Energy Efficiency Building Envelope Retrofits for Houses

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

Figure 1: One-Storey Raised Bungalow

EXTERIOR 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 insulating and airtightening from the exterior. An exterior retrofit covers cracks, holes and thermally conductive materials (called 'thermal bridges'), it allows you to detect and repair water entry problems, it doesn't affect interior finishes or reduce room sizes, it is easier to make the insulation and air-barrier system continuous, it keeps the structure at a more uniform temperature, and it provides an opportunity to update the appearance of the house.

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 exterior 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.

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 granular base

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

- Extend roof sheathing membrane/air barrier down and seal to wall air barrier (sheathing membrane)
- Install exterior I-joists and insulation, ensuring continuity of roof and wall insulation
- Install new roof sheathing with strapping and ventilated drainage cavity

2. Above Grade Walls

- Install exterior insulation with vertical furring and ventilated drainage cavity

3. Windows and Doors

- Replace windows with low-E, argon-filled, triple-glazed units with insulated glazing spacers and low conductivity frames
- Install closed-cell spray foam between windows and doors, and rough openings
- Install insulated doors

4. Below Grade Walls

- Ensure bituminous dampproofing covers foundation from grade to footing
- Install Extruded Polystyrene (XPS) insulation and drainage mat

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 on top of the roof.
- Add insulation on the exterior of below-grade (basement) walls.
- Add insulation on the exterior 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, all proposed retrofit options include increasing airtightness to 1.0 ACH_{50}. The measures required to achieve this level of airtightness can be determined by an energy audit.

The total effective RSI (R)-values that are needed to achieve space heating energy savings of 75 per cent or more are as follows: RSI- 8.8 (R-50) on the roof, RSI 3.5 (R20) in the below-grade walls, RSI-7.0 (R-40) in the above-grade walls, RSI-1.8 (R-10) on the basement floor slab, and RSI-1.0 (R-5.7) windows. Assuming that the pre-retrofit house has similar insulation levels to those outlined in Figure 2, the approximate amount of insulation that is recommended in each of the building envelope locations is shown in Table 1.

TECHNICAL CONSIDERATIONS

Roof and attic

Insulation

Insulating the roof/attic from the exterior makes the most sense when the existing roof is too shallow to accommodate a sufficient amount of insulation or when the roof should be replaced for other reasons. However, there are limits to the amount of insulation that can be added on the exterior; RSI- 8.8 (R-50) is considered to be reasonable for this application. Note that the existing insulation in the attic ceiling will not contribute significantly to the final RSI(R)- value.

Install wood joists (or similar framing) on a new self-adhesive membrane over the existing roof sheathing, and fill the cavity between the joists with rigid (EPS, XPS or polyisocyanurate), or mineral fibre insulation to increase the effective RSI (R-) value to RSI-8.8 (R-50). The 'effective' insulation value accounts for the reduced insulation value of thermally-conductive components in the assembly, such as trusses, rafters and studs,

ACH_{50} value	Retrofit Measures					Space Heating Energy Savings (approximate)
	Add insulation on top of roof	Add insulation to exterior of below-grade walls	Add insulation to exterior of above-grade walls	Add insulation to basement floor slab	Replace windows and doors with best quality windows and doors	
1.0	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-values (R)-values to achieve space heating energy savings of 75 per cent or more

and is usually lower than the nominal value of the insulation itself. Where they exist, the original rafter or truss tails may be cut off and a plywood or OSB sheathing board nailed to the truss ends. This will make it easier to connect the wall insulation and air barrier with the roof insulation and air barrier.

Alternatively, in lieu of installing an I-joist system, a continuous layer of closed-cell polyisocyanurate foam insulation can be installed over the self-adhesive membrane and existing roof sheathing. A new exterior sheathing board, sheathing membrane and roof finish can then be installed over top of the closed-cell insulation. This retrofit may be advantageous if the weight if the I-truss framing is a structural concern on the existing roof.

Airtightness

The roof air barrier retrofit is accomplished by removing the existing shingles and underlay (if present) and installing a continuous self-adhered membrane (air and vapour barrier) on top the existing roof sheathing prior to installing new joists or joist ends (see Figure 4). Ensure the air barrier is continuous at the roof-to-wall connection by sealing the roof air barrier (for example, the self-adhering membrane) to a component that is connected to the wall air barrier (for example, the wall sheathing membrane).

If there is an existing air barrier/vapour retarder in the ceiling, an opening should be made in the ceiling to allow conditioned air into the attic. Otherwise, moisture laden air could become trapped in the attic space (refer to Important Considerations, below).

Vapour Retarder

In the retrofitted roof assembly, the self-adhesive sheathing membrane applied to the plywood sheathing (interior of the insulation) may be considered the vapour retarder. To avoid moisture problems, it is important that the exterior water resistive barrier is vapour permeable.

Water Penetration Control

This assembly sheds all exterior moisture by gravity drainage over shingled materials. The top surface of the sheathing is protected by a water resistant barrier in the form of a vapour-permeable roofing underlayment, and covered by wood or asphalt-fibreglass shingles, roof tiles, or metal roofing. During the retrofit, pay careful attention to the condition of the existing roof sheathing and the attic space. If there are indications of moisture penetration (water staining, mold or wood rot), further investigation and repair will be required.

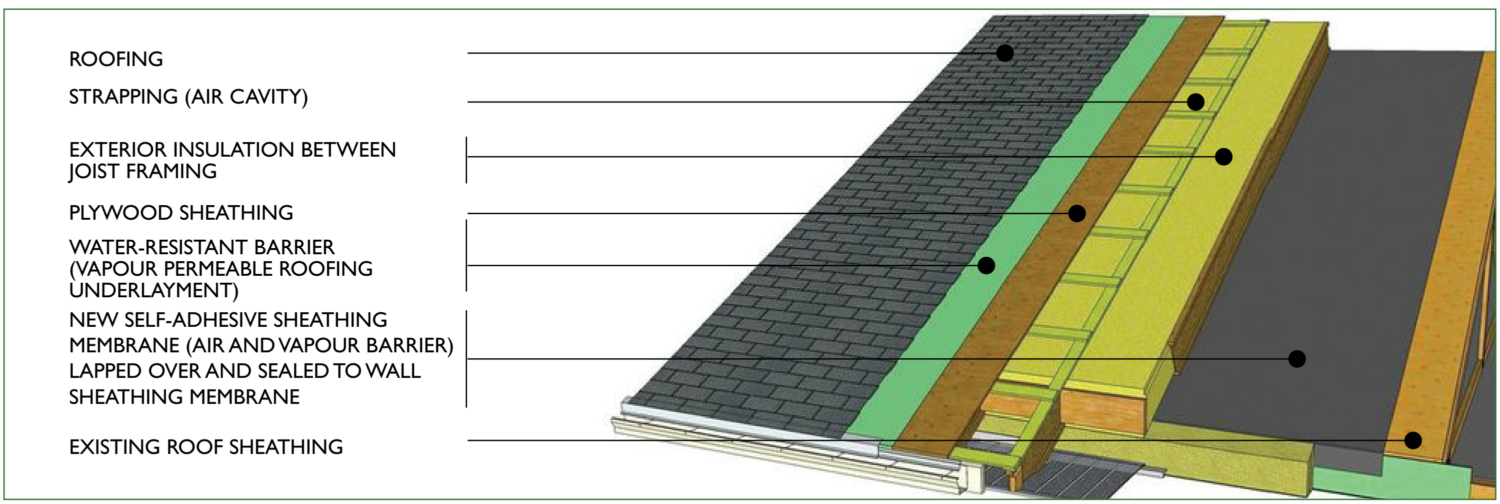


Figure 4: Section through roof

Important considerations

The installation of a new exterior insulated roof assembly makes the existing attic space now part of the interior space. By extending and sealing the wall air barrier to the new roof air barrier, the soffit venting (if it existed) no longer vents the attic. New venting should be installed at the ridge to allow air to flow from the soffit through the strapping above the insulation and out at the ridge.

Vents in the roof and gables should be removed, and their openings covered over with sheathing. The new roof and wall air barriers must extend over the original vent openings to ensure a continuous air seal. In addition, the new wall insulation must extend over the gable ends and connect to the roof insulation.

The attic space must be ventilated when it is part of the interior space. The attic hatch can be removed and replaced with a decorative grate to allow conditioned air from below to rise to the attic, and at least one return air duct for the house space heating system can be extended into the attic to draw the attic air back to the furnace and induce air circulation. In houses with no ducted heating systems, a fan should be installed in the ceiling between the conditioned attic and the space below to circulate the air.

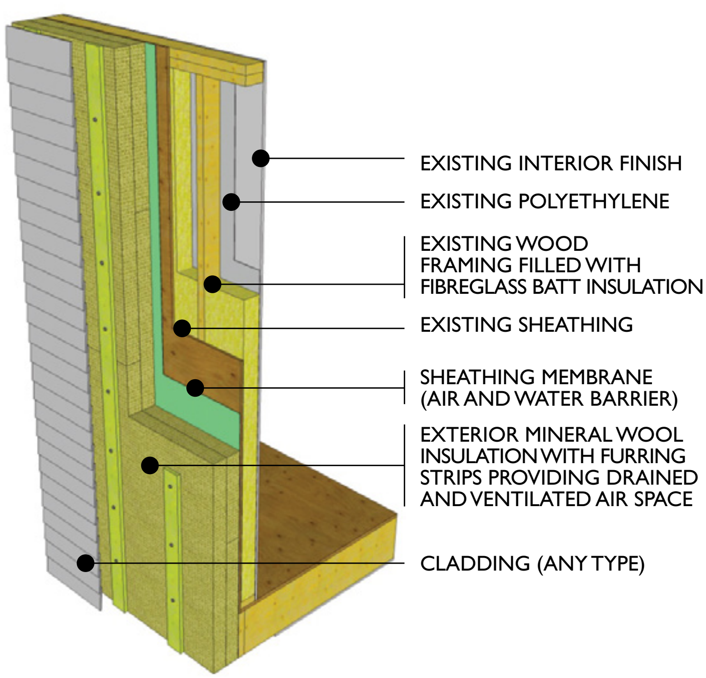
Above-Grade Walls

Insulation

To retrofit above-grade walls from the exterior, rigid mineral wool insulation is attached to the outside of the sheathing in two layers, with joints staggered and overlapped (Figure 5). The insulation is attached with screws through vertical furring on the exterior of the insulation. The added insulation must be sufficient to achieve a total effective insulation value of RSI-7.0 (R-40). New cladding is installed outside of the exterior insulation and attached to the vertical furring.

Airtightness

Airtightness is achieved by installing an air barrier, in this case a sheathing membrane sandwiched between the existing sheathing and the newly installed insulation. Proper detailing is required at all joints and penetrations in the sheathing membrane to ensure air barrier continuity. Connect all components of the wall air barrier with the air barriers in the roof and below-grade assemblies and at all interfaces and joints throughout the house (e.g. windows, floor projections, etc.).



Vapour Retarder

The existing polyethylene on the interior of the wall assembly may act as the primary vapour retarder. Alternatively, vapour retarder paint, in combination with sealant at joints and penetrations, may provide adequate vapour control.

Water Penetration Control

The cladding acts as the assembly's primary water shedding surface while the sheathing membrane acts as a water resistive barrier. Alternatively, an unsealed layer of vapour permeable sheathing membrane (water resistive barrier) can be installed between the insulation and the furring to intercept any water that gets past the cladding. Ensure that there is 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. If there are indications of moisture penetration (water staining, mold staining and wood rot), further investigation and repair will be required.

Figure 5: Section through retrofitted above-grade wall

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

Important considerations

Mineral wool insulation is shown in this retrofit approach since it is sufficiently rigid to support the furring and cladding and is vapour permeable to allow drying. Foam insulation, such as XPS, may also be used for this retrofit; however, the vapour impermeable characteristics of the foam can restrict drying. Therefore, greater care must be taken to reduce and control the indoor relative humidity and minimize the amount of exterior moisture that reaches the sheathing membrane. To encourage drying to the exterior, the air barrier membrane should be vapour permeable, the joints between the foam should be left open (unsealed) and a vented drainage space (ie. a rainscreen) should be provided between the insulation and the cladding.

Windows and doors

Insulation

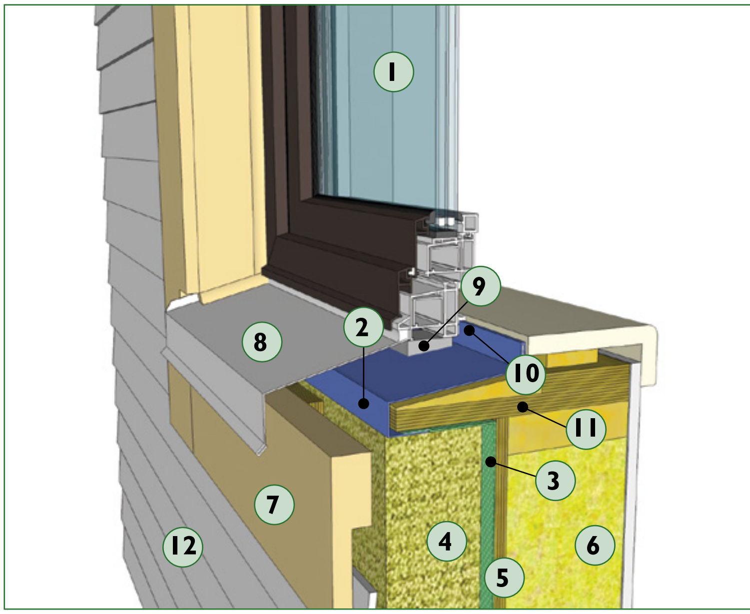
Windows should have triple glazing with low-e coating(s), argon gas fill and low conductivity insulating glass edge spacers which can be customized depending on performance needs. For instance, a low-e coating applied to the inside surface of the outside pane will reflect much of the sun's energy back 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-1.0 (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 window 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 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 1/3 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. Consider selecting windows with low air leakage characteristics and durable seals and gaskets.



1. TRIPLE GLAZED WINDOW WITH LOW CONDUCTIVITY FRAME
2. FOIL FACED SELF-ADHERED MEMBRANE
3. SHEATHING MEMBRANE (AIR AND WATER BARRIER)
4. EXTERIOR INSULATION
5. EXISTING SHEATHING
6. EXISTING STUD CAVITY WITH GLASS FIBRE BATT INSULATION
7. EXTERIOR 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
12. CLADDING (ANY TYPE)

Figure 6: Exterior view of window installation at the sill

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 or door and slope it outwards to the exterior of the wall. Ensure the sill water barrier is effectively sealed to the window or door frame and the weather resistive 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 type, the wall assembly, and the position of the window within the rough opening.

Exterior 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 trims on the exterior. 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.

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. If the house is experiencing foundation moisture problems, an exterior below-grade retrofit may be an opportunity to address the moisture problems at the source. Insulation can be applied to the exterior of both the concrete foundation wall and the above-grade wall (Figure 7).

The below-grade walls are excavated and XPS or mineral wool insulation is installed on the exterior of the concrete foundation wall in sufficient thickness to achieve an effective insulation value of RSI 3.5 (R-20). Alternatively, closed-cell spray foam insulation can be installed in place of XPS or mineral wool insulation.

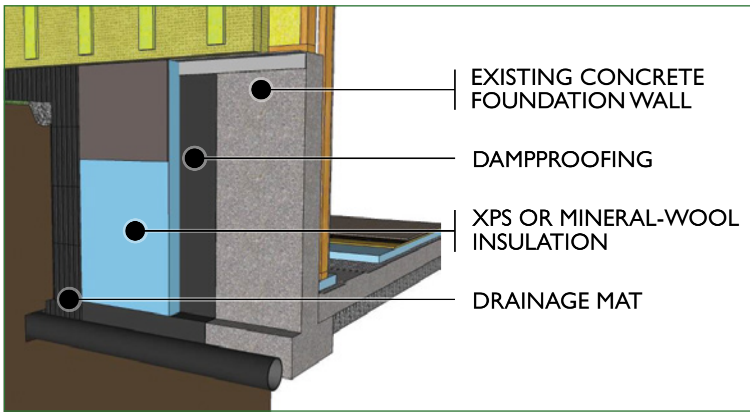
The upper portion of the basement wall may be an insulated stud frame similar to the walls on the main floor of the house. For these areas, the same insulation and airtightening strategies that were used for the above-grade walls may be implemented.

Airtightness

The existing concrete wall acts as the air barrier.

Important considerations

Ensure the insulation, air barrier, and water barrier are continuous, and fitted and sealed together where the below-grade wall meets the above-grade wall.



Vapour Retarder
If there is existing insulation on the inside of the concrete foundation wall, there should also be polyethylene on the inside surface of the insulation to act as the vapour retarder. Alternatively, gypsum board with vapour barrier paint can act as the vapour retarder.

Water Penetration Control
This retrofit strategy incorporates a drainage matt on the outer face of the insulation to shed the majority of ground water. Damp-proofing is applied on the exterior surface of the concrete foundation wall to provide water penetration control. 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

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 floor 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 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 (i.e. the concrete wall). 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 may not be required.

Water Penetration Control

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

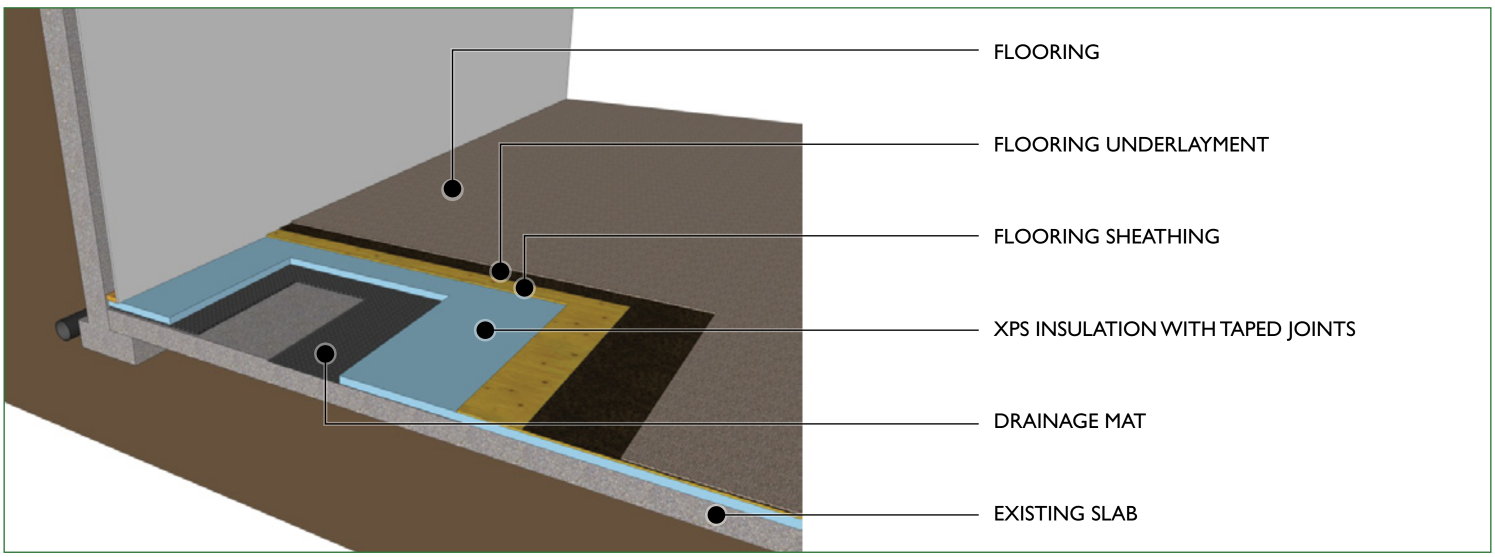
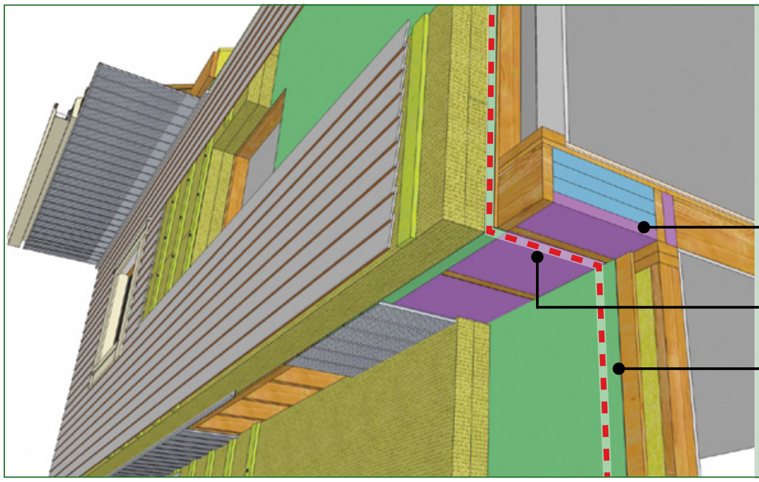


Figure 8: Retrofit to basement floor slab

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:



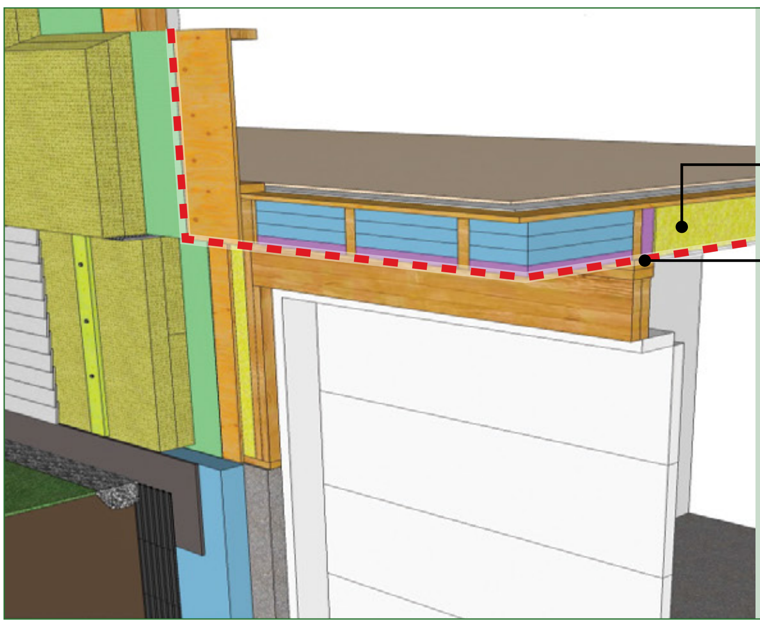
Exposed Floors

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 should 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: Use spray foam to extend airtightness from the top of the lower wall to the rim joist of the exposed floor. Ensure the wall sheathing membrane is continuous and extends from the projecting wall, underneath the exposed floor, and connects to the sheathing membrane on the lower wall.

Figure 9: Section through exposed or overhanging floor



Exposed floor above garage

Unheated garages should be treated as unconditioned spaces. Closed cell spray foam and/or fibreglass or mineral fibre insulation can be installed between the floor joists over the garage, and around ducts in the floor space. Properly-installed spray foam will both reduce air leakage and provide insulation value (Figure 10).

Line of air barrier continuity: Install a vapour-permeable air barrier/sheathing membrane on the underside of the exposed floor framing, and seal it to the air barrier/sheathing membrane on the exterior wall, and to the air barriers on interior walls abutting the garage.

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 and made airtight, similar to the exterior walls. The wall air barrier must be sealed to the air barrier separating the garage from the living areas above.

Figure 10: Section through exposed floor above garage

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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