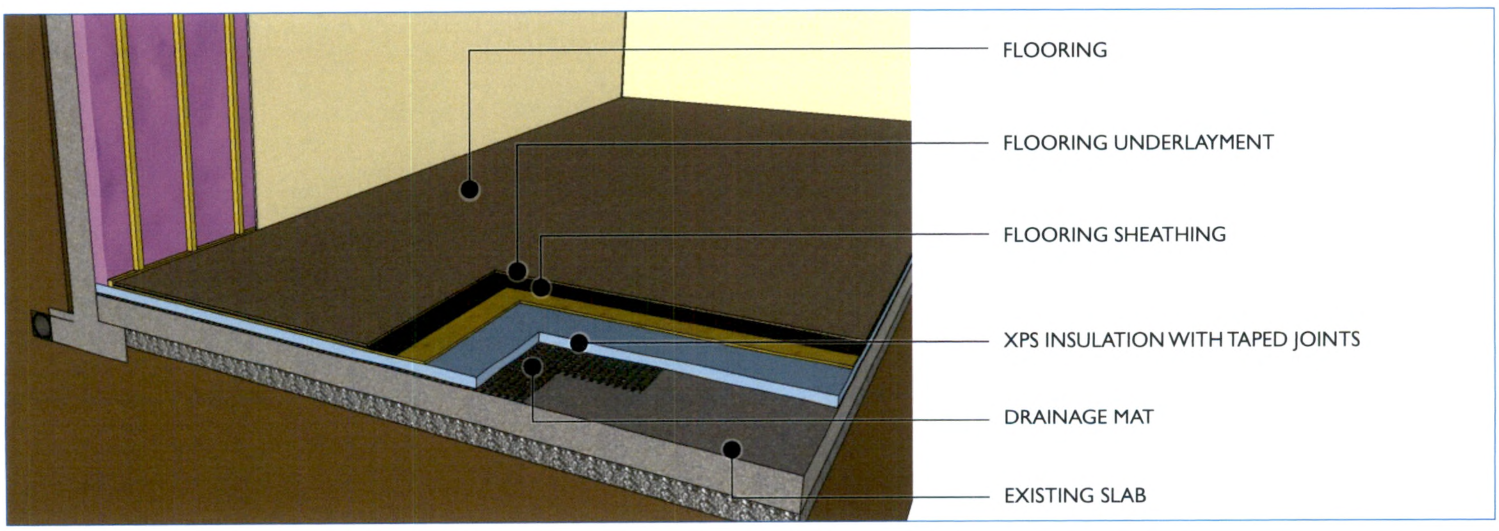


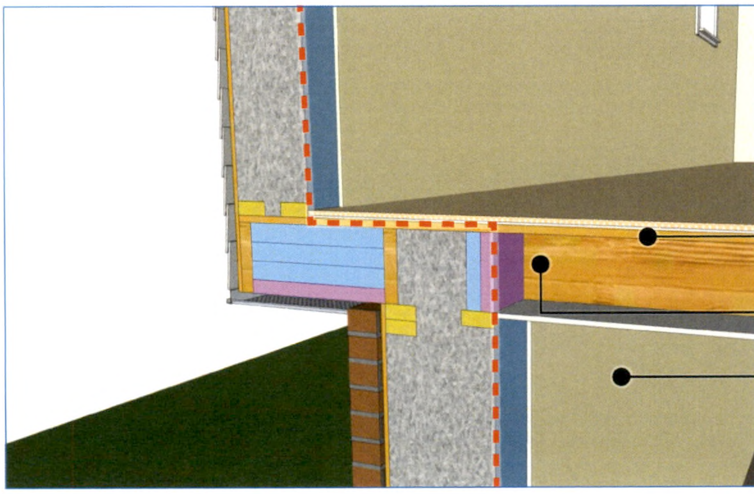
Figure 8: Retrofit to basement floor slab

ADDITIONAL DETAILS

A 1960s and 1970s era raised bungalow may have other areas where insulation should be installed, or that may require more attention to air sealing. Two common areas are described below:

Garage Wall

It is important to install a continuous air barrier between any adjacent interior space and the garage. Interior walls abutting the garage should be insulated at the interior with the double stud assembly. If the garage is below interior floor space, insulation and an air barrier should be installed in the floor space.



Exposed Floors

Overhanging or exposed floors that have either ground or exterior space below them should be insulated. This is common in the raised bungalow design (Figure 9).

Closed cell spray foam and XPS insulation can be installed between the floor joists at exposed floor locations. Install several layers of XPS insulation first to reduce the thickness of spray foam that is required.

Line of air barrier continuity: Seal the upper wall polyethylene to the bottom plate, and caulk between the bottom plate and the floor sheathing. Install XPS insulation between the joists to hold the blown in insulation in place and cover with spray foam between the top plate and the floor framing. Seal the lower floor polyethylene to the top plate.

Figure 9: Section through exposed (projecting) floor

A WORD OF CAUTION

Assess the condition of the house for pre-existing problems and anticipate the possible effects of the retrofit work on indoor air quality, building envelope durability, heating appliance performance or other possible performance issues, in order to avoid unintended consequences of a building envelope energy efficiency retrofit.

Pre-existing problems: The house may have moisture problems (high humidity, water leaks, dampness, mold, etc.) in the roof, walls, floors or foundation; indoor air quality problems (stale air, lingering odours, soil gas, pollutant emissions from household products, etc); radon or other soil gases; structural sags, cracks and deflections and the presence of hazardous materials such as asbestos, lead paint and rodent/bird waste. Pre-existing problems should be corrected prior to undertaking an energy efficient building envelope retrofit so that the problems do not worsen.

Ventilation: A highly energy efficient building envelope retrofit will provide a more air-tight house, which is important for reducing energy consumption. However, this will also result in less incidental ventilation which would otherwise be provided by a leaky enclosure. This can cause the air in the retrofitted house to seem stale and odours to linger longer. Odours from previously unnoticed sources (e.g. hobbies, pets, stored items) may become more apparent and more objectionable. Therefore, energy efficient mechanical ventilation should also be included in any home energy retrofit strategy. This can be accomplished by adding a heat recovery ventilator (HRV) or an energy recovery ventilator (ERV). This ventilation should improve occupant health and comfort.

Building envelope durability: Installing additional insulation can increase the risk of moisture to the building envelope if inside and outside sources of moisture are not controlled.

Heating appliance performance: Reducing heat losses through the envelope may result in the existing furnace or boiler being oversized for the house. Oversized heating equipment does not operate efficiently as it tends to cycle on and off more frequently. Reducing air leaks in a house, with chimney-vented furnaces, water heaters and fireplaces can reduce the amount of air needed for safe and efficient operation.

Consult with a qualified energy service provider, building professional, home inspector or contractor before the retrofit to better understand, and plan for, pre-existing conditions and possible unintended consequences of the retrofit project. Often, corrective measures can be planned that not only prevent problems but also add value to the overall project.

For more information on retrofit and renovation considerations, visit CMHC's Web site at www.cmhc.ca.

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