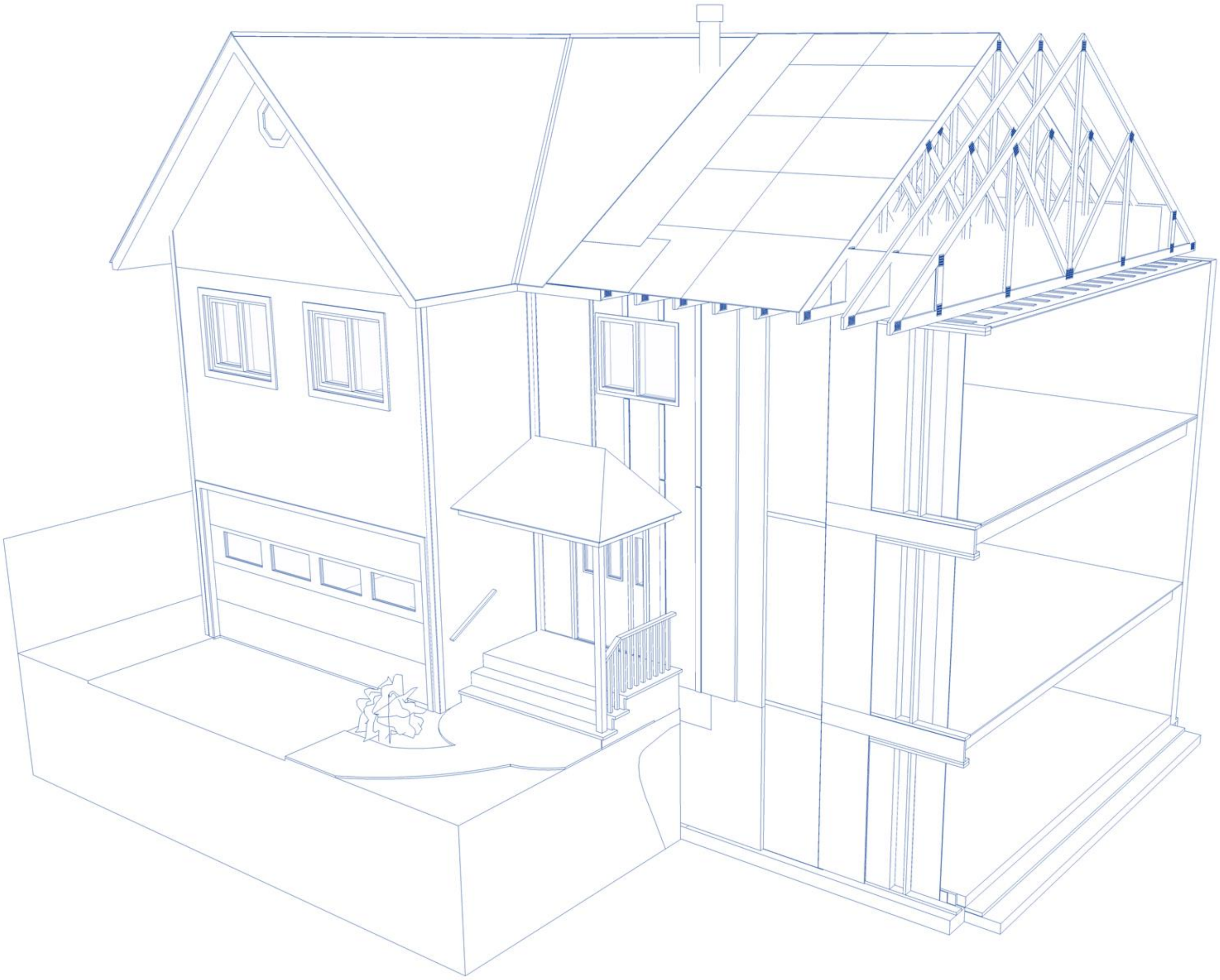
Energy Efficient Housing Guidelines for Whitehorse, YT:

Cost Optimized House



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Natural Resources Canada
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Contents

Introduction – How to Use this Guide

The Energy Efficient Northern Housing Guide covers the design and construction of an archetype energy and cost optimized single family dwelling for Whitehorse, YT. The guide is intended to be an industry utility for achieving higher energy efficiency than the minimum code requirements while maximizing cost savings from lower energy use.

House as a System

Houses are complex systems that operate based on the interaction of various components, occupants and the exterior environment. When considering any one component of a building it is important to also consider the interaction of that component with other building elements. A change in one area of design inextricably affects other areas of the building. For example, greater air tightness while good for energy efficiency and comfort will require a well-designed and controlled mechanical ventilation system; higher insulated wall, roof, and floor assemblies and higher performance windows may reduce the sizing of the heating system. In considering the house as a system, one must consider a number of different design areas, with concern to this guide; the building enclosure and mechanical HVAC (heating, ventilation and air conditioning) systems.

Mechanical Heating, Ventilation and Air Conditioning (HVAC)

Ventilation is the process of supplying air to, or removing air from, a space for the purpose of controlling air contaminant levels, humidity, and temperature within the space. It is an important contributor to the healthiness and comfort of an indoor environment. Mechanical ventilation is the intentional movement of air into and out of a building using fans and associated ductwork, grilles, diffusers and through other penetrations.

There can be a variety of components associated with the HVAC system, including; wood/pellet stove, cold climate air source heat pump (CCASHP), heat recovery ventilator (HRV), bathroom and kitchen exhaust vents, gas or electric furnace and electric baseboard heaters. It is important to carefully design the HVAC system to ensure efficiency and occupant comfort.

Section 2 of this guide outlines options for HVAC design.

Building Enclosure

The building enclosure physically separates indoor from outdoor space and facilitates indoor climate control. The building enclosure includes assemblies such as the basement floor slab, foundation walls, above grade walls, attic and roof, and components such as windows, skylights, and doors. These assemblies are designed to manage bulk water (rain and snow), and control water vapour flow, air flow, and heat loss/gain. Careful construction and detailing of these assemblies and interfaces will improve energy efficiency, occupant comfort and building longevity.

Section 3 of this guide provides sequential 3D details on the construction and detailing of the house assemblies and interfaces.

Disclaimer & Use of This Guide

Cost Optimized House

Due to severe climate and high energy rates, homebuilders in Canada's north have long been building highly-insulated, airtight, energy efficient housing. As a consequence of new green building standards in Whitehorse, YT, many new homes are being heated with electricity instead of oil, placing a growing burden on local generation capacity.

Archetype House

NRCan and CanmetENERGY partnering with Yukon Territory applied an optimization tool and extensive energy modeling to determine the most energy and cost effective combinations of components, assemblies and mechanical equipment for an archetype building in Yukon. The archetype home is a 225m^2 (2 400 ft^2), 2-story wood-frame building with an attached garage. The archetype was selected based on a review of common new construction in Whitehorse, YT.

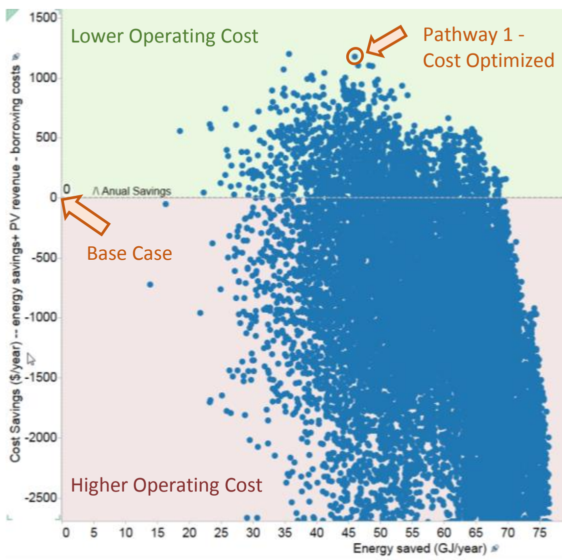
Using ESP-r coupled with Gen-Opt optimization software, over 20,000 simulations were run. Of the 20,000 simulations, specific combinations of assemblies and components emerged as being more cost effective and energy efficient than the building code minimum. A variety of inputs were selected for the modeling, including; material availability, construction design, material and labour costs, energy efficiency and utility rates.

Important output metrics of the optimization scenarios are the upgrade cost over the base case house, the energy savings and the yearly operating cost savings. Only scenarios that saved homeowners money while being equal to or more energy efficient than the base case house were examined further. Certain assumptions were made to determine the overall savings of various alternative building designs. The interest rate was set at 3.5% over a 25 year period, and energy prices were conservatively considered to be constant over the same time period. As energy rates rise, the savings will increase.

The results of the optimization helped to identify options that saved money and energy over the base case building as stipulated in the Whitehorse New Green Building Standards. The figure to the right shows the relative location of the various upgrade options relative to the base case scenario at the XY axes intercept. The blue points represent individual simulations. All alternatives saved energy over the base case, but much less than half of them also saved money.

For the purposes of this guide, the point that proved **most cost effective** (highest on the Y axis) was selected and the various unique components that make up this house a covered here. It should be noted that many of the components (walls, windows, HVAC systems etc.) close to this most cost optimal point are often similar.

Further information about the optimization study can be found on CanmetENERGY's website.

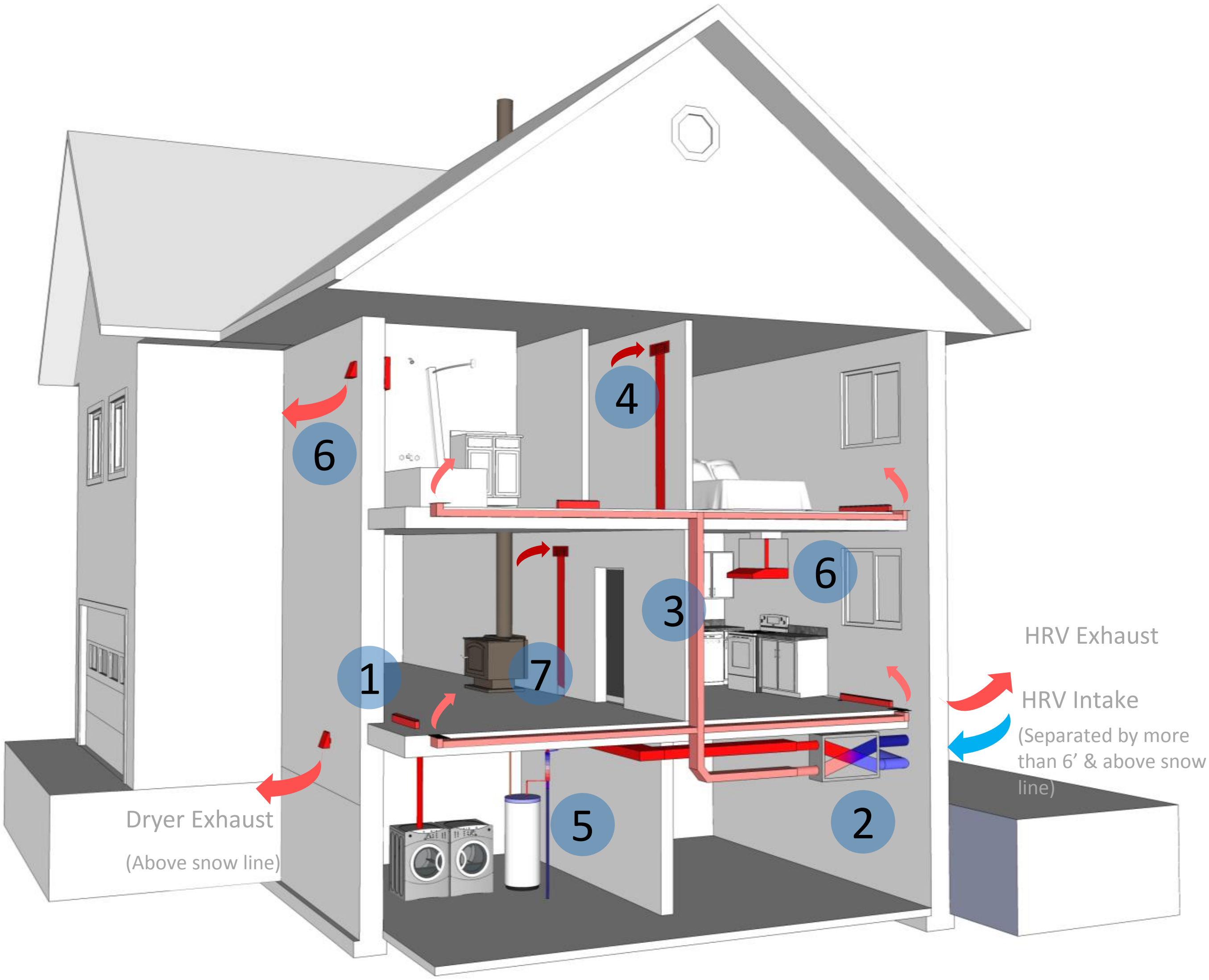


Optimization Simulation Results

The following table presents the combination of components and assemblies for the most cost efficient house as compared to the base case house. The components and assemblies of the cost optimized house are further detailed in this guide.

BASE CASE BUILDING vs COST OPTIMIZED WHITEHORSE, YT HOUSE		
Category	**Base Case**	**Cost-Optimized Pathway**
Basement Slab	Concrete slab with 5mm (2") XPS insulation, RSI- 1.76 (R-10)	Concrete slab with 5mm (2") XPS insulation, RSI- 1.76 (R-10)
Foundation/Basement Wall	2X6 Permanent wood foundation with, RSI-3.5 (R-20) fibreglass batt	2X6 Permanent wood foundation with fibreglass batt and 75mm (3") of exterior EPS, RSI-4.9 (R-28)
Casement Windows	Clear, triple-glazed, USI-1.77 (U-0.31), SHGC 0.68	Triple pane, hard coat with interior low-e coating, USI-0.987 (U-0.174), SHGC 0.46
Attic	Standard truss with 350mm (14") blown-in cellulose insulation, RSI-8.8 (R-50)	530mm (21") Raised-heel trusses with 760mm (30") blown-in cellulose, RSI-19.4 (R-110)
Exposed Floor	2X12 Joists with 200mm (8") fibreglass batt in floor joist cavities, RSI-4.9 (R-28)	2X12 Joists with 150mm (6") fibreglass batt in joist cavities and 130mm (5") of mineral wool exterior the sheathing, RSI-6.7 (R-38)
Air Tightness	1.5 ACH (air changes per hour)	0.5 ACH (air changes per hour)
Domestic Hot Water	Electric Water Heater	Electric Heat Pump Water Heater
Heating	Oil 85% AFUE (ducted forced air	Electric Baseboard Units
Above Grade Wall	2X6 Wood stud @ 610mm (24") o.c. with fibreglass batt and 65mm (2.5") fibreglass batt interior, RSI-4.9 (R-28)	2X6 Wood stud @ 610mm (24") o.c. with fibreglass batt and 130mm (5") of mineral wool exterior the sheathing, RSI-6.7 (R-38)
Heat Recovery Ventilation	Yes (70% SRE @ O°C, 60% SRE @-25°C)	Yes (70% SRE @ O°C, 60% SRE @-25°C)
Drain Water Heat Recovery	No	Yes
Upgrade Cost **(Payments on Principle and Interest)**	$0	**$6566**
Energy Saved and Generated	0 GJ/year	**46 GJ/year**
Energuide Rating System (ERS)	77	**85**
Yearly Operating Cost Savings **(Savings on Energy Bills – Payments on Principle and Interest)/Year**	$0	**$1264**

Mechanical and HVAC Components

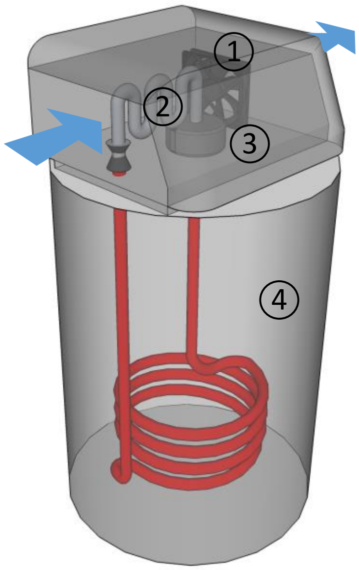


The mechanical and HVAC components can have a large impact on the function and energy efficiency of the house. Careful attention should be paid to design, installation and commissioning of the systems.

The mechanical and HVAC layout and system design will vary between homes. In the cost optimized house, the ductwork has been designed in a similar way to a forced-air furnace system, without the furnace. There are options to return kitchen and bathroom exhaust air to the HRV via dedicated ducting, not shown in this diagram.

1. Electric Baseboard Heaters
2. Heat Recovery Ventilator
3. Supply Ducting
4. Return Ducting
5. Electric Heat Pump Water Heater with Drain Water Heat Recovery Coil
6. Kitchen/Bathroom Exhaust Vents*
7. Wood/Pellet Stove (optional)

* can be returned to HRV via dedicated ducting



Heat Pump Water Heater

The cost optimized house makes use of an air-source heat pump water heater (HPWH). An HPWH is an electrically powered mechanical device that transfers heat energy from indoor air to water. They can operate at a much higher efficiency than gas or electrically powered hot water tanks.

Heat pumps transfer heat by circulating a substance called a refrigerant through a cycle of evaporation and condensation. A fan (1) forces air past the evaporator coil (2) where the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. A compressor (3) pumps the refrigerant to the condenser coil, where it condenses (4) at high pressure. At this point, it releases the heat it absorbed earlier in the cycle.

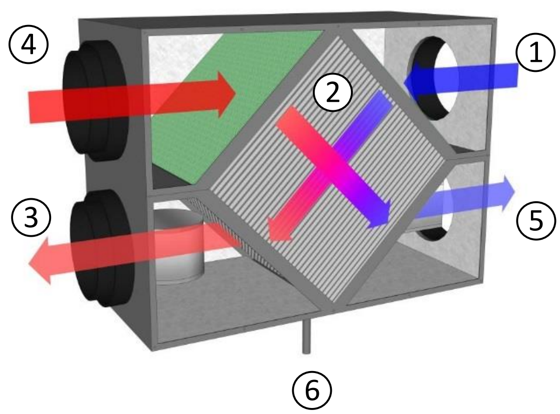
HPWHs should be installed within conditioned or semi-conditioned indoor rooms that do not drop below 5°C. The warmer the surrounding air temperature, the more efficient the heat pump will operate. Additionally, at least 1,000 cubic feet of air space around should be provided around the water heater. Cool exhaust air can be exhausted to the room or outdoors. HPWHs extract heat form the surrounding air and should be combined with other energy efficient HVAC options to ensure that their efficiency is maximized.

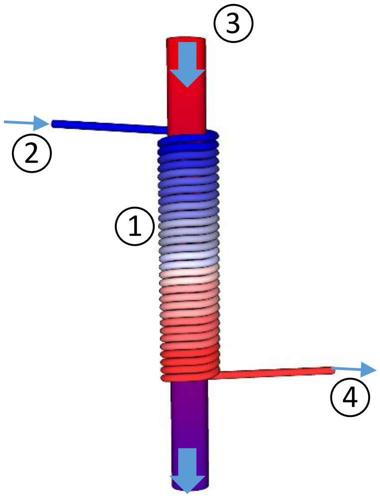
Heat Recovery Ventilator (HRV)

Ventilation systems introduce unconditioned outdoor air and exhaust conditioned indoor air. The cost optimized house saves energy by incorporating heat transfer between the two air streams using a Heat Recovery Ventilator (HRV). This works both during the winter, when warm exhaust air pre-heats the intake air, and during the summer, when cooler exhaust air pre-cools the intake air

The heat transfer core of an HRV is constructed of a series of parallel plates that separate the exhaust and supply air streams. These plates are typically fabricated of metal or plastic.

The two air flow paths are illustrated in the adjacent figure. Outdoor air enters the HRV within an insulated duct (1), passes through the heat exchanger core where it is preheated (2), and is then supplied to the house via a supply fan and a ductwork system (3). A separate duct system and exhaust fan draws return air from the space into the HRV (4), passes it through the heat exchanger transferring air to the supply stream (2), and exhausts it through an insulated duct to the outdoors (5). These processes occur simultaneously, creating a balanced system with equal supply and exhaust airflow. Condensate from the HRV core is plumbed to drain (6).





Drain Water Heat Recovery (DWHR)

Drain water heat recovery (DWHR) makes use of the heat remaining in waste fluids as they drain through the plumbing system to be transferred back to the load for reuse. DWHR is most effective for buildings that have a lot of shower use. The hot water tank is refilling as heated shower water is draining, providing maximum heat transfer to a constant supply of water.

Passive drain water heat works through the installation of a heat recovery coil or power pipe. The coil (1) is typically plumbed into the domestic water supply (2) to the hot water heater and is wrapped around the main domestic water drain pipe. As heated water flows through the drain pipe (3) it transfers heat to the fluid in the coil. The result is a preheated water supply (4) to the domestic hot water tank.

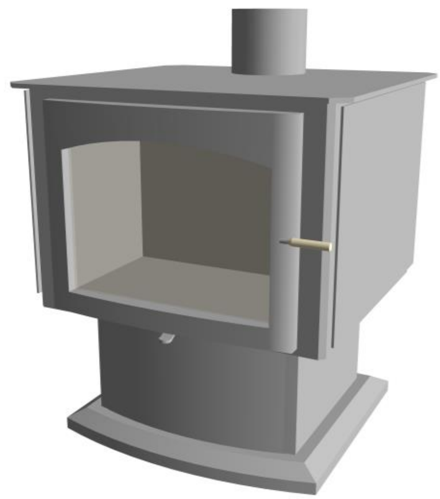
As DWHR units remove some heat from the outgoing sewer this could potentially lead to issues in some municipalities where sewage systems rely on this heat to prevent freezing. Check with your local municipality before integrating this device into the home.

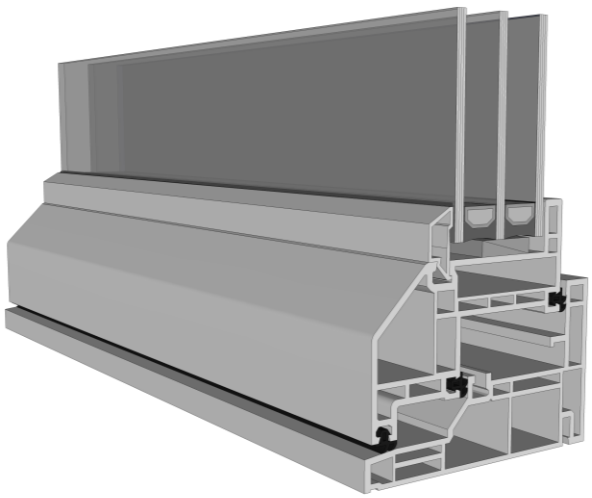
Pellet and Wood Heaters

CSA approved biomass heaters are a potentially cost efficient heating alternative in many locations, including Yukon. More study is required to examine the energy offset and potential cost savings of biomass heaters when integrated into energy efficient homes such as the one shown within this guide.

Biomass heaters are primarily a radiant heat source unless they are used in conjunction with a forced air duct system. Areas closed off from a standalone biomass heater are difficult to heat unless a secondary system, such as electric baseboards, is installed.

Biomass heaters can also be used as a secondary or supplementary heat source. In the case of a CCASHP, when the outdoor temperature is very low (-10°C to -40°C) the efficiency of these heat pumps drops significantly. Using a biomass heater to supplement the heat provided by the heat pump can improve overall energy efficiency and provide a more comfortable interior environment.





Window Specifications for Cost Optimized House	
Glass:	Triple pane (Clear, Clear, Low-E) 3mm individual pane thickness
Low-e coating:	Interior hard coat
Gas fill:	Argon
Solar Heat Gain Coefficient (SHGC):	0.46
U_{SI}-value:	0.987 W/m^2·h
U-value	0.174 Btu/ft^2·h·°F

Window Selection

There are a variety of window options available to the residential builder. Window selection can have a large impact on the functioning of the building as a whole. Important features to consider when selecting an appropriate window type are: orientation, thermal resistance, visible transmittance, solar heat gain and frame design.

The window selected through the optimization process for the cost optimized house is a triple pane, argon filled, low-e hard coat vinyl frame window. Triple pane windows, as the name suggests, feature three panes of glass in the insulating glass unit and offer significantly improved energy efficiency and condensation resistance over dual pane windows. They frequently have additional energy conserving features such one or more low-e coatings, warm edge spacers between the glass panes, and an inert gas fill, most commonly argon. The presence of a low-e coating contributes the approximate energy performance of an additional glass pane, making a triple pane window unit with one low-e coating roughly equivalent to a quad-pane clear glass unit.

Triple pane windows intended for use in cold climates often have thermally improved frames as well, featuring internal insulation or multiple air chambers to improve the energy performance and condensation resistance of the frame portion of the window.

The energy efficiency of windows is measured not only with respect to how well they keep in the heat (indicated by a lower U-value). The Energy Rating (ER), a Canadian measure of window energy performance, evaluates the window’s ability to capture and retain heat from the sun to reduce winter heating energy use. The higher the ER, the more energy efficient the window on a year-round basis.

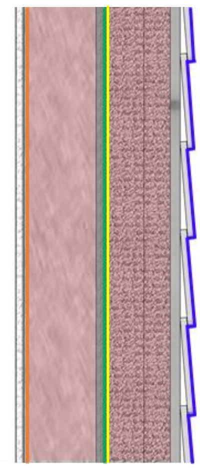
It is important to match the solar heat gain coefficient (SHGC) to the orientation and desired performance characteristics of the window.

Building Science Primer

The building enclosure is a system of assemblies, comprised of various materials and components, which work together to physically separate the exterior and interior environments. The materials and components within the assemblies form critical barriers that function to control: water, air, heat, water vapour, sound, light, and fire.

A critical barrier is a layer within the assembly that is essentially **continuous** in order to perform its **control function**. The critical barriers discussed in this guide are the water shedding surface (**WSS**), the water resistive barrier (**WRB**), the air barrier (**AB**), vapour retarder (**VR**) and **thermal control**. In some cases a material or component will perform multiple functions. As an example, in an above grade wall assembly with an exterior air barrier approach, the sheathing membrane will form the water resistive barrier and the air barrier as will be explained in more detail below.

Cost Optimized House Wall Section Showing the Location of Critical Barriers



WSS- Water Shedding Surface (Cladding)

Thermal Control – (Semi-rigid and batt insulation)

WRB – Weather Resistive Barrier (Sheathing membrane)

AB – Air Barrier (Sheathing membrane)

VR – Vapour Retarder (Polyethylene Sheet)

WSS – The **water shedding surface** is the primary plane of protection against bulk water loads and also known as the *first plane of protection* within the building code. It is commonly the most exterior materials or components of the enclosure (cladding, flashing, etc.)

WRB – The **water resistive barrier** is the secondary plane of protection against bulk water movement and also known as the *second plane of protection* within the building code. It can also be considered the innermost plane that can safely accommodate water, and allow drainage without incurring damage. In residential construction the WRB is usually performed primarily by the sheathing membrane.

AB – The **air barrier** resists the movement of air between the indoor and outdoor environments. The interface detailing between components is essential to the function of the air barrier and the control of air movement. If the barrier is discontinuous, uncontrolled air will be allowed to pass through the assembly resulting in reduced energy efficiency and the potential accumulation of water in the wall assembly due to condensation. In this guide the AB is primarily the taped and sealed sheathing membrane. Careful attention is paid to interfaces between the sheathing membrane and other materials and components to ensure air barrier continuity. The interior polyethylene sheet is also made air-tight for supplemental control.

VR – The **vapour retarder (or vapour barrier)** depending on the materials vapour permeance) is designed to resist the movement of water vapour through the assembly. In cold climates such as the Yukon, the VR must be on the warm side of the insulation to ensure that the bulk of water vapour is retarded before it comes into contact with cold surfaces where it might condense. Most commonly, polyethylene sheet is used as the VR. In many cases, it also forms the air barrier, however, in this guide, the polyethylene sheet is only used as the VR.

Thermal control – Thermal control is usually made up of one or more layers that are as continuous as possible to resist the flow of heat through the building enclosure. Thermal bridging occurs when a material or component allows a disproportionate amount of heat flow through the building enclosure as opposed to the surrounding insulation. An example of a thermal bridge in a conventional wall assembly are the wood studs. An effective way of minimizing this thermal bridging is to add continuous exterior insulation outside the sheathing thereby breaking the heat flow through the studs.

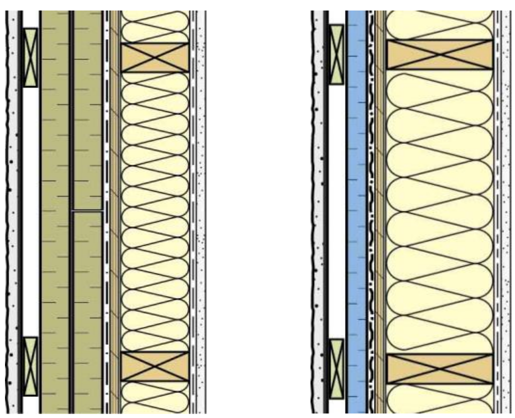
Exterior Insulation Type

A variety of exterior insulation types can potentially be used in split insulated wall assemblies. The insulation can be divided into two categories: 1) vapour permeable insulations such as semi-rigid or rigid mineral wool, or semi-rigid fiberglass, and 2) relatively vapour impermeable insulations such as extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate (polyiso), and closed-cell spray polyurethane foam. While each of these insulation materials can provide adequate thermal resistance, the vapour permeability of the materials is of particular importance with respect to the drying capacity of the wall assembly.

A relatively impermeable foam plastic insulation will not allow for moisture in the wall to dry outwards. If this insulation is installed in conjunction with an interior vapour barrier (i.e. polyethylene sheet) the dual vapour barriers can trap moisture that inadvertently enters the assembly (air leakage, rainwater or built-in) and potentially lead to concealed fungal growth and decay.

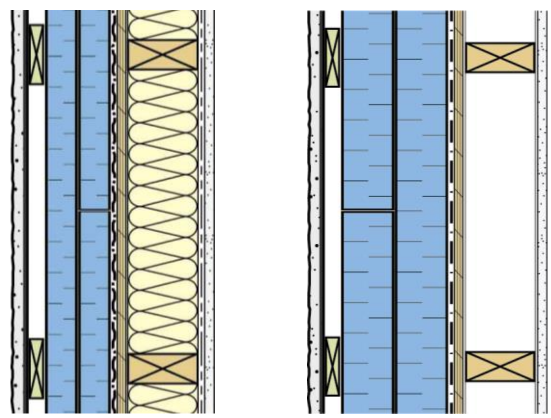
The figures below provide examples of wall assemblies that make use of vapour permeable and vapour impermeable exterior insulation types.

Relatively Permeable Exterior Insulation
(> 60 ng/(s • m^2 • Pa))



When using vapour permeable exterior insulation (defined by code as > 60 ng/(s · m^2 · Pa)) typically does not raise concerns regarding use of an interior vapour retarder. Vapour permeable exterior insulation in combination with an interior vapour barrier provides a lower risk wall assembly than does an assembly using impermeable exterior insulation and is the assembly selected for this guide. If the permeability of the insulation is close to the code specified limit, it is important to also examine how the thickness of the insulation affects its vapour permeance.

Exterior-to-Interior Insulation Ratio for
Impermeable Exterior Insulation



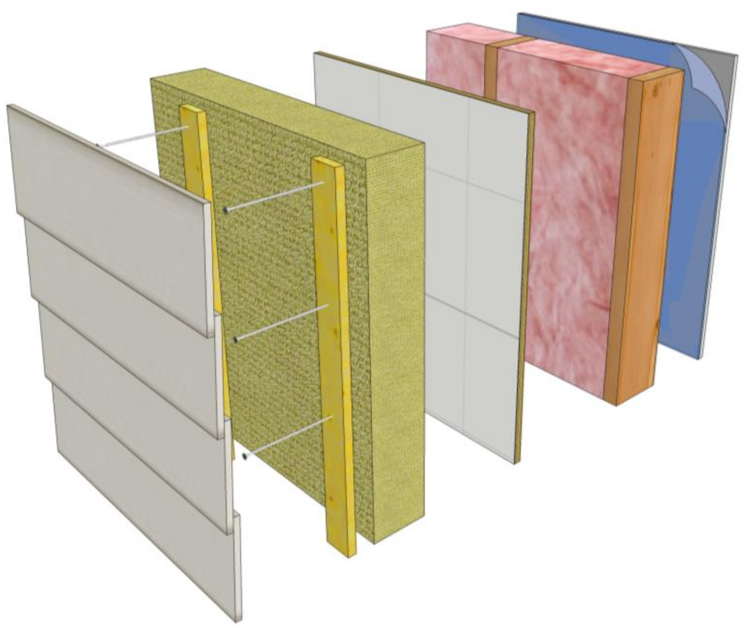
When using vapour impermeable exterior insulation (defined by code as < 60 ng/(s · m^2 · Pa) , the ratio of insulation outboard of the sheathing to insulation in the stud cavity should be carefully considered so as to maintain the temperature of the sheathing at relatively safe levels and avoid condensation. Also, a thin drainage layer such as crinkled or textured housewrap can be installed on the exterior of the sheathing membrane to facilitate drainage of any water which may penetrate behind the insulation, and a relatively more permeable interior vapour barrier (such as vapour retarder paint or smart vapour retarder) could be used to permit some amount of inward drying.

Cladding Attachment

The addition of exterior insulation to traditional wood-framed wall assemblies may be new for some builders with respect to cladding attachment and detailing. In a conventional wood-framed wall assembly, cladding is attached either directly to the sheathing or over vertical strapping fastened directly to the stud wall and wood sheathing. The addition of exterior insulation increases the distance between the sheathing and the cladding, thus changing the loading which must be supported.

There are various approaches which can be used to support the cladding, and the selection of a method often depends largely on familiarity with different systems, but also on the structural loads which must be accommodated. The amount of thermal bridging (i.e. reduction in effectiveness of the exterior insulation) associated with each of these methods varies, and is also an important consideration. In all cases, it is important that other aspects of assembly design including the provision of drainage be considered.

In most cladding attachment approaches, a ventilated and drained rainscreen cavity will be incorporated into the design to assist in bulk water management and facilitate outward drying.



EXTERIOR

- Cladding
- 1X4 Wood furring fastened through insulation with 8" long fasteners
- 5" Rigid mineral wool insulation (2 layers)
- Synthetic sheathing membrane (AB/WRB)
- ½" Plywood sheathing.
- 2X6 Stud wall with fiberglass batt insulation
- Polyethylene sheet (vapour barrier)
- Gypsum drywall & Paint

INTERIOR

Cladding Attachment Alternatives

Fasteners through Insulation:

Cladding can be attached and supported by vertical strapping (i.e. furring) which is fastened with long screws through the exterior insulation and in to the framed wall as depicted in this guide. This is the most thermally efficient mechanically fastened cladding support option as thermal bridging of the exterior insulation is limited to the fasteners through the insulation. The strapping also creates a drainage space, capillary break, and ventilation cavity (i.e. rainscreen cavity) which is consistent with effective moisture-management techniques. To support the cladding, the fasteners and the strapping on the rigid exterior insulation form a structural truss system. Additionally, friction between the insulation and the sheathed wall—created by the force applied by tension on the fasteners when installed into the sheathing or studs—provides additional support in the service load state. Extruded polystyrene (XPS), expanded polystyrene (EPS), polyisocyanurate, and rigid mineral fibre insulations (typically > 8 lbs/ft^3) are suitable for this attachment method.

This cladding attachment method with rigid mineral fibre insulation is the approach shown within this guide, though other options could be considered.

Proprietary Thermally Efficient Spacers and Clips:

Proprietary thermally efficient spacer and clip systems can be used to facilitate installation and/or to support heavier claddings or resist larger wind loads. Low conductivity materials such as fiberglass and stainless steel can provide excellent thermal efficiency. These spacer and clips systems provide the additional benefit of facilitating the use of semi-rigid, or spray-in-place (rather than rigid) insulation.

Continuous Strapping or Wood Spacers:

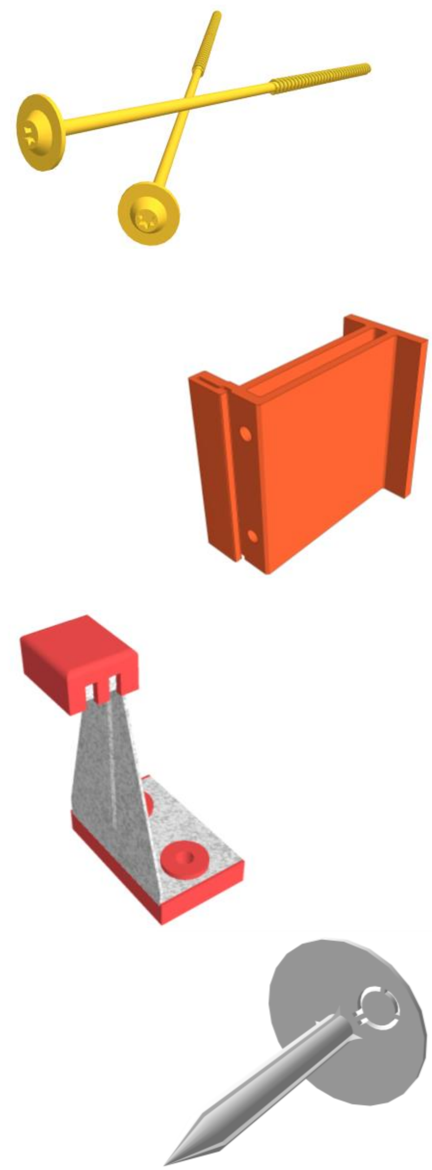
Cladding can also be supported using continuous wood strapping which penetrates the exterior insulation, or alternatively by standard strapping installed over wood spacers. Continuous strapping and wood spacers can also provide the additional benefit of facilitating the use of semi-rigid insulation, rather than rigid. Continuous strapping is not as thermally efficient as other options, due to thermal bridging.

Structural Adhesives:

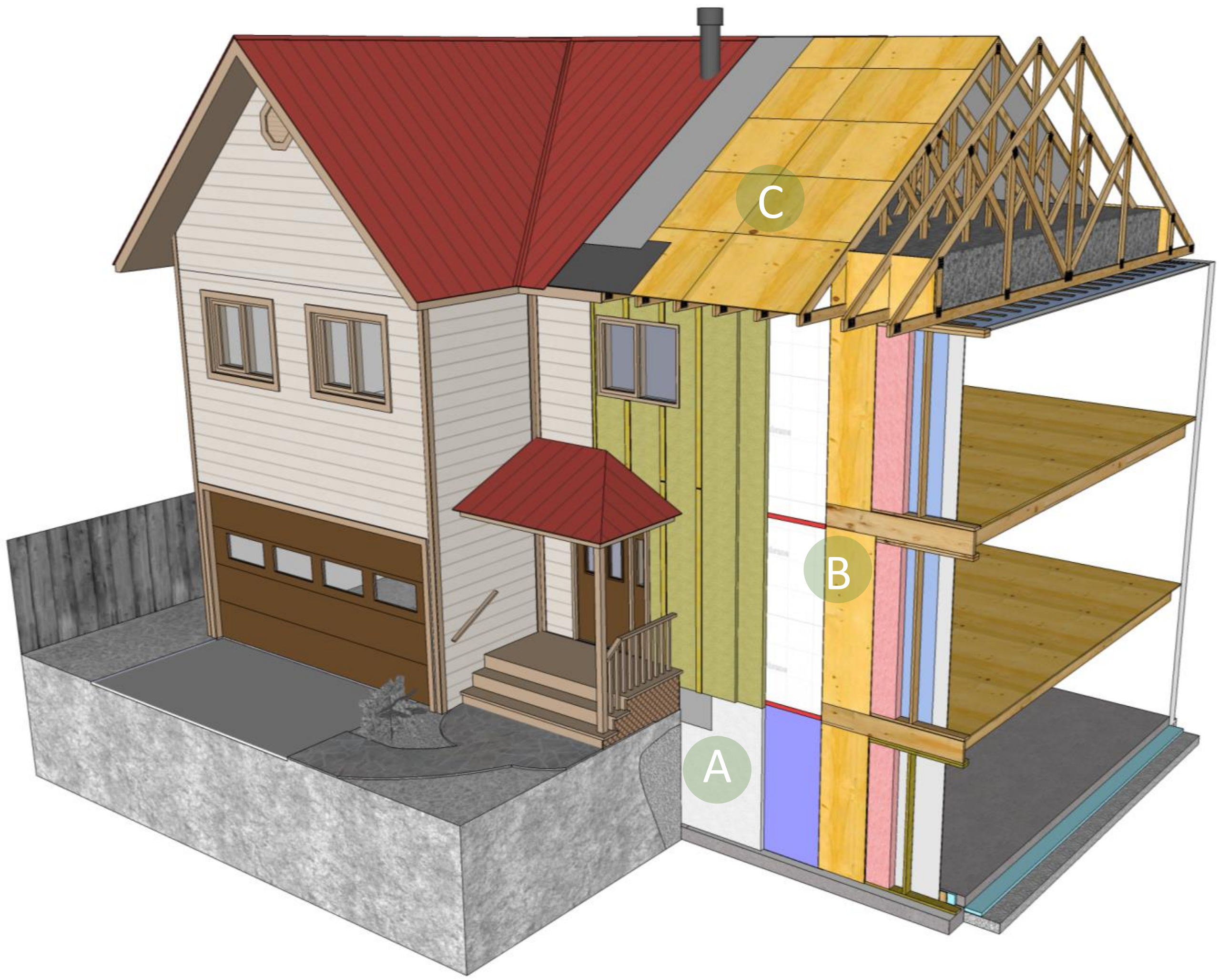
In some applications, such as the below grade assembly presented in this guide, structural adhesives can be used to attach the exterior insulation. An advantage of this system is that no structural elements penetrate the assembly, reducing thermal bridging and the risk of water penetration through the WRB. EIFS is a common example in an above grade application.

Examples of Some Thermally Efficient Cladding Attachment Systems

(screws, fiberglass clips, low-conductivity metal/plastic clips, plastic insulation fasteners)



Building Enclosure Assemblies



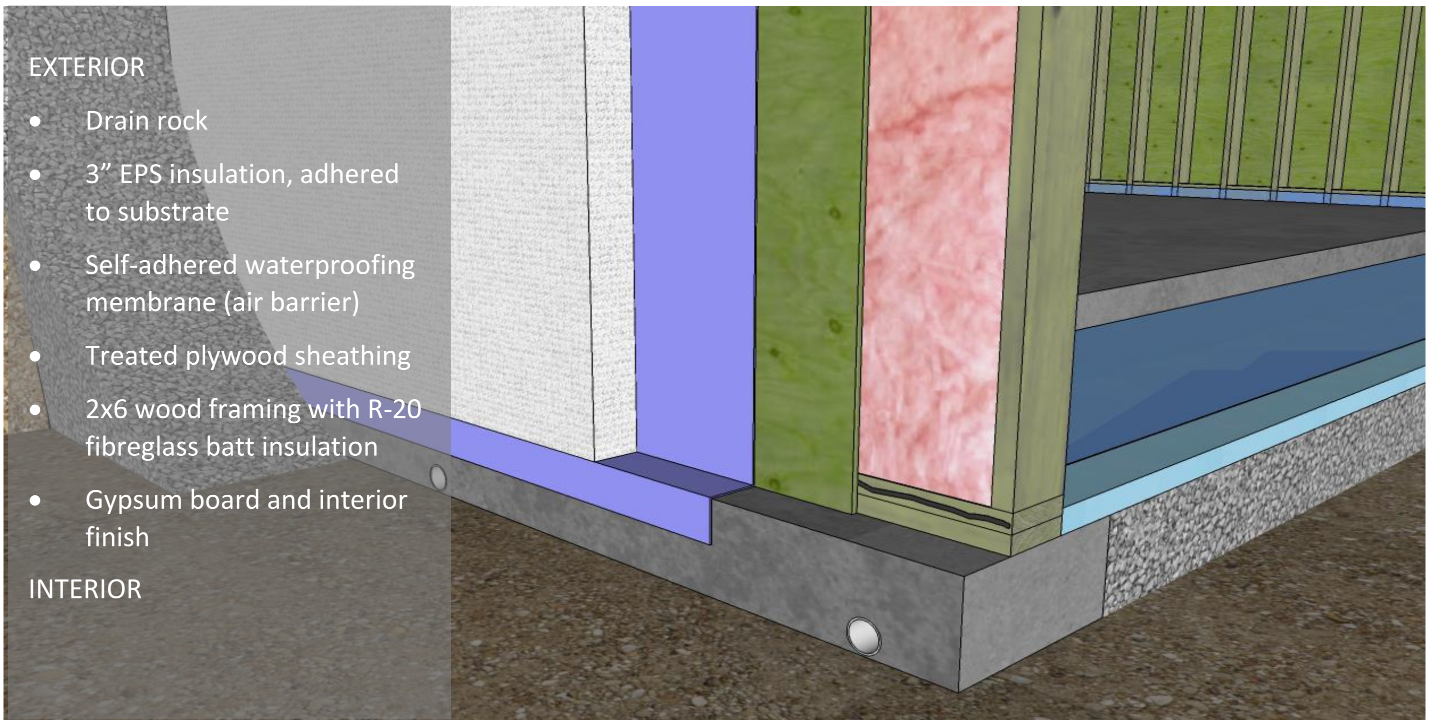
The enclosure assemblies for the cost optimized house are presented in this section. Each assembly is shown in 3D cutaway format with assembly layers clearly marked. Each assembly also has an accompanying description and discussion of how to construct the assembly and some key considerations.

Assembly A	Below Grade Wall
Assembly B	Above Grade Wall
Assembly C	Roof

Assembly A - Below Grade Wall Assembly (R-28 effective)

The below grade wall assembly is comprised of a Preservative Treated or Permanent Wood Foundation (PWF). PWFs work well in cold, dry climates like Yukon and can be an energy and cost efficient alternative to concrete foundation/basement walls. Careful attention must be paid to both air and water management of the wall assembly as there is not the same built in tolerance for moisture penetration and accumulation as there is with concrete.

A PWF is most often constructed with a concrete footing in Yukon. In some cases a 2X10 treated footing plate can be used. In this case, it is important to tamp the drain rock and ensure it is level prior to laying the foundation plate. All wood in the PWF must be pressure treated to resist moisture and decay. A waterproofing membrane is applied outboard of the sheathing to further protect the wood foundation from moisture.



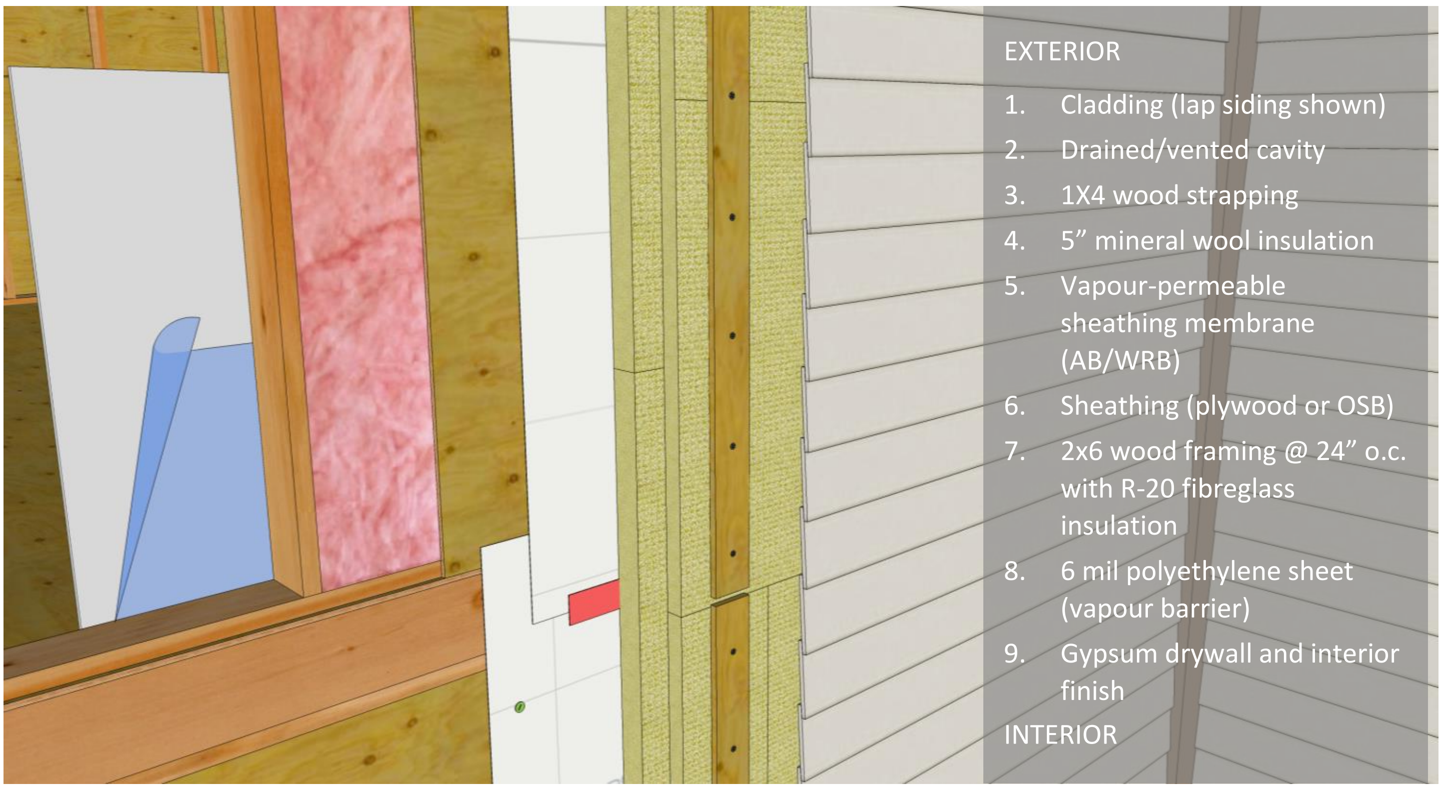
Key Considerations:

- The air barrier transfers from the self-adhered waterproofing membrane through the upper bottom plate to the polyethylene under the slab. It is important that sealant is installed on both sides of the upper bottom plate to maintain air barrier continuity.
- The vapour control layer is the self-adhered waterproofing membrane applied to the exterior of the building. It is not recommended to install a polyethylene sheet on the interior of the framing due to the creation of a double vapour barrier and the inability for incipient moisture to dry from the wood framing. The wall assembly without an interior vapour retarder will not meet code requirements and may require an engineer sign-off. The use of a type II vapour retarder <60 ng/Pa-s-m^2 (<1 Perm), such as vapour retarder paint or a smart vapour retarder, will facilitate some drying and comply with code.
- Review **CAN CSA S406-14** for more information on the construction and design of PWFs.

Assembly B - Above Grade Wall Assembly (R-38 effective)

The split-insulation wall assembly consists of rigid or semi-rigid insulation installed on the exterior of an above-grade, conventional 2x6 insulated wood-frame wall. In some areas, this wall may also be referred to as an exteriorly insulated wall assembly, or a wall with insulated sheathing. Rigid mineral wool insulation is installed on the exterior side of the sheathing membrane, attached with vertical strapping, which provides a cladding attachment surface and drained/ventilated cavity behind the cladding. Rigid mineral wool (≥8 pcf density) has been chosen for this wall for the previously discussed reasons of vapour permeability, rigidity, availability, and cost.

A significant advantage of the split-insulation wall assembly is high effective R-values due to the continuous insulation outside of the structural framing, thereby minimizing thermal bridging. For this reason the continuous exterior insulation provides more effective R-value for the thickness installed than conventional stud cavity insulation. In addition, the interior wood elements of the assembly are kept warmer as a result of the exterior layer of insulation thereby reducing the risk for condensation in these moisture-sensitive layers.



Key Considerations:

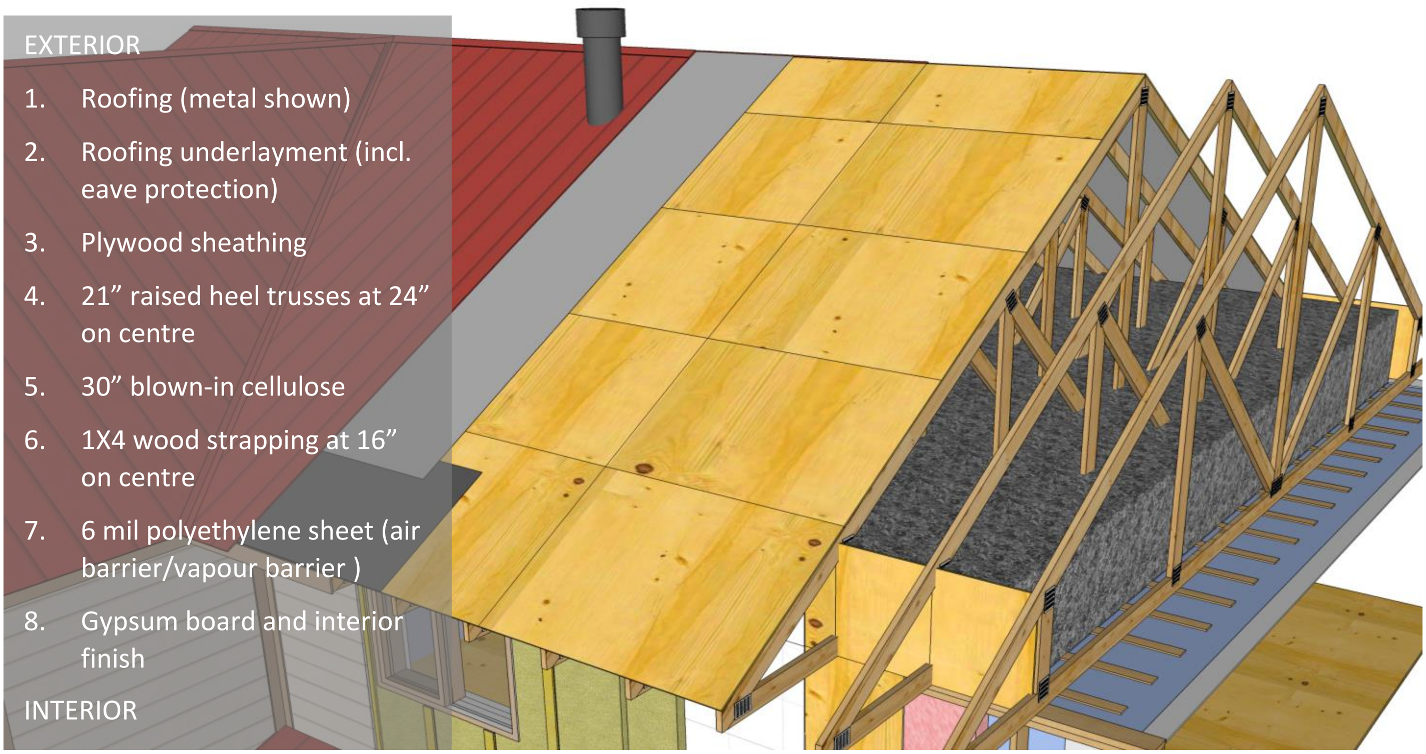
- The primary air barrier component in this wall design is the exterior sheathing membrane. All laps should be taped and sealed in order to maintain air barrier continuity.
- All exterior mineral wool insulation should be installed in a staggered pattern without gaps and should be tight against the wall. Void spaces will transfer heat more quickly and reduce the efficiency of the insulation.
- Cladding and trim is attached to vertical strapping with standard fasteners.

Assembly C - Roof Assembly (R-110 effective)

The roof assembly consists of a 21" raised heel truss with 30" of 1.6 psf (pounds per square foot) blown-in cellulose. The effective R-value of such a roof assembly, including lower R/inch due to compressive weight of the insulation, is R-110. Attic ventilation can be provided through the soffit via insulation baffles, gable end vents, ridge vents or button vents carefully designed to minimize snow and water intrusion. The NBC requires 1:300 ratio for venting for attic spaces (1 ft^2 of vent area per 300 ft^2 of roof footprint area).

A particular consideration for a highly insulated roof is providing support for the additional weight of the insulation. Interior gypsum (1/2") is not typically rated to support more than 2.2 psf of insulation weight. The weight of 30 inches of cellulose, including additional material due to compressive losses, is over 5 psf. Additional 1x4 strapping at 16" on centre can be fastened to the underside of the trusses to help support the insulation and stiffen the ceiling. The polyethylene air barrier and vapour retarder should be installed and taped/sealed continuously to the underside of the 1X4 strapping.

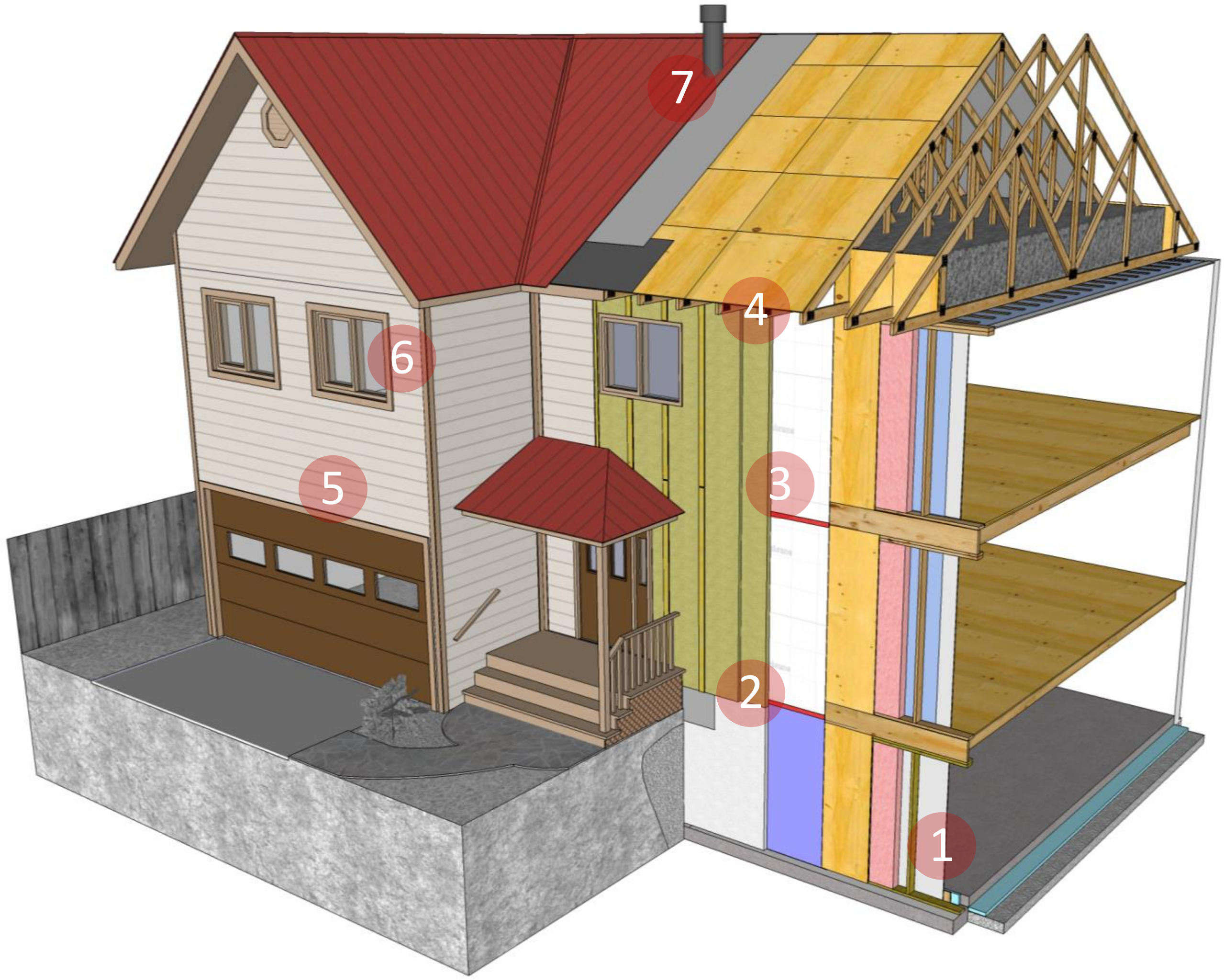
Careful attention should also be paid to construction of the attic hatch framing to ensure ease of access as the depth of insulation may make it difficult to raise and lower the hatch.



Key Considerations:

- The gypsum drywall or other ceiling material should be installed prior to the attic insulation. The weight of the insulation can cause the polyethylene to tear out. The drywall tape and mudding should be performed after the insulation has been installed as the weight/movement in the attic while installing the insulation may crack finished drywall joints.
- The use of 5/8" gypsum drywall is recommended instead of 1/2" to reduce potential for bowing and cracking of drywall joints.

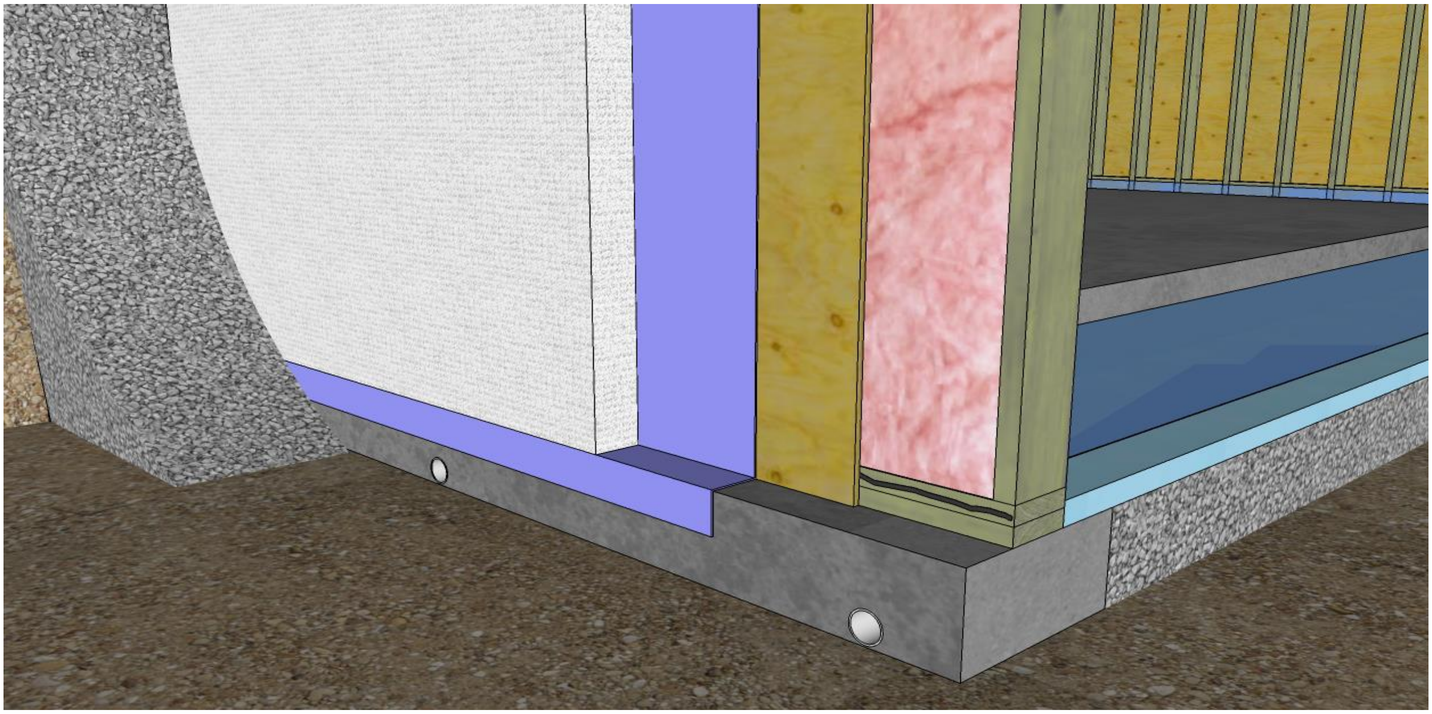
Selected Building Enclosure Details

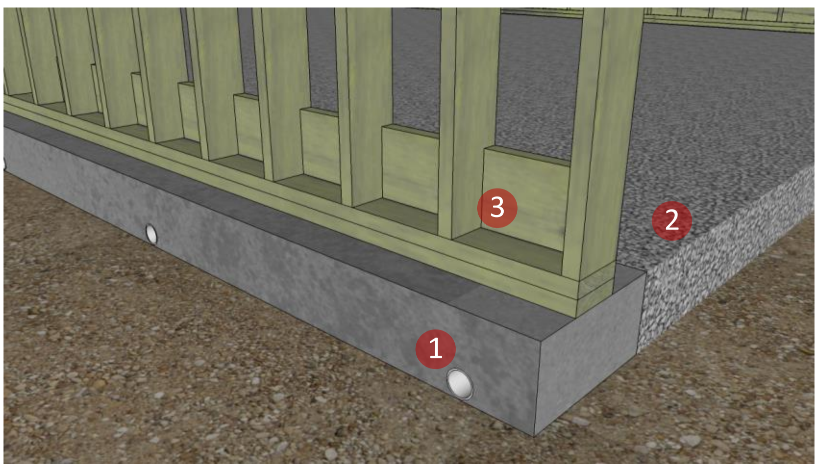


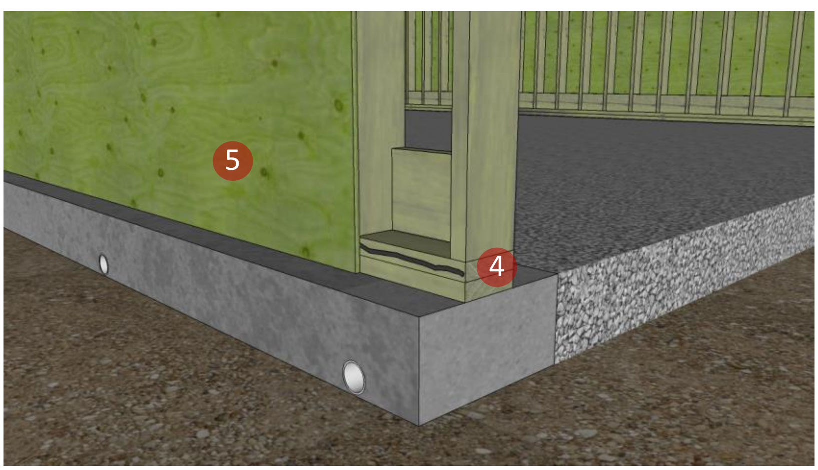
The building enclosure details in this section are important for efficient performance of the cost optimized house. The construction of each detail is explained step-by-step with 3D illustrations in the following section.

Detail 1	Foundation Wall at Footing
Detail 2	Foundation Wall to Above Grade Wall
Detail 3	Rim Joist
Detail 4	Above Grade Wall to Sloped Roof
Detail 5	Exposed Floor
Detail 6	Window (Jamb, Head, Sill)
Detail 7	Chimney Flue

SLAB TO BELOW GRADE WALL







Exterior Steps:

1. Install concrete footing on undisturbed soil with drainage through the footing.
2. Install drain rock capillary break under the basement slab location. Tamp and screed to ensure compaction and levelness.
3. Install treated (CSA 0322) 2x6 stud wall at 12" on centre. Provide two sill plates to allow for air barrier transition later. Install 2X8 blocking between studs flush with the interior side of the stud to provide support for the slab pour and to catch the interior drywall.
4. Install sealant bead at upper sill plate. The air barrier will transition through the top plate to the polyethylene sheet under the slab.
5. Install sheathing.

Key Considerations:

- Review **CAN CSA S406-14** Standard for more information

Exterior steps continued:

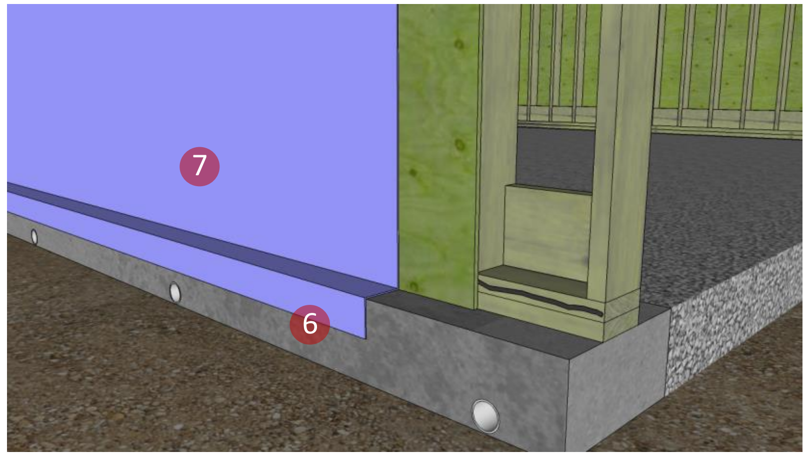
6. Install self-adhered water proofing membrane over primed substrate per manufacturer's recommendations.
7. Install 4" of EPS with spot adhesive to the exterior of the wall.

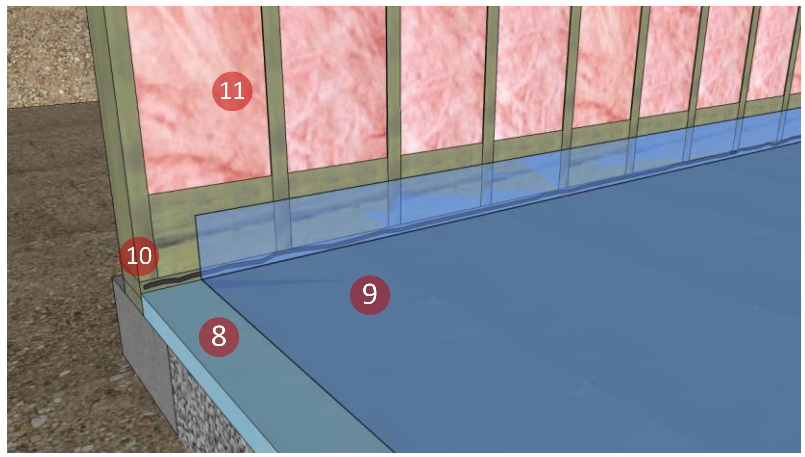
Interior steps:

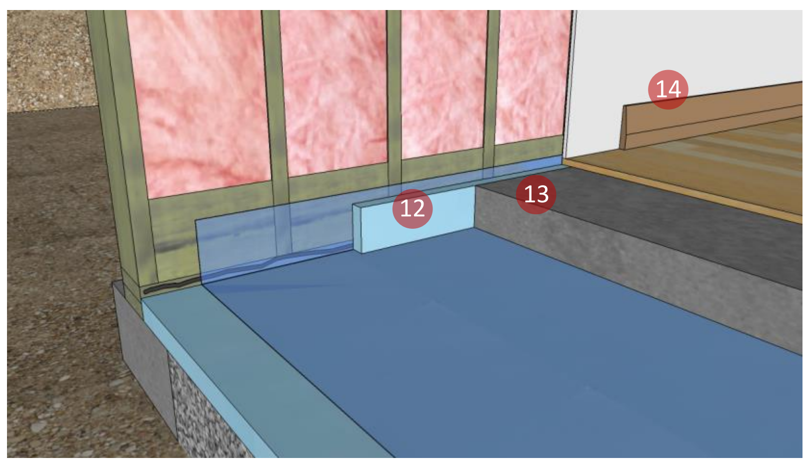
8. Install 2" XPS below slab. Ensure the insulation is continuous without gaps and fully supported by the drain rock.
9. Install polyethylene over the XPS insulation, sealing all laps with sheathing tape to maintain air barrier continuity.
10. Press into bead of sealant at upper sill plate to maintain air barrier continuity.
11. Install fibreglass batt insulation.
12. Install 2" thick XPS insulation to the height of the slab to reduce thermal bridging and to take up differential movement between the slab and below grade wall.
13. Place reinforcing and pour concrete slab.
14. Install gypsum drywall and interior finishes.

Key Considerations:

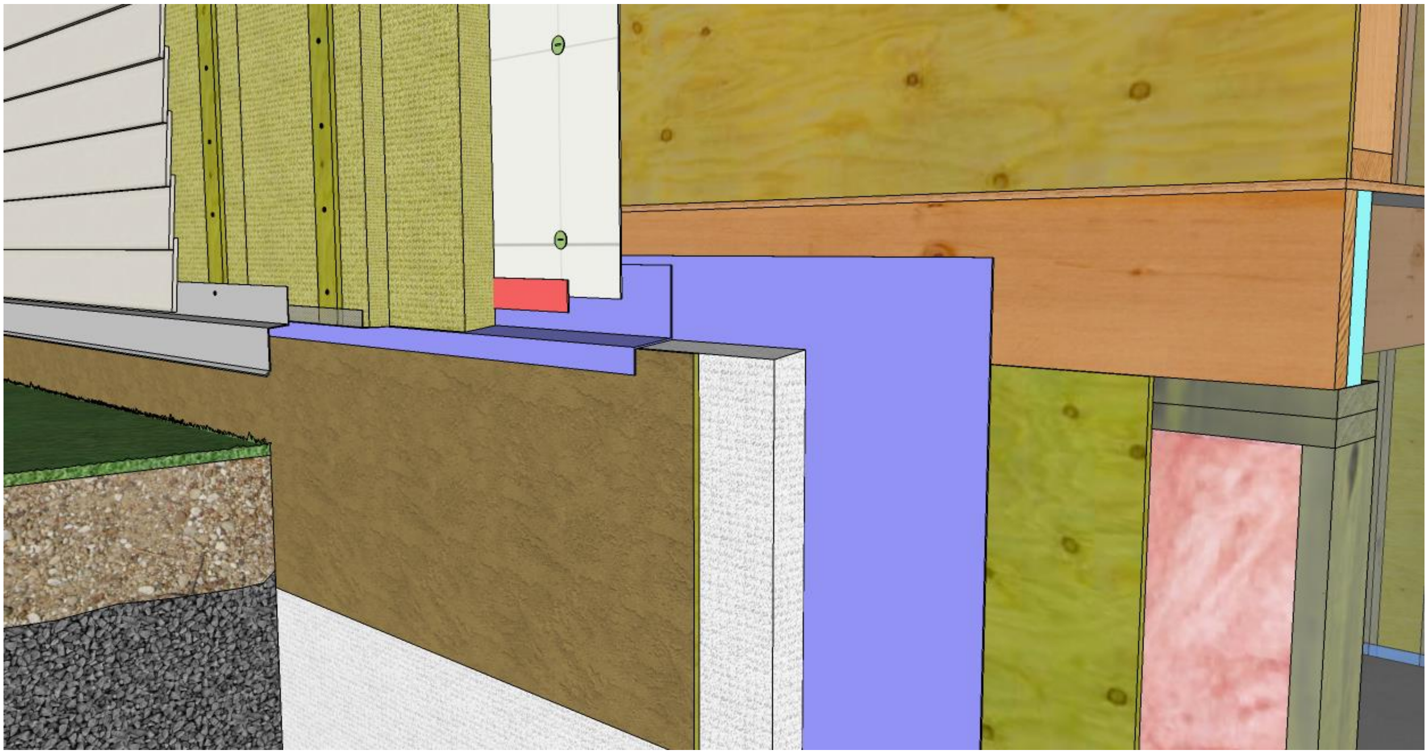
- The air barrier transitions from the slab poly through the sill plate to the self-adhered membrane on the exterior of the wall. Ensure sealant is applied to both sides of the sill plate.
- **Do not backfill** until the slab and floor above have been constructed. The slab and floor are necessary to provide lateral resistance to the wall against the pressure of the backfill.
- The vapour control layer on the exterior makes it inadvisable to install a vapour retarder on the interior side of the wall assembly. This, however, does not meet code and requires and engineer to sign-off on the assembly.

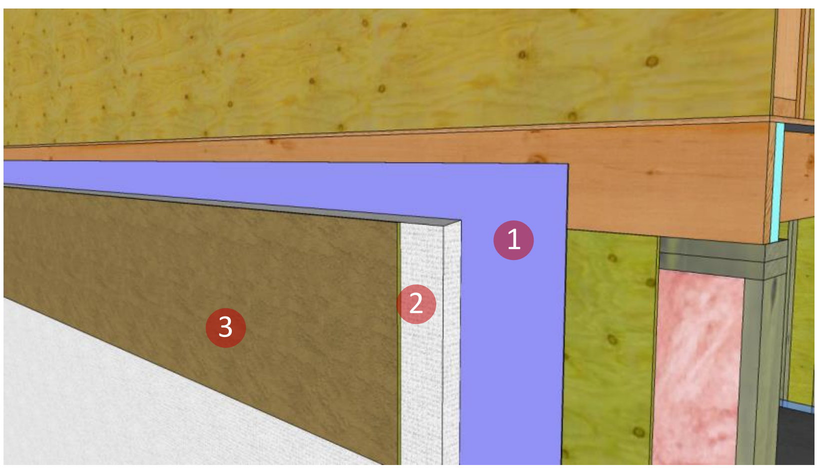


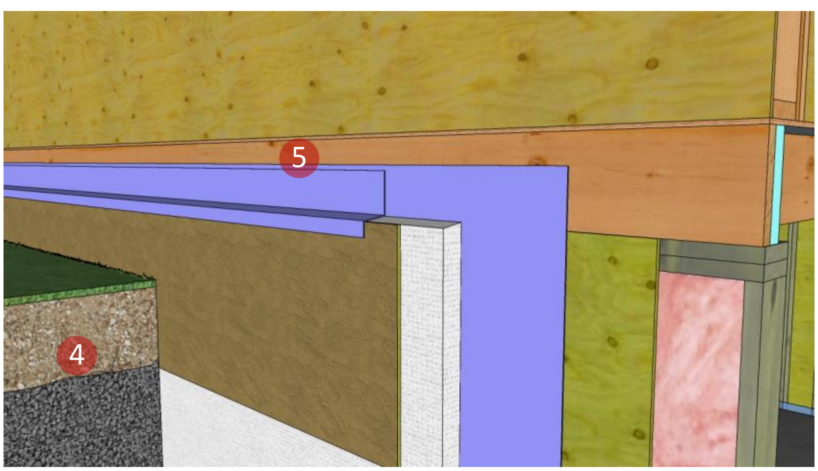




BELOW GRADE WALL TO ABOVE GRADE WALL







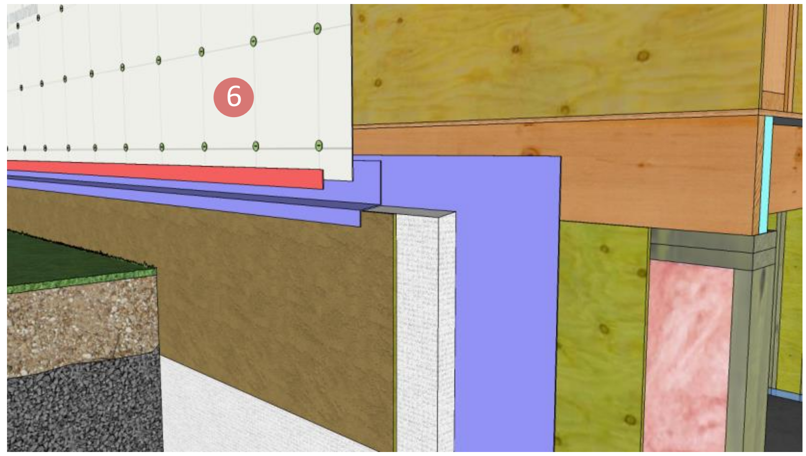
Below Grade Wall Steps:

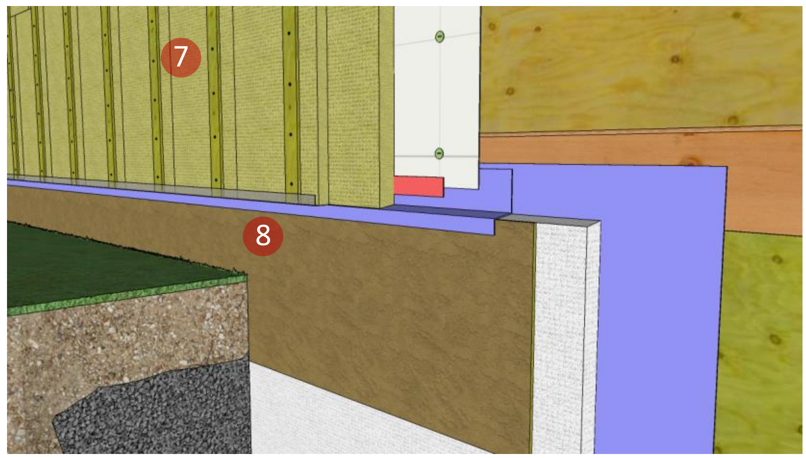
1. Install self-adhered membrane on below grade sheathing and extend a minimum 5" above rim joist.
2. Install 3" EPS insulation with spot adhesive and protection board to the exterior of the below grade wall and extend to the bottom plate of the above grade wall. Taper the top of the insulation at a 1:6 slope away from the wall.
3. Install protection board to extend min. 6" below grade.
4. Backfill against foundation. Provide a minimum 5% slope away from the building for the first 10 feet.
5. Install strip of self-adhered membrane extending from the above grade wall (min. 4") over the insulation and finishing on the protection board (min. 2").

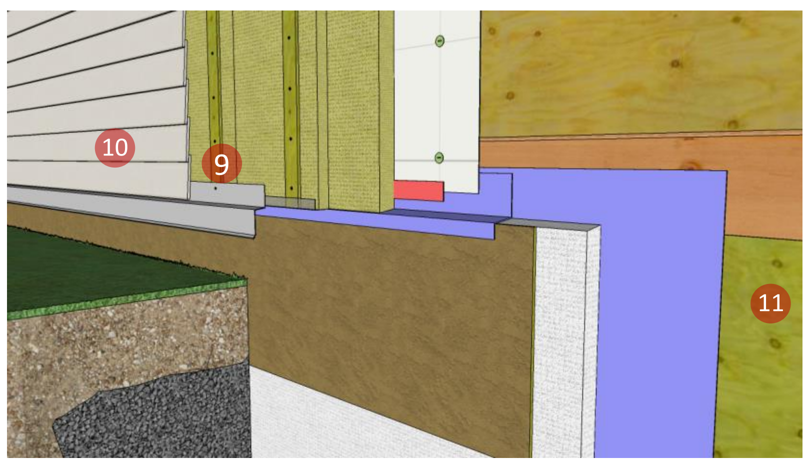
Above Grade Wall Steps:

6. Install sheathing membrane and seal leading edge to the self-adhered membrane with sheathing tape.
7. Install 5” of mineral wool in two layers (3” first and 2” second) ensuring that insulation is continuous without gaps and tight to the wall. Stagger joints in the insulation to improve thermal continuity. Secure with 1X4 strapping.

   **Taper the bottom of the mineral wool to match the slope of the EPS insulation below and fit tightly ensuring there are no gaps.*
8. Install bugscreen at the top and bottom of strapping. Ensure the bugscreen extends through the depth of the insulation.
9. Install prefinished metal flashing to the bottom of the strapping. The flashing aids in water diversion. Ensure it has a minimum 1:6 slope on the kickout leg.
10. Install cladding, leaving a ¾” gap (vision line) between the bottom of the cladding and the flashing kickout to aid in drainage.
11. Install XPS insulation at the interior of the rim joist and seal the perimeter. Refer to the Rim Joist detail in this guide for more information.



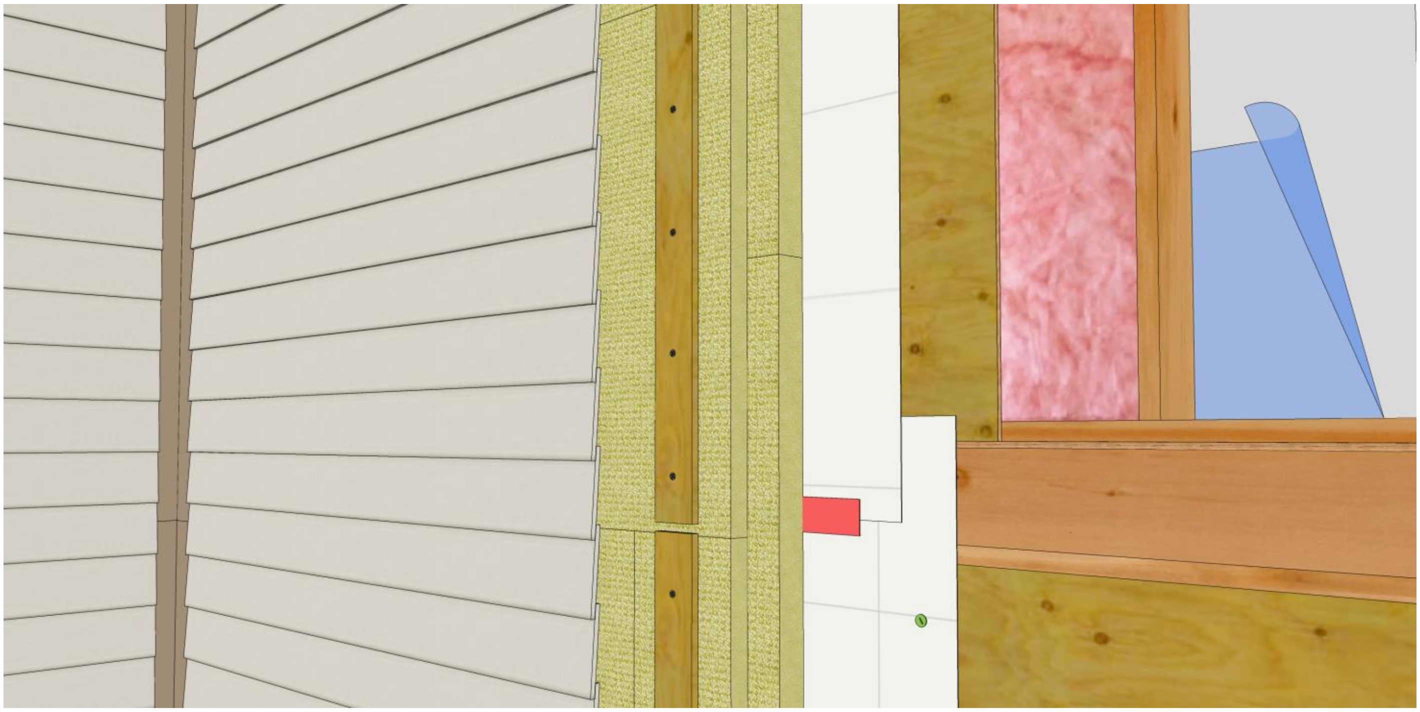


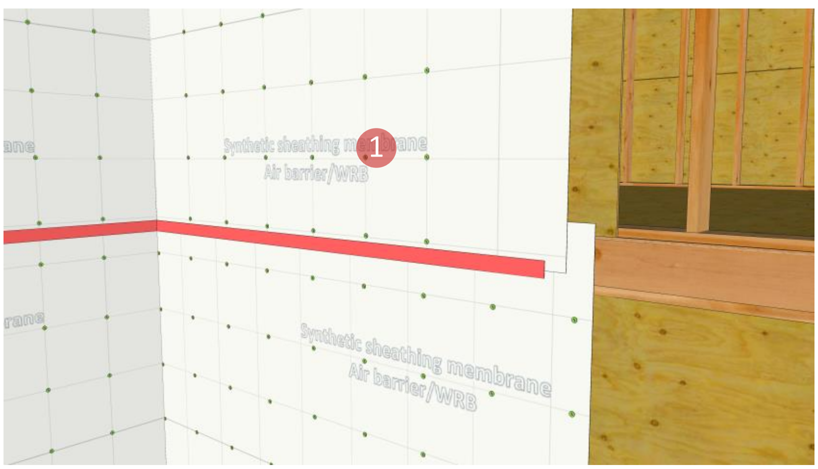


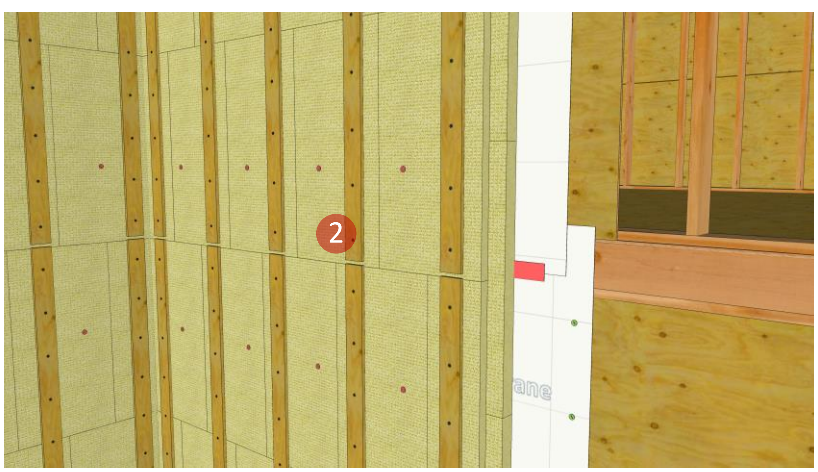
Key Items to Consider:

- Surrounding grade should have a clay cap and be sloped away from the building to aid in surface water drainage. Drain rock should be deposited under the clay cap and adjacent to the PWF wall to allow drainage and prevent hydrostatic pressure buildup.
- Protect all inside and outside corners of the below grade wall insulation with appropriate cover material.
- Review **CAN CSA S406-14** Specification of Permanent Wood Foundations for Housing and Small Buildings for more information.

RIM JOIST







Exterior Steps:

1. Install sheathing membrane. Ensure membrane layers are positively lapped. Seal the leading edge of the sheathing membrane with sheathing tape to maintain air barrier continuity.
2. Install 5" of rigid exterior mineral wool in two layers (3" first and 2" second). Secure with 1X4 strapping. Provide additional strapping at outside and inside corners to support corner trim and cladding material.

Key Considerations:

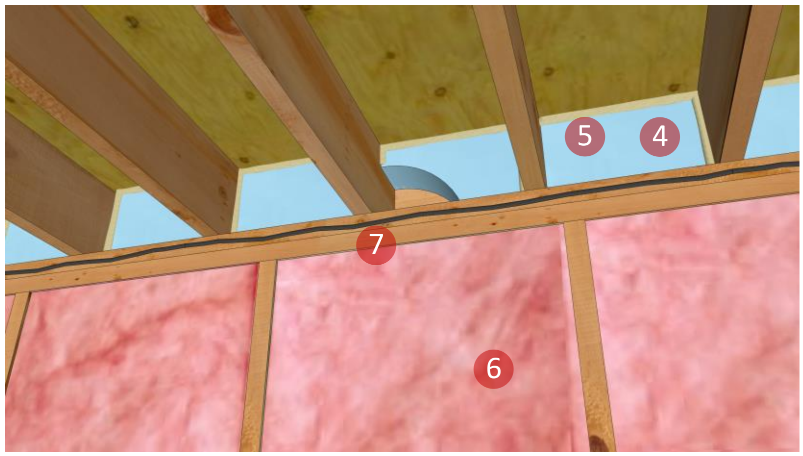
- The sheathing membrane forms the air barrier and must be continuous. All laps should be sealed with sheathing tape.
- The exterior insulation should be continuous without gaps and tight to the sheathing.
- Strapping should be installed in line with the wall studs to provide maximum support and pull out resistance.

Exterior Steps Continued:

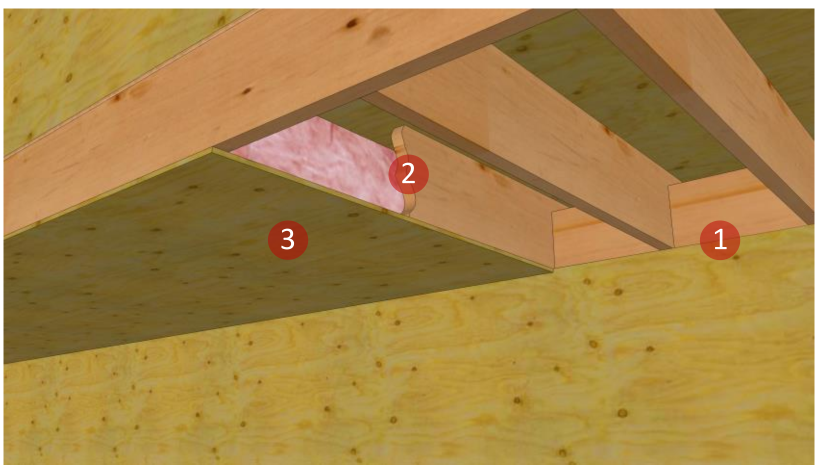
3. Install cladding and trim.

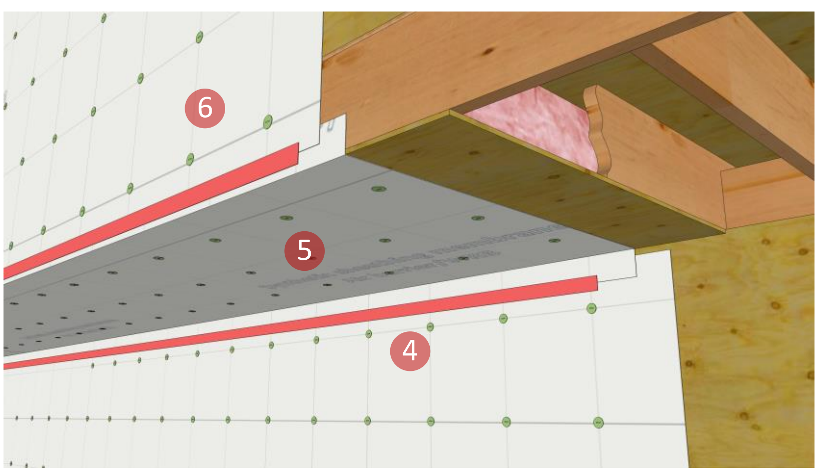
Interior Steps:

4. Install rigid foam insulation in the interior rafter cavities.
5. Use spray foam around the edge of the rigid foam insulation to provide for air tightness and improved thermal performance.
6. Install R-20 fibreglass batt in the interior stud cavities.
7. Install sealant bead along wall top plate.
8. Install polyethylene sheet (vapour retarder) and press into sealant bead to ensure good bond. Fasten with staples.
9. Install gypsum drywall and interior finishes.



EXPOSED FLOOR





Steps:

1. Install blocking between joists. Leave blocking short so that there is a 2" minimum air space between the top of the blocking and the plywood subfloor above.
2. Install fibreglass batt insulation in the floor joist cavity. Ensure a minimum 2" gap is left between the top of the insulation and the plywood subfloor above.
3. Install sheathing at the underside of the exposed floor.
4. Install sheathing membrane, terminating on the vertical of the wall below the exposed floor.
5. Install sheathing membrane to the underside of the floor and terminate lower leading edge with sheathing tape for air barrier continuity.
6. Install sheathing membrane on wall above floor and terminate onto membrane below with sheathing tape for air barrier continuity.

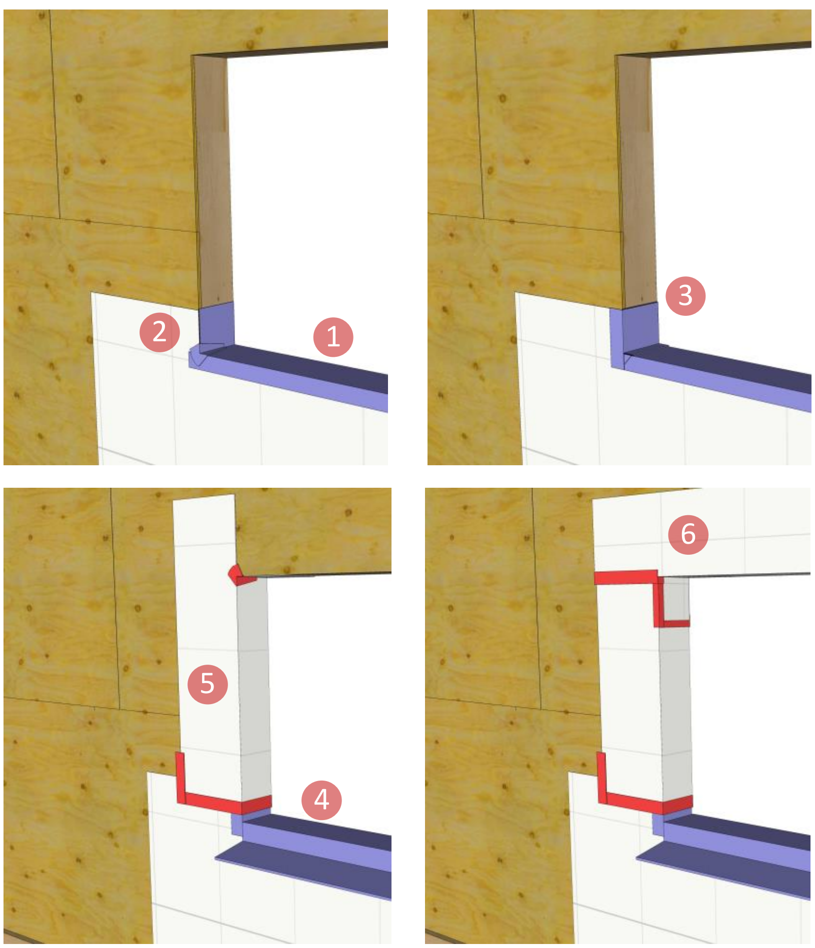
Steps:

7. Install 5” of mineral wool insulation in two layers (3” first and 2” second). Ensure there are no gaps in the insulation and that it is tight to the wall. Stagger vertical joints to improve thermal continuity. Secure with 1X4 strapping.
8. Install bugscreen between planes of strapping.
9. Install flashing to the bottom of the strapping on the wall above the floor. Provide a minimum 1:6 slope.
10. Install cladding and soffit material. Allow a gap to ensure the wall above does not drain into the soffit.

Key Considerations:

- A key feature of an exposed floor in a cold climate is allowing indoor air to circulate to the underside of the subfloor. This will keep the floor warmer. Allowing a 2” gap between the blocking/insulation and the subfloor provides the plenum space to ensure occupant comfort.
- Air barrier continuity occurs at the outside of the wall to allow for the air gap under the sub-floor.

WINDOW (HEAD, JAMB, SILL)



Steps:

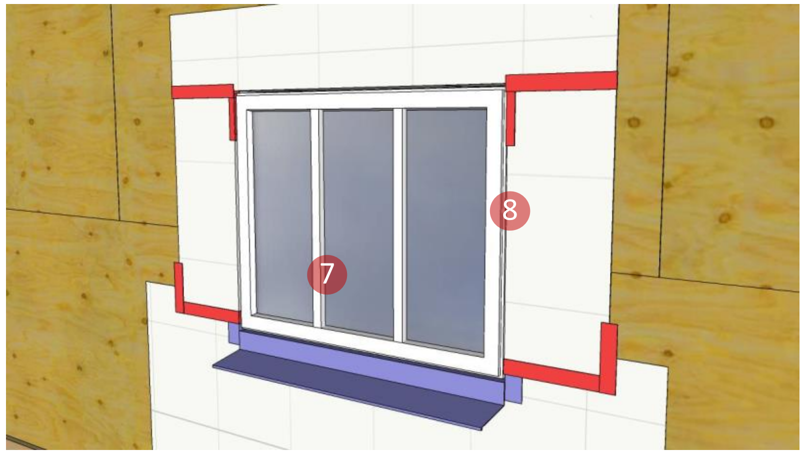
1. Install self-adhered sill membrane. Extend membrane up the jambs and onto the face of the wall.
2. Install self-adhered membrane gussets at lower corners.
3. Install self-adhered membrane at sill corners, extending up the jamb to the height of the sheathing membrane. Finish the self-adhered membrane 2” onto the face of the wall.
4. Install self-adhered subsidiary membrane at the window sill to span over the exterior insulation. Leave the backer on the unsupported portion of membrane until after installation of exterior insulation.
5. Install sheathing membrane pre-strips at the jambs and extend onto face of wall a minimum of 8”. Seal the leading edges with sheathing tape.
6. Install sheathing membrane at the head of the rough opening, extending a minimum of 12” up the face of the wall. Seal the leading edges with sheathing tape.

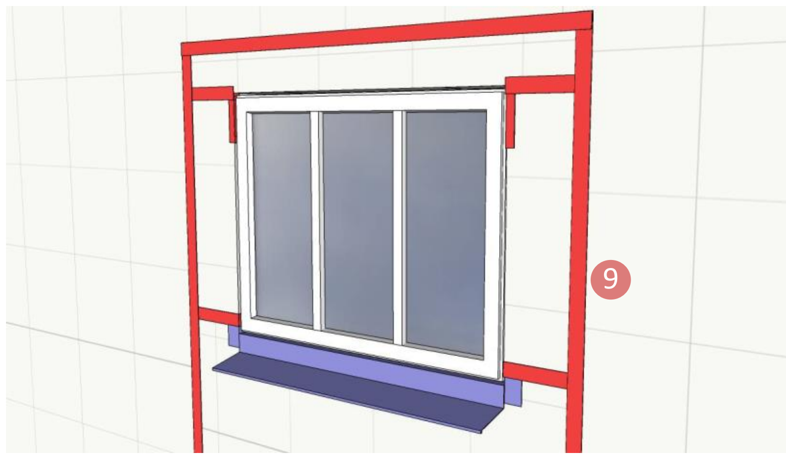
Steps:

7. Install and structurally attach window per manufacturer's specifications.
8. Install backer rod and sealant around the interior perimeter of the head, jamb, and sill of the window.
9. Install sheathing membrane at the field of the wall. Ensure positive laps over all other layers. Seal the leading edge with sheathing tape.
10. Install two layers of mineral wool insulation (3" first, 2" second), ensuring that insulation is continuous without gaps and tight to the wall. Stagger joints to improve thermal continuity. Secure with 1X4 strapping. Provide bugscreen at the top and bottom of the strapping. Lap the subsidiary membrane over the top edge of the exterior insulation.

Key Considerations:

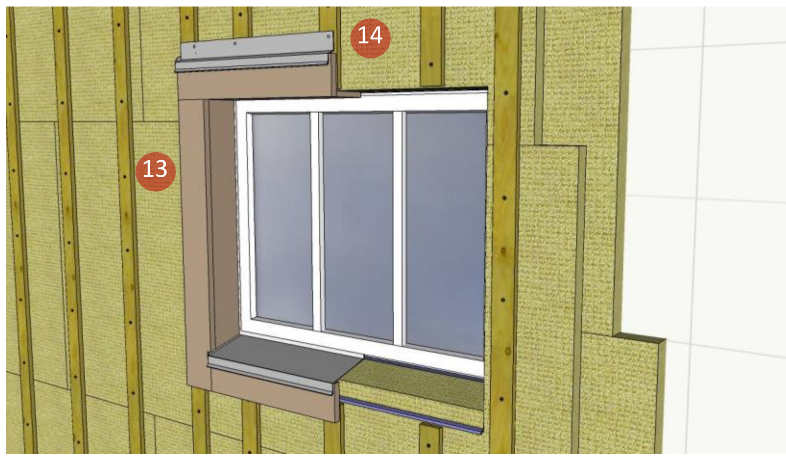
- Ensure all sealant joints are continuous, and installed over backer rod.
- The sheathing membrane is the primary air barrier material and all laps must be sealed with sheathing tape.



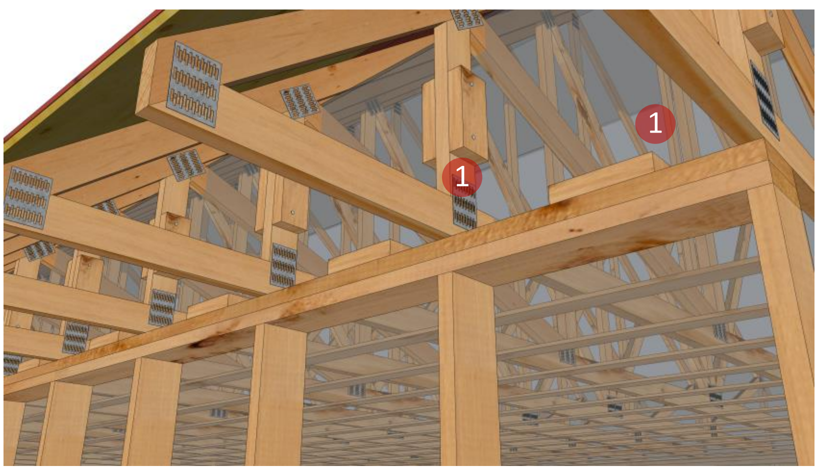


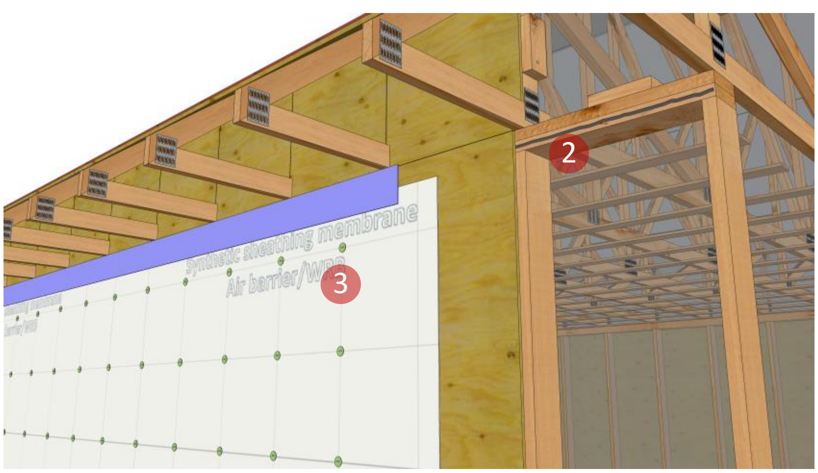
Steps:

11. Install insulation over the subsidiary membrane.
12. Install prefinished metal sill flashing. Refer to window manufacturer's specifications for more information.
13. Install window trim boards. The trim boards (face and returns) must be nailed together either before or during installation.
14. Install metal flashing at the strapping above the top window head trim board to aid in water diversion.
15. Install cladding and trim.
16. Install backer rod and sealant between window trim boards and window frame. Also apply sealant between the metal flashing and the window sill.



ABOVE GRADE WALL TO SLOPED ROOF





Exterior Steps:

1. Install blocking on wall top plate and the raised truss heels to attach the sheathing.
2. Install a sealant bead at the lower top plate prior to the sheathing installation. The air barrier transfers through the top plate.
3. Install sheathing membrane leaving a 3” gap below the top of wall. Seal the leading edge with a 6” strip of self-adhered membrane. Make sure primer is applied prior to the self-adhered membrane to ensure a good bond.

Key Considerations:

- Sealant on both sides of the top plate is essential to transition the air barrier from the wall, through the top plate, to the poly on the interior (refer to interior steps).

Exterior Steps Continued:

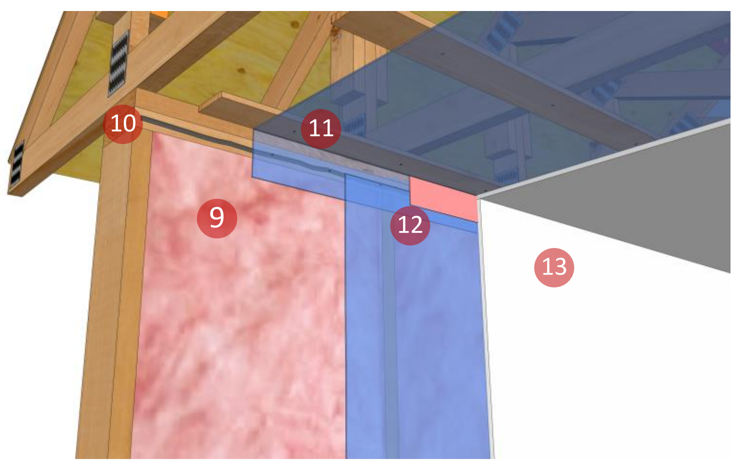
4. Install sheathing membrane above wall. Seal vertical laps and around truss penetration with sheathing tape. This membrane is not part of the air barrier.
5. Install 5” of mineral wool in two layers (3” first and 2” second). Secure with 1X4 strapping. Stagger the insulation board joints to improve thermal continuity. Insulation in the soffit may also be secured with insulation retention fasteners.
6. Install bugscreen.
7. Install soffit material.
8. Install cladding. Leave the cladding 1” short of the soffit material to allow for ventilation of the wall cavity.

Interior Steps:

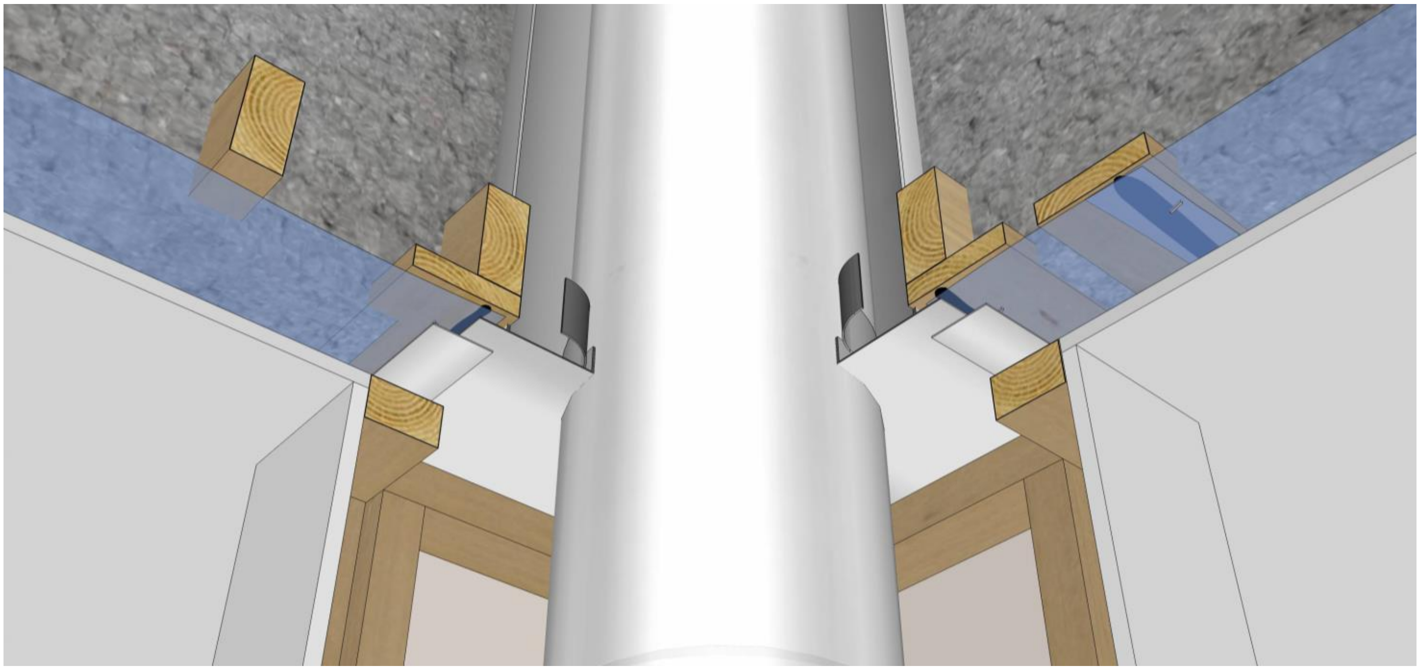
9. Install fibreglass batt into the stud cavities.
10. Install sealant bead to the lower top plate of the wall.
11. Install poly to the underside of the trusses. Ensure the poly laps over the top plates of the wall and fasten with staples at the sealant bead. The poly forms the vapour and air barrier at the ceiling.
12. Install poly from the wall onto the ceiling poly. Seal the leading edge with sheathing tape at the upper top plate.
13. Install interior gypsum prior to insulating the attic space.

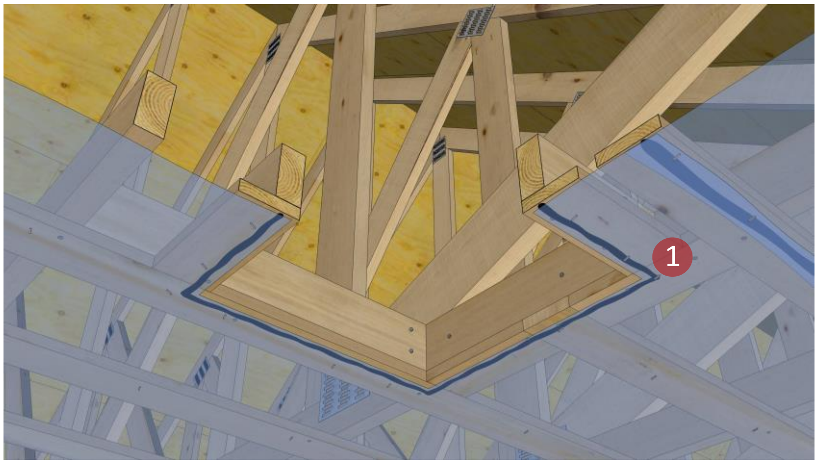
Key Considerations:

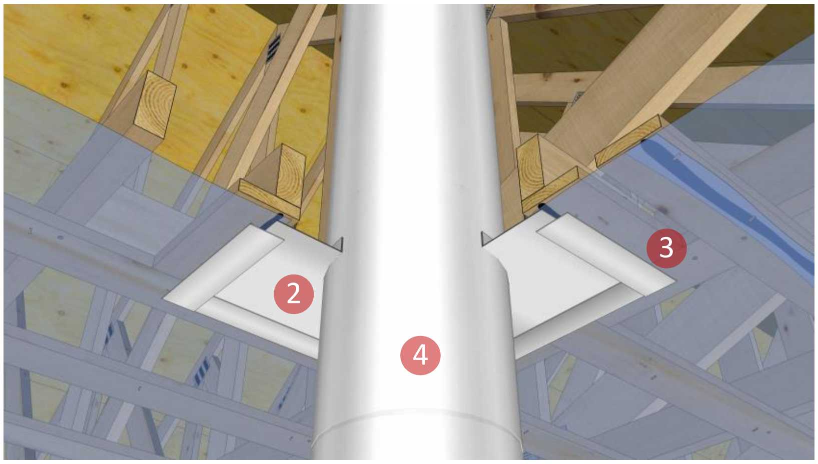
- Within a highly insulated attic, the ceiling should be strapped with 1X4 at 16” on centre to support the weight of insulation. Dry wall fasteners should be installed at 8” on centre.
- Install the gypsum drywall prior to insulating the ceiling; however, the drywall joints should not be mudded or taped as movement in the attic during insulating could crack the joint.



WOOD/PELLET STOVE CHIMNEY







Steps:

1. Install polyethylene at the ceiling around the framed chimney opening. Cut out the polyethylene at the chimney penetration to allow installation and overlap of the support collar. Seal around the perimeter of the opening at the wood framing with acoustical sealant for air barrier continuity.
2. Install and secure the chimney ceiling collar in the ceiling framing per the manufacturer's instructions. Ensure the housing flanges overlap the polyethylene.
3. Install high temperature foil tape or fire resistant silicone sealant around the perimeter of the housing flange to seal it to the polyethylene.
4. Install and secure the chimney per the manufacturer's instructions.

Steps:

5. Install high temperature foil tape or fire resistant silicone sealant around the perimeter of the support collar and the chimney.
6. Install the supplied insulation guard around the chimney per the manufacturer's instructions. The insulation guard must be sized to hold attic insulation away from the chimney for the entire depth of the attic insulation.
7. Install interior housing walls as required and install interior gypsum wall board.

   **The ceiling gypsum wall board should be installed before attic insulation is placed. In order to accommodate potential movement from added weight, it should not be taped or mudded until after the insulation has been installed to the required depth.*
8. Install attic insulation to the required depth.

Key Considerations:

- Ensure clearance between the chimney and all combustible building materials is 3", unless otherwise instructed by an approved HVAC contractor.
- Use only fireproof sealing material in contact with the chimney where needed.
- Do not cover the insulation guard with insulation or place attic insulation in contact with the chimney.
- The polyethylene is the primary ceiling air barrier, care should be taken to ensure it is continuous.