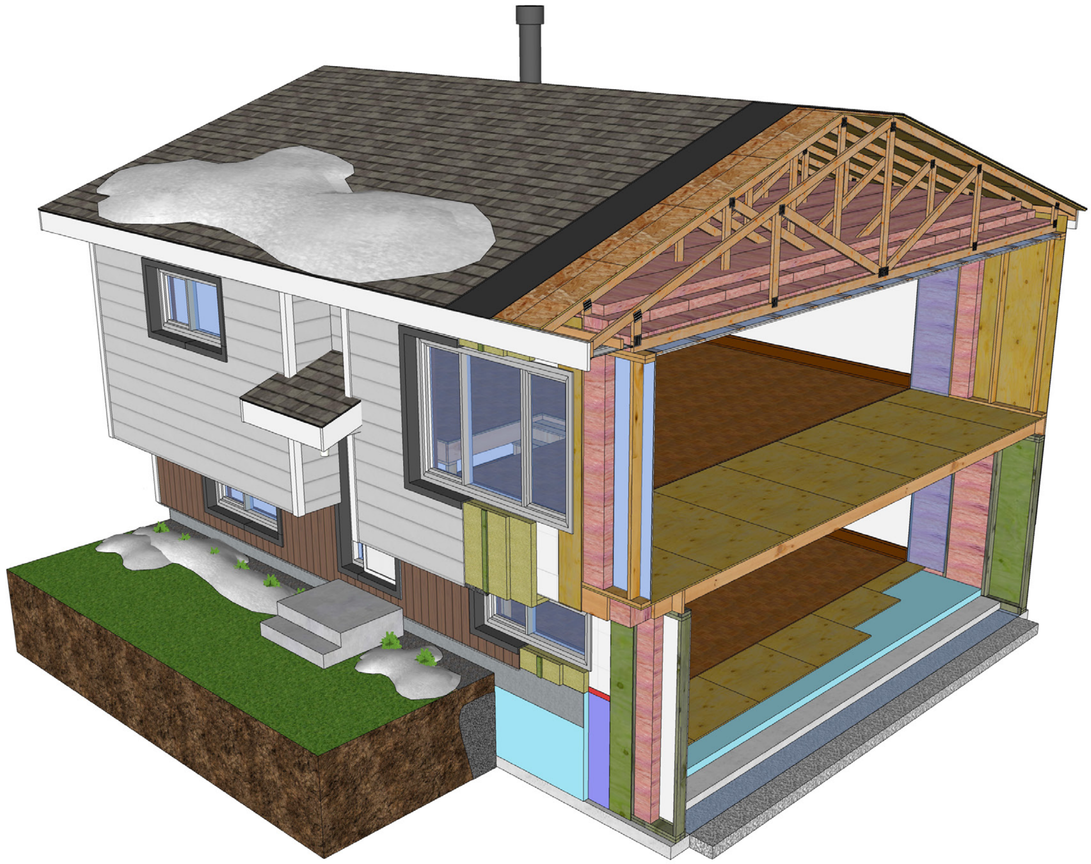
Energy Efficient Housing Retrofit Guide for Yukon

December 2021



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Acknowledgments

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1.0 Introduction

Home energy retrofits have the potential to reduce energy consumption, improve building durability, lower maintenance costs, lower greenhouse gas emissions, lower energy costs, and increase interior comfort for homeowners and renters. Building enclosure energy retrofits typically consist of air sealing and adding or upgrading insulation, either as stand-alone work, or during other planned renovation and repair activities. Simple retrofit work can often be performed by homeowners, while more extensive repairs or renovations typically require a contractor.

How to Use this Guide

The *Energy Efficient Housing Retrofit Guide for Yukon* covers several possible retrofit programs for typical single-family homes in Whitehorse, YT. Retrofits can involve relatively small amounts of work and cost (e.g., minor air sealing work) or more costly and complex work (e.g., below-grade retrofits). The guide is intended to be used by homeowners and builders as a reference for achieving higher levels of energy efficiency and maximizing utility cost savings and passive survivability through lower energy use. Where permafrost is present, only above-grade retrofits based on this guide are applicable. While this guide is based on a single-family home archetype with a finished basement and floor area of approximately 144 m^2 (1550 ft^2), the general guidance provided within can also be applied to other forms of residential wood-framed construction including low-rise housing.

Archetype House, front view

Archetype House, rear view

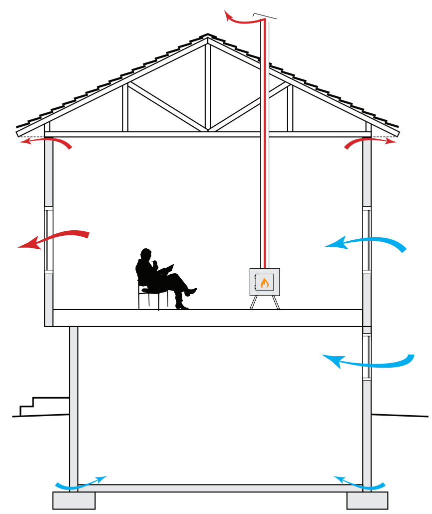
Archetype House, side view

House as a System

Houses are complex systems that involve interactions between various building components, occupants, the indoor environment, and the exterior environment. When considering modifying any one component of a building it is important to consider the impacts of the change on other building systems. With energy retrofit projects, it is particularly important to consider interactions between the building enclosure and the mechanical heating, ventilation, and air conditioning (HVAC) systems.

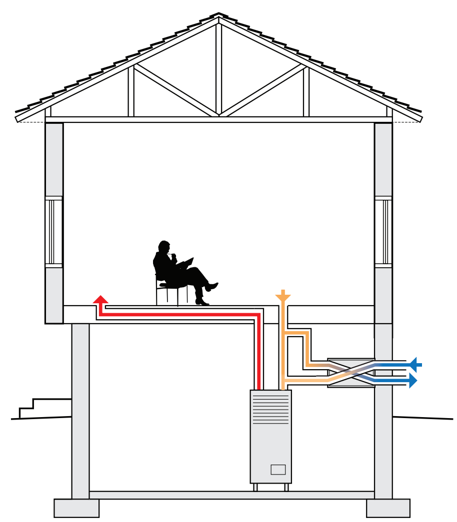
The following list highlights several energy retrofits that may impact other building systems and homeowner comfort:

- Air sealing work can make a home less drafty and more comfortable, and can reduce space conditioning costs.
- In some situations, an air sealing retrofit without consideration for make-up air can depressurize the building enclosure due to unbalanced exhaust appliances, leading to combustion appliance (oil furnaces, wood stoves, etc.) backdrafting and resulting in the potential spillage of hazardous combustion by-products into the home.
- Adding insulation can reduce space conditioning costs and can make indoor spaces more comfortable and interior surfaces less prone to condensation and subsequent deterioration.
- Adding insulation to walls, roofs, and floors without making airtightness improvements can lead to lower surface temperatures and condensation in concealed spaces which increases the risk of mould and deterioration of moisture-sensitive materials.
- Adding new insulation and sealant materials to an airtight home can reduce indoor air quality if the specified products contain harmful chemicals such as volatile organic compounds (VOCs). Furthermore, chemicals in new furnishings (furniture, curtains, etc.) and household cleaning products may also contribute to poor indoor air quality if not managed appropriately after an air sealing retrofit is completed.



Typical Older Inefficient House

Ventilation through air leakage (drafty house)
Poor enclosure performance (low R-values)
Higher space conditioning costs ($$$)



Higher Performance House

Mechanical ventilation with HRV (comfortable house)
High enclosure performance (high R-values)
Lower space conditioning costs ($)

Building Enclosure

The building enclosure separates interior and exterior spaces. Building enclosure assemblies include foundations, exposed floors, above-grade walls, roofs and attic spaces, and windows and doors. These assemblies are designed to manage bulk water (rain, snow, ground and melt water), water vapour, air movement, and heat loss/gain. Increasing building airtightness and insulation levels can improve energy performance, occupant comfort, and building longevity.

The Enclosure-First Approach which this guide is intended to illustrate, is an approach to reducing energy consumption and improving occupant comfort that is primarily focused on the performance of the building enclosure.

Occupant Behaviour

Occupant behavior should be considered when reviewing the implications of building changes. The people and animals living in a space can affect interior moisture levels, air leakage, and space conditioning requirements. Over time, occupant behavior can have a sizable impact on the long-term durability of a home.

The following are some examples of how occupant behavior can affect home performance.

Interior Moisture

Activities like boiling water, cooking, and showering represent large sources of moisture within a home. Exhaust fans should be utilized in locations where these activities occur, so that air carrying high levels of moisture can be effectively removed. However, these exhaust fans will only serve their purpose if they are activated by occupants during/after moisture producing activities.

The presence of plants, aquariums, people, and pets also contribute to overall moisture level within a home, so even in the absence of moisture generating activities effective exhaust ventilation is required.

Use and Maintenance of Windows and Doors

Ineffective closing and sealing of windows and doors can greatly increase building air leakage. Windows that rely on gaskets to seal operable vents require building occupants to adequately compress the seals to maintain airtightness. Additionally, occupants must maintain crucial air seals like weatherstripping and gaskets on doors and windows to avoid air leakage at these points. Increased air leakage can result in cold drafts, leading to reduced thermal comfort and higher space conditioning costs.

Space Conditioning Costs

Typically, occupants have complete control over their home mechanical system, meaning that they control whether it is operating properly. The improper use of the home space heating system can result in higher home space conditioning costs as well as increased interior relative humidity and related durability issues. **A simple energy efficient measure occupants can implement is to slightly lower the temperature set point in their home while still maintaining adequate thermal comfort.** Note that while setting a lower temperature will reduce the space conditioning costs, it can also negatively impact the durability of the building if sufficient heating is not provided.

Mechanical Heating, Ventilation, and Air Conditioning (HVAC)

HVAC systems are made up of multiple components, such as stoves, furnaces, boilers, heat recovery ventilators (HRVs), heat pumps, bathroom and kitchen exhaust fans, and hot water heaters.

The ventilation system is responsible for the provision of fresh outdoor air as well as the removal of contaminants, smells, and moisture from interior spaces in order to maintain a healthy and comfortable interior environment for building occupants. Mechanical ventilation is the intentional movement of air into and out of a building using fans and associated ductwork, grilles, diffusers, and other components. Generally, a balanced ventilation system is desirable where the amount of fresh air supplied to the home is roughly equal to the stale interior air that is exhausted.

Space heating systems are responsible for generating warmth within the building. The generation and distribution of heat has a significant impact on occupant comfort and home energy performance. Heat can be generated by combusting solid, liquid, or gaseous fuels or, alternatively, by transforming electricity into heat (resistance heaters, heat pumps). Multi-zone space heating systems often rely on the ventilation system to transport heated air through ducts to all areas of the building, but some multi-zone systems (multi-split heat pumps, boilers) may also utilize a piping system to distribute heated fluids. Stand-alone space heaters (wood/pellet stoves, direct vent heaters, mini-split heat pumps) are also common in the North and can be utilized for targeted heating applications and do not typically rely on the home ventilation system. Space heating systems must also generate sufficient heat to balance the heat losses through the building enclosure and ventilation system at any given time.

Water heating is the process by which water is heated for domestic uses including cooking and cleaning. An energy source (electricity or heating fuel) is required to heat cold incoming water. Improving the energy efficiency of the water heating appliance can have an important impact on overall building energy performance. Insulating hot water piping, particularly the first 2m (6ft) of pipe leaving the water heater, is an inexpensive DIY job available for homeowners to reduce water heating costs.

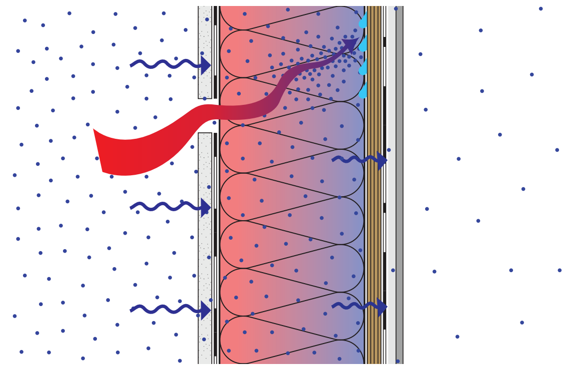
Conflicting demands on the HVAC system (e.g., utility cost savings vs. occupant comfort) can have a significant impact on energy efficiency in buildings. While improving ventilation in existing homes can result in improved indoor air quality and occupant health, it may also lead to increased energy use and higher utility costs. It is important to acknowledge that other building demands must sometimes be prioritized over energy efficiency improvements.

Durability Concerns

Home energy retrofit work should aim to increase the thermal resistance and airtightness of the building enclosure, without compromising the durability of its assemblies. The following are some common durability concerns.

Air Leakage Condensation

Air flowing freely through an assembly from the interior to the exterior has the capacity to carry large amounts of water vapour in contact with cold surfaces at the exterior of the assembly (typically sheathing). Over the course of one heating season, a hole the size of a quarter through an air barrier can allow for almost 30 litres of water vapour. This may lead to condensation and potential mould growth and deterioration of moisture sensitive components. When interior insulation is added to an existing assembly, air barrier improvements should also typically be completed to minimize condensation risk.

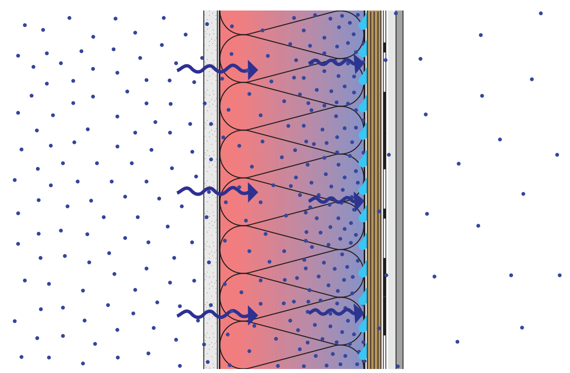


Air Leakage Condensation

Condensation risk associated with air leakage through the building enclosure.

Vapour Diffusion Condensation

Vapour diffusion from the interior to the exterior can contribute to moisture transfer through and into an assembly, and must also be accounted for in energy retrofit work. An effective vapour control layer or vapour retarder should be in place at the interior (warm) side of most assemblies. **The introduction of non-vapour permeable insulations or membranes at the exterior of existing enclosure assemblies should be avoided under most circumstances as this intervention typically limits the ability of the assembly to dry to the exterior.** Please see pg. 28 for further information. In general, an assembly that uses a **vapour retarder at the interior and vapour-open materials for the rest of the assembly** is the safest approach.



Vapour Diffusion Condensation

Condensation risk associated with vapour diffusion through the building enclosure.

Material Incompatibilities

Care must be taken when selecting retrofit materials, as some products are incompatible with each other and with existing building components. For example, some foam plastic insulations and adhesives are incompatible and may react. Tapes, sealants and membranes should exhibit adequate adhesion to existing substrates and to each other. Always read the manufacturer's instructions and technical specifications to avoid any potential material compatibility issues.

Replacing Important Components After Retrofits

Where energy retrofit work requires the removal of existing assembly layers like cladding or roofing, care must be taken to replace these components. Typically, in situations where the existing cladding must be removed to install insulation or complete air sealing work, a new sheathing membrane and cladding should be installed according to modern water deflection and moisture management designs and installation principles. Air sealing and insulation retrofits that also include other exterior component improvements can greatly improve the overall durability of the assembly. Where the removal of assembly components exposes moisture issues such as rot of structural components (particularly around windows) these components must be replaced before covering.

2.0 Energy Retrofit Considerations for Yukon

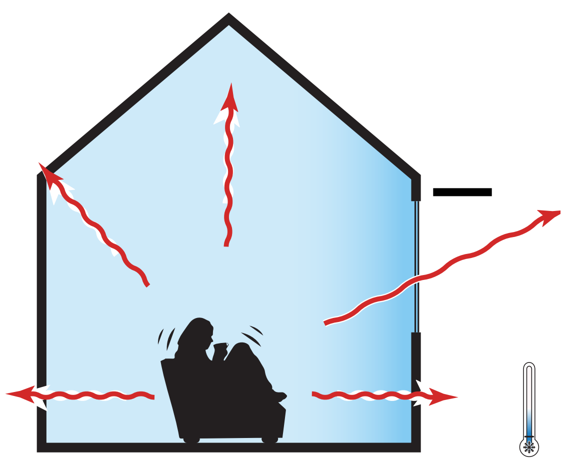
Thermal Comfort

High-performance building enclosures typically result in a more comfortable interior environment throughout the year. Highly insulated assemblies tend to have warmer interior surfaces and a more uniform interior ambient temperature. The closer surface temperatures are to equilibrium with an occupant's body temperature, the less heat that will transfer between the occupant and the surface (Second Law of Thermodynamics). Buildings with continuous exterior insulation are less likely to have the cold surfaces that often occur at framing locations like studs, top and bottom plates, and framing around openings in conventional, stud-cavity-insulated buildings.

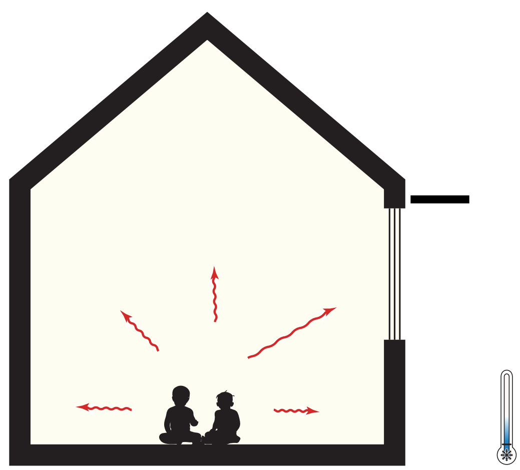
Thermally efficient high performance doors and windows also result in warmer interior frame surfaces. Because windows and doors are typically the poorest performing assemblies in the building enclosure, thermally efficient windows can have a profound effect on comfort. High performance doors and windows also typically provide improved noise control.

Uncontrolled air leakage can result in excessive heat loss that leads to occupant discomfort and energy waste, and can also lead to moisture issues such as mould and rot within building enclosure assemblies. Air sealing work and the installation of new airtight windows and doors can significantly improve overall thermal comfort and building durability.

Improving occupant comfort is a primary objective of enclosure retrofits. While heat flow through the building enclosure cannot be prevented, it can be greatly reduced through increased thermal insulation levels, window replacement, and air sealing retrofits. Together these improvements can increase interior surface temperatures and reduce unwanted drafts.



Poorly insulated and 'leaky' building, thermally uncomfortable



Well-insulated and airtight building, thermally comfortable

Ice Damming

Ice dams are ridges of ice that form on roof eaves and impede roof drainage, potentially causing water leakage. Snow that melts in areas of the roof that unintentionally receive heat from the interior (areas with reduced insulation or uncontrolled air leakage, etc.) can run down the roof to colder roof areas, such as roof eaves, where it refreezes. When it refreezes it creates an ice dam that restricts further drainage of melt water that can result in damage to the exterior roof assembly. Additionally, melt water can leak into the building causing damage to interior finishes.

Ice damming can occur on both pitched and low sloped roofs, where slope and unintentional heating is provided to higher-elevation roof areas. Ice damming occurs most commonly in areas with large amounts of snowfall and is worsened by intermittent warming spells that occur near the end of the winter.

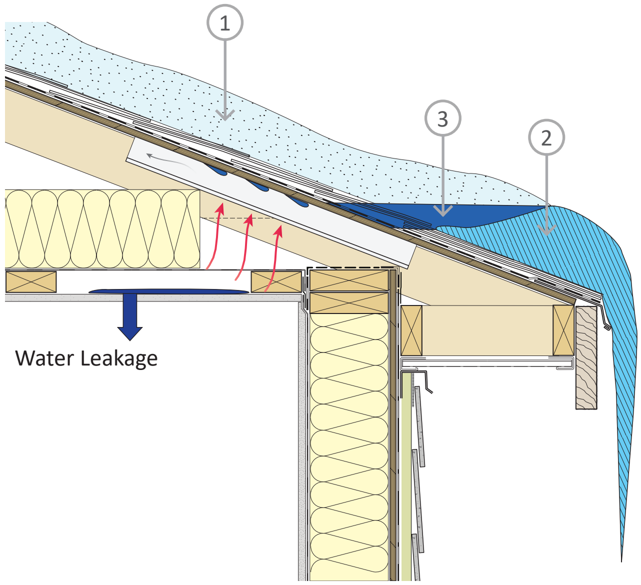
Cause

Snow melt and subsequent ice damming can be caused by:

- Thermal bridging and heat loss at areas of reduced insulation thickness or insulation gaps.
- Leakage of warm interior air through the ceiling plane into spaces below the roof sheathing, leading to localized warming of the roof sheathing.
- Heat sources within attics such as hot water pipes, poorly insulated or leaky exhaust ductwork, chimneys, and skylights.
- Differences in solar exposure and snow thickness on the roof.

Effect

Once an ice dam forms, melt water may backup the roof slope, potentially leading to water leakage into interior spaces. This water leakage can cause damage to the roof sheathing and structure, wall framing, and interior finishes below. Ice damming and snow melt can also lead to the formation of icicles along the roof eaves, which can become a danger to people below.



Ice damming causing damage to interior finishes

1. Local warming melts snow
2. Water freezes at eaves
3. Water builds up and causes leak

Prevention

Roofs should be designed to have a uniform exterior surface temperature that is below the melting point. Effective preventative measures for managing snow melt and ice damming include:

- Ensuring an airtight ceiling plane.
- Increasing attic thermal insulation levels, particularly at roof-to-wall interfaces, ensuring insulation continuity.
- Removing attic heat sources where possible, e.g., by insulating and air sealing all plumbing, electrical, and HVAC components.
- Increasing attic ventilation, which can help keep the sheathing close to exterior temperatures. This is particularly important between the top of wall and roof sheathing. Ventilation should only be used alongside other preventative measures.
- Installing a waterproof membrane that will not leak under standing water, from the eaves extending up the roof. The membrane should extend up the roof high enough to resist a 6" to 8" height of water above the edge of the wall insulation below.
- With low sloped roofs, ensure that a waterproofing membrane has been installed over the entire roof area. A low-sloped roof has a higher potential for ice damming and should be carefully inspected to ensure the waterproofing membrane is continuous and capable of not leaking under standing water.

Soil Freezing and Frost Heave

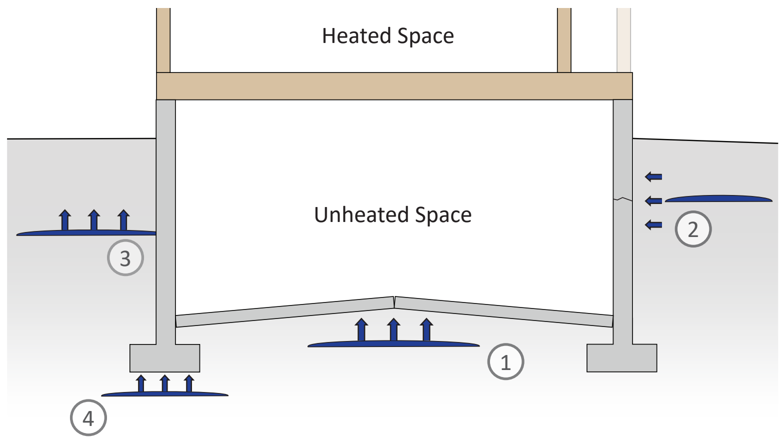
When liquid water becomes ice, its volume increases by approximately 9%; however, when water freezes in frost-susceptible soils, far greater volume increases and related soil displacement are possible. Frost heave is due to the growth of ice crystals that draw water from the surrounding soil under freezing conditions to form ice lenses. Ice lenses develop at the freezing front* and increase in depth as more water accumulates, resulting in soil displacement. Frost heave or frost expansion is not uniform; rather, it is in the direction of least resistance to pressure.

In basements, where the resistance to pressure is less from the ground into a basement, there is a risk of **upward frost heave** from beneath the slab and **inward frost heave** from outside the foundation wall. Another mechanism called **adfreezing** can also cause building damage. Adfreezing is where soil around the exterior of the building freezes and adheres to the foundations. When the frozen soil is displaced upwards from frost heave, the foundation wall moves upward.

Cause

There are three primary requirements for frost heave and related damage to occur:

- The building must be surrounded by frost-susceptible soils (soil with more than 3% grains finer than 0.02 mm in diameter by weight, typically loamy or silty soils).
- Water must be present in the soil.
- Freezing temperatures must occur.



Frost heave damage to building foundations.

Effect

Frost heave can damage a building in several ways:

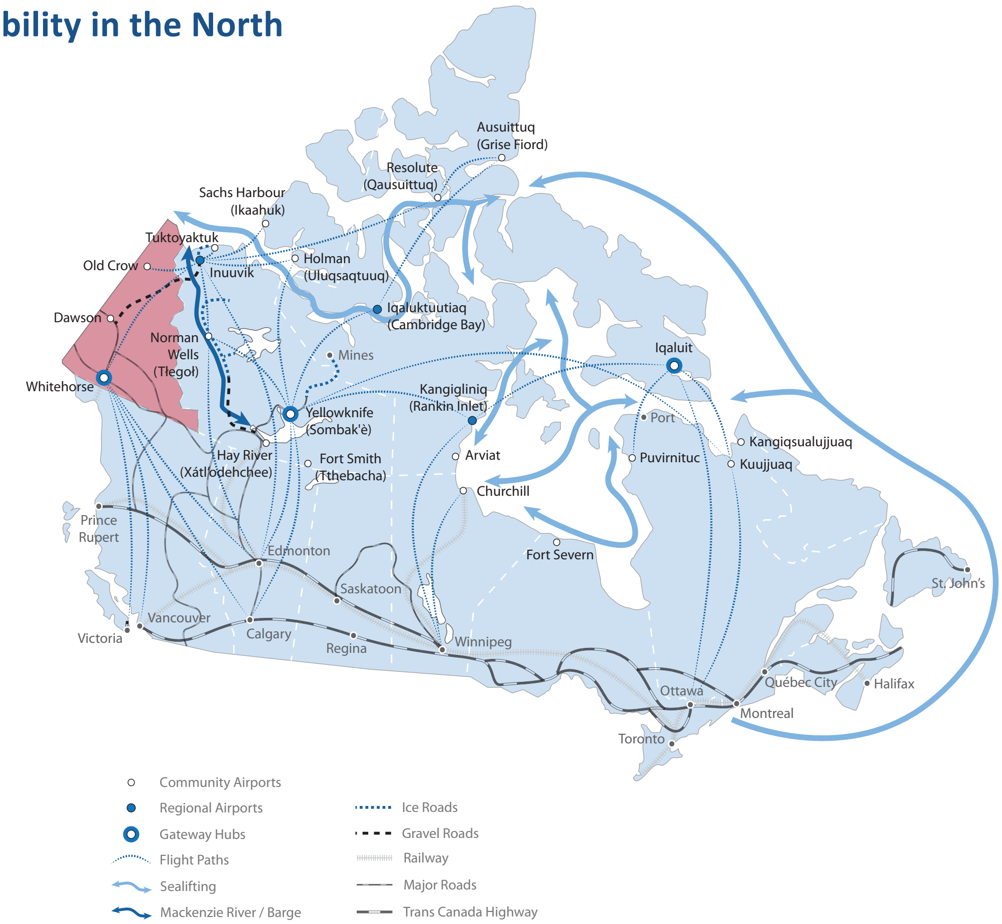
1. Unheated basements can experience upward frost heave, damaging the slab on grade.
2. Unheated basements can experience inward frost heave, that applies a perpendicular force on the foundation wall. This force can cause cracks or even foundation buckling in some extreme cases.
3. Adfreezing can displace foundation walls upward. This can negatively affect building components supported by the foundation, including framing and interior finishes. Adfreezing can displace a foundation even where the footing is installed below the frost line.
4. Frost heave can displace footings upward if they are installed above the frost line and are not adequately protected.

Prevention

- Remove frost-susceptible soils (loamy and silty soils).
- Provide adequate drainage around the home using free draining granular material and backfill to prevent the accumulation of water below-grade near the foundation. Also divert roof runoff away from the foundation with gutters.
- Remove groundwater from foundations by providing drainage to a sump pit, drywell, city sewers, or drainage ditch.
- Increase ground temperatures around basements by:
  - Heating the basement/crawlspace.
  - Providing an insulation “skirt” to reduce heat loss from the soil adjacent to the foundations. The insulation skirt width is typically equal to the average local frost depth; however, always refer to the requirements of the local authority having jurisdiction. The thickness of insulation is usually based on the number of freezing degree days at the location. The insulation skirt should be angled at 45° to provide a higher thermal gradient for the below-grade slab.

*__Freezing front__: The advancing boundary between frozen (or partially frozen) ground and unfrozen ground. The freezing front will typically extend deeper below grade as the winter progresses and often reaches a peak depth in the Spring.

Material Availability in the North



Extreme climate and remoteness have a significant impact on accessibility in many areas of the North. Of particular importance is the transportation networks that allow for the movement of people and goods to and from northern communities. Many towns and smaller communities do not have consistent land access and rely on other transportation modes. Therefore many construction materials are not readily available and/or are excessively expensive. Isolated communities in the Yukon, Northwest Territories, and Nunavut are heavily dependent on important gateway hubs such as Whitehorse as staging points for freight and passengers (see map above).

In general, access to building materials and labour is dependent on the following transportation modes:

- **Flying** - Many northern communities are dependent on airports for passenger access and perishable goods. Aerial transportation in the North follows a hierarchy, where local community airports are dependent on regional airports and regional airports are then dependent on gateway hubs such as Whitehorse. Typically, airlifting goods and passengers is possible year round; however, flights outside the summer months are often delayed by weather conditions.
- **Ice roads** - Seasonal ice roads, constructed over frozen lakes and land, allow commercial trucks and other vehicles to carry goods and passengers between northern communities throughout the winter. Ice roads are generally usable from late December until early April; however, monitoring and maintenance must be performed over this period to ensure the roads function safely.
- **Sealifting and barges** - Large shipping vessels transport heavy goods, including construction materials, from southern locations to northern coastal settlements when sea ice recedes in the summer. Barges are often needed to transport the goods from the shipping vessels to the land. However, it is sometimes possible for large shipping vessels to beach at high-tide and have their goods unloaded as the tide recedes. Typically, goods are available by sealifting immediately after the ice thaws in early July until early October (approximately 3 months). This transportation mode is often required for delivering materials to northern communities located near the Arctic Ocean.

3.0 Health and Safety Considerations

Retrofit-Related Safety Concerns

With proper precautions and training, energy retrofit work on homes should pose little to no threat to the health and safety of the contractor or the occupants of the home. However, improperly used building materials and tools can be dangerous to users or occupants, or can damage the building, so it is important that contractors read and follow all manufacturers' recommended safety and installation procedures. Wherever possible, less harmful and lower volatile organic compound (VOC) releasing materials should be used for retrofit work, particularly if the materials will be exposed to the interior living space.

The following pages summarize some of the key points to consider, with references provided for further information and local occupational health and safety procedures. It should be noted that the health and safety information in this guide is neither comprehensive nor complete, and those performing retrofit work should always be appropriately trained and aware of the safety risks associated with the work. Homeowner's are strongly recommended to confirm that any contractor undertaking work provide proof they are covered by commercial liability insurance.

Structural Elements and Connections

The structure of the home should not be compromised during retrofit work, even if it is necessary to cut, drill, or relocate wood structural elements during the work. Contractors should avoid cutting wood elements such as studs, trusses, joists, and beams when air sealing or insulating unless a structural engineer has been retained to review the modifications and suggest remedial or reinforcing techniques. Any structural elements that have been compromised due to previous moisture issues must be repaired at the time of the energy retrofit project.

Ventilation of the Home

Air sealing work may seal openings in the building enclosure that were previously relied on for natural or passive ventilation in the home. Essentially, as the building becomes more airtight, more mechanical ventilation is necessary. Inadequate ventilation can lead to indoor air quality concerns and moisture problems; therefore, a properly functioning, balanced (air in is to equal air out), and appropriately sized mechanical ventilation system is a critical part of residential energy retrofits. An HRV system typically provides the best option for air quality and moisture control. Further information can be found in several resources on ventilation considerations including Chapter 18 of the *Canadian Home Builder's Association Builders' Manual,* the *HRAI Residential Mechanical Systems Manual,* and section 9.32 of the *National Building Code of Canada.*

Ventilation While Performing Work

Many sealants, adhesives, and spray polyurethane foams release VOCs and other potentially harmful chemicals when curing. The product manufacturers' installation and safety procedures should be followed when performing work, and ventilation should be provided as required: opening windows, using temporary ventilation fans, or using full respiratory equipment, depending on the nature of the work being performed. In some cases—for example, when using large quantities of spray polyurethane foam in attics, roofs, or walls—contractors need full respiratory equipment while in the work area and homeowners may need to leave the house for up to 24 hours after spraying, with all windows kept open for a full-house flush. Note that there is an increasing number of available products that release little or no VOCs.

Asbestos-Containing Products and Vermiculite Insulation

In many older homes, asbestos fibres may be found in building products such as vermiculite insulation, drywall joint compound, stucco, flooring and flooring adhesives, and some older window putties. Several older mechanical and electrical items also contain asbestos, including pipe insulation, chimneys, furnaces, boilers, and hot water heaters (liners and gaskets). Undisturbed materials within walls or attic spaces pose little risk to occupant health. However, if exposed or disturbed as part of a retrofit program, these materials can cause health risks to both the contractor and homeowners. At a minimum, contractors and homeowners should consult some of the publications listed below prior to undertaking retrofit work as appropriate safety measures must be followed:

- ***"Asbestos Abatement"***, published by the Workers' Safety and Compensation Commission
- ***"Special Waste and Solid Waste Regulations - Asbestos"***, published by the Government of Yukon
- ***"Asbestos Hazards When Renovating Older Homes"***, published by WorkSafe BC

Lead Paint

Lead can be found in many paints and coatings in older buildings. Lead-containing paints and coatings do not present a danger if they are left intact; however, touching degraded lead-based paint can cause it to flake off and become hazardous, particularly to small children. If retrofit work damages or removes materials containing lead, appropriate safety measures must be followed. Further information can be found in the document "*Special Waste Regulations - Lead Disposal*", published by the Government of Yukon and available at https://yukon.ca/en/lead-disposal.

Spray Foam Insulation

Spray polyurethane foam (SPF) is a commonly used air sealing and insulation material for retrofit work and this guide suggests its use in various applications. Exposure to isocyanates and other chemicals in the spray foam during the curing period or for some time after installation may cause health effects in some people. Care must be taken to control exposure of contractors and occupants, including possibly vacating the home while spray foam is being applied for up to 24 hours after large applications. In addition, some spray foam types (closed cell, medium density products) can only be applied in lifts of up to 2" at a time and require a cooling-off period between lifts for thicker applications.

Because of these concerns, spray foam should always be installed by a trained contractor. This guide does not provide information or instruction on SPF installation and safety procedures; refer to the spray foam manufacturer for health and safety information.

It should be noted that spray foam should only be applied when the substrate is above the manufacturer's specified temperature. In practice, this often limits the application of spray foam to the warmer months of the year, when temperatures are less severe.

Materials Containing Solvents, VOCs, and Toxins

Sealants, adhesives, and other products used for air sealing and insulation retrofit work may contain flammable solvents and VOCs that can affect contractor or homeowner health and safety. Low-VOC options for many adhesives, paints, and sealants are available and should be used when possible for indoor work, though the use of higher-VOC products may be required for some applications. Additional health and safety information can be found by reviewing the product literature and manufacturers' material data safety sheets.

Some glues used in batt insulations and preservatives found in pressure-treated lumber and manufactured wood products may contain formaldehyde and other toxins. While these materials are necessary for many construction activities, care should be taken to limit skin contact with the use of personal protective equipment such as gloves and appropriate clothing.

Mould, Fungal Growth, and Moisture Damage

Fungal contamination and mould can occur in homes and concealed building enclosure assemblies if the materials are exposed to elevated relative humidity levels (typically above 80% relative humidity for extended periods), condensation, and/or moisture leakage from the exterior. Organic materials, such as paper-faced drywall and wood, are susceptible to fungal growth in the home. Fungal growth is common in bathrooms, but can be easily removed by regular household cleaning. Fungal growth on window frames may occur if there is excessive condensation due to high indoor relative humidity levels. Fungal growth is commonly found in crawlspaces, attics, walls (particularly below windows), and other damp spaces as a result of elevated relative humidity levels due to air leakage condensation, snow and rain, and plumbing and appliance leaks. Depending on the severity and duration of the wetting, fungal growth can lead to decay and deterioration of wood components. Moisture-damaged wood is often uncovered during retrofit work.

If significant fungal contamination or mould is present or suspected in the home, it must be removed and cleaned and the contributing source addressed prior to any air sealing or insulation retrofit work. To reduce the potential for mould growth, control indoor moisture sources and ensure that there is a proper ventilation system with good air distribution within the home.

Where mould growth is severe or moisture damage is extensive, a professional specializing in mould clean-up and structural repair should be retained. Contractors and homeowners can consult the publications listed below for further information on mould health risks, prevention, assessment, and remediation:

- ***"Mould Guidelines for the Canadian Construction Industry"***, published by The Canadian Construction Association
- ***"Guidelines on Assessment and Remediation of Fungi in Indoor Environments"***, published by the New York City Department of Health and Mental Hygiene
- ***"Addressing moisture and mould in your home",*** published by Health Canada
- ***"Mould in Housing",*** published by Canada Mortgage and Housing Corporation

Combustion Safety

Air sealing and other energy retrofit work can affect the combustion safety of a home. Naturally aspirating combustion equipment—such as pellet and wood stoves and oil-burning or propane appliances like boilers, furnaces, or water heaters—typically rely on a degree of natural air leakage through the enclosure to provide the necessary air for fuel combustion and venting. Some homes also include dedicated combustion air vents that must be unplugged if previously plugged and that must not be sealed during retrofit work. When air sealing work is performed on a home with a naturally aspirating combustion appliance, the reduced enclosure air leakage coupled with regular operation of exhaust appliances such as bathroom fans and kitchen range hoods can result in depressurization of the home. This may lead to combustion appliance backdrafting whereby combustion flue gases including carbon monoxide are not vented and instead spill into the home.

Retrofit work in homes with propane-, oil- or wood- burning equipment requires special consideration and should typically include combustion safety testing. Where possible, existing naturally aspirating furnaces, boilers, and water heaters should be replaced with sealed combustion equipment when comprehensive air sealing work is completed to mitigate the risk of backdrafting and combustion gas spillage. Guidance regarding combustion safety, testing, and remedial measures is beyond the scope of this guide. Contractors performing retrofit work should be trained and aware of the potential risks, or they should retain a subcontractor or consultant who has the requisite experience and expertise, such as an energy advisor or an HRAI certified contractor.

Electrical Wiring

Care must be taken when working around electrical wiring so as not to receive a shock, damage the wiring, or cause a fire. Air sealing materials such as spray foam should never be applied within electrical boxes or come into contact with bare wires. Always avoid burying electrical wires in spray foam: the heat build-up in heavily loaded wiring may cause damage to the wire sheathing. Always follow product manufacturers' instructions and warnings, and hire an electrician if any electrical work is required, such as the installation of new fans or motorized dampers to provide mechanical ventilation after air sealing work has been performed.

Other Considerations

Retrofit work can sometimes uncover other issues in a house. For example, exhaust fans may be directly vented into attics instead of outdoors, or a roof or window leak may be discovered. These problems should always be addressed before or as part of the retrofit work.

Radon Exposure Concerns

Radon is an odourless and invisible radioactive gas that occurs naturally and is created by the decay of uranium in rocks and soil. Radon can accumulate undetected within homes leading to negative health outcomes including lung cancer.

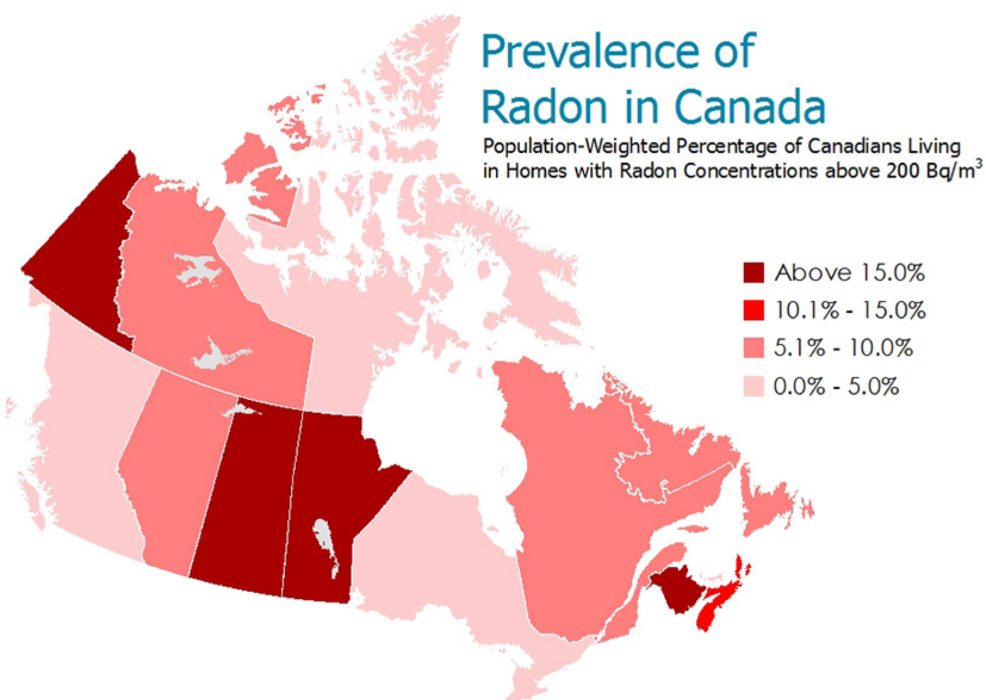
While radon is present in most homes at low levels, higher concentrations represent a significant health risk to occupants. Health Canada recommends a maximum radon concentration in dwellings of 200 Becquerels (unit of measurement for radioactivity) per cubic metre (200 Bq/m³). A Becquerel is a unit that measures the rate of radiation emissions.

Concentrations of indoor radon differ across the country, and are generally higher in areas where there is a greater amount of uranium in the soil. According to a study published by Health Canada in 2012, Yukon has some of the highest indoor radon concentrations in the country. Radon typically enters the home below-grade at cracks in the basement slab, joints between the slab and wood foundation, exposed soil, floor drains, sump pits, and other discontinuities in the basement air barrier.

Homeowners and contractors should be aware that comprehensive air sealing work can lead to home depressurization which may result in higher radon concentrations within the home. Always consider the interaction between enclosure airtightness and the operation of exhaust appliances when completing air sealing work.

Radon Testing

The only way to determine radon levels in a home is to conduct a radon test. Digital radon monitors and do-it-yourself radon test kits are available from hardware stores and through online retailers, or tests can be done by a radon measurement professional. Radon levels vary hourly and by season and the average concentration should be determined. To obtain a reliable measurement, radon testing should be conducted over at least three months. For further information refer to the Health Canada resource on the following page. It is recommended that homes finding radon levels between 200 – 600 Bq/m³ take action to mitigate the problem within two years, and homes with levels above 600 Bq/m³ act within one year. A radon mitigation contractor certified with the Canadian National Radon Proficiency Program (C-NRPP) should be retained to diagnose radon entry locations and determine the most effective mitigation strategy for the home.



Active Soil Depressurization

Active soil depressurization (ASD), also called active sub-slab-suction, is one of the most common and effective methods of radon mitigation in existing buildings. ASD limits infiltration of soil gas by reducing the air pressure in the soil below the foundation. This system requires installing a perforated PVC suction pipe in the crushed rock or soil beneath the basement slab. The pipe is connected to a radon fan that exhausts air directly to the outside, depressurizing the soil and reducing air infiltration into the home. Pipes should be a minimum diameter of 4” to achieve adequate suction.

ASD is most effective when the sub-slab area is filled with at least 4” of coarse gravel to allow for good air movement from the soil. If the sub-slab layer is dense gravel or soil, further action is required to achieve adequate depressurization. Options include installing multiple suction pipes or excavating the slab to install a gravel layer. In homes with a sump pit, an alternative to installing suction pipes below the slab is to seal the hole from the interior and depressurize the sump. If a floor drain is connected to the sump hole, a trap should be installed to prevent sucking indoor air into the drain. Another alternative is to apply suction to existing foundation drain tiles or perforated drainage pipes.

Radon suction pipes are vented to the exterior with an in-line radon vent fan. The suction pipes must be tightly sealed to avoid leakage of radon into the home and should be labelled so they are not confused with plumbing vents. Exhaust vents can be terminated near ground level to mitigate condensation and ice build-up during colder months. Exhaust vents should be located away from any doors, windows, fresh air intakes, and combustion intakes that may allow radon to re-enter the home. Fans should be mounted on flexible straps with rubber ducting couplings to prevent fan vibrations creating noise and should be installed as close to the exhaust vent as possible to minimize the length of positively pressurized pipe within the home. These fans must be run continuously for the system to function properly and have a typical lifetime of five to ten years. A U-tube manometer should be installed in the exhaust pipe to ensure adequate suction pressures are maintained.

Other Radon Mitigation Techniques

Sealing cracks and gaps in the below grade structure will help soil depressurization systems operate more effectively. Cracks in the basement slab should be prepared and sealed. Joints at the base of the foundation wall should be sealed and tied into the interior air barrier. Other slab penetrations such as pipes and drains should also be sealed. These measures are not adequate as a stand-alone radon mitigation strategy but are intended to supplement the ASD method described earlier by reducing the amount of uncontrolled radon entering the home.

Continuous mechanical ventilation for all occupied spaces is recommended so as to dilute radon concentrations with the home. Where possible, explore retrofitting the existing ventilation system with a heat recovery ventilator to ensure that continuous balanced ventilation is provided to all interior spaces.

Introducing venting to unconditioned and unventilated crawlspaces limits the amount of radon present directly adjacent occupied spaces thereby reducing the radon concentrations within the home that occupants are exposed to.

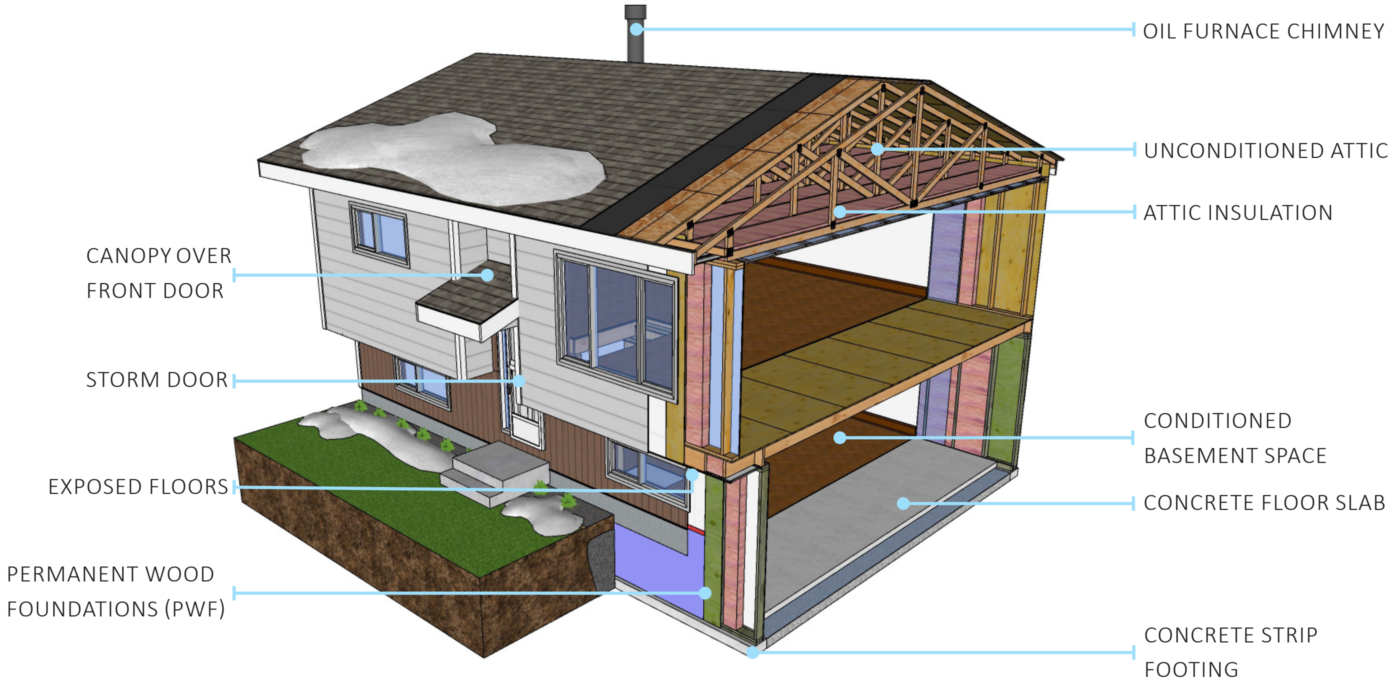
Potential Complications

Complications can occur if vent pipes in ASD systems are not well sealed. Leaks on the negative pressure side (upstream of the radon fan) may contribute to the home becoming excessively depressurized relative to the exterior. This can cause backdrafting of naturally aspirating combustion appliances such as furnaces, water heaters, wood stoves, or fireplaces. Depressuriztion, or backdraft testing should be conducted by an energy advisor or another qualified professional. Homeowners and contractors should always consult a radon mitigation professional before commencing any radon mitigation activities.

Additional Resources

- "***Radon Reduction Guide for Canadians***", published by Health Canada
- "***Whitehorse Radon Information Map***", interactive map of community radon levels in the Yukon

4.0 Energy Retrofit Packages



Archetype House

Oil furnace in basement

Vented attic with loose fill insulation

The Archetype House

An archetype house was developed for homes located below the continuous permafrost zone in southern Yukon. The archetype house is a 1980s 1-storey house with a finished basement and a floor area of approximately 144 m² (1550 ft²). The building includes a pitched roof complete with raised heel trusses and is constructed with platform framing techniques.

The house exhibits many characteristics that are common to existing homes located in Whitehorse, YT:

- Permanent wood foundations (PWF) are used for the basement. The PWF are insulated with batt insulation in the stud cavities.
- The basement is finished and includes an uninsulated concrete slab.
- The main floor is cantilevered at the front of the house; as a result, the exposed floor locations are fully insulated between the joists.
- The unconditioned attic is accessible from within the home and contains loose fill or batt insulation.
- Space and water heating is provided by oil or electric fuel sources. The archetype house includes an oil furnace and an electric hot water heater.

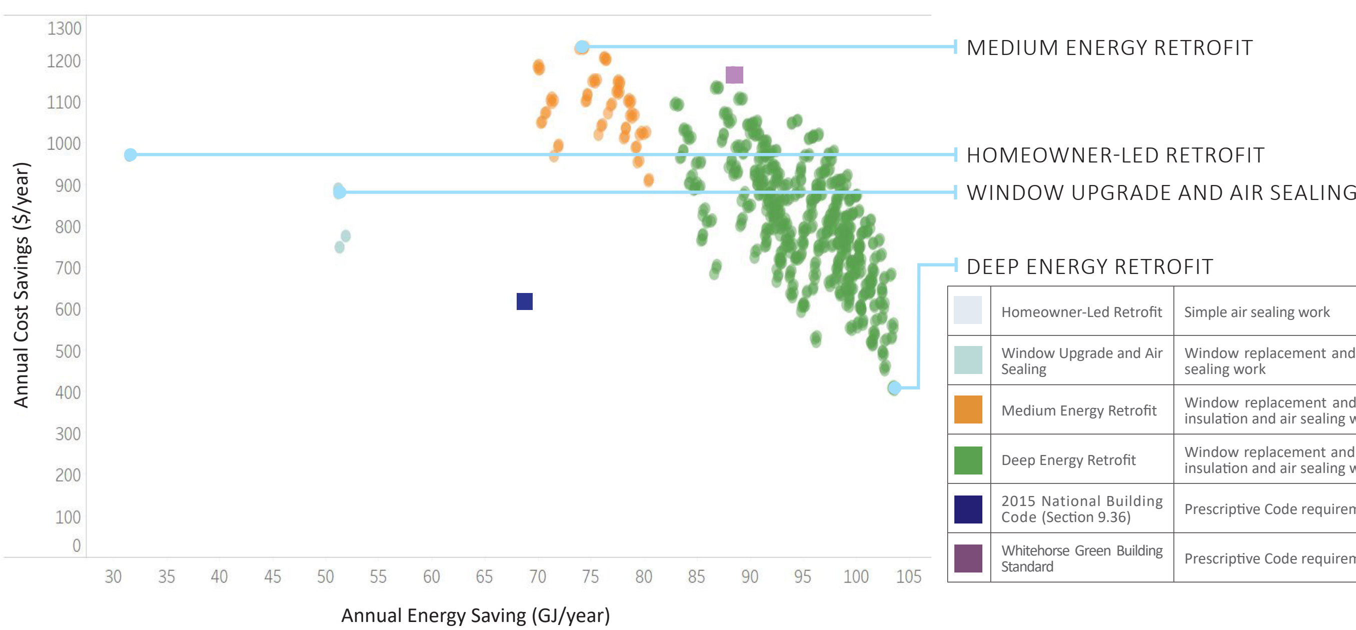
Improving the energy efficiency of existing homes in Yukon can significantly improve housing affordability, occupant comfort and health, passive survivability, and lower green house gas emissions. The cost of heating fuel and electricity in the North is known to be among the highest in Canada: completing air sealing and insulation retrofits can greatly lower homeowner utility bills. Furthermore, more highly insulated and airtight homes are better able to mitigate extreme weather events and provide a degree of resiliency during winter storms where the heating fuel supply is limited and/or the local utility grid is unavailable.

While completing building energy retrofits typically provides several positive benefits to homeowners, society, and the environment, selecting the optimal package of energy efficiency measures can be challenging with building enclosure, HVAC, and other equipment retrofits all having differing upgrade costs and energy savings. Recent energy modelling work completed by Natural Resources Canada (NRCan) in partnership with Yukon Housing Corporation (YHC), the Government of Yukon Energy Branch, and Canada Mortgage and Housing Corporation (CMHC), has resulted in an optimization tool that can analyze the most energy optimal and cost effective building enclosure retrofit combinations for a single-family homes in Yukon. The energy modelling is based on the previously presented archetype house located in Whitehorse, Yukon. The archetype house uses approximately 164 gigajoules (GJ) of energy per year as a base case scenario.

Over 1,000 building enclosure energy upgrade options were modelled, including new windows, improved airtghtness, and increased insulation levels, in order to determine the optimal retrofit strategies. Construction design, material availability, local utility rates, energy efficiency, and material and labour costs were all considered during the modelling process. Important output metrics from the optimization process include the following energy retrofit packages:

- **Homeowner-Led Retrofit**
- **Window Upgrade and Air Sealing Retrofit**
- **Medium Energy Retrofit**
- **Deep Energy Retrofit**

The figure below identifies the location of the various upgrade options relative to the base case scenario (existing house) at the XY axis intercept where each point represents one of the potential retrofit packages with an associated energy and cost savings. Data points have also been included to represent homes that meet current National Building Code requirements and the Whitehorse Green Building Standard. The following tables and graphics present the combinations of components and assemblies for the identified energy retrofit packages as compared to the base case home. The individual energy efficiency retrofits are detailed later in this guide.

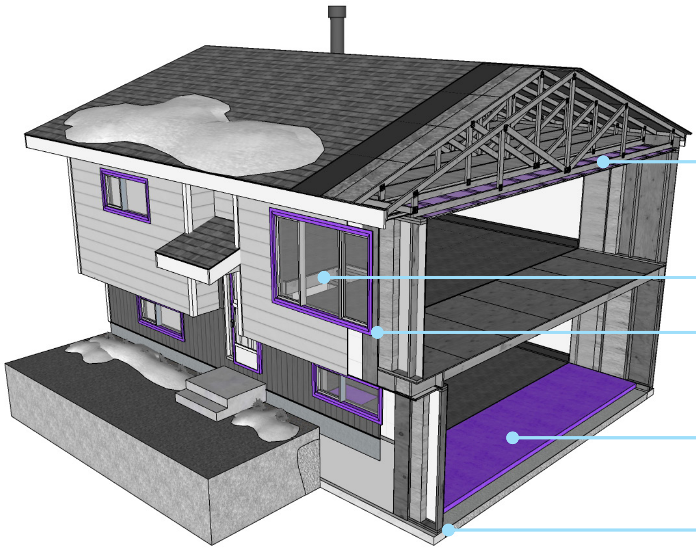


	Homeowner-Led Retrofit	Simple air sealing work
	Window Upgrade and Air Sealing	Window replacement and simple air sealing work
	Medium Energy Retrofit	Window replacement and moderate insulation and air sealing work
	Deep Energy Retrofit	Window replacement and significant insulation and air sealing work
	2015 National Building Code (Section 9.36)	Prescriptive Code requirements met
	Whitehorse Green Building Standard	Prescriptive Code requirements met

Annual Cost Savings = Annual Savings on Energy Bills - Annual Payments on Principal and Interest (25 year amortization period, 3.5% interest rate)

Homeowner-Led Retrofit

Air Sealing - Complete simple air sealing work in accessible areas of the home. Air sealing activities include sealing large holes and penetrations in the attic and basement and replacing the weatherstripping at existing windows and doors.



Base Case Building vs. Homeowner-Led Retrofit Package

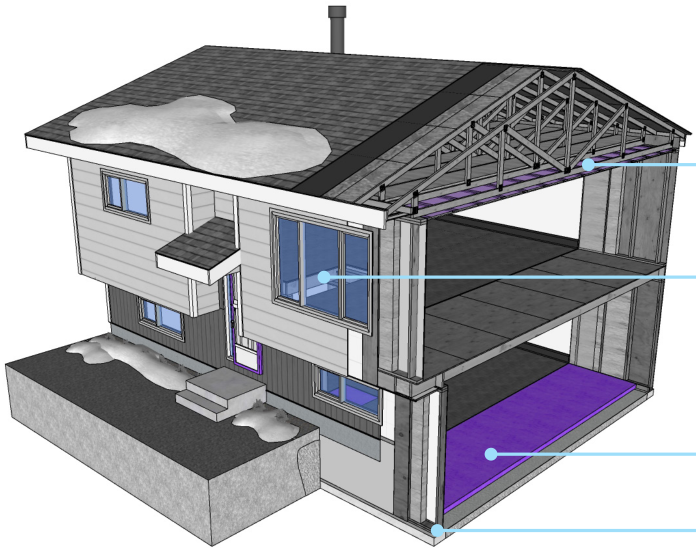
Category	Base Case	Homeowner-Led Retrofit
Airtightness*	8.17 ACH (air changes per hour)	**5.0 ACH** (air changes per hour)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI 5.5 (R-31)	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI 5.5 (R-31)
Exposed Floor	2x10 joists @ 406mm (16") O.C. with batt insulation, RSI 4.0 (R-23)	2x10 joists @ 406mm (16") O.C. with batt insulation, RSI 4.0 (R-23)
Basement Slab	Uninsulated concrete slab	Uninsulated concrete slab
Above-Grade Wall	2x4 wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)	2x4 wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)
Foundations	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)
Casement Windows	Double-glazed, clear, air fill, USI-2.94 (U-0.52), SHGC 0.60	Double-glazed, clear, air fill, USI-2.94 (U 0.52), SHGC 0.60
Furnace	Oil, 83% efficient	Oil, 83% efficient
Domestic Hot Water	Electric, 82% efficient, conventional tank	Electric, 82% efficient, conventional tank
Annual Energy Savings	0 GJ, 0%	**31 GJ, 19%**
Annual Cost Savings**	$0	**$969** (3.5% interest rate, 25 yr amortization)

* Refer to *Best Practice Guide - Air Sealing and Insulation Retrofits for Single Family Homes, 2nd Edition* for guidance on homeowner air sealing retrofits. Available at www.bchousing.org

** Annual Cost Savings = Annual Savings on Energy Bills - Annual Payments on Principal and Interest (25 year amortization period, 3.5% interest rate)

Window Upgrade and Air Sealing Retrofit

Window Upgrades - Replace the existing windows with thermally improved windows complete with new installation details. **Air Sealing -** Complete simple air sealing work in accessible areas of the home. Air sealing activities include sealing large holes and penetrations in the attic and basement.



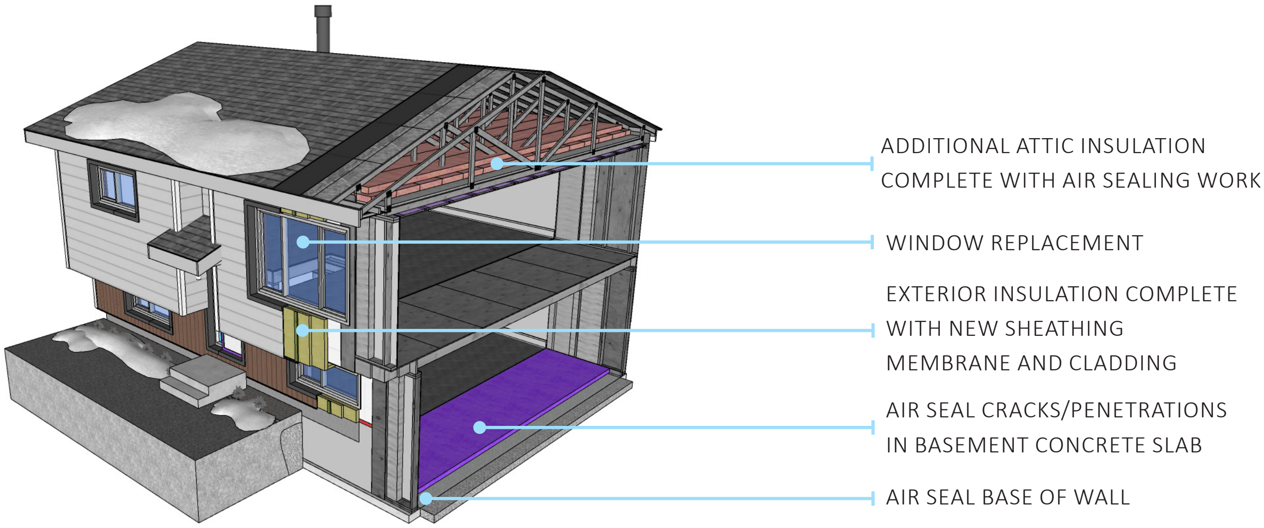
Base Case Building vs. Window Upgrade and Air Sealing Retrofit

Category	Base Case	Window Upgrade and Air Sealing Retrofit
Airtightness*	8.17 ACH (air changes per hour)	**4.0 ACH** (air changes per hour)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI 5.5 (R-31)	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI 5.5 (R-31)
Exposed Floor	2x10 joists @ 406mm (16") O.C. with batt insulation, RSI 4.0 (R-23)	2x10 joists @ 406mm (16") O.C. with batt insulation, RSI 4.0 (R-23)
Basement Slab	Uninsulated concrete slab	Uninsulated concrete slab
Above-Grade Wall	2x4 wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)	2x4 wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)
Foundations	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)
Casement Windows**	Double-glazed, clear, air fill, USI-2.94 (U-0.52), SHGC 0.60	**Triple-glazed, 1 low-e, argon gas fill, USI-1.17 (U-0.21), SHGC 0.28**
Furnace	Oil, 83% efficient	Oil, 83% efficient
Domestic Hot Water	Electric, 82% efficient, conventional tank	Electric, 82% efficient, conventional tank
Annual Energy Savings	0 GJ, 0%	**51 GJ, 31%**
Annual Cost Savings***	$0	**$889** (3.5% interest rate, 25 yr amortization)

* Refer to *Best Practice Guide - Air Sealing and Insulation Retrofits for Single Family Homes, 2nd Edition* for guidance on homeowner air sealing retrofits. Available at www.bchousing.org
***Best Practices for Window and Door Replacement in Wood-Frame Buildings. Available* at www.bchousing.org
*** Annual Cost Savings = Annual Savings on Energy Bills - Annual Payments on Principal and Interest (25 year amortization period, 3.5% interest rate)

Medium Energy Retrofit

Additional Insulation Above Grade - On the above-grade walls, remove the cladding and building paper and repair the existing sheathing and framing as necessary. Install a new sheathing membrane, exterior insulation, and cladding. Add additional insulation in the attic space. **Window Upgrades -** Replace the existing windows with thermally improved windows complete with new installation details. **Air Sealing -** Complete simple air sealing work in accessible areas of the home.



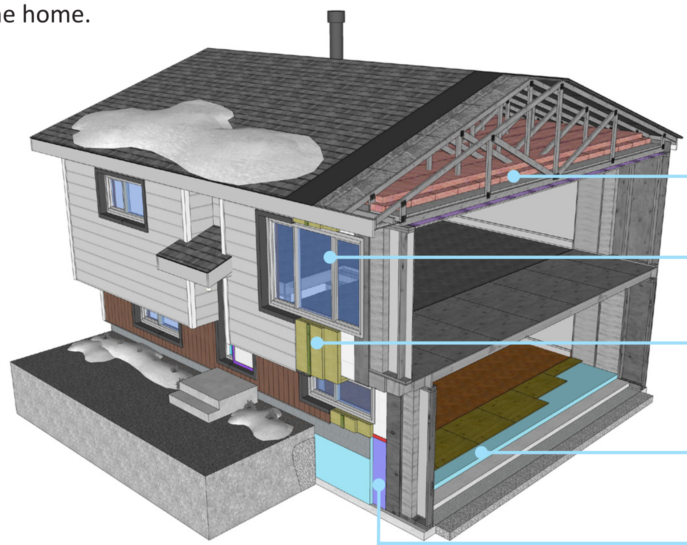
Base Case Building vs. Medium Energy Retrofit

Category	Base Case	Medium Energy Retrofit
Airtightness*	8.17 ACH (air changes per hour)	**3.0 ACH** (air changes per hour)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI 5.5 (R-31)	v
Exposed Floor	2x10 joists @ 406mm (16") O.C. with batt insulation, RSI 4.0 (R-23)	2x10 joists @ 406mm (16") O.C. with batt insulation, **new 102mm (4") exterior insulation, RSI 6.5 (R-37)**
Basement Slab	Uninsulated concrete slab	Uninsulated concrete slab
Above-Grade Wall	2x4 wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)	2x4 wood stud @ 406mm (16") O.C. with batt insulation, **new 102mm (4") exterior insulation, RSI 4.9 (R-28)**
Foundations	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)
Casement Windows	Double-glazed, clear, air fill, USI-2.94 (U-0.52), SHGC 0.60	**Triple-glazed, 1 low-e, argon gas fill, USI-1.17 (U-0.21), SHGC 0.28**
Furnace	Oil, 83% efficient	Oil, 83% efficient
Domestic Hot Water	Electric, 82% efficient, conventional tank	Electric, 82% efficient, conventional tank
Annual Energy Savings	0 GJ, 0%	**74 GJ, 45%**
Annual Cost Savings**	$0	**$1,230** (3.5% interest rate, 25 yr amortization)

* Refer to *Best Practice Guide - Air Sealing and Insulation Retrofits for Single Family Homes, 2nd Edition* for guidance on homeowner air sealing retrofits. Available at www.bchousing.org
** Annual Cost Savings = Annual Savings on Energy Bills - Annual Payments on Principal and Interest (25 year amortization period, 3.5% interest rate)

Deep Energy Retrofit

Additional Insulation Below Grade - Excavate the perimeter of the building and install a new moisture barrier and insulation. Air seal the concrete slab and install insulation. **Additional Insulation Above Grade -** On the above-grade walls, remove the cladding and building paper and repair the existing sheathing and framing as necessary. Install a new sheathing membrane, exterior insulation, and cladding. Add additional insulation in the attic space. **Window Upgrades -** Replace the existing windows with thermally improved windows complete with new installation details. **Air Sealing -** Complete simple air sealing work in accessible areas of the home.



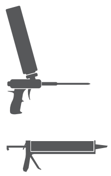
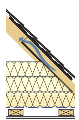
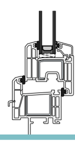
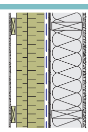
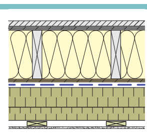
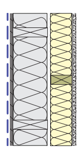
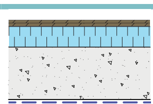
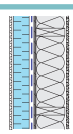
Base Case Building vs. Deep Energy Retrofit

Category	Base Case	Deep Energy Retrofit
Airtightness*	8.17 ACH (air changes per hour)	**1.0 ACH** (air changes per hour)
Attic	Raised heel truss @ 610mm (24") O.C. with batt insulation, RSI 5.5 (R-31)	Raised heel truss @ 610mm (24") O.C. with **additional batt insulation, RSI 15.7 (R-89)**
Exposed Floor	2x10 joists @ 406mm (16") O.C. with batt insulation, RSI 4.0 (R-23)	2x10 joists @ 406mm (16") O.C. with batt insulation, **new 254mm (10") exterior insulation, RSI 10.2 (R-58)**
Basement Slab	Uninsulated concrete slab	Concrete slab, **new 102mm (4") interior XPS insulation, RSI-3.5 (R-20)**
Above-Grade Wall	2x4 wood stud @ 406mm (16") O.C. with batt insulation, RSI 2.2 (R-12)	2x4 wood stud @ 406mm (16") O.C. with batt insulation, **new 254mm (10") exterior insulation, RSI 8.6 (R-49)**
Foundations	2X6 PWF @ 406mm (16") O.C. with batt insulation, RSI 2.7 (R-15)	2X6 PWF @ 406mm (16") O.C. with batt insulation, **new 102mm (4") exterior XPS insulation, RSI 6.2 (R-35)**
Casement Windows	Double-glazed, clear, air fill, USI-2.94 (U-0.52), SHGC 0.60	**Quad-glazed, 2 low-e, argon gas fill, USI-0.88 (U-0.15), SHGC 0.18**
Furnace	Oil, 83% efficient	Oil, 83% efficient
Domestic Hot Water	Electric, 82% efficient, conventional tank	Electric, 82% efficient, conventional tank
Annual Energy Savings	0 GJ, 0%	**104 GJ, 63%**
Annual Cost Savings**	$0	**$402**

* Refer to *Best Practice Guide - Air Sealing and Insulation Retrofits for Single Family Homes, 2nd Edition* for guidance on homeowner air sealing retrofits. Available at www.bchousing.org
** Annual Cost Savings = Annual Savings on Energy Bills - Annual Payments on Principal and Interest (25 year amortization period, 3.5% interest rate)

How to Prioritize Retrofit Activities

Least Comprehensive & Least Costly

Air Sealing (Interior/ Exterior)		Air seal with spray foam, tapes, membranes and sealant throughout the home. Sealing all the large holes in the house will have the largest effect. Service penetrations not intended for airflow or venting should be sealed where possible. Consider replacing the weatherstripping on windows and doors. Air sealing can improve the thermal comfort of the home, and decrease heating costs. For further information on homeowner air sealing techniques refer to *Best Practice Guide - Air Sealing and Insulation Retrofits for Single Family Homes*, published by BC Housing*.
Accessible Attic (Interior/ Exterior)		Air seal from within the attic space and install additional batt or loose blown insulation.
Windows and Doors (Exterior)		Remove existing windows and replace with high-performance triple-glazed or quad-glazed windows. Install windows according to best practices and over-insulate frames where possible. For further info refer to *Best Practices for Window and Door Replacement in Wood-Frame Buildings*, published by the Fenestration Association of BC and BC Housing**.
Above-Grade Walls (Exterior)		Remove existing cladding and building paper. Repair the existing sheathing and framing as necessary. Install new sheathing membrane and detail as the air barrier. Install exterior insulation with new strapping and exterior cladding.
Exposed Floors (Exterior)		Remove existing soffit material. Repair the existing framing and install new sheathing. Install new sheathing membrane and detail as the air barrier. Install exterior insulation with new strapping and vented soffit panels.
Unfinished Below-Grade Walls (Interior)		Remove the existing basement interior finishes and polyethylene vapour retarder. Repair/ replace existing framing and batts as necessary. Install an additional insulated stud wall on the interior side of the existing PWF wall complete with a new smart vapour retarder. This approach is less durable than adding exterior insulation to the foundation wall; however, this retrofit is significantly easier to execute.
Unfinished Floor Slab (Interior)		Install rigid insulation on the interior surface of the floor slab complete with sealed board joints. Above the insulation, install a new subfloor (plywood and sheathing) and flooring. Finished basements will require additional work and cost.
Below-Grade Walls (Exterior)		Excavate around existing PWF walls and remove any existing waterproofing, drainage mat, and protection board. Install new waterproofing, rigid insulation, drainage mat, and protection board.

Most Comprehensive & Most Costly

* *Best Practice Guide - Air Sealing and Insulation Retrofits for Single Family Homes, 2nd Edition*. Available at www.bchousing.org

** *Best Practices for Window and Door Replacement in Wood-Frame Buildings.* Available at www.bchousing.org

Financial Considerations

Homeowners typically have several potential home retrofit packages available to choose from. Retrofits can involve relatively small amounts of work and cost (e.g., minor air sealing work) or more costly and complex work (e.g., below-grade retrofits). There are also many options for homeowners when it comes to financing home retrofits. Some retrofit packages have higher upfront costs, but will also result in larger annual utility cost savings as compared to simpler, cheaper retrofits like minor air sealing improvements. It is important for homeowners to understand the financial implications of different retrofit options before proceeding with the workThis can be accomplished by way of a simple cost optimization calculation to review value of the energy savings as compared to the retrofit project costs. Homeowners should also consider that there are several ancillary benefits associated with more comprehensive retrofit programs including improved enclosure durability and thermal comfort some which may not be possible to easily quantify.

The annual cost savings for the four home retrofit packages (shown on the previous pages) were determined by comparing the annual utility bill savings and the annual loan servicing cost of each retrofit package. The calculated annual cost savings assumes the homeowner has taken out a loan with an interest rate of 3.5% and a loan amortization period of 25 years in order to pay for the rerofit package.

Annual utility bill savings were calculated based on the modeled amount of energy saved due to the completed home retrofits, multiplied by the local utility rates (i.e. cost of 1 Kwh of electricity or 1L of heating oil). The annual loan servicing of the retrofit package is the yearly loan payment the homeowner must make to a bank or other lending institution (to pay off the loan they took for the retrofit work). The monthly cost savings can be found by taking the monthly energy savings minus monthly annuity payments (annual loan payments divided over 12 months). The value of annual loan payments was calculated using the formula shown below:

$$\text{Annuity} = p \cdot (i/(1-(1+i)^{-n}))$$

Definitions

- **Annuity:** An annuity is a series of payments made at equal intervals, for example regular payments on a bank loan. Annuities can be classified by the frequency of payment dates. The payments (deposits) may be made weekly, monthly, quarterly, yearly, or at any other regular interval of time.
- **P (Principal):** Initial size of a loan or the cost of the retrofit.
- **i (Interest Rate):** The proportion of a loan that is charged as interest to the borrower, typically expressed as an annual percentage of the loan outstanding. An interest rate of 3.5% is assumed for all calculations in this guide.
- **n (Amortization Period):** The amortization period is the total length of time it takes to pay off a loan, usually months or years. An amortization period of 25 years is assumed for all calculations in this guide.

5.0 Building Science Considerations

Building Science Primer

The building enclosure is a system of assemblies, made up 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 the movement of liquid water, air, heat, water vapour, sound, light and fire.

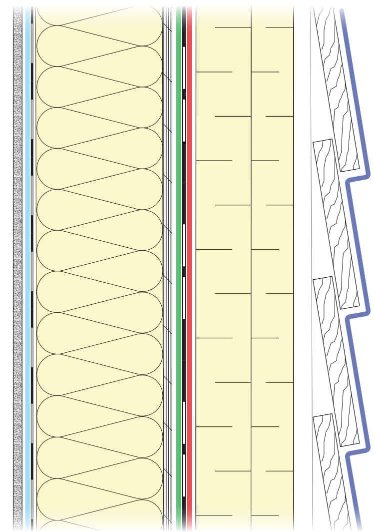
The **water-shedding surface (WSS)** refers to the outer surface of assemblies, interfaces, and details that deflect or drain the vast majority of exterior water that contacts the assembly. For wall assemblies, the water-shedding element is the cladding, which can be wood siding, vinyl, masonry veneer, or a variety of other materials. For windows, the WSS is a combination of the outer portion of the frame, exterior gaskets, glazing tape, and/or sealant, and the insulating glass unit. For roofs, it is the shingles, metal roofing, or membrane.

The **water-resistive barrier (WRB)** is the surface farthest from the exterior that can accommodate moisture without incurring damage to interior finishes or materials within the assembly. It is not always easy to identify this barrier since some surfaces can accommodate small amounts of moisture for limited periods of time without damage, while larger quantities of water or longer exposure to moisture will lead to premature deterioration or migration of moisture further into the assembly. For many wall assemblies, the WRB is the sheathing membrane in combination with membrane flashings and sealants at penetrations.

The **air barrier (AB)** controls the flow of air through the building enclosure, either inward or outward. Airflow has a significant impact on space conditioning costs, condensation control, and rain water penetration control. Air barriers should be installed with the focus on creating the best air seal by installing a consistently continuous air barrier. For most window frames, the air barrier (and WRB) is likely the interior portion of frame members in combination with gaskets, glazing tape and/or sealants that are not directly exposed to the exterior. Note that the glazing in windows acts as a WSS, WRB, and air barrier. This illustrates the point that specific materials within an assembly may perform several critical barrier functions.

A **vapour retarder (VR) (also known as the vapour barrier)** is another critical barrier, and often consists of sheet polyethylene located behind the interior gypsum board. Drywall painted with latex based primer and paints can also act as a vapour retarder. The vapour retarder limits the flow of water vapour through materials and is important with respect to condensation control.

Smart vapour retarders are becoming more common in place of traditional sheet polyethylene as their permeance varies based on the humidity. This allows for the wall or roof assembly to dry inwards if subject to incidental moisture.



Location of Critical Barriers (after completing an exterior retrofit)
Shown in a Split-Insulated Wall Assembly

- **Water-Shedding Surface (WSS)**- Cladding
- **Thermal Insulation** - Semi-rigid or rigid and batt insulation
- **Water-Resistive Barrier (WRB)**- Sheathing membrane
- **Air Barrier (AB)** - Sheathing membrane
- **Vapour Retarder (VR)**- Polyethylene sheet

The **thermal insulation** primarily controls conductive heat flow out of the building, a significant aspect of the thermal performance and energy efficiency of the building enclosure. Insulation must be considered together with the vapour permeability of various materials in the assembly in order to control condensation.

In addition to critical barriers, the shape and configuration of a building can also help protect enclosure assemblies from exposure to water. **The use of roof eaves and projections at entrances is strongly recommended.** For exterior doors, a 1:2 overhang ratio (overhang projection : door height) typically provides adequate protection.

Retrofit-Specific Considerations

Before beginning any retrofit project, it is important to carefully review the existing building enclosure assemblies and components in order to establish their condition. Any existing components that have experienced moisture-related or other damage (including batt insulation, wood studs, sheathing, and roof trusses) should be repaired or replaced prior to completing the energy retrofit upgrades. Interior air quality and moisture problems (high levels of radon, humidity, roof leaks, etc.) require correction and undersized and/or poorly functioning mechanical systems must be repaired or replaced before commencing an enclosure retrofit. Additionally, a thorough investigation of the existing building condition may indicate that some retrofit activities will be prohibitively expensive or challenging to complete. This may allow a limited energy upgrade budget to be targeted at more effective retrofits.

In many cases, the scope of the retrofit package will determine what existing components get removed or replaced during the course of the upgrade work. Typically, the existing wall assemblies will include building paper, stud cavity insulation, and a polyethylene sheet vapour retarder. If the energy retrofit package requires removing the cladding or, alternatively, the interior finishes, it may be possible to upgrade membranes or insulation at the same time such that the overall durability of the assembly is improved. Exterior insulation upgrades and other more comprehensive energy retrofits often provide an opportunity for these ancillary improvements to be made to the building enclosure.

Fungal growth and decay present within attic space requires remediation before undergoing a retrofit. The moisture source must be identified and dealt with and any damaged sheathing and structural framing must be repaired.

Damaged sheathing due to failure of existing building paper or condensation due to air leakage around windows. Sheathing must be repaired before undergoing a retrofit.

Material Selection

The following four factors should always be considered in material selection. As with all products, consult the manufacturer's instructions for products, and consult with appropriate design professionals and building authorities regarding issues of material selection and Code compliance.

Durability

Durability refers to long-term performance of the material in service under expected operating conditions, and the robustness of the material as it is installed and while it is exposed during construction before being covered or protected with finishes.

Damage to materials can result from wind pressure, abrasion, heat, moisture, and ultra-violet radiation. This is significant when the material is left exposed during construction prior to the installation of exterior finishes. Exposed materials should be protected from the elements as soon as possible or be robust enough to withstand damage and degradation while exposed. Building enclosure materials with no resistance to exposure must only be installed in fully-enclosed buildings.

Many materials available in the South may not be suitable for northern climates. For example, some vinyl sidings, tapes, and membranes may become brittle and fail when exposed to extreme low temperatures. Care must be taken to ensure that all construction materials will function as intended when utilized in a northern context.

Compatibility

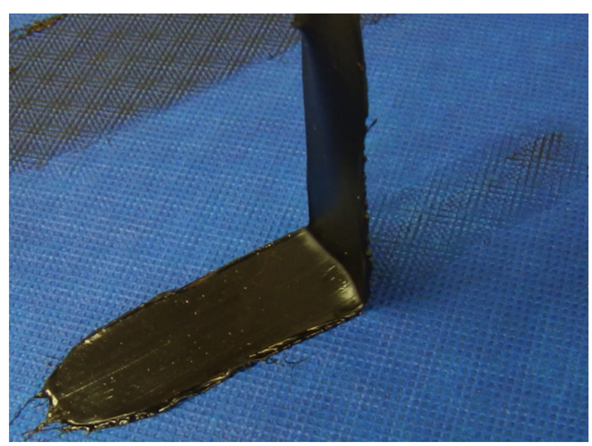
Material compatibility refers to chemical compatibility between materials to avoid premature degradation of interfacing components, as well as substrate and bond compatibility. For example, bituminous membranes are not compatible with a number of common roofing and flashing materials such as PVC membranes, asphaltic polyurethanes, and silicones. This chemical incompatibility can result in plasticizer migration, where the chemical plasticizers from one material (for example PVC) move to another material through direct contact. The result is damage to or potential failure of either or both materials. CMHC has a freely available research report on ***"Incompatible Building Materials"*** that provides extensive information on building material incompatibilities.

Adhesion

It is difficult to establish good adhesion between silicone or urethane sealants and synthetic sheathing membrane materials, such as polyethylene or spun-bonded polyolefin products. Where possible, a transition membrane, such as foil-faced self-adhered membrane, or specialized sealant products designed specifically for adhesion to synthetic materials are recommended. Refer to the product manufacturer's literature for compatibility guidelines, or consider completing preliminary mock-ups or material testing to ensure chemical and adhesive compatibility before using a specific combination of materials.

Damage to brittle vinyl cladding during extreme cold

Signs of plasticizer migration from a self-adhered membrane through to the PVC-based liquid-applied membrane.



Sealant adhesion test showing adhesive failure from a synthetic vapour-permeable self-adhered membrane.

Non-Adhered Vapour Permeable Sheathing Membranes

Non-adhered vapour permeable sheathing membranes also known as house wraps rely on a system of tapes and sealants for sealing laps and penetrations. These products are highly vapour permeable allowing for outward drying if the wood sheathing is wetted during construction or in-service. The lap and penetration seals are critical for maintaining a continuous air barrier. Fastenings (typically staples or capped nails) are necessary to resist wind/building pressure loads such that damage and/or air barrier discontinuities are avoided.

Example products (trademark symbols omitted throughout this section for ease of viewing):

- DuPont Tyvek Home Wrap
- DuPont Tyvek DrainWrap
- VaproShield WrapShield
- Dorken DELTA-VENT S
- SIGA Majvest
- SRP AirOutshield WALL
- TYPAR HouseWrap and Metrowrap
- NovaWrap GP Building Wrap

DuPont Tyvek Home Wrap

Dorken DELTA-VENTS

SIGA Majvest

Self-Adhered Vapour Permeable Sheathing Membranes

Self-adhered vapour permeable membranes (SAMs) are bonded directly to the sheathing and generally result in a more robust installation than non-adhered membranes. They also have self-sealing properties, reducing the risk of water ingress at fastener penetrations. As such, they are highly recommended when considering an exterior insulation retrofit. Similarly, to non-adhered sheathing membranes, these products are vapour permeable allowing for outward drying if the wood sheathing is wetted during construction or in-service. Most products include an aggressive acrylic adhesive that allows them to adhere to most substrates without the need for primers; however, some products still require the use of primer on the substrate and at laps to promote adhesion, especially when installed at cold temperatures. Application of primers should be considered in sequencing and constructability. While the membrane materials are not inherently more air tight than non-adhered sheathing membranes, the improved durability of the membrane installation typically results in a more airtight building.

Example products:

- SOPREMA SOPRASEAL STICK VP
- VaproShield WrapShield SA
- Dorken DELTA-VENT SA
- SIGA Majvest 500 SA
- SRP AirOutshield SA 280
- 3M 3015 VP
- Henry Blueskin VP160
- RESISTO REDZONE STICK VP


SOPREMA SOPRASEAL STICK VP

3M 3015 VP


RESISTO REDZONE STICK VP

Liquid-Applied Membranes

Liquid-applied sheathing membranes can be effective once cured and in service; however, they are often very sensitive to moisture during installation and cannot be easily installed during wet and/or cold weather. They usually have minimum operational and application temperatures and typically must be used with compatible membrane tapes or sealants as part of a product system. Additionally, the physical properties of liquid-applied membranes are highly dependent on thickness: membrane installations must always be reviewed to ensure that the membrane thickness is consistent with the manufacturers requirements. Given the temperature extremes present in the North, sheet based products are typically recommended over liquid-applied membranes.

Example products:

- GE Elemax 2600 AWB
- DOWSIL DEFENDAIR 200
- DOW LIQUIDARMOUR CM and LT
- Tremco ExoAir 220 and 230
- DuPont Tyvek Fluid Applied WB+
- Prosoco Cat 5

Liquid-applied membrane frozen due to extreme cold

Self-Adhered Flashing Membranes

Air and water control membrane systems require suitable vapour impermeable flashing membranes to maintain air and moisture barrier continuity. Flashing membranes play an important role in the systems' performance at details and penetrations. Butyl and rubberized asphalt membrane products with polyethylene facers are commonly used for rough-opening preparation, as through-wall flashing membranes, for roof-to-wall transitions, and for above-grade to below-grade transitions. They offer robust waterproofing for surfaces that may be exposed to standing water, and can also act as transition material for other adhered products like coatings and sealants. Note that most bituminous flashing membranes require the substrate (plywood, OSB, concrete, etc.) to be primed prior to application. In many cases a primer specifically intended for cold weather applications is required.

Example products:

- Henry Blueskin SA
- SOPREMA SOPRASEAL STICK 1100T
- RESISTO REDZONE PRO
- Protecto Wrap PS 45 Butyl
- GCP Perm-A-Barrier

Tapes

Durable building tapes with high-quality acrylic adhesive should be used where possible. Some products come with a silicone release film for unrolling the spool easier and allow for potentially longer continuous tape seals as the film protects the adhesive until it is set in place. Note that most sheathing tapes are not considered permeable unless explicitly noted by the manufacturer.

Example products:

- Tuck Tape Construction Grade Sheathing Tape
- DuPont Tyvek Seam Tape
- Dow Weathermate Construction Tape
- SIGA Wigluv, Rissan, and Fentrim
- 3M All Weather Flashing Tap
- Owens Corning JointSealR Foam Joint Tape
- Soprema Sopraseal Stick Flashpro HT
- Rothoblaas "Band" product line

Interior Sheet Vapour Retarders

6-mil polyethylene sheet is typically installed to resist the movement of vapour into enclosure assemblies and if taped and sealed can also be used as part of an air barrier system. Proprietary smart vapour retarders (i.e. CertainTeed MemBrain) are available that allow for some amount of interior drying and are recommended if the exterior insulation to be installed has a low vapour permeance.

Sealants

The only sealant types that should be used for exterior retrofits are neutral-cure silicone, polyurethane, and/or hybrid chemistries. Other common sealants such as acrylic latex and acoustical are not suitable for exterior enclosure purposes. Note that most sealants have operational and installation temperature ranges: exposure to temperatures outside this range during installation or in service can result in sealant failure.

Tooling is critical for achieving the proper sealant joint design. Most sealants allow at least some amount of tooling after they are initially installed to smooth the profile, and ensure to the substrate is fully coated for the depth and width of the sealant joint. The sealant gun tip can be used to tool the sealant in some circumstances as shown in the images below. Note that sealant tooling is typically more difficult at cold temperatures or if the incorrect tools and/or product is used for a given application. Refer to the manufacturer's literature for correct installation procedures and operating temperatures. When the installer is not confident in a selected sealant's compatibility with the substrate being applied to, an adhesive pull test should be completed.

Example of installation with simultaneous tooling of sealant at window perimeter interface.

Silicone Sealants: Silicones sealants, specifically neutral-cure silicones, are typically the best sealant type for exterior use. Silicones are generally longer lasting with less incompatibility issues than other sealant types and also UV stable and typically perform well at temperature extremes. Adhesion to low-energy surfaces including the plastic facers of many common membrane products can be challenging and may require a specifically formulated silicone, such as DOWSIL 758 by DOW (DOWSIL 758 also adheres well to vinyl window frames and is therefore ideal for sealing window perimeters). Acid-cure silicone sealants, identified by the strong odour they emit during curing, should be avoided as the acid emitted during curing can cause premature degradation of adjacent building materials.

Polyurethane and Hybrid Sealants: Polyurethane sealants have many of the same uses as silicone, but may achieve greater adhesion on a wider variety of substrates though like silicones some plastic surfaces are difficult to adhere to. The application of polyurethane sealants can be more versatile as they can be paintable and and can be easier to install. The primary challenge with polyurethanes is that they are not UV stable and degrade over time in many exterior applications. Hybrid sealants combine some of the properties of both silicones and polyurethanes and may be appropriate for many of the same applications as other high performance sealants; however, due to variations in the compounds used, their performance and compatibility can be less predictable. Guidance on their use cannot be confidently provided without reviewing the manufacturer's product literature. Polyurethane and hybrid sealants do not stick well to polyethylene materials and films and debond once cured. Polyurethanes are also incompatible with bituminous materials, such as those used in some self-adhered flashing membranes, and will degrade if in contact.

Acoustical Sealants: Acoustical sealants are intended for interior use and in particularly sealing laps and terminations of the interior polyethylene sheet vapour retarder. In general, given that they are fully encapsulated inside the wall and are formulated to remain uncured (i.e. sticky) throughout their life-cycle, product selection is generally straightforward.

Exterior Insulation

There are numerous types of insulation and manufacturers to choose from and each manufacturer can provide technical data for their proprietary formulation.

Exterior Insulation Permeability

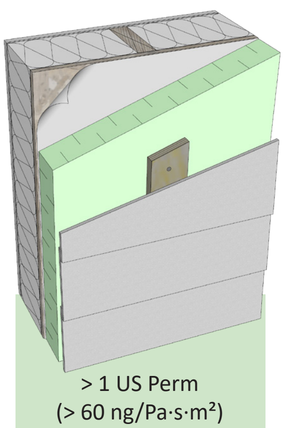
A variety of insulation types can potentially be used in wall assemblies with exterior insulation. The insulation can be divided into two categories depending on it's level of vapour permeance:

1. **Vapour-permeable insulations** (greater than 1 US Perm) such as semi-rigid or rigid mineral wool, semi-rigid fibreglass, wood fibre and cellulose insulation within an exterior Larson Truss cavity.
2. **Relatively vapour-impermeable insulations** (less than 1 US Perm) 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 retarder (i.e. polyethylene sheet) the dual vapour retarders can trap moisture that inadvertently enters the assembly and can potentially lead to concealed fungal growth and decay. The thickness of the insulation affects the permeance as well and must be taken into account.

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

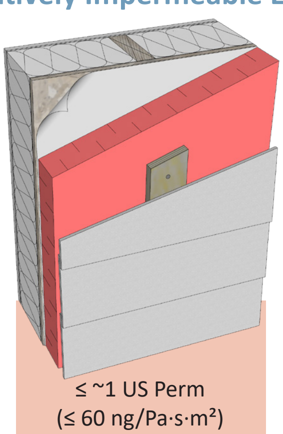
Permeable Exterior Insulation



Insulation retrofits with vapour-permeable exterior insulation over an existing wall assembly containing an interior vapour retarder are low risk for moisture issues. Vapour-permeable exterior insulation allows the assembly to dry to the exterior if moisture accumulates. Note that if the insulation vapour permeance is close to the Code-specified limit, than the thickness of the exterior insulation will need to be carefully considered.

Typical permeable insulation types are discussed on page 30.

Relatively Impermeable Exterior Insulation



Insulation retrofits using vapour-impermeable exterior insulation over an existing wall assembly containing an interior vapour retarder can be high risk for moisture issues. The resulting assembly contains two impermeable layers. The "new" impermeable exterior insulation and the existing interior vapour retarder (polyethylene sheet) can trap moisture within the stud cavity. The trapped moisture and the inability of the assembly to dry in either direction (outwards or inwards) can lead to an increased risk of premature decay within the assembly.

However, impermeable exterior insulation can be used for insulation retrofits if more than 2/3 of the wall's effective R-value is contributed by the exterior insulation. With an appropriate ratio of exterior to interior insulation, the sheathing will be above the interior air dew point and condensation risk within the framing cavity will be less of a concern.

Typical impermeable insulation types are discussed on page 31.

The following table includes the typical vapour permeance of different insulation materials at thickness up to 8 inches.

Approximate Dry Cup Permeance of Typical Exterior Insulation Types (US Perms)

	1"	2"	3"	4"	5"	6"	7"	8"
XPS	0.9	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Closed Cell Spray Foam	1.7	0.9	0.6	0.4	0.3	0.3	0.2	0.2
Polyiso with Paper Facer	2	1	0.7	0.6	0.4	0.4	0.3	0.3
Polyiso with Foil Facer	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Unfaced EPS	3.5	1.8	1.2	0.9	0.7	0.6	0.5	0.4
Open Cell Spray Foam	60.2	30.1	20.1	15.1	12	10	8.6	7.5
Rigid Mineral Wool	88.8	49.5	29.6	22.2	17.8	14.8	12.7	11.1
Cellulose	92.3	46.1	30.8	23.1	18.5	15.4	13.2	11.5
Rigid Fiberglass	145.1	72.5	48.4	36.3	29	24.2	20.7	18.1

Insulation Ratios

When impermeable exterior insulation is used, the ratio of new insulation outboard of the sheathing to existing insulation in the stud cavity should be carefully considered so as to maintain the temperature of the sheathing at relatively safe levels (above the dew point), which will prevent condensation. Additionally, while not explicitly required by the Building Code, a relatively more permeable interior vapour retarder such as a smart vapour retarder or vapour retarder paint can sometimes be used to permit some amount of inward drying. In retrofit applications, a vapour-permeable exterior insulation is typically recommended as the existing polyethylene sheet vapour retarder usually remains in place.

Exterior Insulation and Window Bucks

Deep exterior insulation retrofits can make window detailing significantly more complex. After the exterior insulation is added, the cladding may be located several inches away from the wall sheathing. This may require that long flashing or trim returns be installed at the perimeter of all window rough openings, which can greatly increase the difficulty of the retrofit. An alternative approach is to install a plywood buck-out at rough openings that extends to the outer plane of the exterior insulation. In this way, the window can be located in the same plane as the outer layer of insulation such that the flashing and trim details are greatly simplified and more similar to traditional window detailing practices.

Permeable Insulation Types, Properties, and Acceptable Uses

Type	Properties	Acceptable Uses	Considerations
Open Cell Spray Foam 	R-value per inch *(R-values for all insulation types are reported at 24 ⁰C mean temperature with a 10 ⁰C temperature differential)* 3.2 to 3.8 Density 0.4 to 1.2 lb/ft³	• Cavity insulation • Air sealing penetrations	• Open cell spray foam is installer dependent and should be reviewed to ensure continuity of the installation • An interior vapour retarder is typically required when used as cavity insulation • Combustible
Mineral Wool 	R-value per inch 3.7 to 4.2 Density 1.8 lb/ft³ (Loose) >2.0 lb/ft³ (Batt) >4.3 lb/ft³ (Semi-Rigid) >11 lb/ft³ (Rigid)	• Cavity insulation • Above grade exterior insulation (semi-rigid & rigid as required for cladding attachment, see Long Screw Cladding Attachment section) • Attic insulation • Low-sloped roof insulation	• Non-combustible insulation - can be used as part of fire separation systems • A range of densities available for suitable applications • Will deteriorate after prolonged UV exposure
Cellulose 	R-value per inch 3.5 (Loose) 4.0 (Dense Pack) Density 1.5 to 2.0 lb/ft³ (Loose)	• Attic insulation • Densely packed cellulose insulation can be installed in roof and wall framing cavities	• Must be protected from moisture. Once wetted it is difficult to dry and susceptible to mold growth • Cellulose thermal performance is highly dependent on installation density • Combustible
Fiberglass 	R-value per inch 3.6 to 4.2 Density 0.5 to 1.0 lb/ft³	• Cavity insulation • Attic insulation	• Once wetted it is difficult to dry • Ensure batt joints are staggered when installing multiple layers of insulation • Non-combustible but kraft facers may be combustible

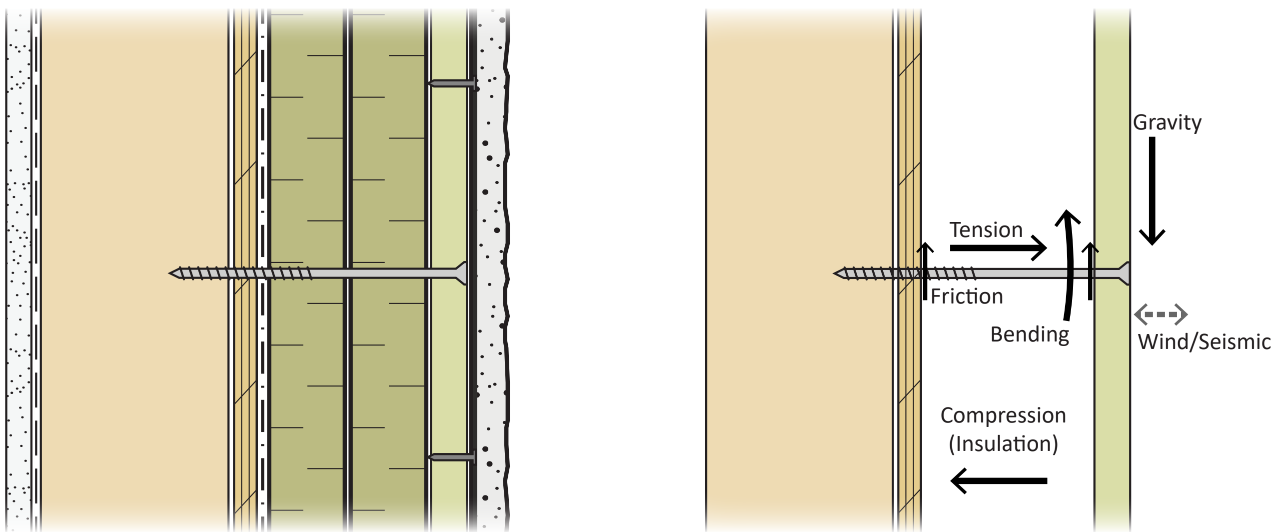
Relatively Impermeable Insulation Types, Properties, and Acceptable Uses

Type	Properties	Acceptable Uses	Considerations
Extruded Polystyrene (XPS) 	R-value per inch 4.7 to 5.0 Density 2.4 to 2.8 lb/ft^3	• Below-grade exterior insulation • Exterior wall insulation • Exterior roof insulation • Slab insulation	• All thicknesses are vapour impermeable. Must carefully consider insulation balance if installing as exterior insulation • Higher compression products available if required • Combustible
Closed Cell Spray Foam 	R-value per inch 6.0 to 6.5 Density 1.4 to 2.4 lb/ft^3	• Cavity insulation • Air sealing penetrations • Exterior wall insulation • Exterior roof insulation	• Effective as an air and vapour retarder. An interior vapour retarder is not required • Closed cell spray foam is installer dependent and should be reviewed to ensure continuity of the installation • Combustible
Polyisocyanurate 	R-value per inch 5.7 Density 2.0 to 2.5 lb/ft^3	• Exterior wall insulation • Low-sloped roof insulation - requires a non-combustible coverboard for torched-on membranes	• Sensitive to moisture. • Thermal resistance is highly tempearture dependent - the R-value decreases at lower operating temperatures • Combustible
Expanded Polystyrene (EPS) 	R-value per inch 3.6 to 4.2 Density 0.7 to 2.8 lb/ft^3	• Exterior wall insulation	• Similar uses to XPS but with higher water absorption potential. Absorbed water reduces R-value • Combustible

Long Screw Cladding Attachment

Structural Considerations

For wall retrofits using fasteners through exterior insulation, vertical strapping on the front face of the exterior insulation is fastened with long screws through the insulation and into the framed wall. The cladding is then attached and supported with separate fasteners through the strapping. The bending resistance from the screw (when installed into the sheathing and studs), coupled with a truss system (where the fasteners take tension loads and the compression loads are resisted by the bearing of the strapping on the insulation layer) provides the primary support for the cladding in the service load state. Additionally, the friction between the insulation and the strapping and sheathed wall (created by the force applied by the fasteners) provides some resistance to the vertical load, though it is generally not accounted for in the structural design. Insulation that is rigid enough to be used in this manner includes XPS, EPS, polyisocyanurate, and rigid mineral fibre products. However, due to the fact that existing wall assemblies typically contain an interior vapour retarder, vapour-permeable insulations like rigid mineral fibre are often recommended for retrofits.



Service load state (section view)

Note that this cladding attachment system requires that the existing sheathing and studs be in good condition and uncompromised. Some retrofits may require significant framing replacement, prior to considering this cladding attachment approach.

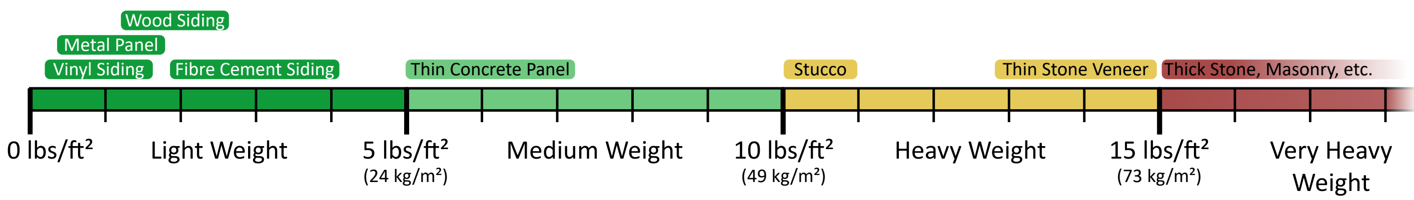
This cladding attachment system can be used effectively for claddings with weights up to 15 lbs/ft² (73 kg/m²), excluding the weight of the insulation. Within this limit, the screw size and installation will vary depending on the cladding weight. Based on research and current industry practice, it is recommended that claddings that weigh over 15 lbs/ft² (73 kg/m²) be attached using an engineered approach specific to the cladding type and weight. Though cladding weight will generally govern the structural support requirements on low-rise wood-frame buildings, the potential forces generated by wind as well as seismic activity must also be considered in the structural design to confirm that these loads can be accommodated.

In addition to cladding weight, important considerations include the stud spacing of the backup wall, the sheathing type and thickness, and the exterior insulation thickness and type, all of which will affect the required fastener spacing, size, and minimum embedment into the backup wall, as well as the strapping thickness and width.

Lower-density rigid and semi-rigid mineral fibre insulation less than 8 lbs/ft³, 126 kg/m³ are not considered rigid enough for this application and would likely compress excessively under the vertical strapping during installation. Therefore, these products are not included in the subsequent guidance on cladding attachment with fasteners through exterior insulation. Additionally, this structural system relies on the increased pullout strength of large screws as compared to nails. Nails are not recommended for use in this application.

Cladding Weight

Cladding weights, for the purpose of the structural calculations included in this guide, are categorized as **Light** (less than 5 lbs/ft^2, 24kg/m^2), **Medium** (5 to less than 10 lbs/ft^2, 24–49 kg/m^2), **Heavy** (10–15 lbs/ft^2, 49–73 kg/m^2), and **Very Heavy** (over 15 lbs/ft^2, 73 kg/m^2). The approximate weight and category for various common cladding types is shown below. Each cladding type will have different weights for different brands and cladding arrangements, so the specific cladding weight should be determined from product technical data to confirm which category it is in.



Strapping

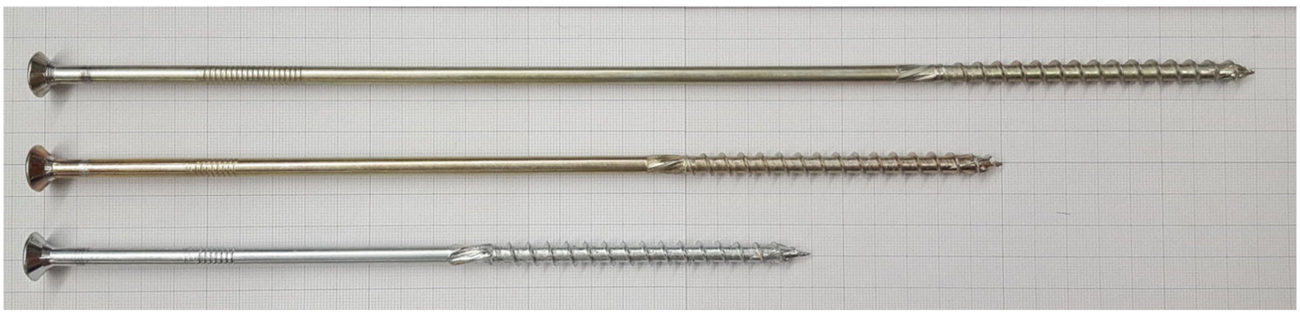
In general, the most appropriate strapping for this application will be plywood strapping* ripped to width, since the requirements for large screws at close spacings risk splitting strapping made from dimension lumber. Additionally, after the strapping is installed, more fasteners are installed through the strapping to secure the cladding. Larger dimension lumber strapping such as nominal 1x4 with a staggered fastener pattern may also be adequate in this application. The required strapping thickness and width for structural purposes is a function of the cladding weight and insulation density. Thicker and wider strapping may be necessary when used with rigid mineral wool products (compared to rigid foam) in order to reduce potential bowing or twisting of the strapping between fasteners as it is installed and as cladding is attached. Extra-wide length strapping may be necessary at corners to provide adequate backing for siding, which can be observed in the illustrations found in the Above-Grade Wall at Outside Corner section of this guide.

Strapping thickness and width should meet the minimum requirements given in the tables at the end of this section, though they are not constrained to the sizes given and can be wider and thicker where appropriate. For example, some cladding products may require a minimum fastener embedment that is thicker than the minimum strapping thickness given in the tables. In these situations, refer to the manufacturer's requirements.

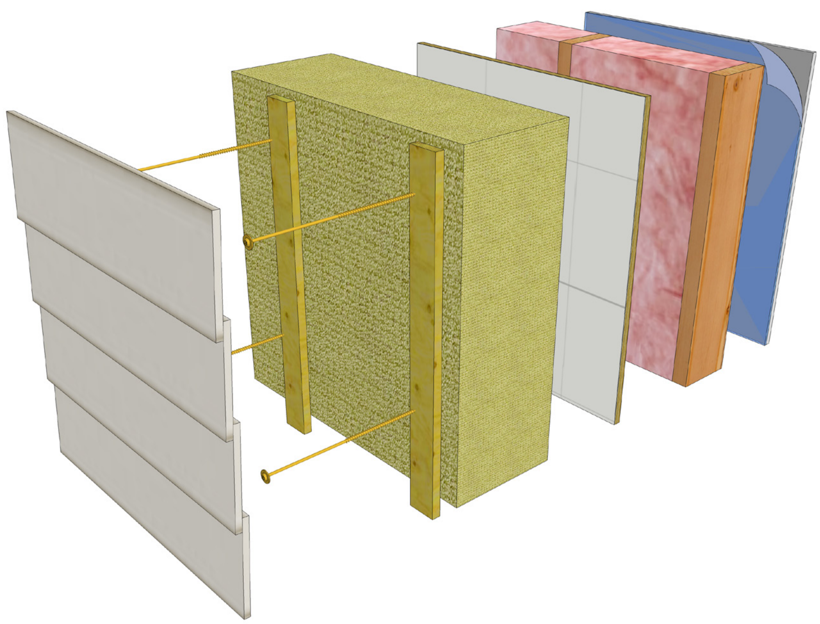
*Borate treatments are often suitable for wood strapping, and are recommended for most applications. Borate treatments are used to prevent mold growth and resist bugs such as roachess and termites as these treatments are typically deadly for unwanted pests. Alkaline copper quat (ACQ) may also be a suitable wood treatment, though compatibility with fasteners and adjacent metals should be considered.

Screws

Screws used to attach the strapping over the insulation should be either stainless steel or galvanized steel, as they will be exposed to the exterior environment and should be protected from corrosion to ensure long-term durability. Additional resistance may be required in highly corrosive environments. Always ensure the screw type is compatible with both the strapping material (i.e. wood preservatives) and the cladding material*. This application may require specialty screws designed to accommodate the potentially large torque expected as they are installed through thick layers of insulation and into the backup wall. One important construction consideration is the use of screws with a countersunk head so that the screw head can be embedded into the front face of the strapping and out of the way of cladding materials and attachment accessories. In many case, predrilling the wood straps can minimize the risk of splitting and can greatly reduce installation challenges.



Typical long screws used for cladding attachment with exterior insulation



Exploded wall assembly using long screw cladding attachment

*Stainless steel fasteners should be used when using ACQ treated wood, and either stainless steel or hot-dipped galvanized steel fasteners can be used when using borate-treated wood. Caution should be exercised when using aluminum-based materials in conjunction with copper-based wood treatments such as ACQ. For further information refer to **"Builder Insight #8: Compatibility of Fasteners and Connectors with Residential Pressure Treated Wood"** by BC Housing, available at www.bchousing.org

Existing Backup Wall and Minimum Fastener Embedment

The stud spacing of the existing exterior framed wall will govern the horizontal spacing of the strapping and fasteners, as all fasteners through exterior insulation **must be installed through the exterior sheathing into the studs**. Closely spaced existing studs will require closer strapping horizontal spacing (i.e. maximum 16" o.c.) in order to adequately support the cladding. For wider spaced framing than the archetype house used in this guide, closer vertical spacing of screws may be required.

The structural design included in this section assumes all of the screws used to fasten the strapping in place are installed through wood sheathing and into structurally sound wood framing in the existing backup wall, and standard plywood or oriented strand board (OSB) is used as the sheathing material. For exterior insulation retrofits, the condition of the existing wood framing and plywood/ OSB sheathing should first be evaluated before attempting long screw cladding attachment. Additionally, the screws used to fasten the strapping should be installed so that they do not damage existing plumbing, electrical or other services that may be located within the backup wall*.

For ease of construction, consider using markers or snap lines on the outside face of the wall sheathing membrane in line with the stud framing in order to clearly indicate the correct location of screws into the backup wall. Note that screws that unintentionally miss the framing should not be removed for repositioning, as the hole created in the sheathing membrane by the screw may introduce a risk of water ingress and air leakage into the wall assembly. Screws should be left in place, with a secondary screw installed as close as possible into the stud.

The minimum fastener embedment length as given in the tables is measured from the outside face of the wood sheathing. The minimum embedment length only accounts for the non-tapered portion of the screw where the screw threads are at full diameter, and does not include the tip of the screw. As a rule of thumb, approximately the front 1/4" of the screw should be ignored in determining the appropriate screw length. Contact the screw manufacturer for further information.

Deflection

Testing has shown that some minor deflection of the strapping and cladding may be experienced for wall assemblies with heavy weight claddings. In most cases, the deflection is constrained to less than 1/32" for typical heavy weight cladding loads. Claddings that may be prone to cracking such as stucco or adhered stone should be installed so as to reduce continuous inside corners and irregular shapes, and wherever possible should be segmented into smaller areas across the face of the wall assembly using crack control joints.

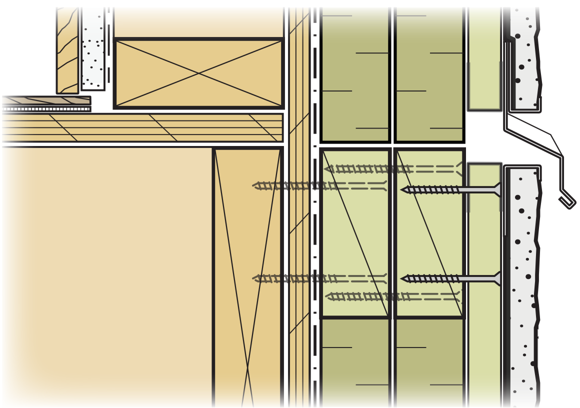
The potential deflection of heavy weight claddings may be reduced by using intermittent deflection blocks at the top of the strapping pieces, or by installing screws at an upwards angle into the backup wall. The deflection block approach uses pressure-treated dimensional lumber blocking to "hang" the cladding, installed at the top of the strapping either at the rim joist or at the top of the wall (see illustration on next page). This provides a solid wood support and minimizes the deflection of the cladding. Note that the blocking attachment should be designed to provide 100% of the vertical support for the cladding in order to prevent vertical loading on the screws at portions of the strapping without deflection blocks. In addition to vertical deflection, this approach can also serve to minimize over-tightening of the screws laterally through the exterior insulation. The structural design in this section does not account for installation of deflection blocks at the top of the strapping, and therefore, specific structural design should be completed for wall assemblies where this configuration is desired.

*Screws should be selected to meet the length requirements of the application. Over length screws can increase the risk of hitting sensitive services in the stud cavity and can result in health and safety risks.

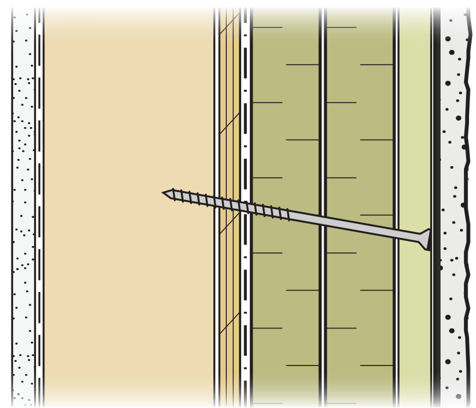
For further information refer to the ***Illustrated Guide R22+ Effective Walls in Residential Construction in British Columbia*** by BC Housing, available at www.bchousing.org

Also refer to ***REMOTE: A Manual*** by the Cold Climate Housing Research Center, available at http://www.cchrc.org/manual-remote-walls

Where screws are installed at an upward angle, the support system will rely more readily on the truss action of the screw tension and insulation compression, rather than screw bending resistance. Therefore, the potential for deflection that may occur from supporting heavy weight cladding on the strapping is reduced. Note that screws installed at an upwards angle may need to be longer than those used horizontally, as they must achieve the same embedment depth into the backup wall. The structural design in this section does not account for screws being installed at an upwards angle and therefore specific structural design should be completed for wall assemblies where this configuration is to be used.



Deflection block (section view)



Screw at upward angle into stud (section view)

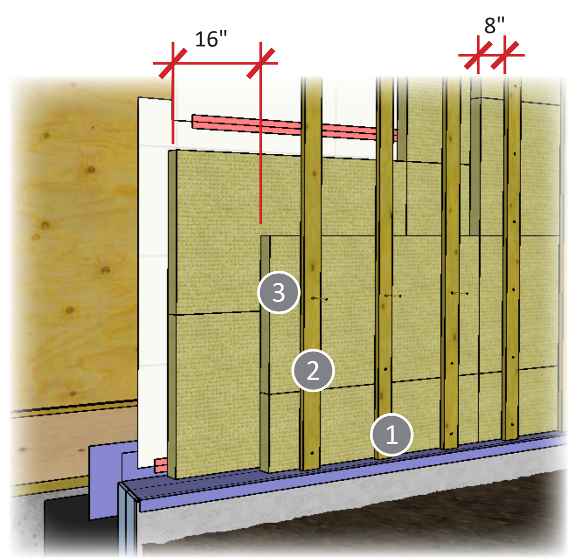
Installation Methods of Insulation Boards

Installation of one or multiple layers of exterior insulation requires a stepped approach, as each insulation board should be held in place using only the strapping as much as possible, so as to reduce the number of fastener penetrations through the insulation and sheathing membrane. This approach is most easily completed using the following installation procedure (see illustration):

1. Install the starter course of insulation using the strapping fastened at the bottom edge and held upright in place as needed. Insulation boards should be installed with the vertical edges offset 8" from the strapping so that each board (usually 48" wide) will be secured behind 3 separate straps. Ensure that a minimum spacing of 3/8" between the flashing and insulation.

2. Place the insulation behind the strapping and "stack" it on the starter course, with screws installed along the strapping through the insulation boards as they are installed up to the top edge.

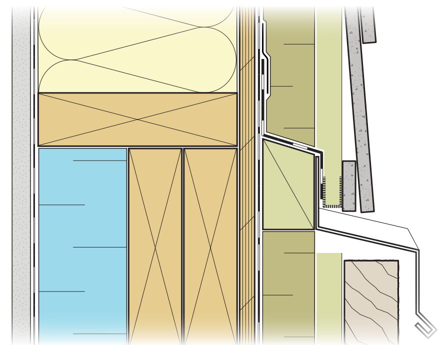
3. Insulation boards in a single layer can be stacked directly above the course below or offset horizontally, and should be offset 16" horizontally between layers if multiple insulation layers are used.



An alternative installation approach is to use one or two fasteners to temporarily pin the insulation boards in place before the strapping is installed. This approach may require screws with large washers to adequately secure heavier insulations. Refer to the insulation manufacturer's product data for further guidance on fastener layout and installation requirements.

Continuity of Insulation

Boards should be installed in the largest pieces possible over the wall area. Pieces can be cut after installation to ensure all wall surfaces are covered, including around openings and penetrations, while minimizing gaps and insulation board joints. Multiple layers of insulation should be used when possible, with joints staggered to reduce thermal bypass at the insulation. Exterior insulation should only be interrupted by necessary service penetrations and structural elements. Cladding accessories such as trim and flashings should be installed in front of the insulation where possible. For example, the back face of through-wall flashings can be installed onto intermittent pieces of pressure-treated lumber in the plane of the insulation (see illustration) instead of installing the flashing at the face of the sheathing. The self-adhered membrane can then be relied on instead of the metal flashing (while still necessary to install) to divert water out from the sheathing membrane plane.

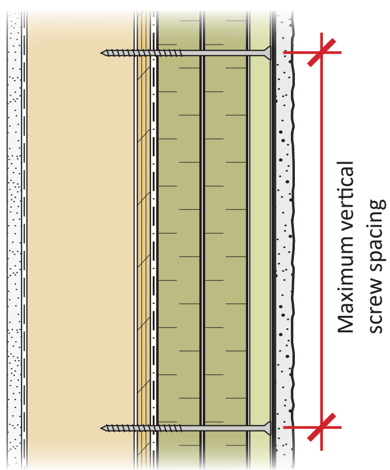


Flashing set out from the face of the sheathing

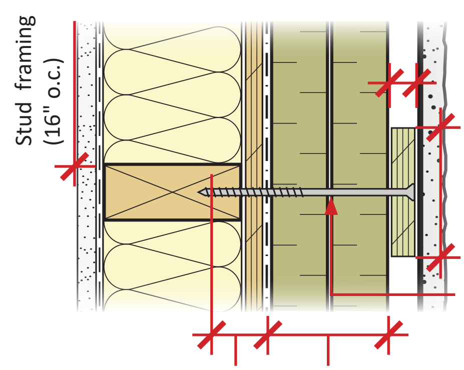
Fastener Tables

The following information provides the structural requirements for attaching strapping over exterior rigid mineral wool insulation using screws. The tables are organized by cladding weight, with fastener requirements shown for insulation thicknesses up to 12”. Illustrations for each aspect of the fastener and strapping installation requirements are shown below. Note that the following structural tables are predicated on the existing wood studs and sheathing being in good condition and undamaged. Always review the condition of the existing framing and sheathing and replace as necessary before proceeding with long screw cladding attachment.

Section View



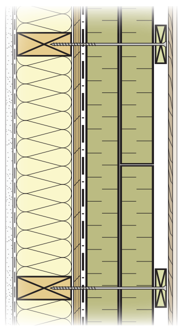
Plan View



Fastener Tables

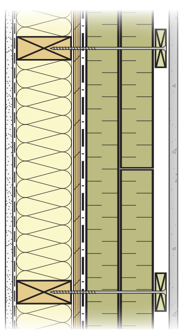
Assumed Structural Properties		
Rigid foam minimum compressive strength	Rigid mineral wool minimum compressive strength	Stainless /galvanized steel screw allowable tensile strength
10psi (69 kPa) @10% compression, ASTM C165 testing	3.05psi (21 kPa) @ 10% compression, ASTM C165 testing	60,000 psi (414 MPa)

Light Weight Cladding



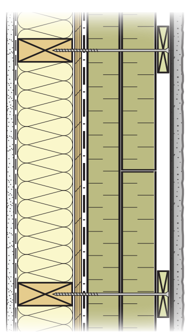
Fastener/Strapping Installation Requirements - Light Weight Cladding					
Thickness of Exterior Insulation	**Maximum Vertical Screw Spacing**	**Minimum Screw Size**	**Minimum Screw Embedment**	**Minimum Strapping Size**	
				Rigid Foam	**Rigid Mineral Wool**
Light Weight Cladding Below 5 lbs/ft² - 16” o.c. Stud Framing					
1” to 2” *	24”	#10	1-1/2”	3/4” × 2-1/2”	3/4” × 2-1/2”
>2” to 8”	16”				
Light Weight Cladding Below 5 lbs/ft² - 24” o.c. Stud Framing					
1” to 2” *	16”	#10	1-1/2”	3/4” × 3-1/2”	3/4” × 3-1/2”
>2” to 8”	12”				
8” to 12”	12”	#10	1-1/2”	3/4” × 3-1/2”	3/4” × 3-1/2”

Medium Weight Cladding



Fastener/Strapping Installation Requirements - Medium Weight Cladding					
Thickness of Exterior Insulation	**Maximum Vertical Screw Spacing**	**Minimum Screw Size**	**Minimum Screw Embedment**	**Minimum Strapping Size**	
				Rigid Foam	**Rigid Mineral Wool**
Medium Weight Cladding Between 5 lbs/ft² and 10 lbs/ft² - 16” o.c. Stud Framing					
1” to 4”	16”	#12	1-1/2”	3/4” × 2-1/2”	3/4” × 3”
>4” to 8”	12”				
Medium Weight Cladding Between 5 lbs/ft² and 10 lbs/ft² - 24” o.c. Stud Framing					
1” to 4”	12”	#12	1-1/2”	3/4” × 3-1/2”	3/4” × 3-1/2”
>4” to 8”	8”				
8” to 12”	8”	#12	1-1/2”	3/4” × 3-1/2”	3/4” × 3-1/2”

Heavy Weight Cladding



Fastener/Strapping Installation Requirements - Heavy Weight Cladding					
Thickness of Exterior Insulation	**Maximum Vertical Screw Spacing**	**Minimum Screw Size**	**Minimum Screw Embedment**	**Minimum Strapping Size**	
				Rigid Foam	**Rigid Mineral Wool**
Heavy Weight Cladding Between 10 lbs/ft² and 15 lbs/ft² - 16” o.c. Stud Framing					
1” to 2”	16”	#14	1-1/2”	3/4” × 3”	3/4” × 3”
>2” to 8”	12”				
Heavy Weight Cladding Between 10 lbs/ft² and 15 lbs/ft² - 24” o.c. Stud Framing					
1” to 2”	16”	#14	1-1/2”	3/4” × 3-1/2”	3/4” × 3-1/2”
>2” to 4”	12”				
>4” to 8”	6"				

Note: The values provided in the above tables pertain only to wood-frame wall assemblies on low-rise buildings less than three storeys.

Air Barrier Selection

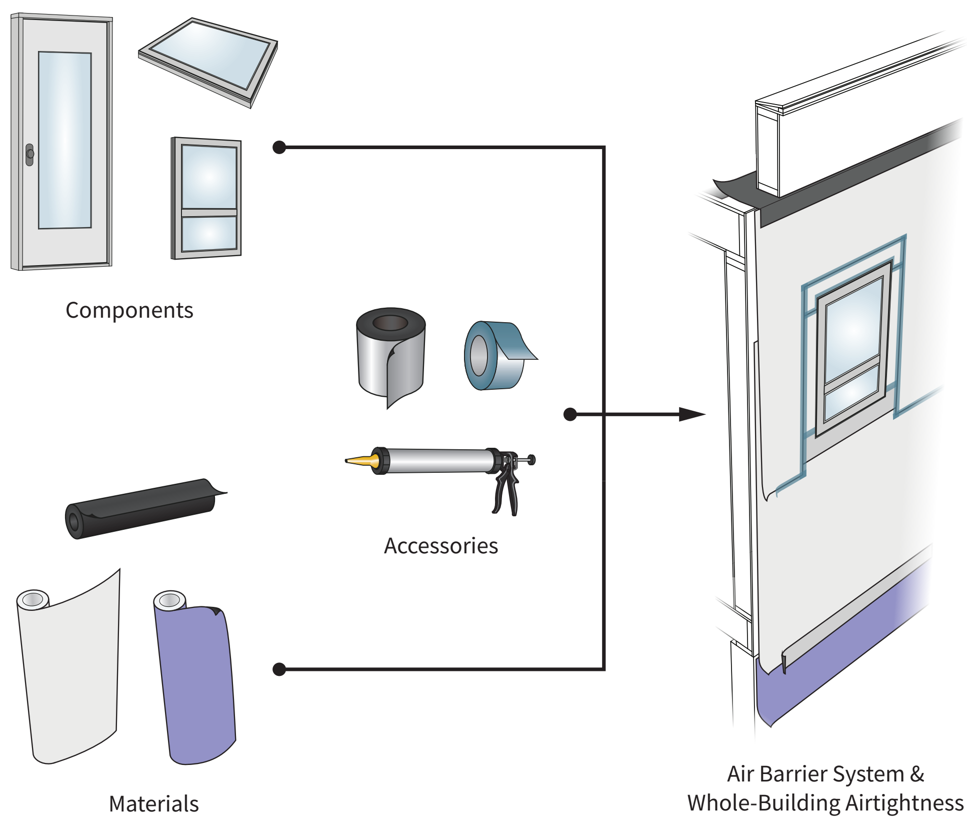
An effective air barrier system consists of a continuous system of materials (building wrap, membranes, etc.), components (doors, windows, etc.), and accessories (tapes, sealants, spray foam, etc.). The air barrier may be comprised of new and existing building materials, components, and accessories. The air barrier must be continuous, durable, strong, and stiff. All the materials, components and accessories used as part of the air barrier must be air impermeable. "Air impermeable" is typically defined in industry standards referenced by the National Building Code as an air permeability of less than 0.02 L/s·m² (0.004 cfm/f²) at 75 Pa.

Due to the nature of retrofit activities, it may be difficult to create a continuous air barrier in an existing assembly. The resulting air barrier may need to transition through several different building materials and components to achieve continuity.

Some materials and accessories that can be used to achieve an effective retrofit air barrier include:

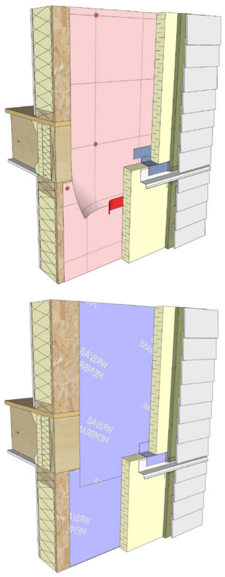
- **House wrap** - Mechanically attached sheathing membranes.
- **Peel and stick** - Self-adhered membrane flashings or self-adhered sheathing membranes.
- **Sheathing** - Rigid sheet materials (plywood, OSB...) sealed with tape, gaskets or sealant.
- **Framing** - Dimensional lumber (studs, joists, ledgers) may need to be used to transition the air barrier through the existing structure.
- **Tape** - Tapes can be used to transition between different materials and components.
- **Spray foam** - Spray polyurethane foam (SPF) can be used to transition between different materials/ components and as a field-applied air barrier material.
- **Sealant** - Can be used to transition between different materials and components.

Building components like windows, doors, and mechanical penetrations are all part of the air barrier system and should be detailed as such.



Retrofit Air Barrier Strategies

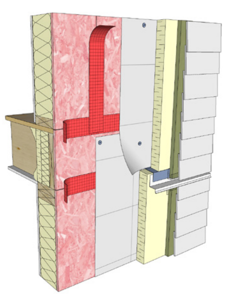
Retrofit air barrier strategies typically fall into two categories: exterior air barrier systems, where the primary airtight elements placed at the exterior side of the enclosure, and interior air barrier systems, where the primary airtight elements are installed at the interior side of the enclosure. Air barrier materials can be either vapour-open or vapour-closed depending on the overall design of the assembly. A variety of retrofit air barrier strategies can potentially be used in existing wall assemblies, including but not limited to:



Sheathing membrane strategy (mechanicaly fastened and self-adhered)

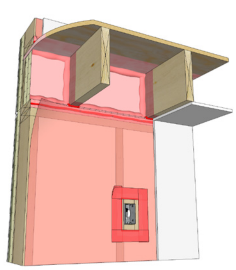
Sheathing Membrane: This approach uses an airtight sheathing membrane, also referred to as house wrap, attached to the exterior sheathing with fasteners and washers. Joints, penetrations, and laps are made airtight using sealant, tape, and self-adhered membrane strips. Where staples are necessary to install into the sheathing, staple caps should be used to create an air seal around each penetration. Care should be taken to ensure the sheathing membrane is adequately attached to the building during construction and it should be supported by insulation, strapping, and/or cladding to avoid damage. The sheathing membrane must be continuously sealed to the attic/ceiling air barrier and to the foundation walls. In this application the sheathing membrane is also used as the water-resistive barrier, and must be installed and detailed as such.

Self-adhered, or "peel and stick" sheathing membranes (SAMs) are used similarly to mechanically fastened but are adhered directly to the sheathing. The membrane should be installed onto an adequately dry substrate that provides continuous backing for the membrane. SAMs are recommended over mechanically fastened systems for a variety of reasons discussed previously in the Materials Selection sub-section.



Sealed exterior sheathing strategy

Sealed Exterior Sheathing: The exterior sheathing, when sealed at joints and interfaces, can also act as the primary air barrier element. This approach uses the exterior sheathing together with sealant, strips of membrane, and sheathing tape to create a continuous air barrier system. The sheathing must be continuously sealed to the attic/ceiling air barrier and to the foundation walls. A sheathing membrane is still required with this approach to provide a water-resistive barrier.



Sealed interior polyethylene strategy

Sealed Interior Polyethylene: In this system, polyethylene sheet is sealed at penetrations and to the interior framing. All laps in the polyethylene sheet are also sealed and clamped between the framing and the interior finish. Locations where interior finishes are not normally provided require specific measures to ensure the polyethylene is adequately supported. Also, occupants may inadvertently damage the polyethylene when installing drywall anchors at exterior walls to hang pictures, TVs, shelves, etc.

The various interfaces between the exterior walls and interior elements such as staircases, interior walls, floor framing and service penetrations can make the sealed interior polyethylene approach a difficult air barrier system to implement successfully by most builders.

Most of the details shown in this guide utilize a sealed sheathing membrane (exterior air barrier system) for the below- and above-grade walls and taped and sealed polyethylene (interior air barrier system) for the ceiling. Because the majority of the retrofit activities featured in this guide do not include replacing interior finishes (such as gypsum wall board), the condition of the existing interior polyethylene cannot be determined and the necessary repair/ air sealing cannot be done. The exception to this is the roof assembly, where the interior polyethylene sheet can typically be sealed from within the attic space.

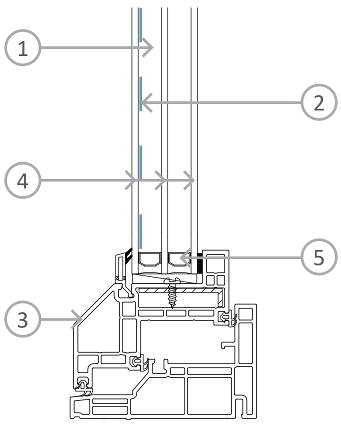
Window Selection

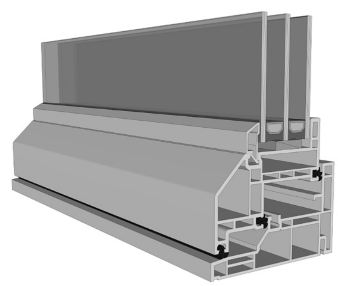
There are several window options available for home energy retrofits. Homeowners can choose between different frame designs and materials (wood, vinyl) as well as glass arrangements. Moving from a standard double-glazed window product to a triple-glazed or quad-glazed window can dramatically improve overall building efficiency, and can result in reduced utility bills and improved thermal comfort for occupants.

Window energy performance is primarily influenced by the type of window frame, the low-emissivity (low-e) coatings applied to the glass surface(s), the number of panes of glass, amount of air leakage, and the gas fill between the glass. Secondarily, the performance is also affected by the quality of the installation and the location of the window relative to the wall insulation.

The following are some key metrics and descriptions regarding window performance:

- **Solar Heat Gain Coefficient (SHGC)**: The fraction of solar radiation admitted through a window, both directly transmitted and absorbed, and subsequently released inward. The lower a window's SHGC, the less solar heat it transmits.
- **U-Value**: A measure of the heat transmission properties of a material or assembly of materials. Lower U-values indicate improved thermal performance. U-Values (USI) are the inverse of R-value (RSI).
- **Air-Leakage Rating:** The amount of air leakage expected for the window product. Operable windows are more leaky than fixed windows and typically slider type vents are leakier than casement or awning vents.





Triple-glazed window, vinyl frame, two low-e coatings, argon gas fill

(1) **Gas fill:** Gases are often inserted between the glass panes in order to reduce heat transfer across the insulated glass unit (IGU). A variety of gas fills are possible, including air, argon, or krypton. Argon is the most common gas fill, as it is economical and resists heat transfer more than air.

(2) **Low-e coating:** The ability of a material to radiate energy is called its emissivity. Standard uncoated glass has a high emissivity where heat radiates largely uninhibited through the glass. Low-e coatings are microscopically thin, transparent coatings that are applied to the surface of glass panes to reduce radiative heat transfer by reflecting heat energy, instead of absorbing and transferring the energy. Having more than 1 low-e coatings will further help to reflect heat energy and further reduce the amount of light that travels through the glass. This concept is also referred to as visible light transmission (VLT).

(3) **Type of window frame:** Window frame material and design can have a significant impact on overall window performance. Low-conductivity frames made of vinyl, wood, or fibreglass often feature internal insulation or multiple air chambers that help improve the thermal performance and condensation resistance of the window.

(4) **Panes of glass:** This refers to the layers of glass in the IGU. "Quad pane" indicates four layers of glass. Quad-pane IGU's can incorporate 3 warm edge spacers and 3 gas-filled gaps, which offer improved thermal performance and condensation resistance over triple-pane or double-pane windows.

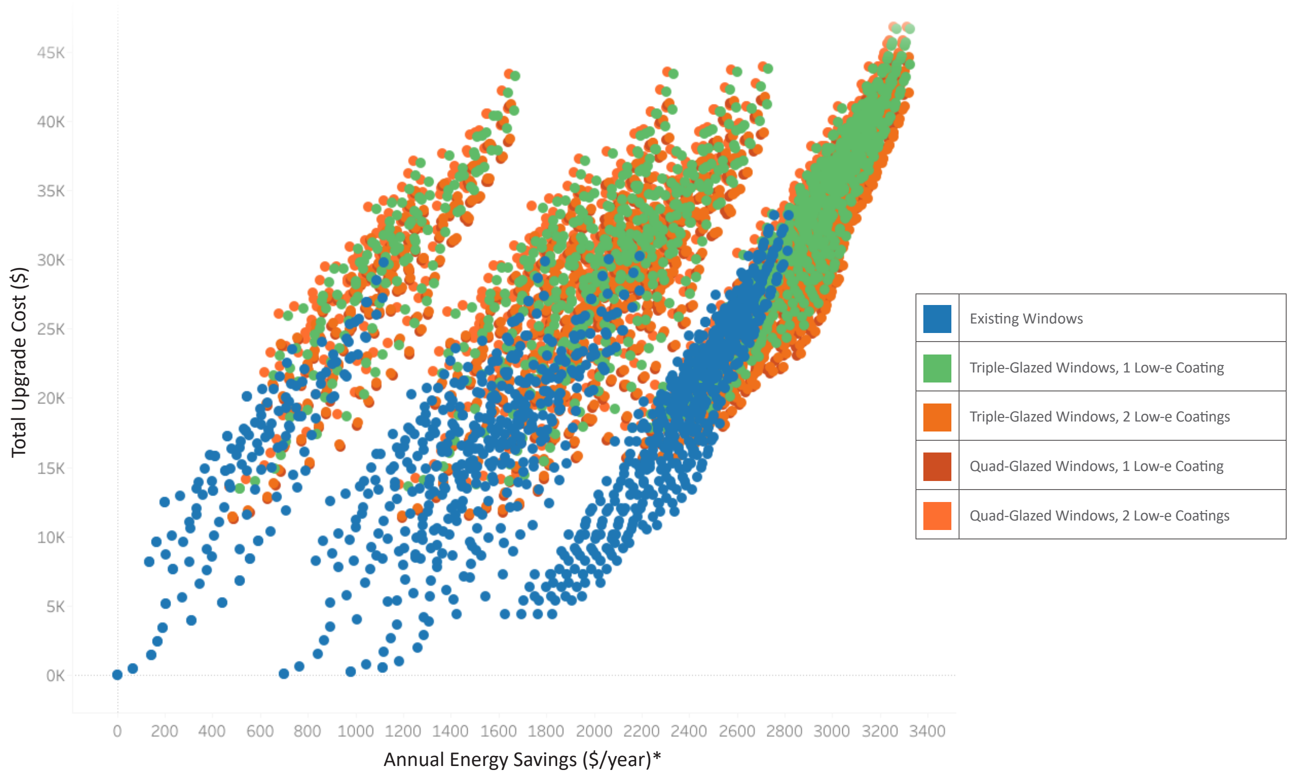
(5) **Edge Spacers:** Edge spacers are small blocks located at the outer perimeter of glass panes that are used to hermetically seal and hold together two or more panes of glass at a specific distance. Warm-edge spacers made of plastic composites typically conduct less heat than standard aluminum spacers and thus result in an improvement in window thermal performance.

High-performance windows tend to be more expensive due to the technologies needed to improve performance, including highly insulated frames, additional low-e coatings, and additional panes of glass. However, this increase in initial cost is typically recovered over time through energy savings.

Whenever a window replacement scope is considered, a triple- or quad-glazed window is recommended. However, choosing between a triple-glazed and quad-glazed window can be a very nuanced decision. Homeowners must carefully weigh the improvement in thermal and sound performance typically granted by quad-glazed windows with the associated cost premium as compared to triple-glazed products. While quad-glazed windows typically outperform triple-glazed windows, triple-glazed windows with superior frame design and/or additional low-e coatings can provide equivalent performance. The table below provides several window specifications for products that are locally available in Yukon.

Sample Casement Window Specifications Locally Available in Yukon		
Configuration	Operable Window Performance	
	USI ($W/m^2 \cdot K$)	SHGC
Triple Glazed, Vinyl Frame, 1 Low-e Coating	1.17	0.28
Triple Glazed, Vinyl Frame, 2 Low-e Coatings	0.96	0.20
Quad Glazed, Vinyl Frame, 1 Low-e Coating	1.03	0.26
Quad Glazed, Vinyl Frame, 2 Low-e Coatings	0.88	0.18

The figure below demonstrates the importance of window upgrades when considering home energy retrofits. Recent energy modelling work completed by Natural Resources Canada (NRCan) indicates that triple- or quad-glazed products are an essential component of deep energy retrofit packages where high levels of energy savings are desired.



***** Annual Utility Savings based on standard electricity and oil utility rates in Whitehorse, YK

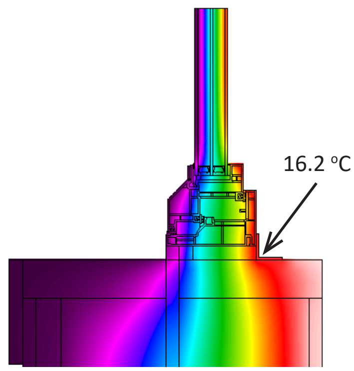
Window Positioning in Deep Retrofit Wall

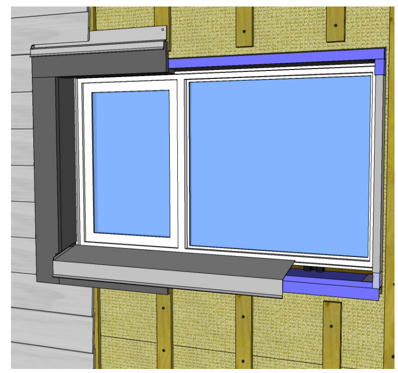
When retrofitting houses with additional exterior insulation, the window location within the wall needs consideration. The window location not only affects thermal performance, but also solar heat gains, light transmittance, window durability, maintenance needs, and architectural appearance. The benefits and drawbacks of different window locations are discussed below along with visual reference of the thermal performance.

Thermal Analysis of Window Location | **Isometric of Window Location**

- **Interior:** Installing windows at the same location as before the retrofit reduces the solar heating potential due to shading at the jambs and head. Daylight distribution to the interior is also decreased. The risk of condensation is low and the frame is kept warmer then the other placement locations. Deeper sill flashing and trim returns are required. Snow may accumulate on the recessed sill and restrict drainage from the sill.

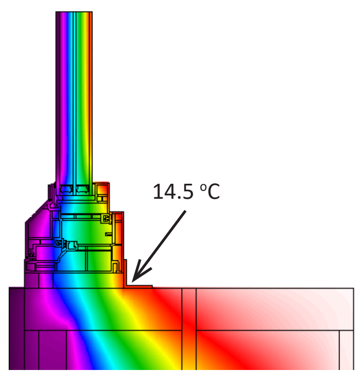
Interior Location

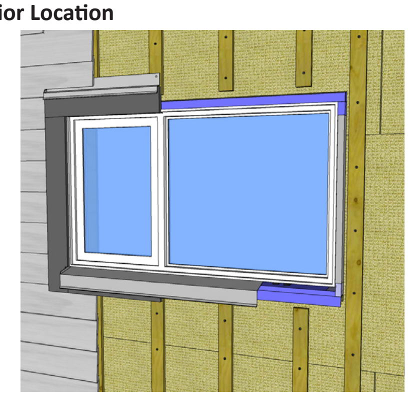




- Exterior: Installing windows in plane with the outer face of the additional exterior insulation may be considered more aesthetically pleasing but increases the condensation risk due to greater wind exposure causing lower window temperatures. This location benefits from increased solar heating and better daylight distribution to the interior.

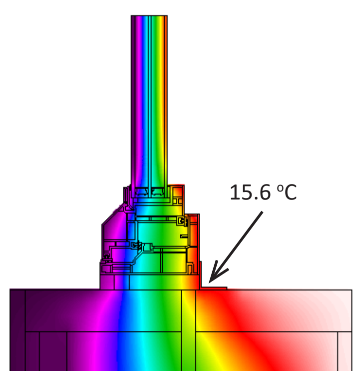
Exterior Location

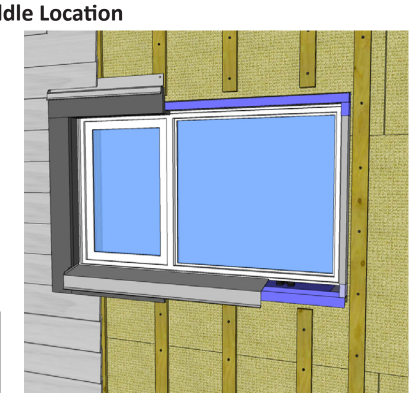




- Middle: Installing windows at the middle of the wall is generally the best compromise between the other two locations. It provides increased solar heating as compared to the interior placement option and has a lower condensation risk profile than the exterior placement option.

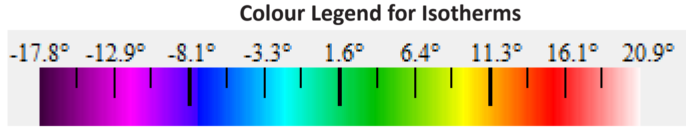
Middle Location





Relocating the window to the middle or exterior of the wall requires the construction of a window buck and the use of non-flanged windows or flanged deep set windows complete with brick mold. Details 1 to 5 in Section 8.0 provide installation guidance for multiple window placements.

Colour Legend for Isotherms



6.0 Mechanical System and Other Considerations

Ventilation

Poor indoor air quality can have severe impacts on human health, particularly among the young, the elderly, and people with respiratory conditions. Impacts can include increased asthma, headaches, cancer risks, and fatigue. Health Canada has published ***"Residential Indoor Air Quality Guidelines"***, which advise on recommended exposure limits for a range of indoor air contaminants including benzene, carbon monoxide/dioxide, fine particulate matter, formaldehyde, mould, naphthalene, nitrogen dioxide, ozone, radon, and toluene - all of which can be found in homes. While source control is an essential first step toward limiting exposure to indoor pollutants, adequate and balanced ventilation (paired with filtration) is a critical means of establishing and maintaining indoor air quality. Air sealing during retrofits may seal openings in the building enclosure that were previously relied on for natural or passive ventilation in the home; therefore, it is recommended to have an energy advisor assess the suitability of indoor air exchange rates when completing a home retrofit. NRCan provides an online database of available service providers in your community.

Codes and Standards

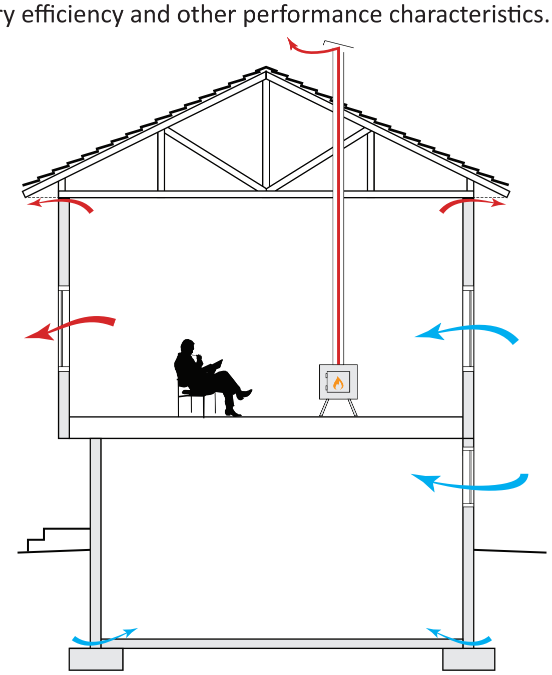
The fabrication, design, and installation of HVAC systems are guided by best practices and Building Code requirements that vary between jurisdictions. Although retrofits are not typically governed by the Building Code, it is illustrative of acceptable HVAC system use and design. Part 9 of the National Building Code (NBC) requires the installation of a mechanical ventilation system in all newly constructed homes. Some design and installation requirements influencing a home's ventilation system are outlined below:

- **Ventilation systems and indoor air quality:** Section 9.32 of the NBC requires a principal ventilation system that exhausts air from bathrooms and kitchens and supplies fresh air to bedrooms and living areas. This requirement is met with a balanced mechanical ventilation system with controls to run it on low speed continuously, and high speed when required to control acute increases in humidity or pollutants. It also dictates minimum outdoor air supply and exhaust air quantities by room type.
- **Energy performance:** Section 9.36 of the NBC requires a continuous air barrier to improve energy efficiency. While this is not a ventilation system Code requirement, a more airtight enclosure means less ventilation air can be pulled through the building enclosure. The resulting reduction in air leakage is one of the key drivers for the requirement of a principal ventilation system.
- **Performance of heat recovery ventilators (HRVs):** Section 9.36 of the NBC prescribes minimum performance requirements for HRVs. It is imperative that the HRV manufacturer has verified performance through testing by a Standards Council of Canada accredited certification organization such as the Heating and Ventilation Institute, CSA International or ULC. Performance test standards define how a manufacturer can determine HRV heat recovery efficiency and other performance characteristics.

Natural (Passive) Ventilation

In many existing homes, natural ventilation through operable windows and leaks in the enclosure is the primary means of ventilation. Natural pressure differences due to wind and stack effect can cause air movement through a house, particularly if it has an open floor plan. Natural ventilation can save energy by reducing fan power for ventilation, or providing "free" cooling in shoulder seasons in mild climates (typically spring and autumn, or at night during the summer, when outside temperatures are cooler than interior spaces).

However, natural ventilation can significantly increase space heating and cooling-related energy consumption. Opening windows in cool and cold weather can also lead to uncomfortable temperatures and represent a security concern particularly if left open overnight or when the home is vacant. Providing ventilation air through windows and leaks in the enclosure does not enable the tempering and filtration of air contaminants, as a mechanical system with filtration would. For this reason, **"build tight – ventilate right"** has become one of the mottos of the energy efficient home building movement. In addition, natural ventilation is unpredictable and unreliable and may not be present when needed or provide the ventilation rates required at all times.



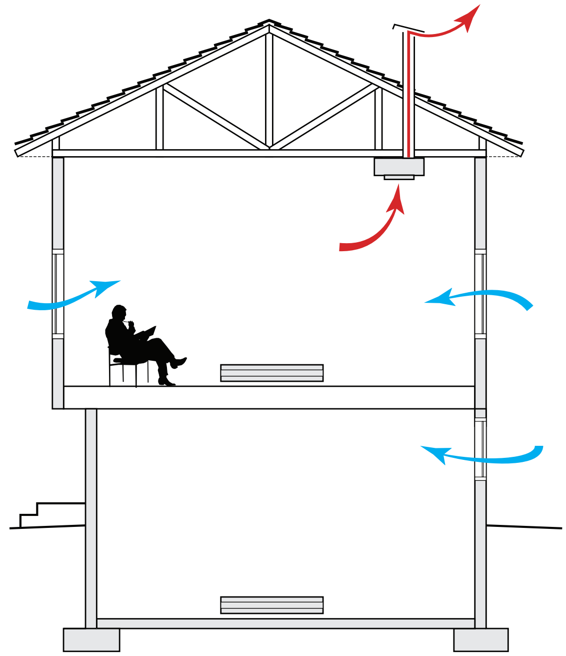
House with Natural Ventilation

Air movement through operable windows due to wind effect (large arrows), and air movement through enclosure leaks and chimney due to stack effect (small arrows)

Mechanical Exhaust-Only Systems

Exhaust-only systems rely on one or more fans to exhaust stale air from the house. Although not typically part of a ventilation system, dryer vents also provide exhaust only ventilation when the dryer is operating. Replacement (or “make-up”) air is provided through passive air inlets (such as trickle vents), operable windows, and by air leakage through the enclosure. Exhaust fans are usually manually controlled by the occupants and when operating, the house may be under negative pressure relative to the exterior. Exhaust-only ventilation systems are not a recommended ventilation strategy as these systems are not balanced with make-up air intakes and can cause backdrafting of fuel-fired appliances, fireplaces and woodstoves if the house becomes depressurized. This ventilation approach also does not reliably deliver fresh air where it's needed and typically adds to space conditioning costs.

Exhaust-only systems do not meet current Building Code standards.



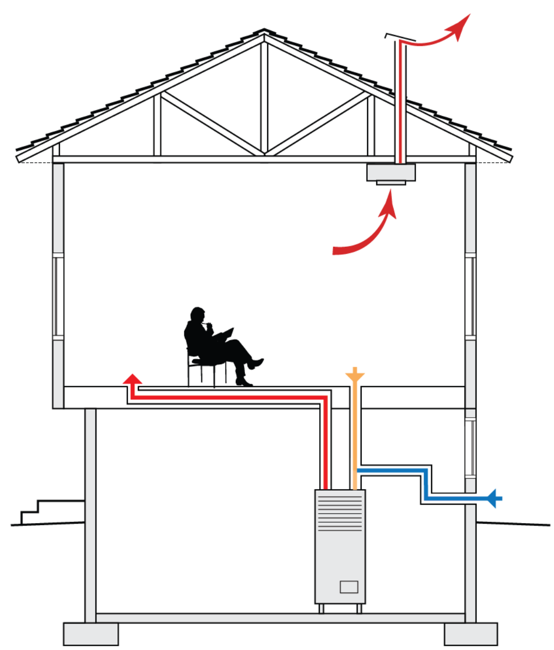
House with Mechanical Exhaust-Only System

Air movement through windows due to negative pressurization from bathroom fan.

Mechanical Supply-Only Systems (with Intermittent Exhaust)

Supply-only systems use one or more fans to deliver outdoor air throughout the house. The house will likely still have occupant controlled exhaust fans in rooms where moisture and odours are generated, such as bathrooms, kitchens, and laundry rooms. In homes with a forced air system (such as a furnace), a supply-only system is often provided by connecting an insulated intake duct to the air handler return plenum. Outdoor air is drawn into the air handler when the furnace fan is operating. This air is mixed with the house return air and delivered to the home via the forced air system. In houses without a forced air system, a dedicated ductwork system is needed to supply outdoor air.

Supply-only systems provide the advantage of being relatively simple and inexpensive to install and they can take advantage of an existing forced air system to deliver the ventilation air throughout the house. They also provide an opportunity to filter and temper outdoor air before it is introduced into occupied spaces. However, when the exhaust fans are not operating the supply-only system can positively pressurize the house, driving warm humid indoor air through the building enclosure. In cold climates typical of the North, this can greatly increase the potential for condensation within enclosure assemblies, leading to mould growth and damage. As such this ventilation approach is not recommended



House with Mechanical Supply-Only System (with Intermittent Exhaust)

Fresh air supplied by furnace intake. Intermittent exhaust through bathroom/kitchen fans.

Balanced Mechanical Ventilation (with intermittent exhaust)

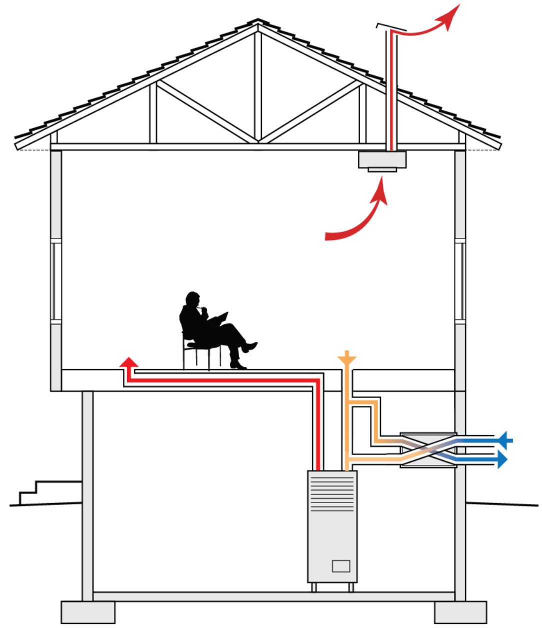
Balanced mechanical ventilation systems use fans to simultaneously exhaust stale air and supply outdoor air in equal quantities. It is the preferred ventilation strategy, and in many jurisdictions, such as the City of Whitehorse, it is the required approach. Balanced ventilation is a recommended upgrade during energy retrofits. With retrofits, intermittent exhaust is typically still present in bathrooms and kitchens to control short term increases in humidity and air contaminants.

Balanced ventilation systems reduce building pressures that drive air leakage into and out of a house. This typically creates better indoor air quality, more ventilation control, and reduces opportunities for contaminant migration between adjoining spaces (e.g., secondary suites, garage and work spaces, and attics).

These systems can include the following configurations:

- A central air exchanger, such as an HRV, that continuously exhausts stale air from the bathrooms, kitchen and laundry rooms, and supplies air to bedrooms and living, dining and recreation rooms through dedicated ventilation ducts as part of a forced air heating system.
- A furnace or air handler fan with an outdoor air duct connected to the furnace return that is interlocked to a preheater, motorized damper, and central exhaust fan so that both operate simultaneously (i.e., the furnace draws in as much outdoor air as is exhausted by the central exhaust fan). This approach is more difficult to design and install than a "packaged" HRV system.

Systems that utilize the furnace or air handler for distribution of ventilation air tend to use more energy than ventilation systems that use dedicated supply and exhaust ductwork because of the need to continuously operate the large furnace or air handler fan. Retrofits are typically limited to such an approach as it does not require installing new ductwork throughout the home. It is recommended that the air handler fan is driven by an energy-efficient brushless direct current motor, as this will significantly reduce the operating costs of the balanced ventilation system over conventional furnace motors.



House with Balanced Mechanical Ventilation and Intermittent Exhaust

HRV provides balanced ventilation and preconditions the intake air for reduced heating loads. Intermittent exhaust fan is for immediate control of moisture and air contaminants.

Retrofit Considerations

Many existing houses have poor ventilation and/or no mechanical ventilation system. Before a retrofit is undertaken, the existing ventilation system performance must be evaluated to inform the appropriate solution. This investigation includes assessing the performance of the existing mechanical fans and distribution system (if applicable), the airtightness of the building enclosure, and the resultant ventilation flow rates to various interior spaces.

Heat Recovery Ventilator (HRV)

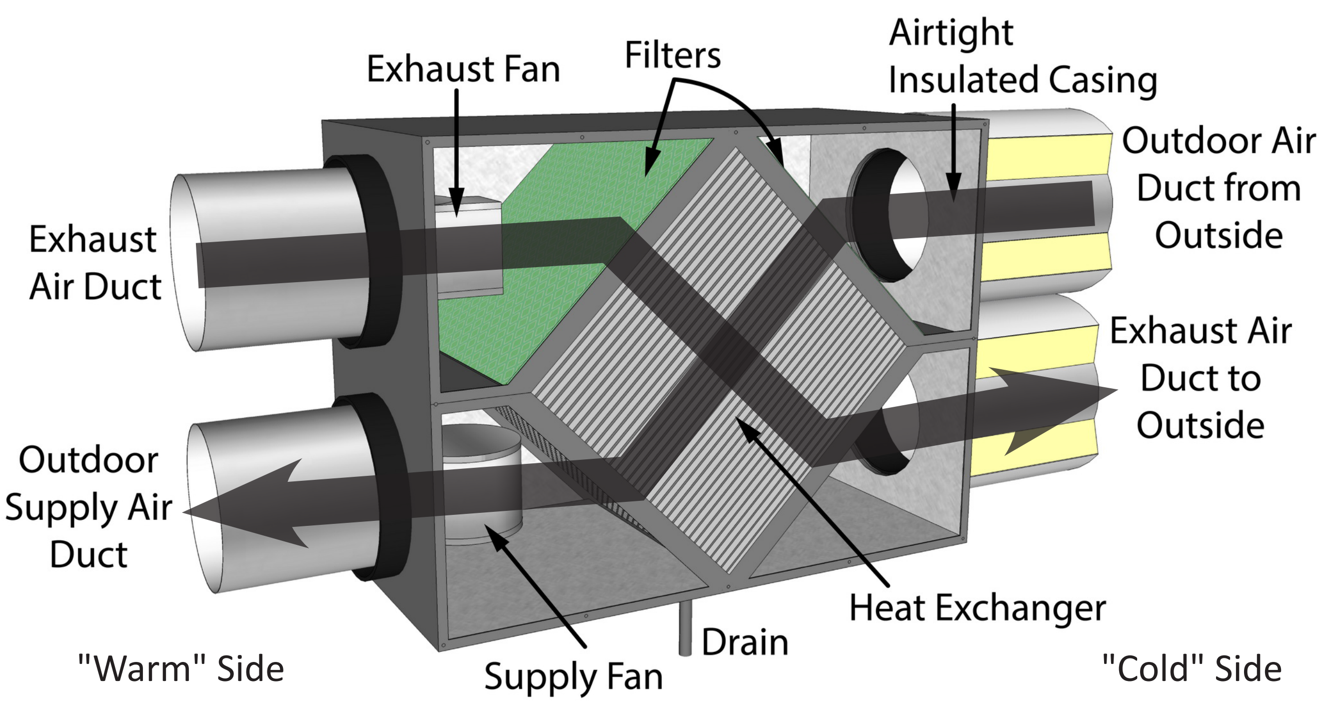
Buildings are intended to be conditioned to a comfortable temperature and relative humidity for human occupancy. Heating can account for over 50% of annual energy consumption in houses. Since typical ventilation systems introduce unconditioned outdoor air and exhaust conditioned indoor air, there is potential for energy savings by incorporating heat exchange between the two air streams. This can work both during the winter, when warm exhaust air pre-heats the intake air, and during the summer, when cooler air-conditioned exhaust air pre-cools the intake air.

HRVs simultaneously supply and exhaust air to and from a house while transferring heat between the two air streams (with minimal mixing of air in the two streams). This reduces the energy consumption associated with heating or cooling ventilation air. HRVs are typically operated as balanced ventilation systems, supplying and exhausing equal quantities of air.

HRV Components

HRVs typically consist of the following elements:

- An airtight insulated case
- Supply and exhaust fans
- Outdoor air inlet from outside (shown with insulated duct connected)
- Outdoor supply air outlet (shown with duct connected)
- Exhaust air inlet (shown with duct connected)
- Exhaust air outlet to outside (shown with insulated duct connected)
- Heat exchanger core
- Condensation drain pan connecting to a drain
- Sensors and controls
- Removable /cleanable filters
- In some cases motorized dampers to aid in defrost



Cutaway of a typical HRV showing components and direction of air flows

HRV Operation

An HRV exchanges heat between supply and exhaust air in an element called a cross-flow core. During the heating season, cold outdoor air (labelled 1 in the figure below) enters the HRV and passes through the heat exchanger core (2), where it is tempered by the warm exhaust air (4). It is then supplied to the house via a supply fan and ductwork system (3). A separate duct system and exhaust fan draws stale air from the house into the HRV (4) and through the heat exchanger (2), transferring heat to the cold supply stream before it is exhausted outdoors (5). These processes occur simultaneously and, if set up properly, create a balanced system with equal supply and exhaust airflows so that risks of positive or negative pressures are not imposed on the interior of the house.

When heat is transferred from the exhaust to the outdoor air stream during the heating season, condensation can form inside the heat exchange core. For this reason, drain pans are located inside the HRV to collect any water buildup, and the HRV is connected to a sanitary drain (6).

In persistently colder winter conditions such as Yukon, the condensation inside the core can freeze and block the exhaust air stream. Some HRVs are designed to protect against freezing and clear the core of frost with an automatic defrost mode. This is typically accomplished by a damper that closes off the outdoor air supply and allows warm indoor air into the HRV to circulate through the core and melt any ice on the exhaust side. When operating in defrost mode, there is a temporary discontinuation in the indoor-outdoor air exchange. During periods of extreme cold the HRV may operate in defrost mode too often to provide adequate ventilation. To reduce this risk, a preheater may be required to be installed within the outdoor air supply stream.

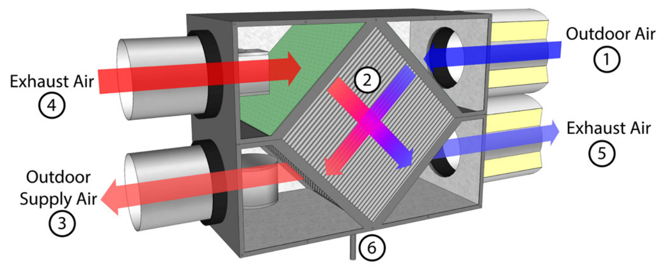


Diagram of HRV operation

Benefits of HRVs

HRV systems have several benefits beyond the key ones of energy and cost savings. Some of these benefits are specific to HRV systems, while others are simply a benefit of providing continuous ventilation air directly to rooms.

- **Enhanced Indoor Air Quality:** HRV systems enhance the indoor air quality in a space by exhausting indoor air pollutants and replacing that air with filtered outdoor air.
- **Building Enclosure Durability:** HRVs help control indoor humidity levels by exhausting moist indoor air and reducing the risk of condensation on windows and cool indoor surfaces that could lead to mould growth and moisture damage.
- **Combustion Appliance and Soil Gas Safety:** In homes with naturally aspirated combustion appliances, flue gas spillage or backdrafting can occur when negative pressure conditions (inward acting) on the home overcome the natural draft (outward acting) of the combustion appliances. Similarly, in houses with below-grade levels, soil gases such as radon can be drawn into the home during periods of depressurization. HRVs with balanced airflows do not contribute to the depressurization of a home.

Limitations of HRVs

HRVs have a few limitations that should be considered:

- **Cost:** HRV systems are relatively expensive and require annual replacement of filters. Installation of return and supply ducts is required if there is no existing ducting.
- **Size:** Adding an HRV requires additional space within the mechanical room.
- **Efficiency:** HRV systems are most effective when installed in air tight homes. Limited benefits are gained if installed without completing air-sealing retrofits.

Retrofit Considerations

- If there is a furnace in the house, it is possible to simply interconnect the HRV with the return air duct. Return air is exhausted through the HRV with a connection upstream of the furnace. The HRV also preconditions the outside air before it enters the furnace return air duct, up stream of the furnace but after the exhaust vent. Controls for the furnace fan and HRV fan are required to ensure that they operate simultaneously such that balanced ventilation occurs. This approach typically still necessitates the use of kitchen and bathroom exhaust fans for immediate control of moisture and air contaminants.
- Plan how the unit will connect its drain pan to a sanitary pipe, whether a gravity-fed connection or a connection via a condensate pump.
- Ensure enough space is provided so the unit can be easily inspected, serviced, and replaced.
- Try to locate the unit as close to an exterior wall as possible to limit the amount of insulated cold-side flex duct needed as flex ducting can restrict the airflow capacity of the HRV.

Air-Source Heat Pumps

An air-source heat pump (ASHP) is an electrically powered heating and cooling system that transfers heat energy from the outside air and into the home. Heat pumps are much more efficient than other types of heating equipment, particularly electric resistance based systems such as baseboard heaters. During the heating cycle, ASHPs transfer heated fluid (refrigerant) between two heat exchanger coils, one located outdoors (the evaporator) and one indoors (the condenser). ASHPs also contain reversing valves, allowing them to not only provide heating in the winter, but cooling in the summer.

ASHP Operation

The cycle of refrigerant evaporation and condensation allows heat to be "pumped" from a lower-temperature environment to a higher-temperature environment. The cycle works as follows:

1. High-temperature liquid refrigerant travels outside and passes through an expansion device, reducing the pressure and temperature of the liquid.
2. This low-temperature liquid moves through the evaporator coil, where it absorbs heat from the outdoor air and evaporates into a vapour.
3. This low-temperature vapour is then pumped through the compressor, where compression increases the vapour's temperature.
4. This high-pressure vapour then travels indoors and passes through the condenser coil, exchanging heat to warm the indoor air. Exchanging heat causes the refrigerant to change back into a liquid, where it restarts the cycle.

During winter operation frost will often accumulate on the ASHP's outdoor unit due to the low temperature of the evaporator coil. This reduces the efficiency of the coil, so ASHPs are programmed to intermittently run a defrost cycle and melt away the frost. The defrost cycle works by switching the reversing valve to operate the unit in cooling mode for a short period of time, sending warm refrigerant through the outdoor coil and melting the frost.

Equipment Efficiency

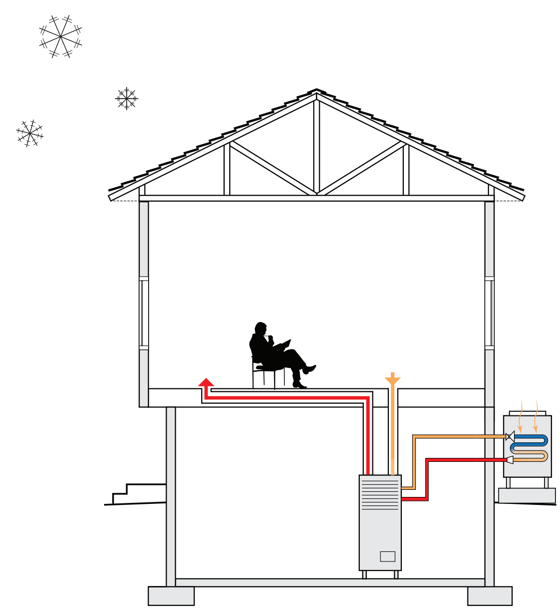
Heat pump efficiency is typically measured using the coefficient of performance (COP). The COP is a unit-less ratio of the rate of heating or cooling output to electrical power input (both measured in kW). The COP is similar to equipment efficiency – a COP of 3.0 is equivalent to an efficiency of 300%. The COP varies with several factors and is generally reported for both heating and cooling modes.

Seasonal performance metrics are used to describe the performance of the ASHP over a typical year, accounting for variations in temperature throughout the year. Other common efficiency metrics for ASHPs include:

- **Energy efficiency ratio (EER):** a metric that is used to describe the cooling efficiency of the heat pump. It is the ratio of cooling output (in Btu/h) to electrical power input (in kW).
- **Heating seasonal performance factor (HSPF):** a ratio of how much heat energy the heat pump delivers over a full heating season (in Btu) to the electrical energy used (in Wh).
- **Seasonal energy efficiency ratio (SEER):** a metric describing the cooling efficiency of the heat pump over a full cooling season. It is a ratio of annual cooling energy delivered (in Btu) to electrical energy consumed (in Wh).

Operation in Northern Climate Zones

Conventional air source heat pumps typically operate down to temperatures around -8°C. Below this temperature they do not operate as efficiently, but are still more efficient than electric resistance heaters down to approximately -15°C. Some ASHPs are designed for colder climates and are called cold climate Air Source Heat Pumps (ccASHPs). These systems may include larger outdoor evaporator coils, more sophisticated control systems, and larger, variable capacity, high-efficiency compressors that allow them to operate efficiently at lower temperatures. ccASHPs can extract heat from the air down to -25°C or colder. Typical ccASHP have heating COPs ranging from 3.0 at 5°C to 1.5 at -21°C.



Ducted ASHP in Heating Mode

System Design

The heating capacity of air source heat pumps is reduced when they operate at colder exterior temperatures. **Due to this reduced capacity, ASHPs require a backup heating system in cold climates.** Backup systems depend on building type, but may include a propane or oil furnace, pellet or wood stove, electric baseboard heaters, or in-duct electric heating coils. This backup system provides supplementary heating when the ASHP can no longer meet the required heating demand. ASHPs should be carefully sized using heating and cooling load calculations to ensure an appropriate balance of heat pump and backup system operation.

ASHP heating systems can be installed in two configurations:

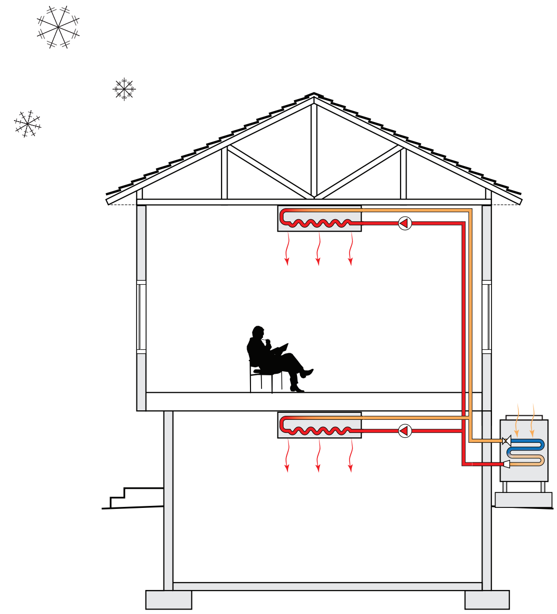
- **Ducted ASHPs** (shown on previous page) have the indoor unit located in the central ductwork of the home. The coil functions like a combination of a forced air furnace and central air conditioner, supplying hot or cold air to the home through supply ducts.
- **Ductless ASHPs** have the indoor unit located within the living space of the home. These indoor units are generally mounted on the wall but can also be floor-mounted or recessed into the wall or ceiling. Mini-split ductless ASHPs have a single outdoor unit supplying a single indoor unit, while multi-split ductless ASHPs have a single outdoor unit supplying multiple indoor units.

Ducted ASHPs are most easily installed in homes with existing forced air heating systems while ductless ASHPs are typically installed in homes that do not have an existing forced air heating system.

Retrofit Considerations

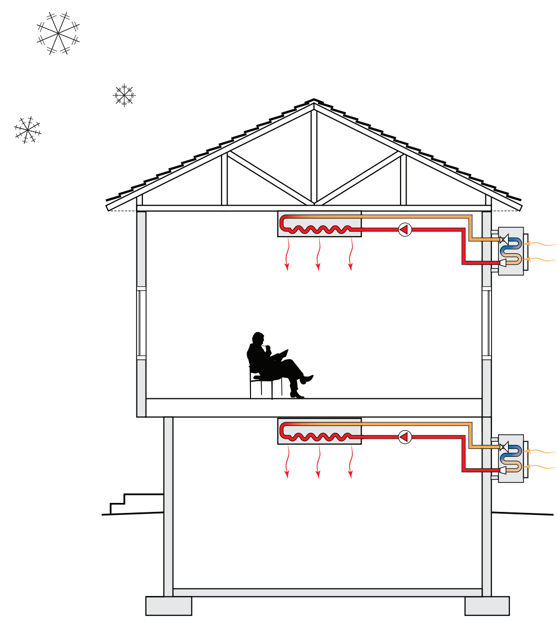
The outdoor unit requires clearance at the front and back to allow enough air to flow over the evaporator coil. Inadequate airflow will reduce the heating capacity and efficiency of the ASHP. The unit should also be elevated or protected from snow cover during the winter months. If possible, the outdoor unit should be installed on wall-mounted brackets and away from roof drip lines. New penetrations for electrical and refrigerant connections through the building enclosure must be sealed and made watertight during the retrofit.

Several installation factors can affect the efficiency of the unit and its ability to meet the home's heating load. These factors include duct leakage, undersized ductwork, low or high refrigerant charge, and oversized ASHPs. Equipment sizing and installation should be conducted by a qualified professional.



Multi-split Ductless ASHP in Heating Mode

Multiple indoor units are supplied by a single outdoor unit and provides heat directly to the living space.



Mini-split Ductless ASHP in Heating Mode

Each indoor unit is supplied by a single outdoor unit and provides heat directly to the living space.

7.0 Solar Power Opportunities

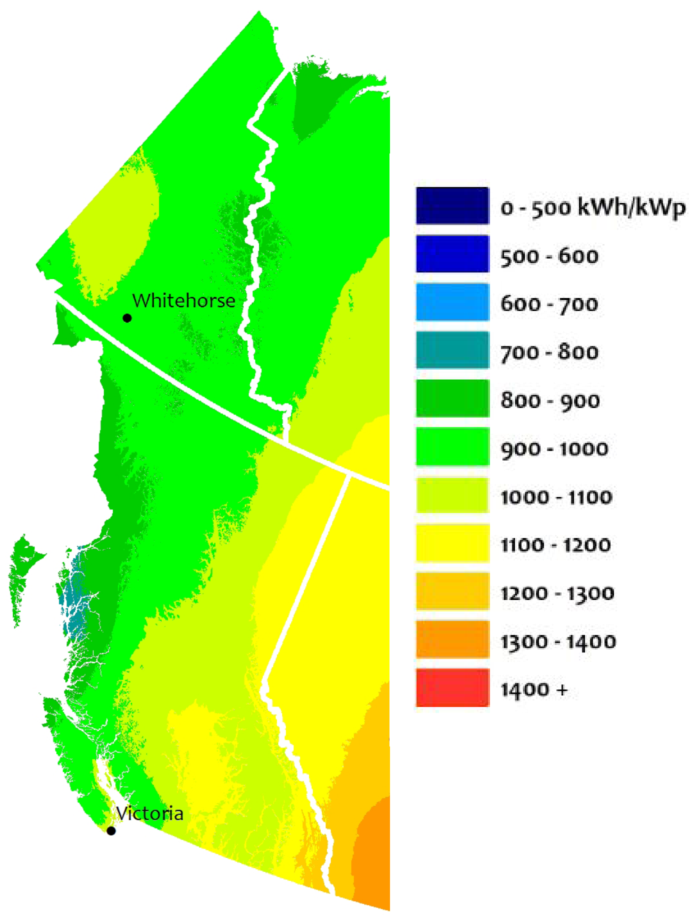
The Government of Yukon encourages its residents to use solar energy to reduce their power consumption. While Yukon enjoys renewable hydroelectricity, capacity is limited, and increasing demand will require new generation facilities. Yukon Energy Branch would like customers to reduce power consumption and consider installing solar energy systems using photovoltaic (PV) panels. Residential PV installations generate power at costs close to current utility rates. Yukon's Energy Branch Net Metering program allows customers to send any excess power they generate back into the grid for a credit. This credit can be used to pay for grid electricity when the PV system is not generating enough energy for the home, such as overnight or during the winter.

Solar Potential in Yukon

PV potential represents the expected lifetime average electricity production (in kWh) produced per kilowatt of installed direct current capacity rated at Standard Test Conditions for grid-connected PV systems without batteries. The PV potential map from Natural Resources Canada shows that Yukon has a PV potential similar to the coastal and semi-interior areas of BC, albeit with a majority of the electricity being generated during the summer months. Owners can assess the economics associated with installing a PV system using the Economics of Household Photovoltaic Solar Systems tool provided by the Government of Yukon.

Benefits of Installing PV Panels

- **Renewable:** Solar energy is a renewable energy source that is available at varying capacities year-round. Utilizing renewable energy sources decreases the reliance on non-renewable energy sources such as fossil fuels. This reduces the users greenhouse gas emissions and related environmental impact.
- **Lower electricity bills:** Customers meeting some of their energy needs with a PV system will experience lower utility bills. Moreover, customers with PV systems connected to the grid can be reimbursed through feed-in-tariff programs.
- **Low maintenance costs:** PV systems don't require extensive maintenance. Panels should be cleaned a few times a year to maintain optimal performance. PV panels do not have wear components that require changing during their lifetime. Manufacturers generally offer 20-25 year warranties on panels. The only part of the system that requires more frequent replacement is the inverter, which has a typical lifespan of 5-10 years. It is recommended to inspect cables and connectors bi-annually to ensure the system operates efficiently.
- **Increase in property value:** Properly installed PV systems may increase property values by providing potential buyers with annual energy cost savings. PV systems are also visible statements highlighting that the owner lives "sustainably" and is socially responsible, providing intrinsic value.
- **Easily expandable:** PV panels can be grouped together in arrays and additional panels can be added in at future dates fairly easily.
- **Backup power:** If an energy storage system is included, the PV system can provide backup power during periods of extended power outages.



Solar Potential Map of Canada

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Drawbacks of Installing PV Panels

- **Upfront cost:** The initial cost of purchasing a PV system is high, however the payback period begins immediately once the system is operational.
- **Weather dependent:** Although PV systems can still generate electricity during cloudy and rainy days, their output drops considerably. While less of an issue for systems connected to the grid, off-grid systems dependent on energy storage should have a back-up generator in case the storage system is depleted. Snow coverage will completely block power generation and requires clearing.
- **Expensive energy storage:** Energy storage systems are expensive but are only required for off-grid systems.
- **Space requirements:** For roof mounted systems the available roof area limits the size of the PV system that can be installed on the roof.
- **Roof orientation:** For roof mounted systems, the orientation of the roof greatly impacts the overall output of the PV system and requires consideration early in the retrofit design. Panels have the highest generation potential when oriented due south. However as panels have become more efficient, acceptable outputs can still be achieved with panels oriented to an azimuth of 115° to 265° (25° south of the east-west axis). Ground mounted units have greater flexibility but are at greater risk of being blocked by adjacent structures or tree cover.

Components

A typical roof mounted PV system includes the following basic components with the associated functions:

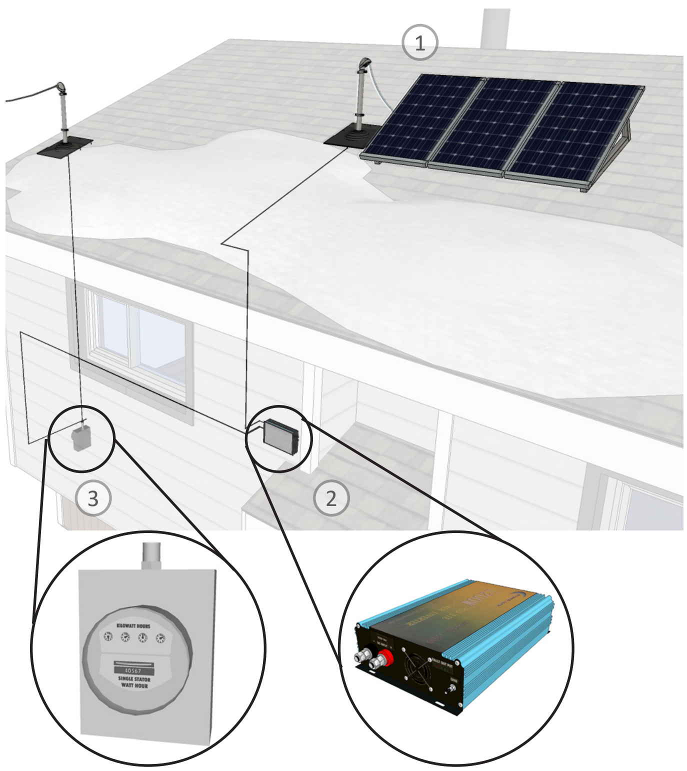
1. **PV array on rack system:** The panels convert solar energy to direct current (DC) electricity. The DC electricity is then sent to the inverter through conduits.
2. **Inverter:** The inverter converts DC electricity to alternating current (AC) and is the most sophisticated part of the PV system. From the inverter, AC electricity is sent to the electricity meter. Using a quality inverter is recommended to improve reliability and system efficiency. The inverter should be located in an accessible location within the house and requires adequate ventilation to prevent overheating. It is recommended that inverters not be located within attic spaces.
3. **Electricity meter:** A two-way grid-tied meter is required and typically provided by the utility service. Electricity can flow through the meter in either direction, depending on the amount of electricity the system is producing and how much electricity is being used.

Retrofit considerations

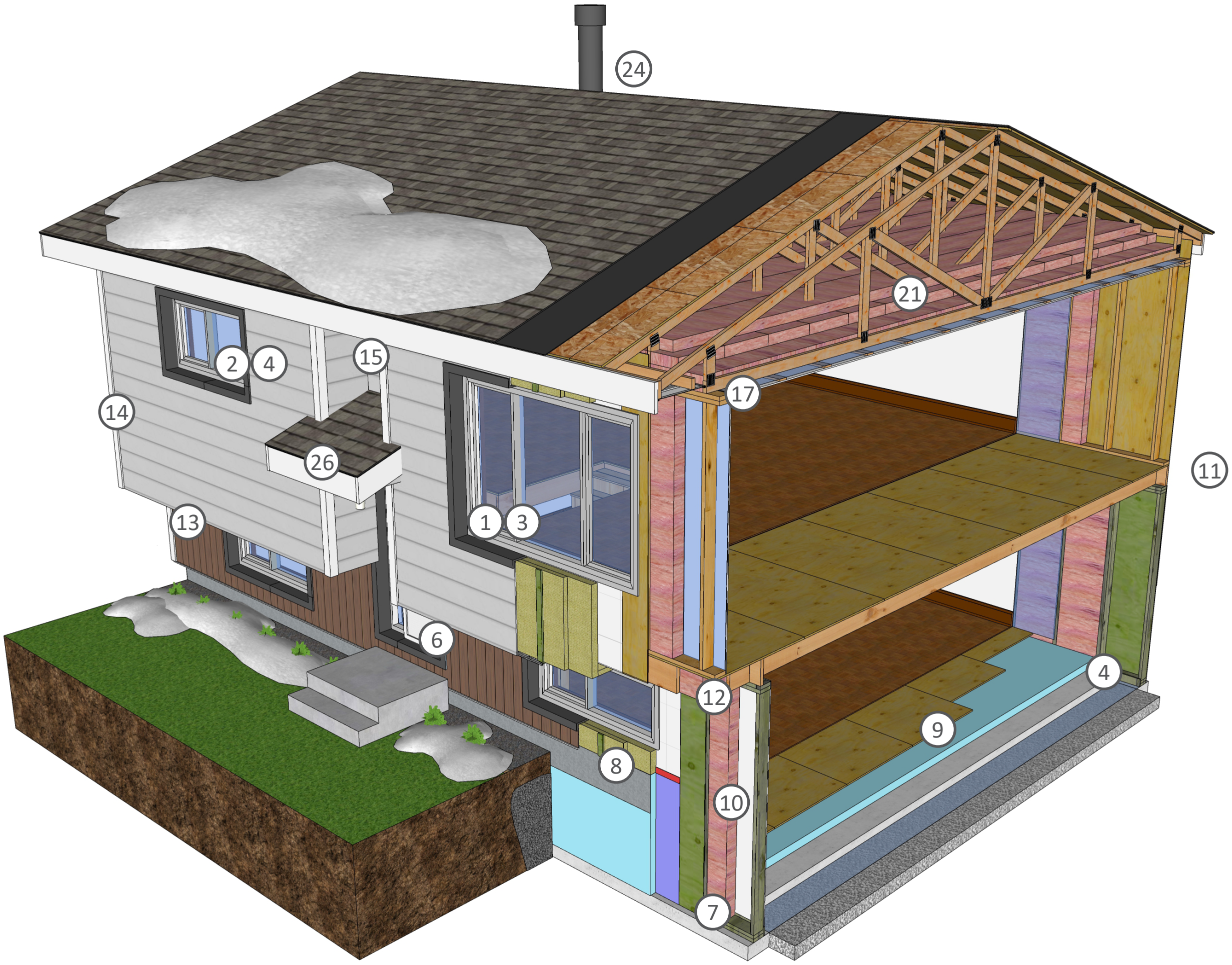
The age and condition of the existing roof should be considered before a PV system is installed. PV panels need to be removed and re-installed ("re- & re-") to facilitate roofing replacement which risks damaging PV components and adds labour costs to any future re-roofing project. To mitigate the risk of damage and added labour costs, it is important to consider re-roofing before installing a PV system. Typically, this means if the roofing is going to be replaced within the next 4 to 7 years, it is worth considering re-roofing prior to installing a PV system. If however the roof life is expected to exceed 10 to 15 years then a system re- & re-could be considered.

It should be noted that the installation of a solar PV system can accelerate roofing degradation (e.g. trapped heat can rapidly degrade shingles). As such, it is important to consider the configuration of the arrays to minimize heat build-up which can impact system performance and prematurely age the roofing system.

Only PV systems designed for installation onto sloped roofs should be used and the roof support structure should be evaluated before adding a PV system to reduce the risk of overloading the roof structure during heavy snow events. Wind uplift should also be considered as a dislodged panel can cause considerable property damage. Engineered mounting systems are recommended and the manufacturer's installation requirements must be followed.



8.0 Building Enclosure Details

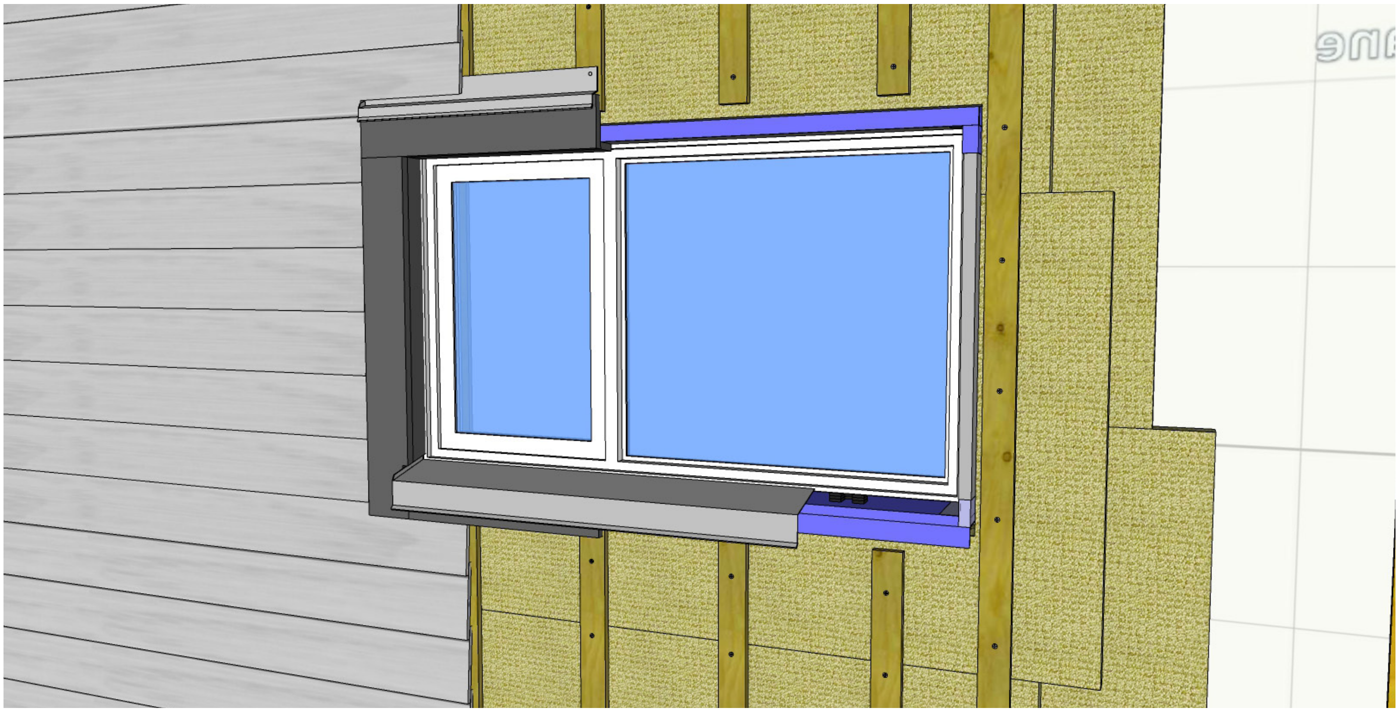


*Locations not shown: Details 5 (Flanged Window with Deep Set Brick Mold, 11 (Interior Rim Joist Area), 16 (Above-Grade Wall to Pitched Roof- Raised Heel Truss), 18 (Additional Roof Structure), 19 (Chainsaw Retrofit- Blown-in Insulation), 20 (Chainsaw Retrofit- Rigid Foam Board Insulation), 22 (Plumbing Vent Stack - Attic), 23 (Attic Hatch), 25 (Electrical Penetration - Attic), 27 (Exhaust Vent- Wall), 28 (Hose Bib), 29 (Exterior Light Fixture), 30 (Exterior Electrical Outlet), 31 (HRV Installation - No Exterior Retrofit), 32 (ASHP Installation- No Exterior Retrofit), 33 (PV Panel Installation), 34 (Radon Retrofit- Active Soil Depressurization), 35 (Radon Retrofit- Radon Vent)

The key building enclosure details for the proposed enclosure retrofits are presented in this section. The construction of each detail is explained with 3D illustrations and text.

Building Enclosure Detail List

Detail 1 Non-Flanged Window with Buck



Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Remove the existing window to expose the window rough opening.
2. Install window buck. Window buck depth should match the depth of the future exterior insulation. Install sloped window head at top of buck-out where feasible.
3. Install vapour-permeable air barrier membrane (sheathing membrane) starter strip below the rough opening, extending 6" above the sill of the rough opening. Tape leading edge of the membrane with sheathing tape.
4. Install self-adhered membrane gussets at the lower corners.
5. Install self-adhered membrane between sheathing membrane and wood-frame buck-out.

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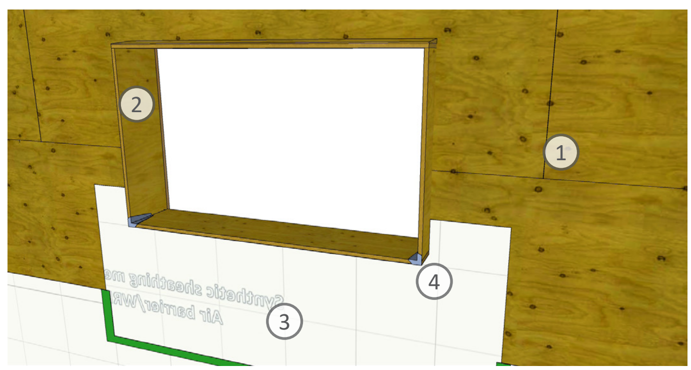

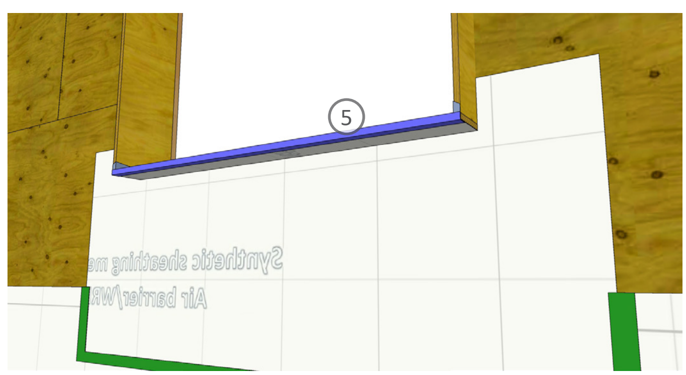

Retrofit Steps Continued:

6. Install self-adhered membrane skirt to exterior face of wood buck-out to aid in water diversion over the exterior insulation. Leave backer on unsupported portion of the membrane until after exterior insulation is installed.
7. Install self-adhered sill membrane. Extend membrane up the jambs and over the self-adhered membrane skirt.
8. Install self-adhered membrane at sill corners, extending up the jamb to the height of sheathing membrane and wrapping around the buck-out onto the sheathing membrane pre-strip a minimum 3".
9. Wrap the buck-out jambs and window head with vapour-permeable self-adhered membrane and positively lap over the membrane below.
10. Install self-adhered membrane gussets at the top corners of the buck-out and at transition to plywood sheathing.
11. Apply self-adhered membrane to upper corner of bucks to transition gussets to plywood sheathing at wall.

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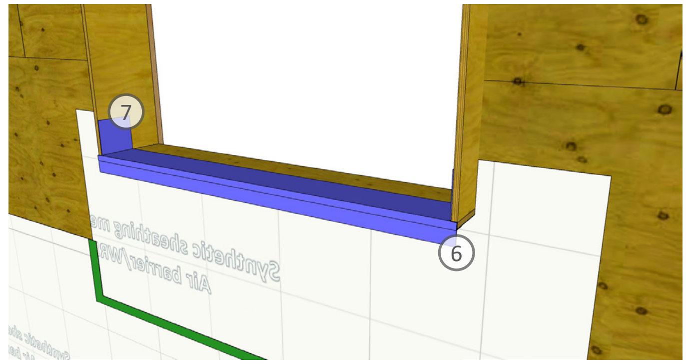
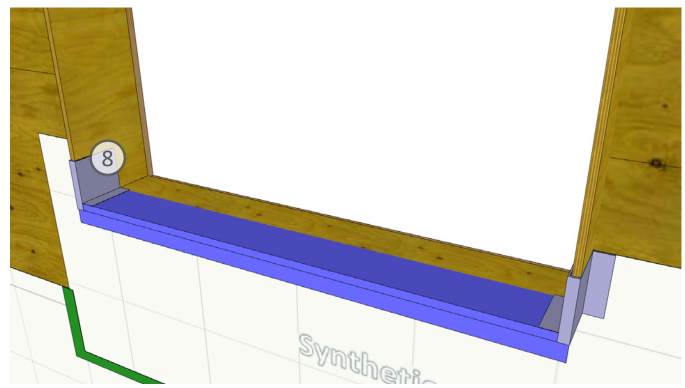
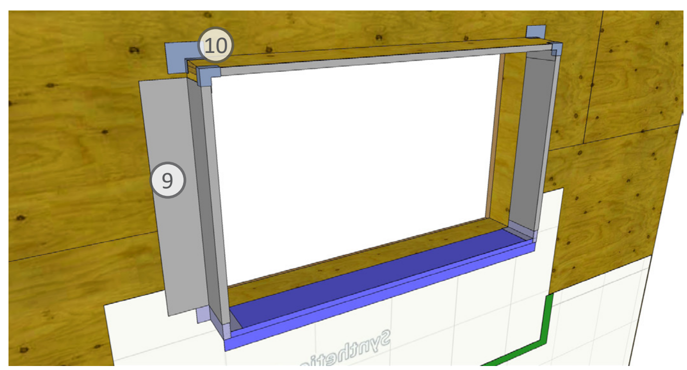
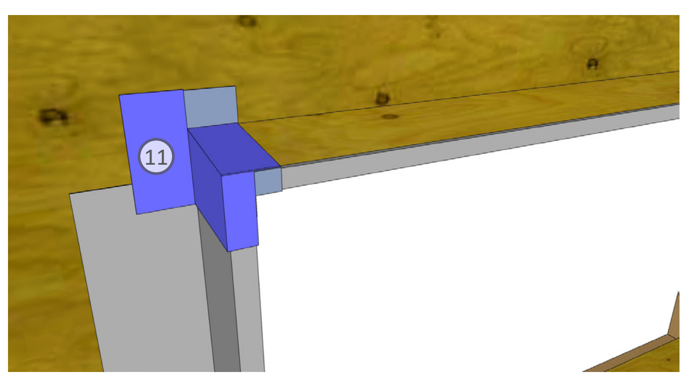




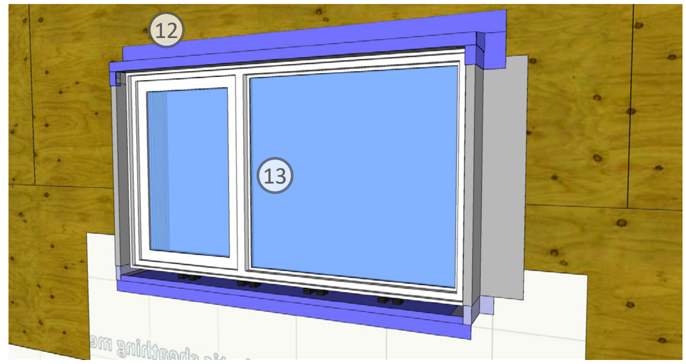


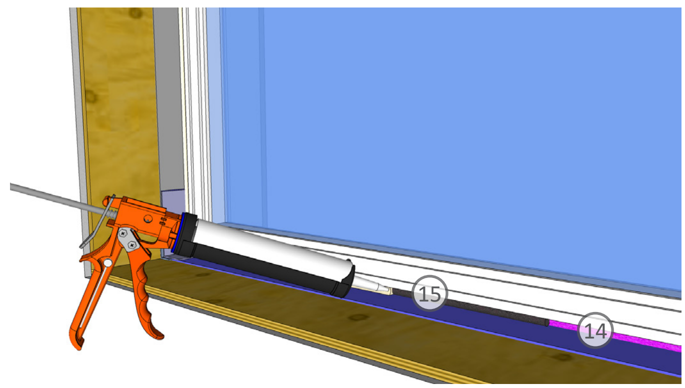


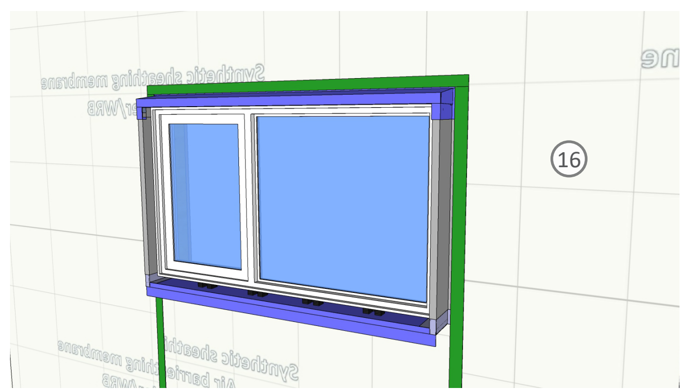
Retrofit Steps Continued:

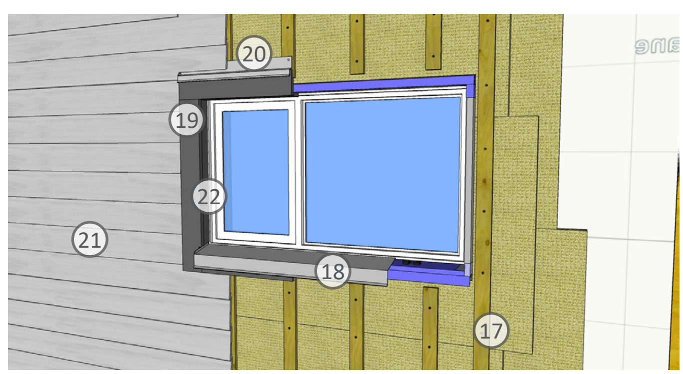
12. Install self-adhered membrane over the top of the wood buck-out extending onto the plywood sheathing a minimum 6".
13. Install window on intermittent shims and structurally attach per the window manufacturer's specifications.
14. Install polyurethane spray foam around the interior perimeter of the window. Ensure the expanded foam does not impede installation of backer rod.
15. Install backer rod and sealant around the interior perimeter of the window to complete air barrier continuity.
16. Install sheathing membrane. Ensure positive laps over all other layers. Seal all membrane laps with sheathing tape.
17. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
18. Install pre-finished metal sill flashing with *end dams. Attach the sill flashing to the nailing flange under the window sill. Apply sealant between the metal flashing and the window sill.
19. Install window trim boards to strapping.
20. Install metal head flashing complete with end dams to the strapping above the window trim board.
21. Reinstall existing cladding where possible or install new cladding.
22. Apply sealant around the perimeter of the window (top and sides) between the frame and window trim boards.

*End Dams: Typically formed on both the sill flashing and head flashing before installation. Extended siding of flashing is folded upwards to prevent water from moving laterally into the wall.

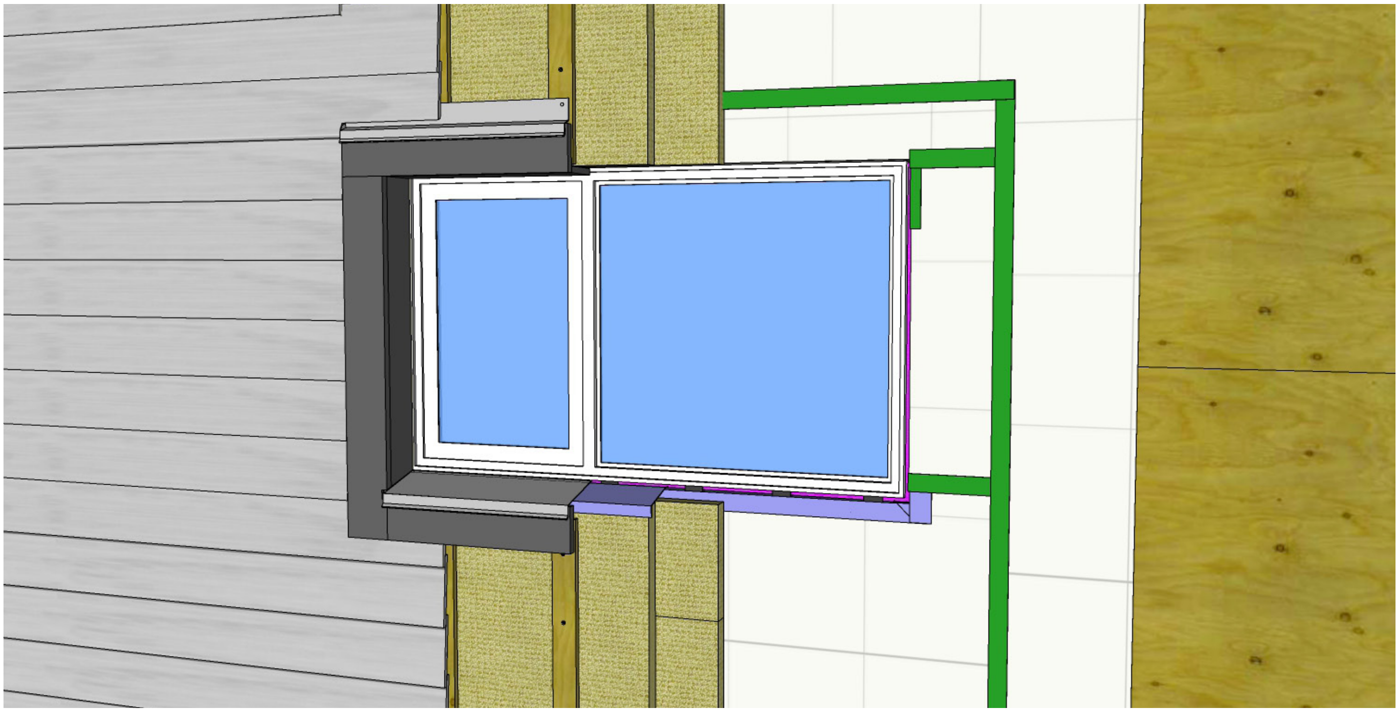








Detail 2 Non-Flanged Window without Buck



Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Remove the existing window to expose the window rough opening.
2. Install vapour-permeable air barrier membrane (sheathing membrane) starter strip below the rough opening, extending 6" above the sill of the rough opening.
3. Install self-adhered sill membrane. Extend membrane up the jambs and onto the face of the wall.
4. Install self-adhered membrane gussets at the lower corners.
5. Install self-adhered membrane at sill corners, extending up the jamb to the height of the sheathing membrane. Finish the self-adhered membrane minimum 2" onto the face of the wall.

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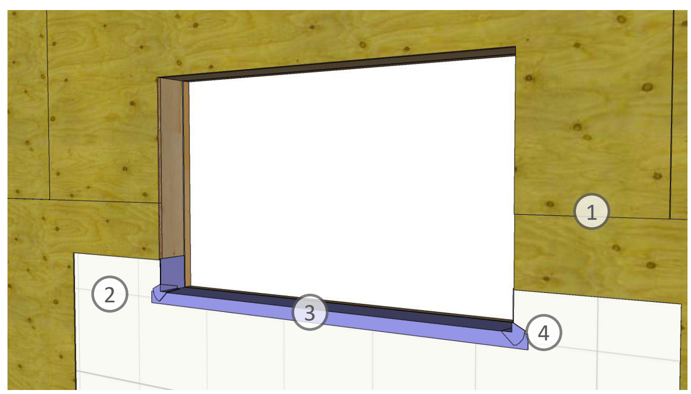
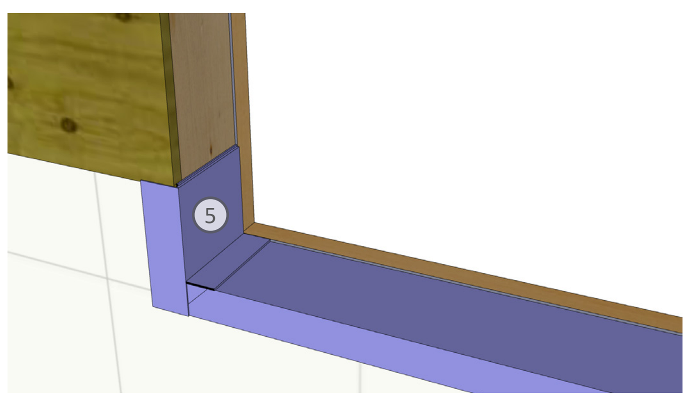
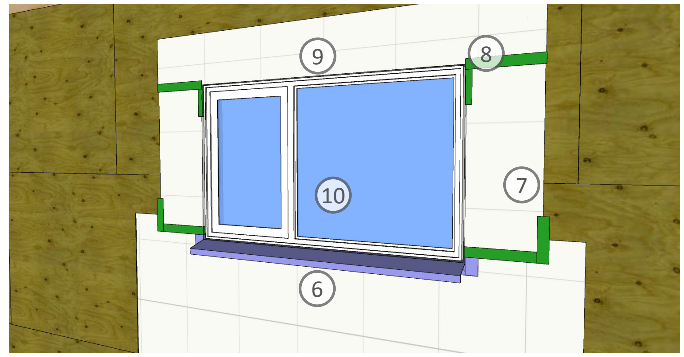
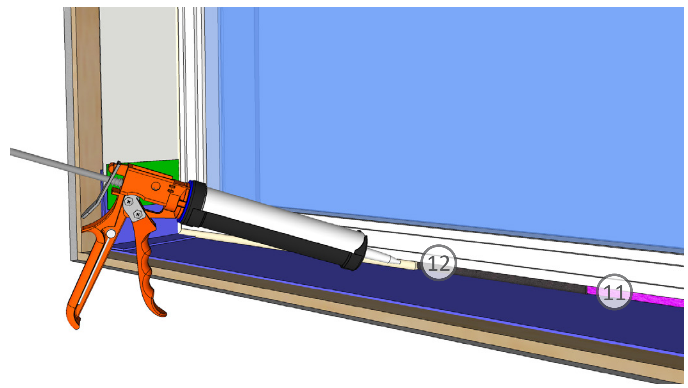


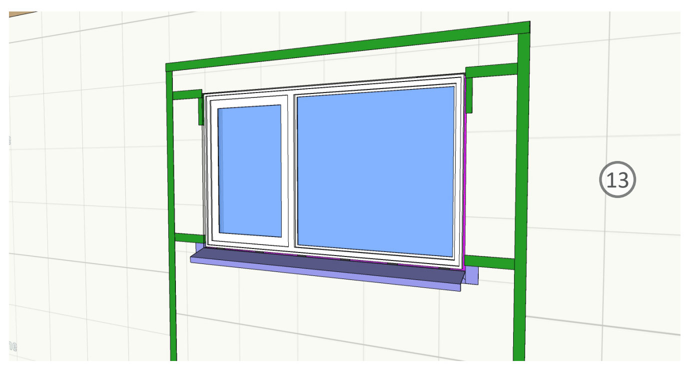


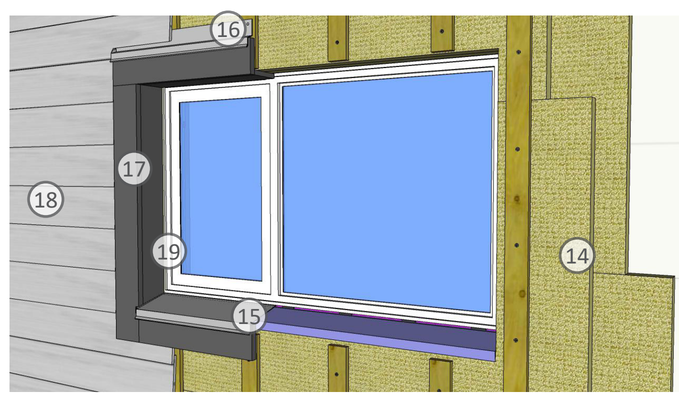
Retrofit Steps Continued:

6. Install self-adhered skirt membrane to aid in water diversion. Leave backer on unsupported portion of the membrane until after exterior insulation is installed.
7. Install sheathing membrane pre-strips at the jambs and extend onto the wall face a minimum 8”. Seal all leading edges with sheathing tape.
8. Install sheathing tape gussets at the top corners of the rough opening.
9. Install sheathing membrane at the head of the rough opening, extending a minimum 12” above the head of the rough opening.
10. Install window on intermittent shims and structurally attach per the window manufacturer's specifications.
11. Install polyurethane spray foam around the interior perimeter of the window. Ensure the expanded foam does not impede installation of backer rod.
12. Install backer rod and sealant around the interior perimeter of the window to complete air barrier continuity.
13. Install sheathing membrane in the plane of the wall. Ensure positive laps over all other layers. Seal membrane laps with sheathing tape
14. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
15. Install pre-finished metal sill flashing with end dams. Attach the sill flashing to the nailing flange under the window sill. Apply sealant between the metal flashing and the window sill.
16. Install metal head flashing complete with end dams to the strapping above the window trim board.
17. Install window trim boards to strapping.
18. Reinstall existing cladding where possible or install new cladding.
19. Apply sealant around the perimeter of the window (top and sides) between the frame and window trim boards.

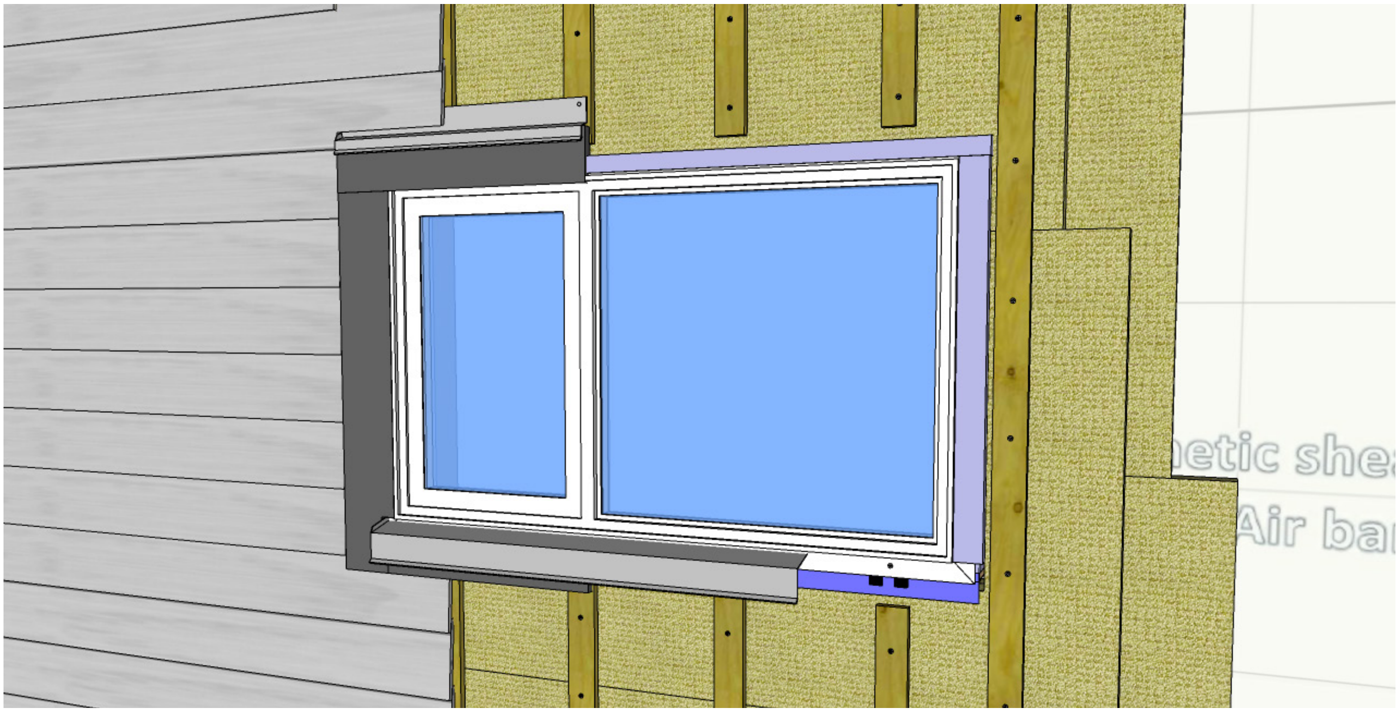








Detail 3 Flanged Window with Buck



Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Remove the existing window to expose the window rough opening.
2. Install window buck (2x12 dimensional lumber ripped to size). Window buck depth should match the depth of the future exterior insulation. Install sloped window head at top of buck-out where feasible.
3. Install vapour-permeable air barrier membrane (sheathing membrane) starter strip below the rough opening, extending 6" above the sill of the rough opening.
4. Install self-adhered membrane gussets at the lower corners.
5. Install self-adhered membrane between sheathing membrane and wood-frame buck-out.

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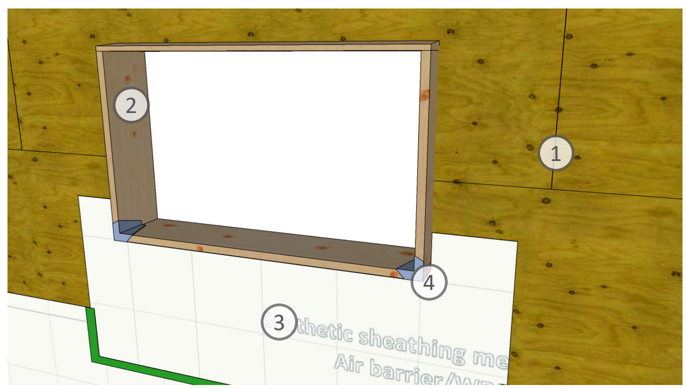

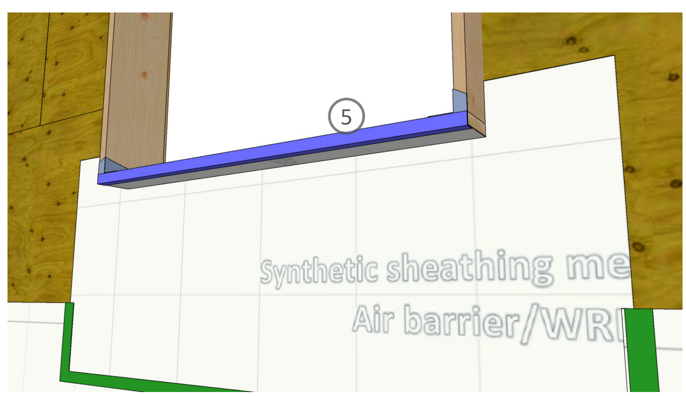

Retrofit Steps Continued:

6. Install self-adhered membrane skirt to exterior face of wood buck-out to aid in water diversion over the exterior insulation. Leave backer on unsupported portion of the membrane until after exterior insulation is installed.
7. Install self-adhered sill membrane. Extend membrane up the jambs and over the self-adhered membrane skirt.
8. Install self-adhered membrane at sill corners, extending up the jamb to the height of sheathing membrane and wrapping around the buck-out onto the sheathing membrane pre-strip a minimum 3".
9. Wrap the buck-out jambs and window head with vapour-permeable self-adhered membrane and positively lap over the membrane below.
10. Install self-adhered membrane gussets at the top corners of the buck-out and at transition to plywood sheathing.
11. Apply self-adhered membrane to upper corner of bucks to transition gussets to plywood sheathing at wall.

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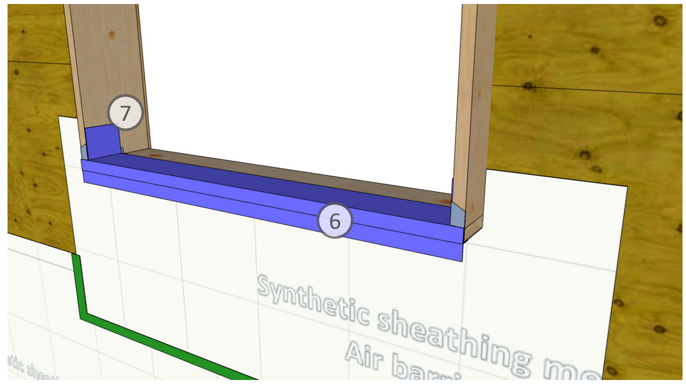
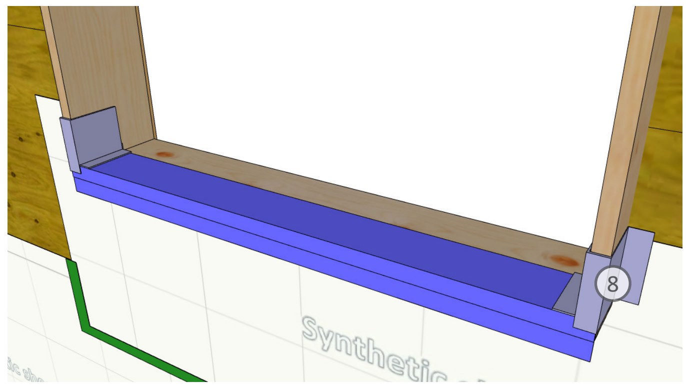
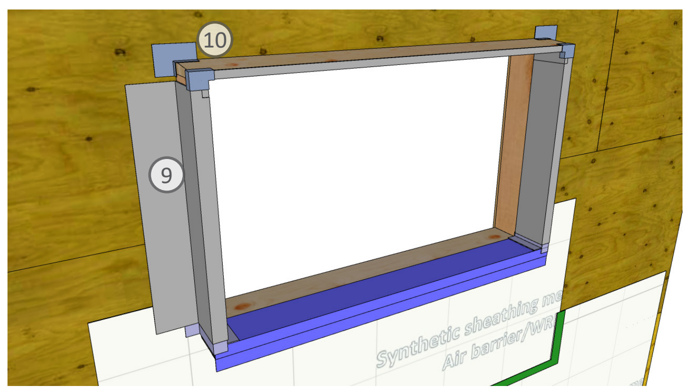
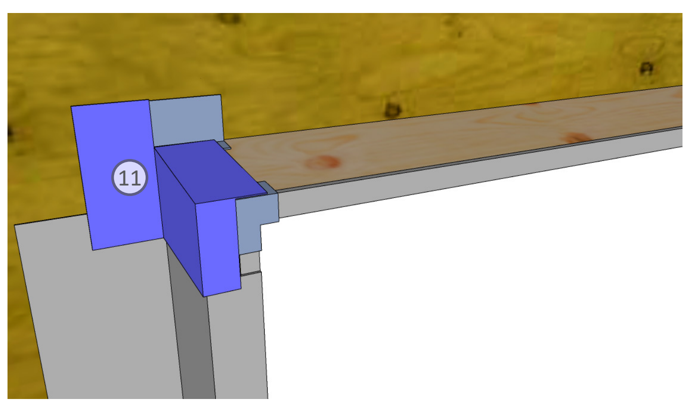






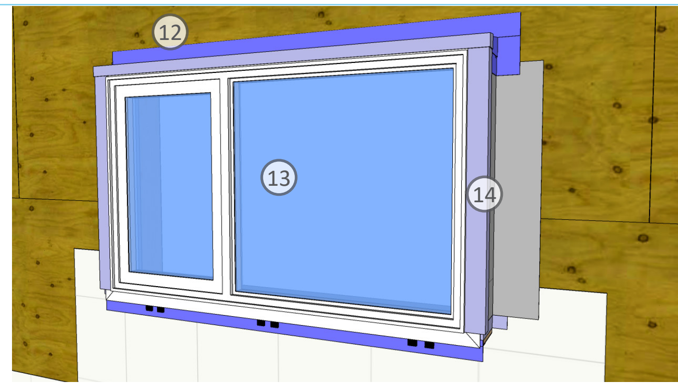


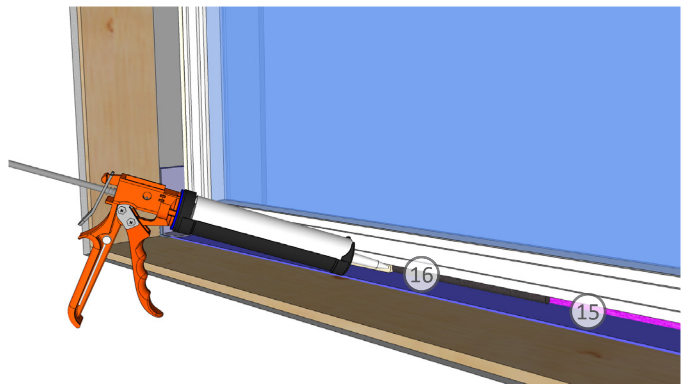
Retrofit Steps Continued:

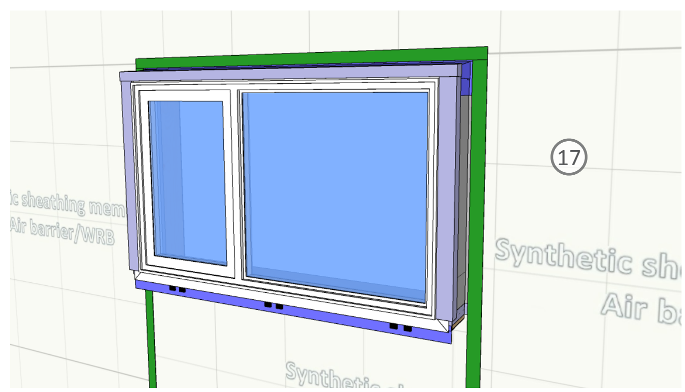
12. Install self-adhered membrane over the top of the wood buck-out extending onto the plywood sheathing a minimum 6".
13. Install window on intermittent shims and structurally attach per the window manufacturer's specifications.
14. Install high-performance tape onto window flange at head and jambs, extending a minimum 2" onto jamb membrane.
15. Install polyurethane spray foam around the interior perimeter of the window. Ensure the expanded foam does not impede installation of backer rod.
16. Install backer rod and sealant around the interior perimeter of the window to complete air barrier continuity.
17. Install sheathing membrane. Ensure positive laps over all other layers. Seal all membrane laps with sheathing tape.
18. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
19. Install pre-finished metal sill flashing with end dams. Attach the sill flashing to the nailing flange under the window sill. Apply sealant between the metal flashing and the window sill.
20. Install metal head flashing complete with end dams to the strapping above the window trim board.
21. Install window trim boards to strapping.
22. Reinstall existing cladding where possible or install new cladding.
23. Apply sealant around the perimeter of the window (top and sides) between the frame and window trim boards.

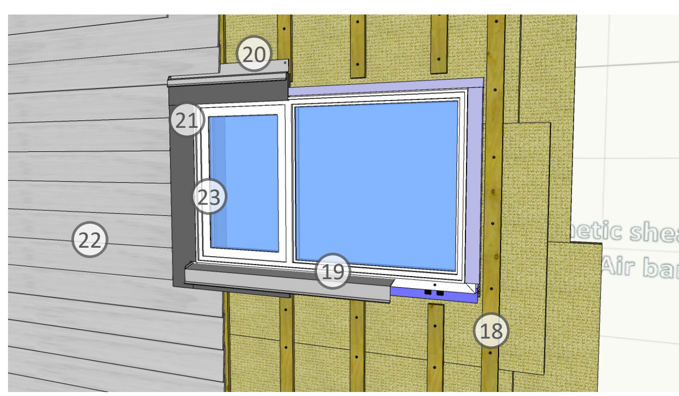
Key Considerations:

Sill drainage can be provided by notching sill flange or cutting sill buck 1/2" shorter then jamb and head. Insert shims behind sill flange to provide support for fasteners (shown).

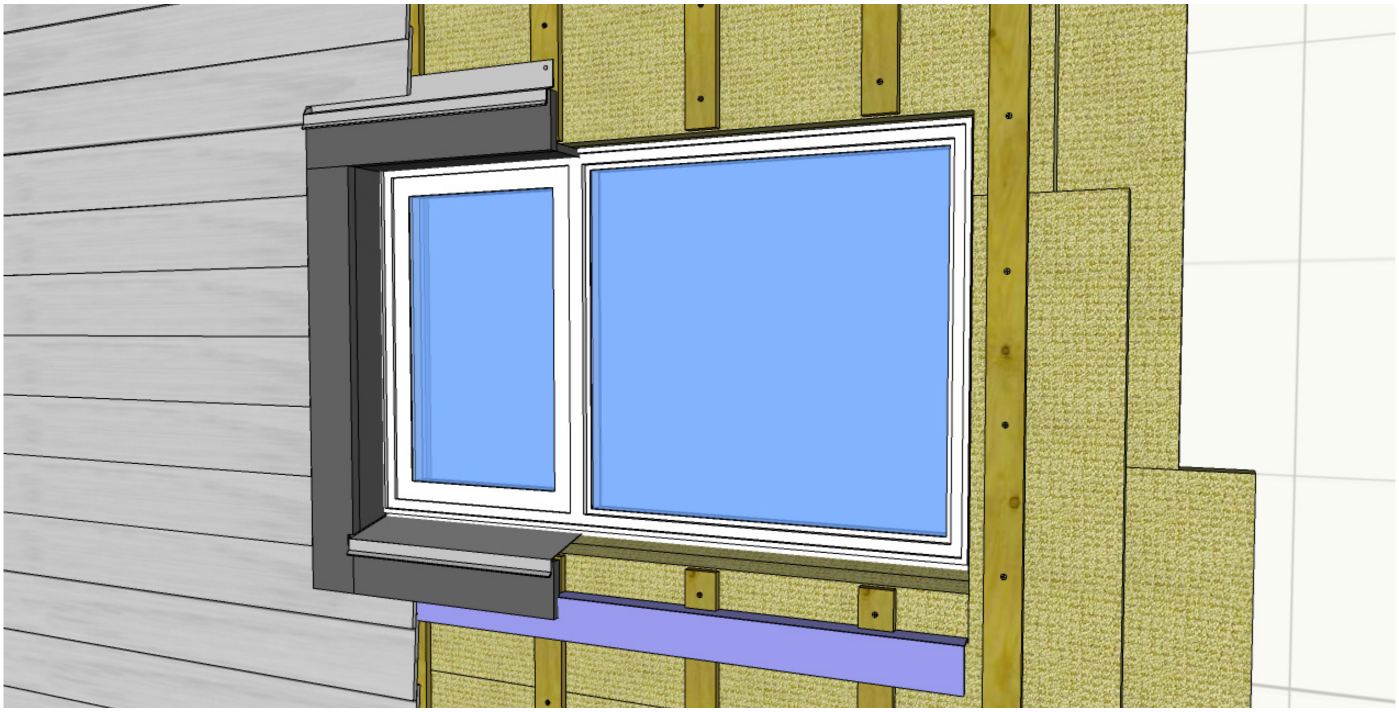








Detail 4 Flanged Window without Buck



Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Remove the existing window to expose the window rough opening.
2. Install vapour-permeable air barrier membrane (sheathing membrane) starter strip below the rough opening, extending 6" above the sill of the rough opening.
3. Install self-adhered sill membrane. Extend membrane up the jambs and onto the face of the wall.
4. Install self-adhered membrane gussets at the lower corners.
5. Install self-adhered membrane at sill corners, extending up the jamb to the height of the sheathing membrane. Finish the self-adhered membrane minimum 2" onto the face of the wall.

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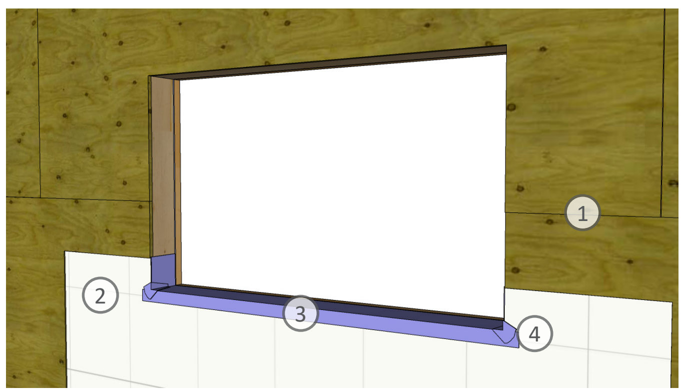
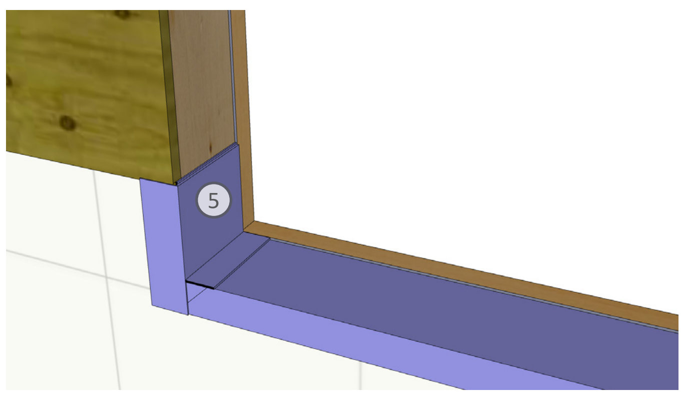
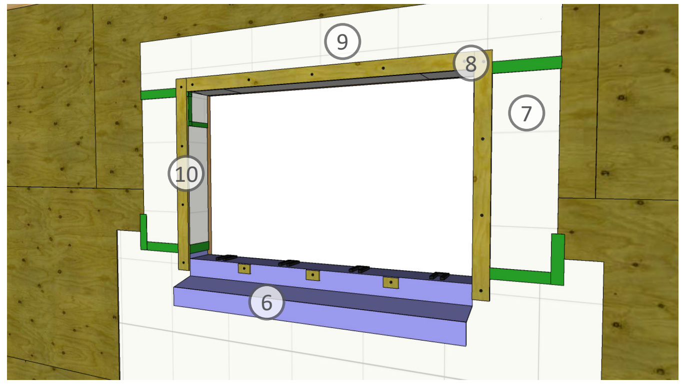
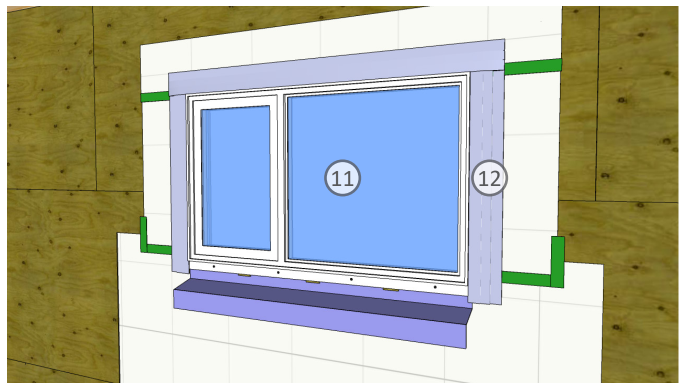


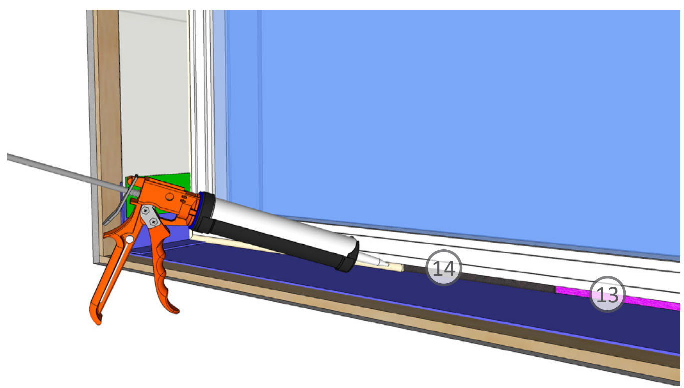


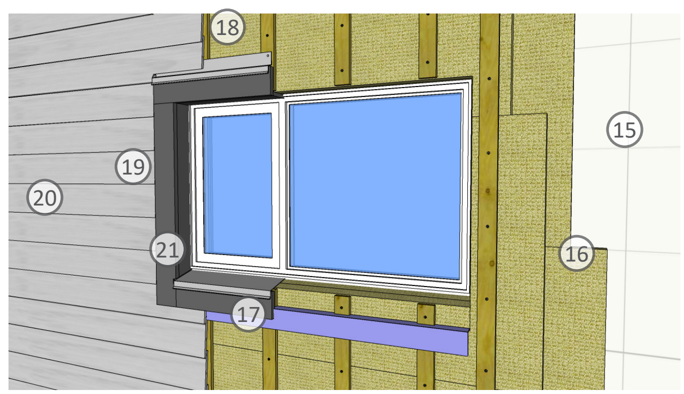
Retrofit Steps Continued:

6. Install self-adhered skirt membrane to aid in water diversion. Leave backer on unsupported portion of the membrane until after exterior insulation is installed.
7. Install sheathing membrane pre-strips at the jambs and extend onto the wall face a minimum 8”. Seal all leading edges with sheathing tape.
8. Install sheathing tape gussets at the top corners of the rough opening.
9. Install sheathing membrane at the head of the rough opening, extending a minimum 12” above the head of the rough opening.
10. Install 1/2" furring strips.
11. Install window on intermittent shims and structurally attach per the window manufacturer's specifications.
12. Install high-performance tape onto window flange at head and jambs, extending a minimum 2" onto jamb membrane.
13. Install polyurethane spray foam around the interior perimeter of the window. Ensure the expanded foam does not impede installation of backer rod.
14. Install backer rod and sealant around the interior perimeter of the window to complete air barrier continuity.
15. Install sheathing membrane in the plane of the wall. Ensure positive laps over all other layers. Seal membrane laps with sheathing tape
16. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
17. Install pre-finished metal sill flashing with end dams. Attach the sill flashing to the nailing flange under the window sill. Apply sealant between the metal flashing and the window sill.
18. Install metal head flashing complete with end dams to the strapping above the window trim board.
19. Install window trim boards to strapping. Apply sealant around the perimeter of the window (top and sides) between the exterior frame and window trim boards.
20. Reinstall existing cladding where possible or install new cladding.

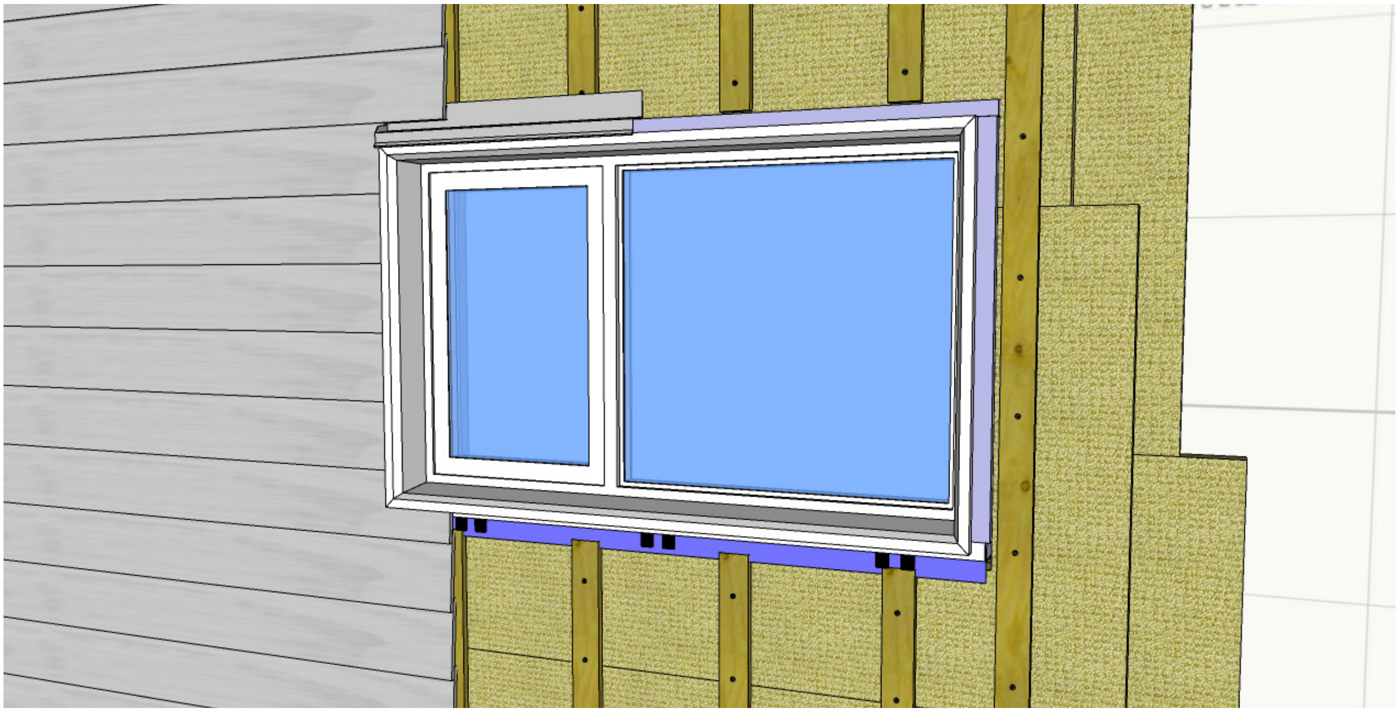








Detail 5 Flanged Window with Deep Set Brick Mold



Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Remove the existing window to expose the window rough opening.
2. Install window buck (2x12 dimensional lumber ripped to size). Window buck depth should match the depth of the future exterior insulation. Install sloped window head at top of buck-out where feasible.
3. Install vapour-permeable air barrier membrane (sheathing membrane) starter strip below the rough opening, extending 6" above the sill of the rough opening.
4. Install self-adhered membrane gussets at the lower corners.
5. Install self-adhered membrane between sheathing membrane and wood-frame buck-out.

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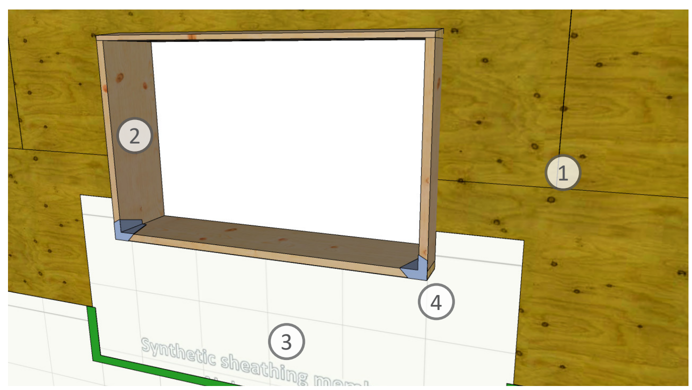

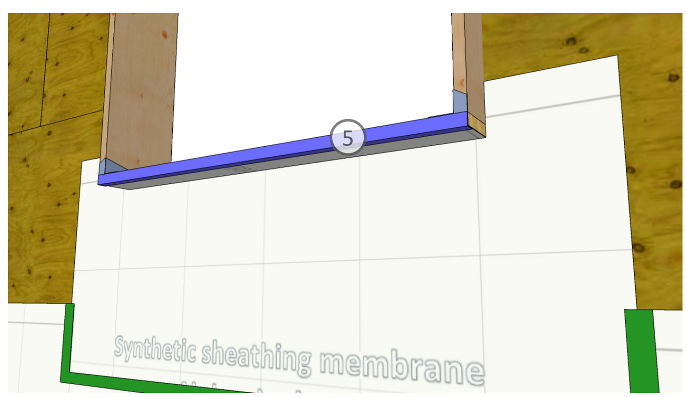

Retrofit Steps Continued:

6. Install self-adhered membrane skirt to exterior face of wood buck-out to aid in water diversion over the exterior insulation. Leave backer on unsupported portion of the membrane until after exterior insulation is installed.
7. Install self-adhered sill membrane. Extend membrane up the jambs and over the self-adhered membrane skirt.
8. Install self-adhered membrane at sill corners, extending up the jamb to the height of sheathing membrane and wrapping around the buck-out onto the sheathing membrane pre-strip a minimum 3".
9. Wrap the buck-out jambs and window head with vapour-permeable self-adhered membrane and positively lap over the membrane below.
10. Install self-adhered membrane gussets at the top corners of the buck-out and at transition to plywood sheathing.
11. Apply self-adhered membrane to plywood sheathing immediately above window head to transition gussets to plywood sheathing, ensuring membrane continuity.

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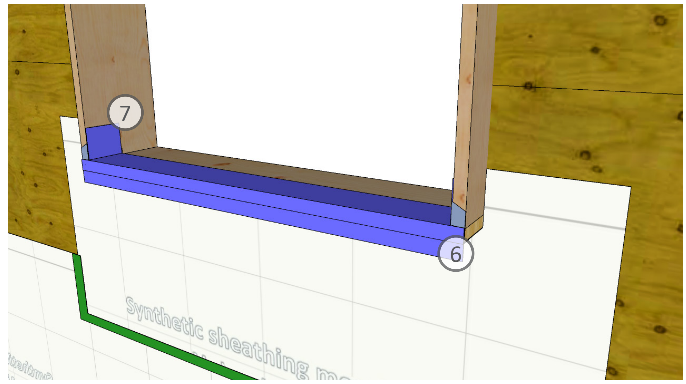
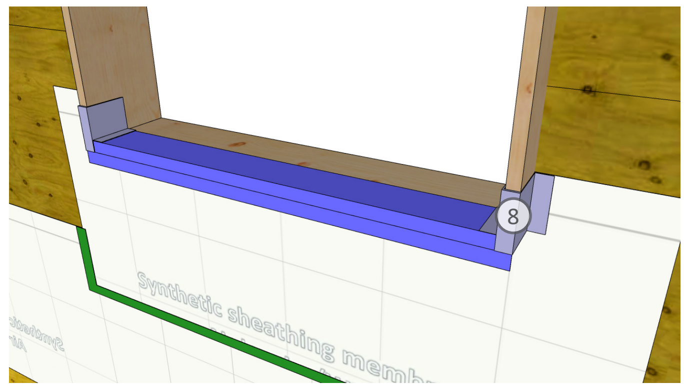
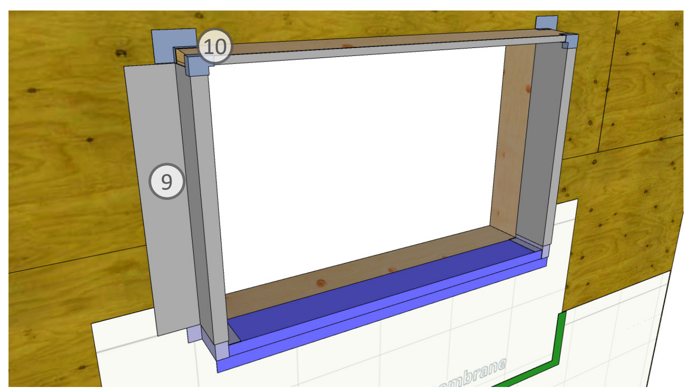
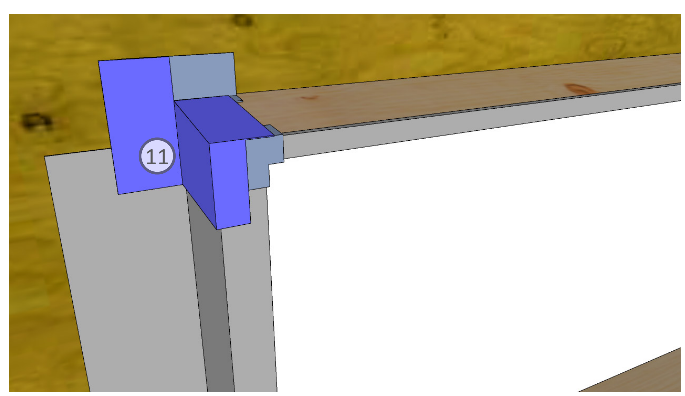








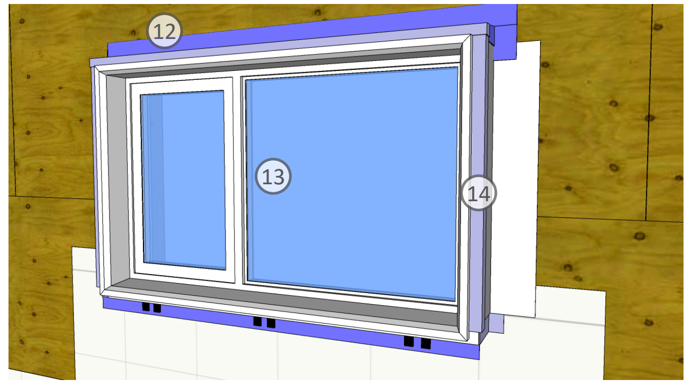
Retrofit Steps Continued:

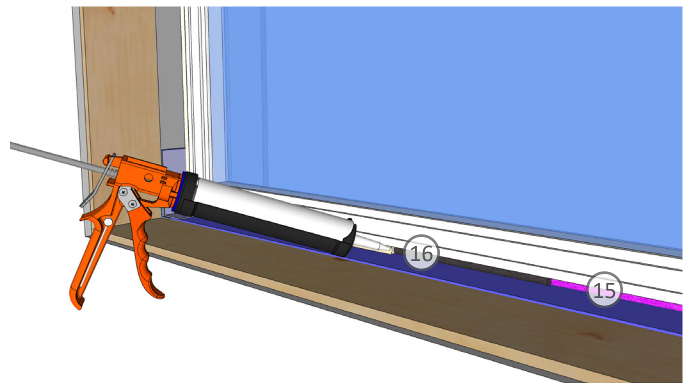
12. Install self-adhered membrane over the top of the wood buck-out extending onto the plywood sheathing a minimum 6".
13. Install window on intermittent shims and structurally attach per the window manufacturer's specifications.
14. Install high-performance tape onto window flange at head and jambs, extending a minimum 2" onto jamb membrane.
15. Install polyurethane spray foam around the interior perimeter of the window. Ensure the expanded foam does not impede installation of backer rod.
16. Install backer rod and sealant around the interior perimeter of the window to complete air barrier continuity.
17. Install sheathing membrane. Ensure positive laps over all other layers. Seal all membrane laps with sheathing tape.
18. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
19. Install metal head flashing complete with end dams to the strapping above the window trim board.
20. Install window trim boards to strapping.
21. Reinstall existing cladding where possible or install new cladding.
22. Apply sealant around the perimeter of the window (top and sides) between the frame and window trim boards.

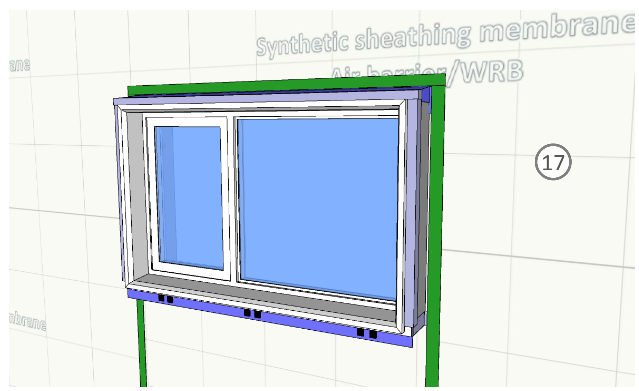
Key Considerations:

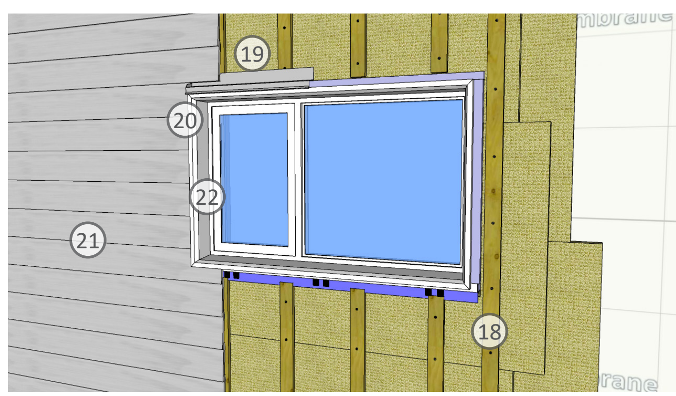
Sill drainage can be provided by notching sill flange or cutting sill buck 1/2" shorter than jamb and head. Insert shims behind sill flange to provide support for fasteners (shown).

*End Dams: Typically formed on head flashing before installation. Extended siding of flashing is folded upwards to prevent water from moving laterally into the wall.

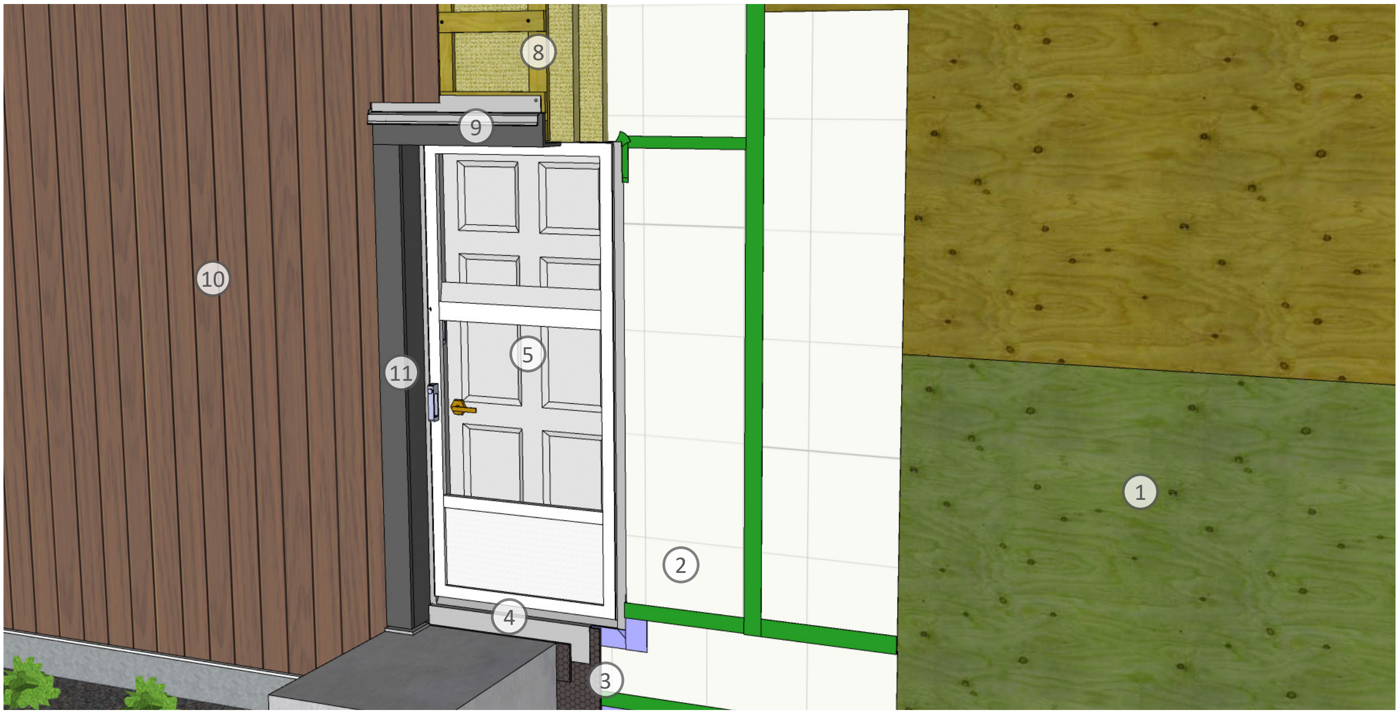


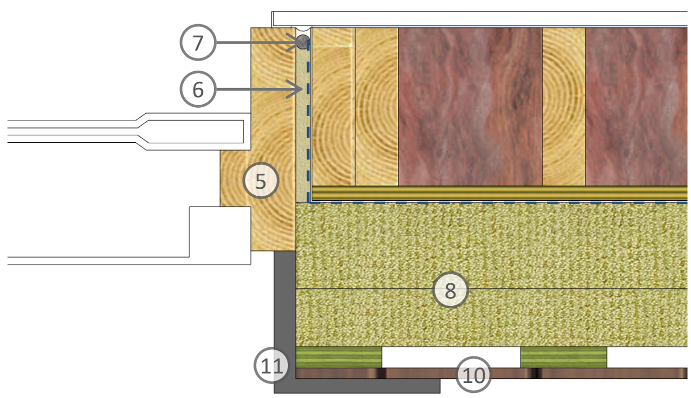






Detail 6 Exterior Door

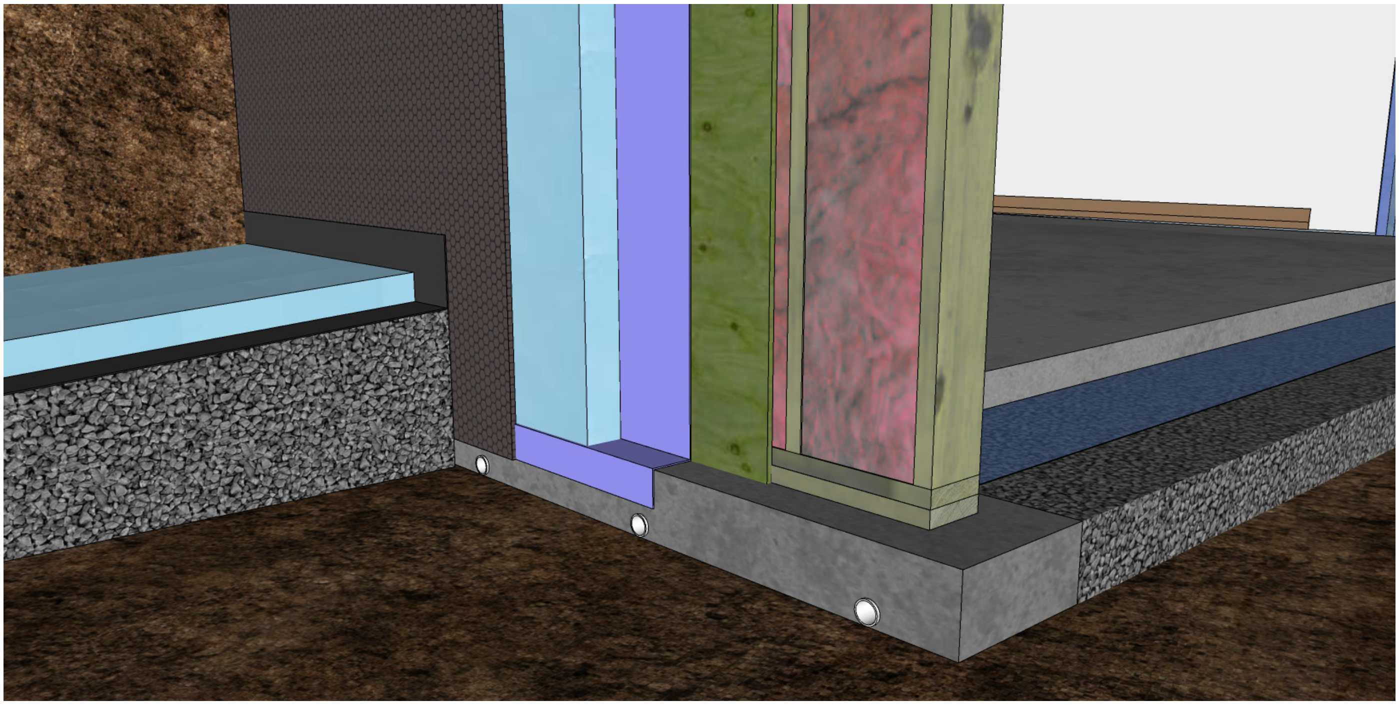


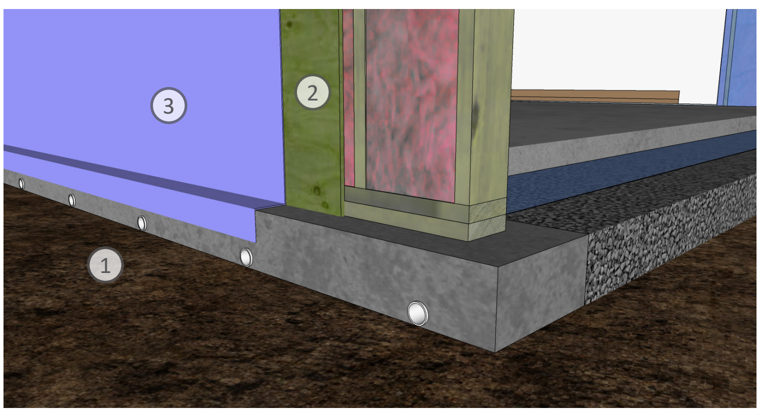


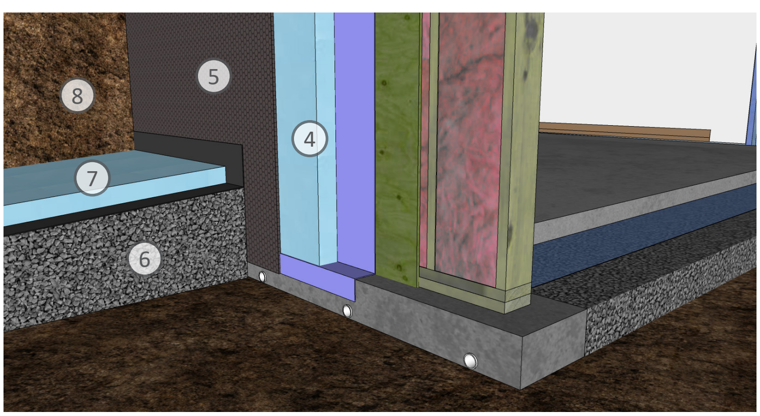
Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Remove the existing door to expose the door rough opening.
2. Install vapour-permeable air barrier membrane at sheathing (pre-strip sheathing membrane) and self-adhered membrane at door sill. Ensure positive laps and seal all sheathing membrane laps with sheathing tape for air barrier continuity. Refer to window details for membrane sequencing.
3. Install new drainage mat between front steps and sheathing membrane.
4. Install sill metal flashing at bottom of door rough opening.
5. Reinstall swing door and storm door in rough opening.
6. Install polyurethane spray foam or around the interior perimeter of the door. Ensure the expanded foam does not impede installation of backer rod.
7. Seal the interior perimeter of the door frame with backer rod and sealant to the pre-strip membrane installed in the door rough opening (head, jambs, and sill).
8. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
9. Install metal flashing onto strapping above the door head to deflect moisture out over the door.
10. Reinstall existing cladding where possible or install new cladding.
11. Install finish trim (or cladding returns) where needed to cover the depth of the sides of the exterior insulation on all exposed sides.

Detail 7 Exterior Below-Grade to Foundation







Retrofit Steps:

1. Excavate ground around existing PWF walls and expose below-grade assembly.
2. Remove any existing drainage mat and protection board. Expose existing PWF wall sheathing and inspect and repair sheathing and framing as required. Repair and replace batt insulation if necessary.
3. Install new self-adhered waterproofing membrane over primed substrate per manufacturer's recommendations.
4. Install rigid foam insulation (EPS/XPS) with spot adhesive to the exterior of the wall.
5. Install new drainage mat over the insulation.
6. Install drain rock around perimeter of footing and cover with filter fabric, extending filter fabric up drainage mat. Ensure that clear drainage is provided through the footing to the interior sump.
7. Install insulation skirt extending out and angled outwards from the wall as required to mitigate frost heave concerns.

(Continued on next page)

Retrofit Steps Continued:

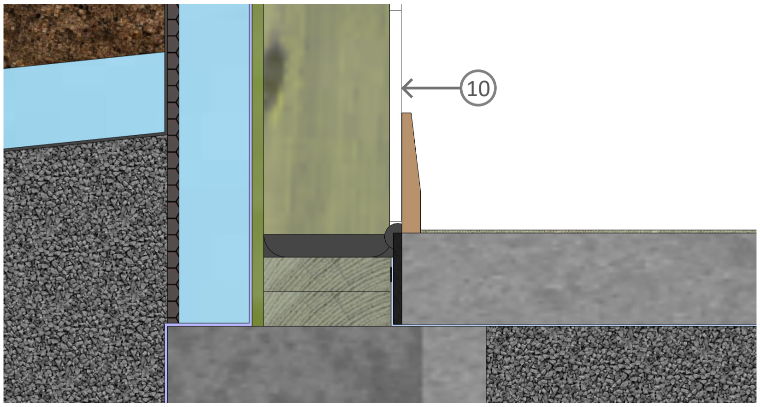
8. Backfill over insulation skirt around perimeter of PWF.
9. Install clay cap at finished grade around the PWF that is sloped away from the building.

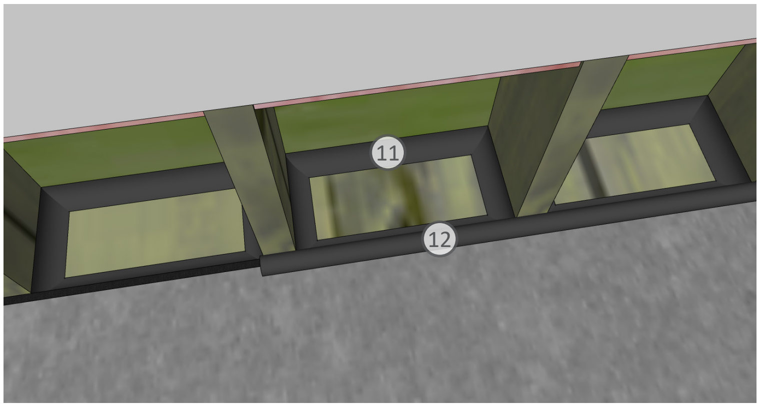
Interior Retrofit Steps:

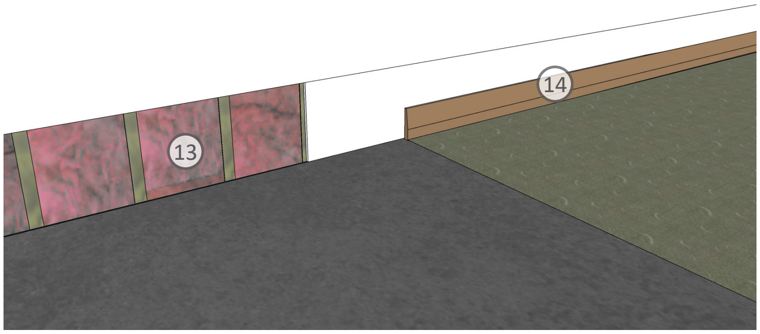
10. At base of PWF wall, remove roughly 12"-16" of existing wall finishes (gypsum board) and batt insulation as necessary to expose bottom plate.
11. Install sealant around the perimeter of each stud cavity at the sill plate.
12. Install appropriate sealant continuously between slab and sill plate.
13. Reinstall batts if still in good condition or install new batt insulation into areas previously removed.
14. Install gypsum wall board and interior finishes as required and do not install vapour retarder (i.e. polyethylene) on the inside of the assembly.

Key Considerations:

- Surrounding grade should have a minimum 12" clay cap (impervious soil) and be sloped away from the building at minimum 1:12 to aid in surface water drainage. Drainage should be provided adjacent to the PWF wall to prevent water buildup adjacent the foundation.
- Protect all inside and outside corners of the below-grade wall insulation with appropriate cover material.
- Refer to CAN/CSA-S406-16 for all PWF repairs.
- The below-grade water management strategy for the archetype house is an existing sump located within the basement slab area. Drainage through the footing to the interior sump must be maintained after the retrofit work is complete.
- Alternative materials such as drainmat can be used in place of a clay cap if clay is not available for backfill.

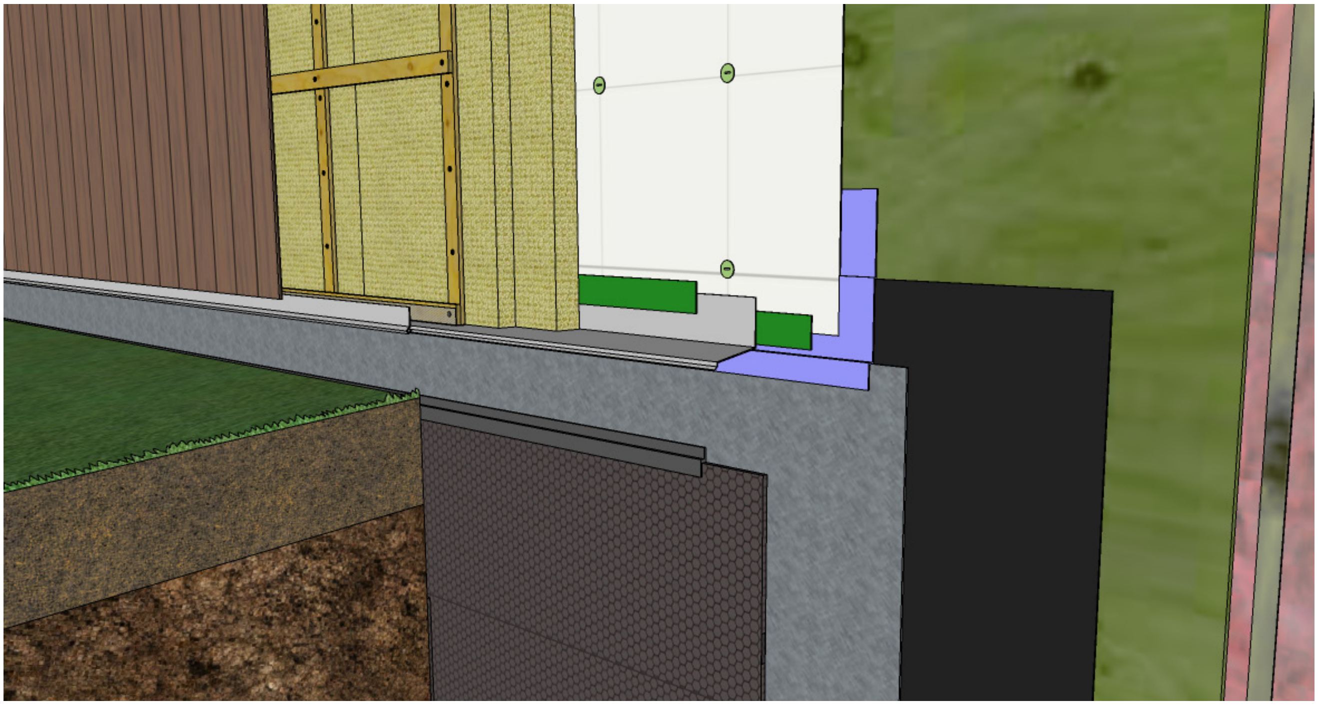


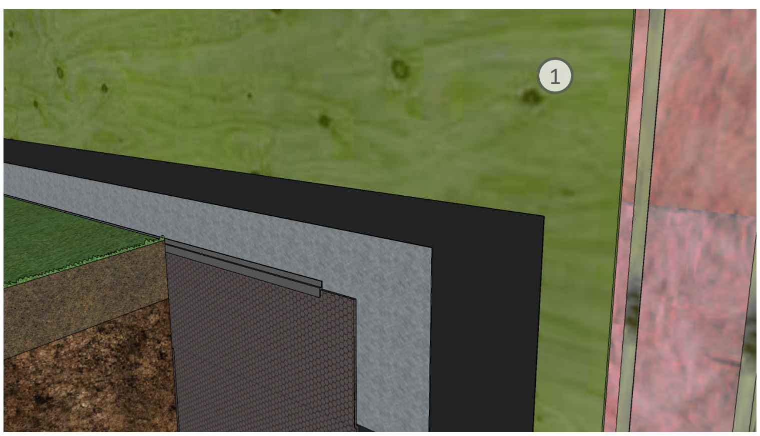


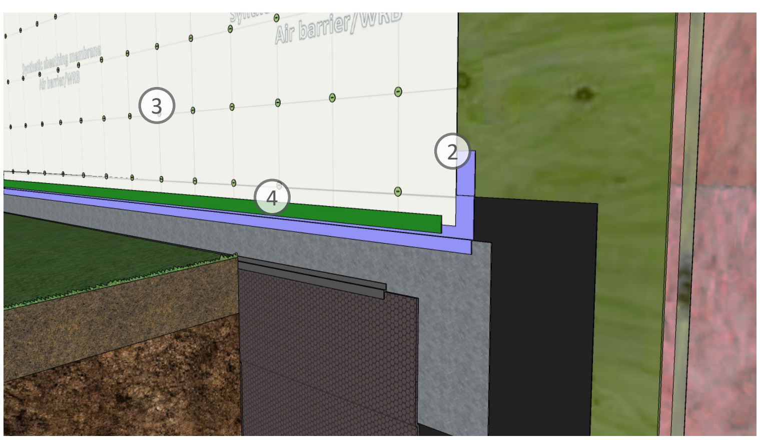


For further information on PWF refer to "CAN/CSA-S406-16 Specification of permanent wood foundations for housing and small buildings" by Standards Council of Canada, available at https://store.csagroup.org/ccrz__ProductDetails?sku=S406-16

Detail 8 Foundation to Above-Grade Wall







Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary. Repair and replace batt insulation as required.
2. Install strip of self-adhered membrane on existing sheathing that laps onto existing below-grade waterproofing / protection board.
3. Install vapour-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity.
4. Install sheathing tape at leading edge of sheathing membrane, sealing it to the self-adhered membrane strip to ensure air barrier continuity.

(Continued on next page)

Retrofit Steps Continued:

5. Install the first part of a two-part pre-finished metal through-wall flashing, equal to the depth of the exterior insulation. The flashing aids in water diversion and also acts as a closure to protect the underside of the insulation. Ensure the flashing has a minimum 1:6 slope. Seal the top edge of the flashing to the sheathing membrane with sheathing tape for greater water diversion.

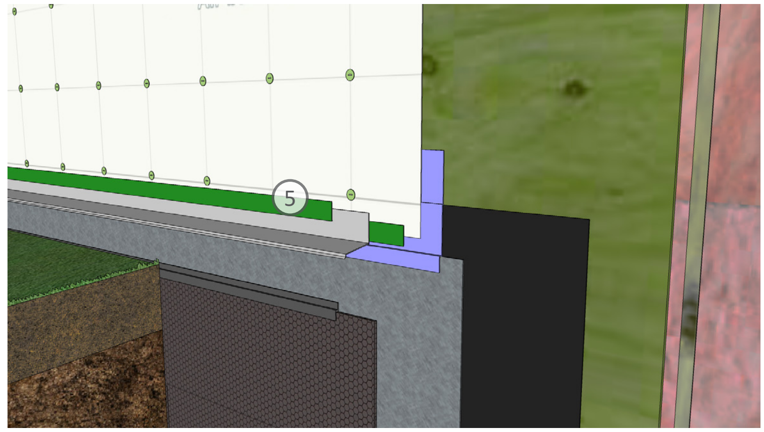
6. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping. Ensure strapping is exposed at the bottom to provide venting.

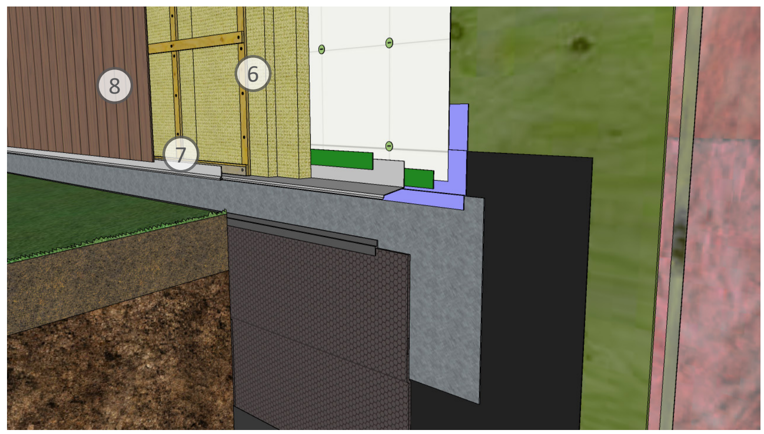
7. Install the second part of a two-part pre-finished metal through-wall flashing. Secure the flashing to the exterior face of the strapping with appropriate fasteners.

8. Reinstall existing cladding where possible or install new cladding. Leave a ¾" gap (vision line) between the bottom of the cladding and the flashing kickout to aid in drainage/drying.

Key Considerations:

- Taper the bottom edge of the exterior insulation to match the slope of the through-wall flashing below and fit tightly, ensuring there are no gaps.





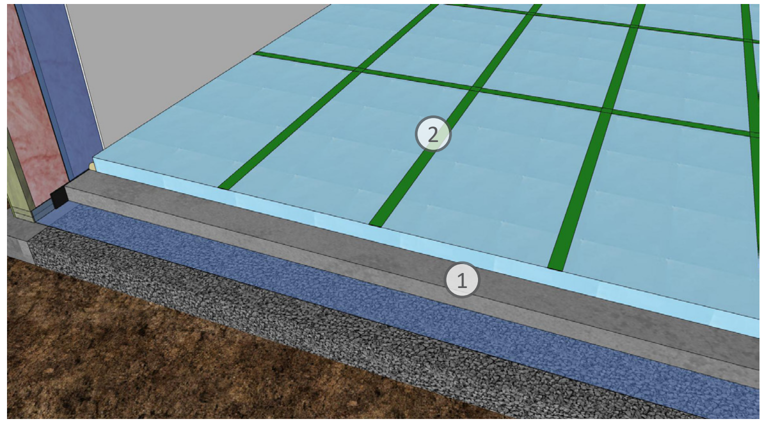
Detail 9 Interior Insulated Slab

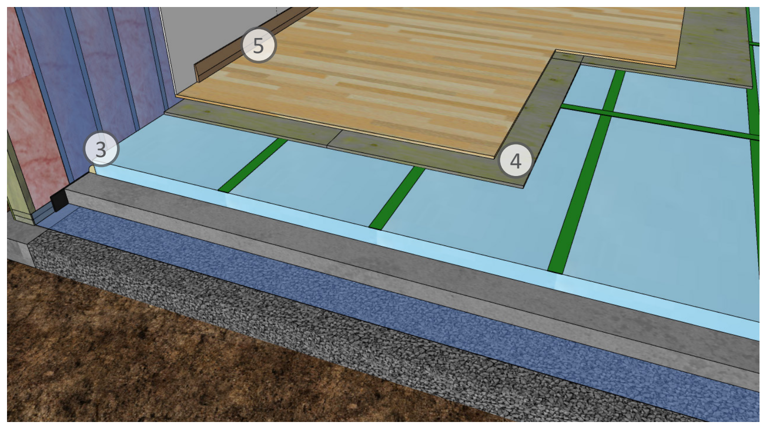
Retrofit Steps:

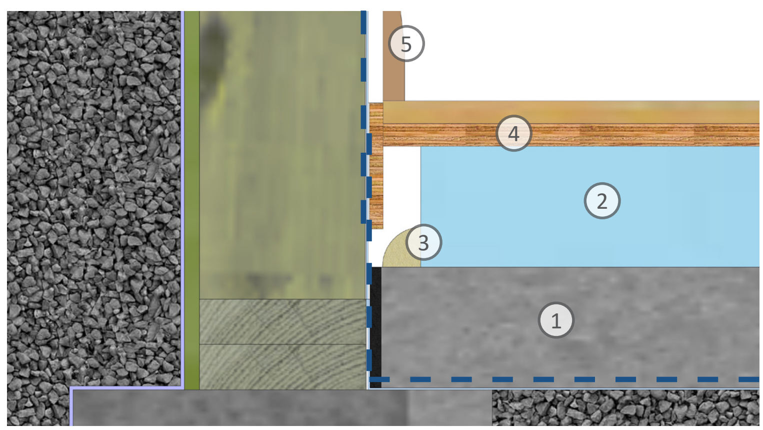
1. Remove any existing slab sub-floor and/or flooring. Repair concrete as needed, seal all cracks, holes, and penetrations in slab. Seal the perimeter of the existing sump pit to the slab and weatherstrip the sump lid to maintain air barrier continuity.
2. Install rigid foam above slab and seal all board joints with compatible tape. Keep rigid insulation back minimum 2" from exterior walls (bottom plates). Raise interior partition walls as necessary to allow for the rigid foam to pass beneath.
3. Install spray foam between rigid insulation and concrete slab.
4. Install pressure treated sub-floor sheathing (plywood).
5. Reinstall gypsum wallboard as required and install interior finishes.

Key Considerations:

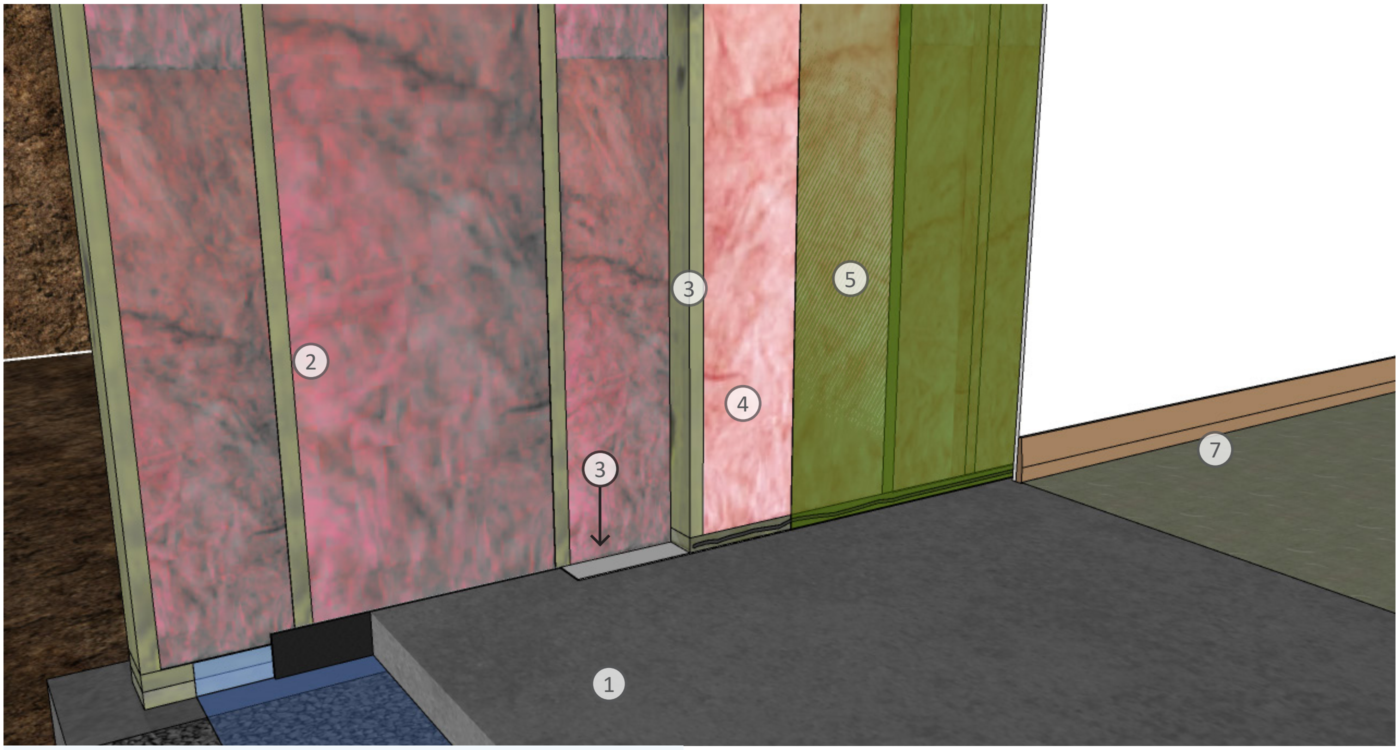
- Door rough openings at interior partition walls may require modification to account for the raised floor height.







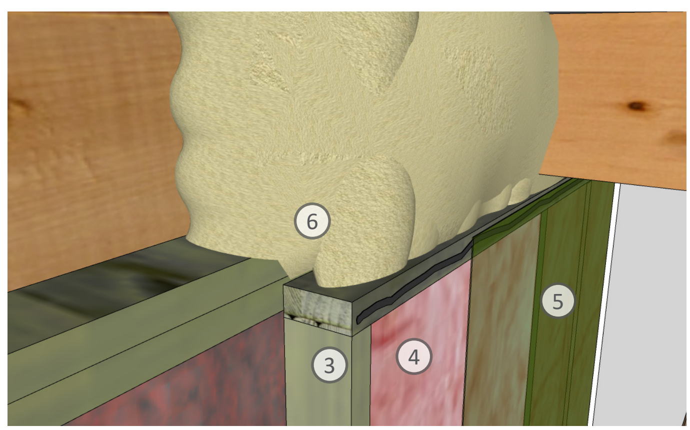
Detail 10 Interior Insulated Foundation Wall



Retrofit Steps:

1. Cut back existing flooring. Repair concrete as required.
2. Remove existing gypsum wallboard from exterior walls and existing vapour retarder (polyethylene).
3. Install new 2x4 stud wall with studs @ 24" o.c. Ensure pressure treated framing is used. Place compression gasket beneath the bottom plate. Stagger studs such that they do not line up with existing PWF wall studs
4. Install fibreglass batt into the new wall's stud cavities.
5. Install *smart vapour retarder and seal to bottom and top plates. Seal smart vapour retarder at all wall penetrations (electrical receptacles, pipes, etc.)
6. Apply spray foam within rim joist to insulate and create air seal between existing frame and new 2x4 stud wall.
7. Install gypsum wallboard and interior finishes.

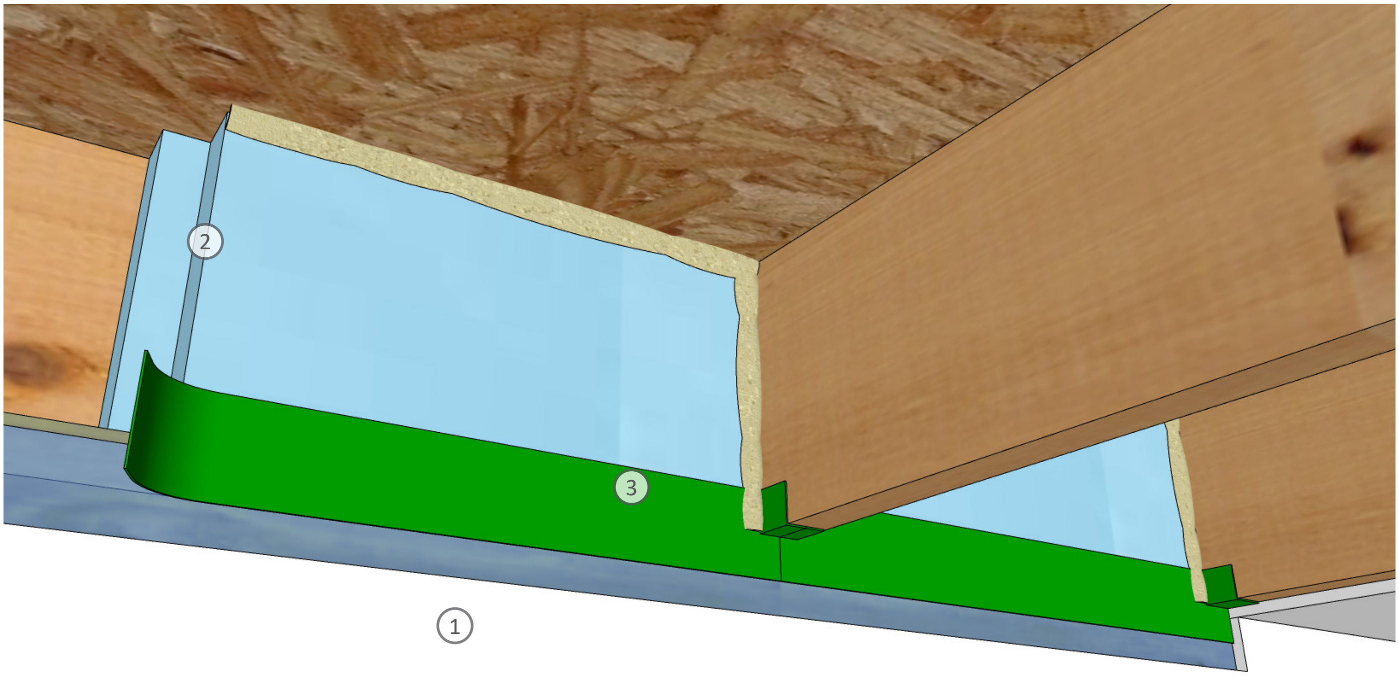
*Smart Vapour Retarder: A permeable vapour retarder which allows water vapour to move through the material as humidity increases, and restricts vapour movement when humidity is low.



Key Considerations:

- Wood framing in direct contact with exposed concrete must be pressure treated.

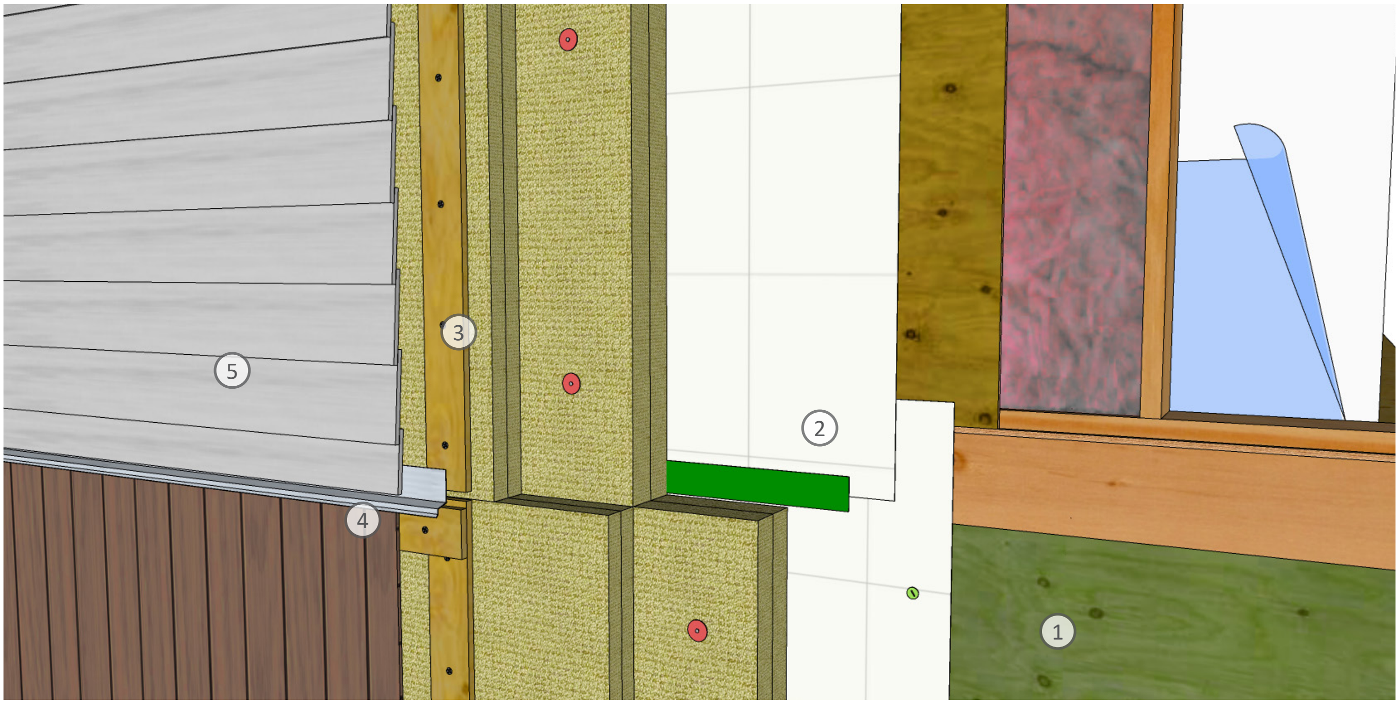
Detail 11 Interior Rim Joist Area



Retrofit Steps:

1. Remove existing gypsum wallboard from top of exterior walls and adjacent ceilings.
2. Cut extruded polystyrene (XPS) blocking to fit between ceiling joists. Install blocking tight against rim joist, floor sheathing, wall top plate, and floor joist.
3. Seal bottom edge of XPS to polyethylene vapour retarder with appropriate tape and apply spray foam around top and bottom edges of XPS blocking for a continuous seal between XPS, existing framing, and existing vapour retarder.
4. Install new gypsum wallboard and finishes.

Detail 12 Exterior Rim Joist Area



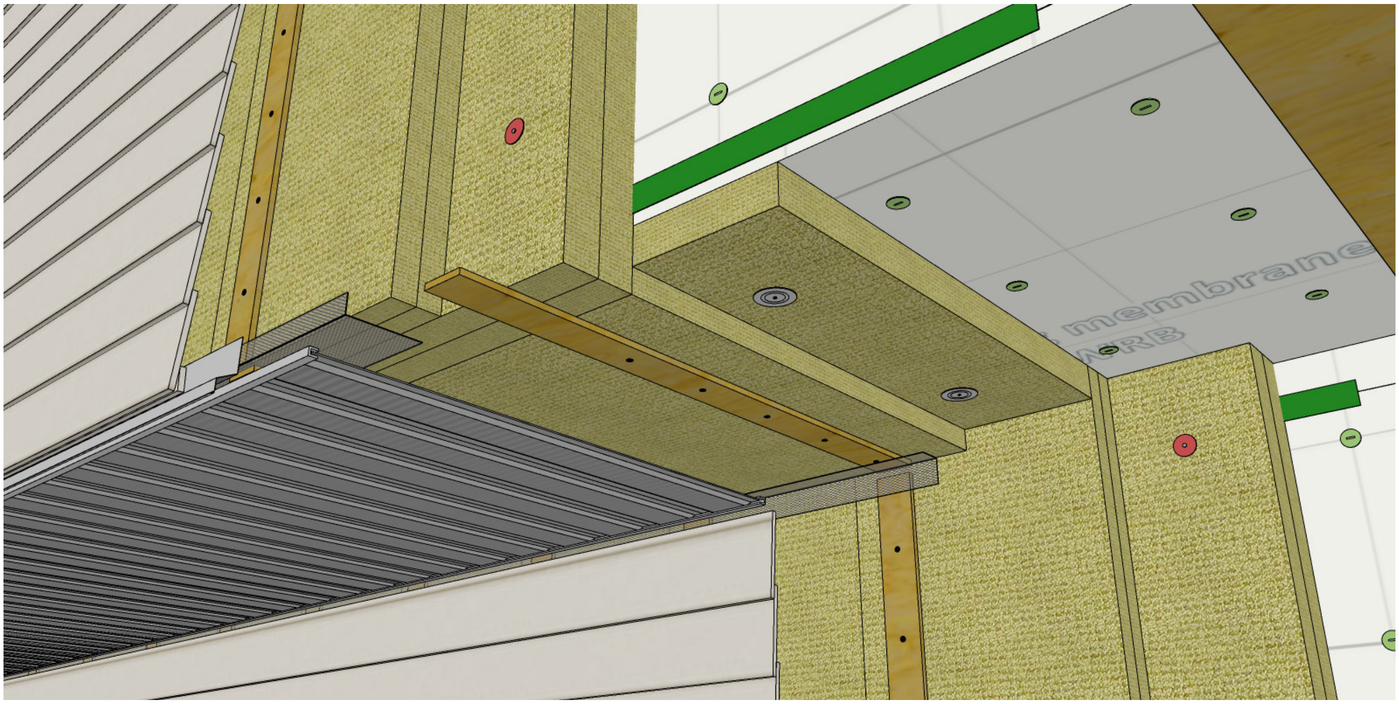
Retrofit Steps:

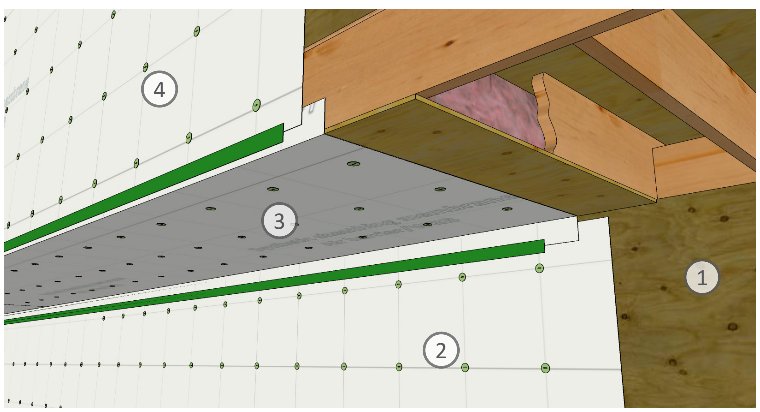
1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary.
2. Install vapour-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity.
3. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity.
4. Install kickout flashing secured to strapping.
5. Reinstall existing cladding or install new cladding complete with trim as required.

Key Considerations:

- Strapping should be installed in line with the wall studs to provide maximum support and pullout resistance.
- Buildings that have two stories or more above grade require through-wall flashings. Through-wall flashings must be the full depth of exterior insulation and must return to the wall sheathing.

Detail 13 Exposed Floor





Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall sheathing. Inspect and repair sheathing and framing as necessary. Replace batt insulation if required.
2. Install vapour-permeable air barrier membrane (sheathing membrane), terminating on the vertical face of the wall below the exposed floor.
3. Install sheathing membrane on the underside of the floor and shingle over sheathing membrane plane below. Install sheathing tape for air barrier continuity.
4. Install sheathing membrane on wall above floor and terminate onto membrane below with sheathing tape for air barrier continuity.

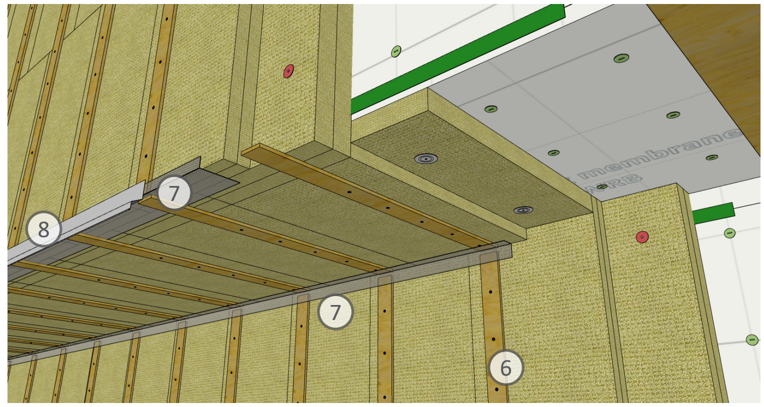
(Continued on next page)

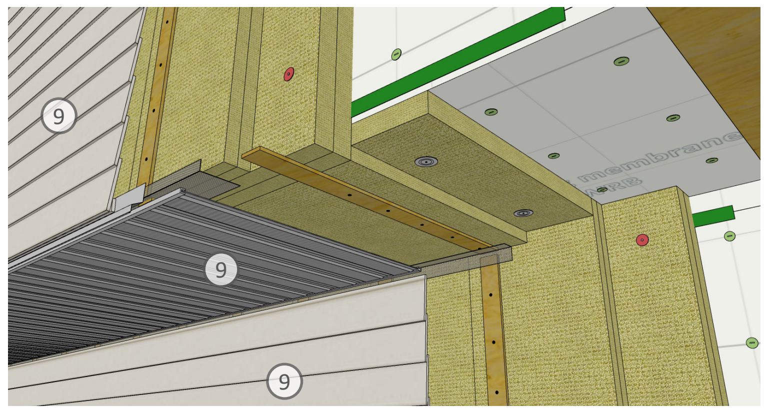
Retrofit Steps Continued:

6. Install exterior insulation and secure with wood strapping on walls and underside of exposed floor.
7. Install bug screens at top and bottom of adjacent walls.
8. Install flashing to the bottom of the strapping on the wall above the floor. Provide a minimum 1:6 slope.
9. Reinstall existing cladding and soffit materials where possible or install new components.

Key Considerations:

- Air barrier continuity occurs outside the wall sheathing. The sheathing membrane is sealed at laps and penetrations.
- Ensure there are no gaps in the insulation and that it is tight to the wall. Stagger vertical joints to improve thermal continuity

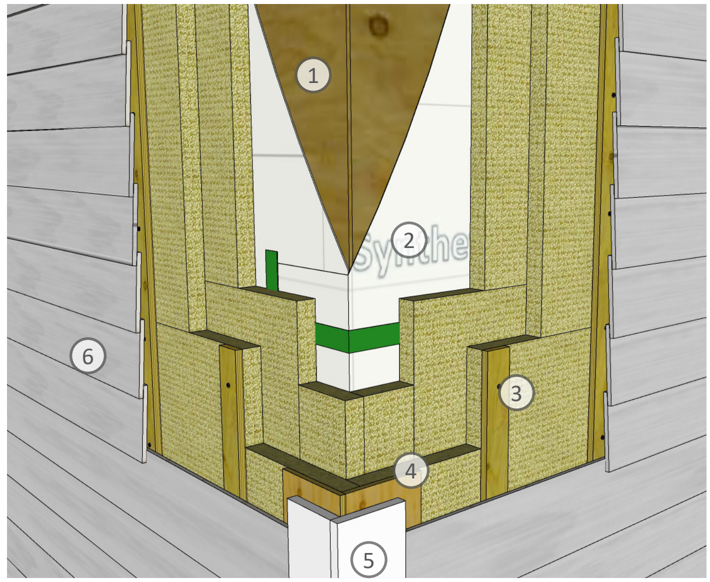


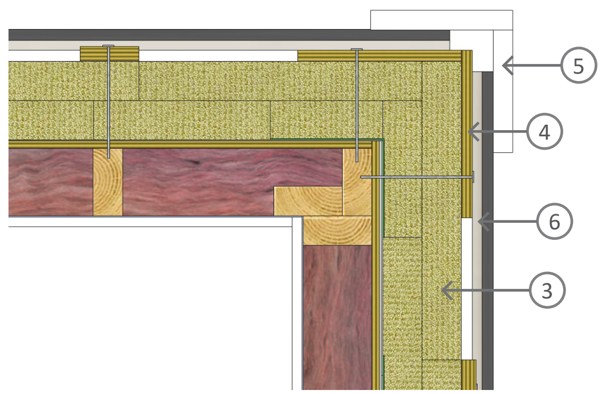


Detail 14 Above-Grade Wall at Outside Corner

Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary.
2. Install vapour-permeable air barrier membrane (sheathing membrane) at outside corner. Seal all laps with sheathing tape to maintain air barrier continuity.
3. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
4. Install solid pressure treated plywood at corners as required to support the corner trim boards and cladding.
5. Install trim boards. The corner trim boards must be nailed or screwed together as well as to the strapping to form the corner.
6. Reinstall existing cladding where possible or install new cladding.

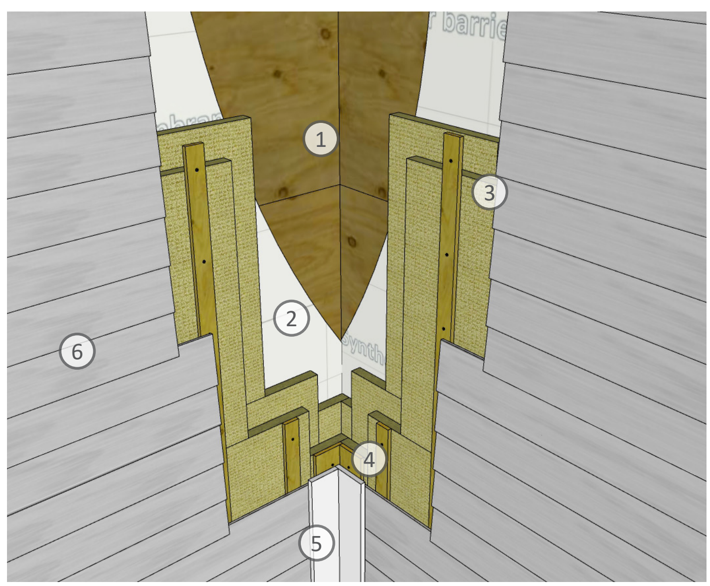




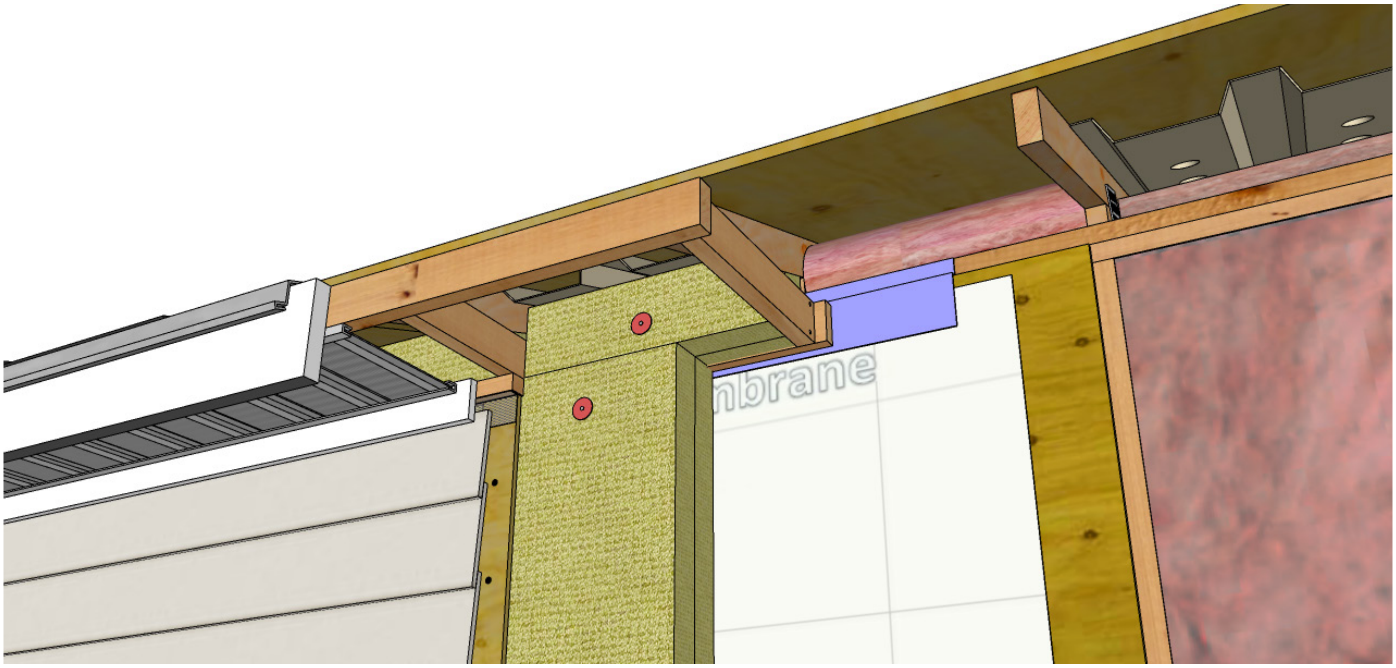
Detail 15 Above Grade Wall at Inside Corner

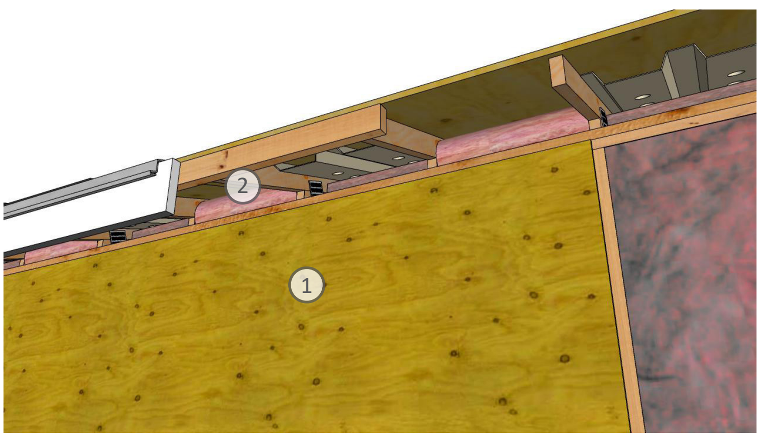
Retrofit Steps:

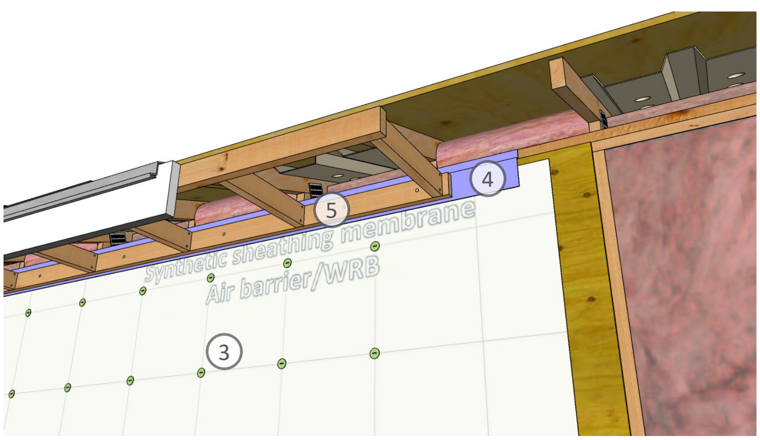
1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary.
2. Install vapour-permeable air barrier membrane (sheathing membrane) at outside corner. Seal all laps with sheathing tape to maintain air barrier continuity.
3. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.
4. Install strapping as required to support the corner trim boards and cladding.
5. Install trim boards. The corner trim boards must be nailed or screwed together as well as to the strapping to form the corner.
6. Reinstall existing cladding where possible or install new cladding.



Detail 16 Above Grade Wall to Pitched Roof — Conventional Truss







Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary.

2. Remove existing roof soffit material and framing. Remove the wall sheathing as needed to expose the upper top plate (double top plate) if not already exposed.

3. Install vapour-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity. Install sheathing membrane, leaving a 1.5" gap below the top of the wall sheathing.

4. Seal the leading edge of the sheathing membrane to the wall sheathing and the upper top plate (double top plate) with a 6" strip of self-adhered membrane. Make sure primer is applied prior to the self-adhered membrane to ensure a good bond.

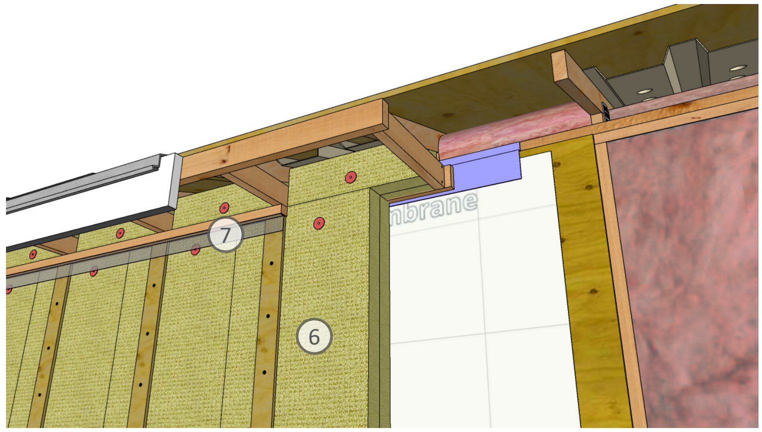
(Continued on next page)

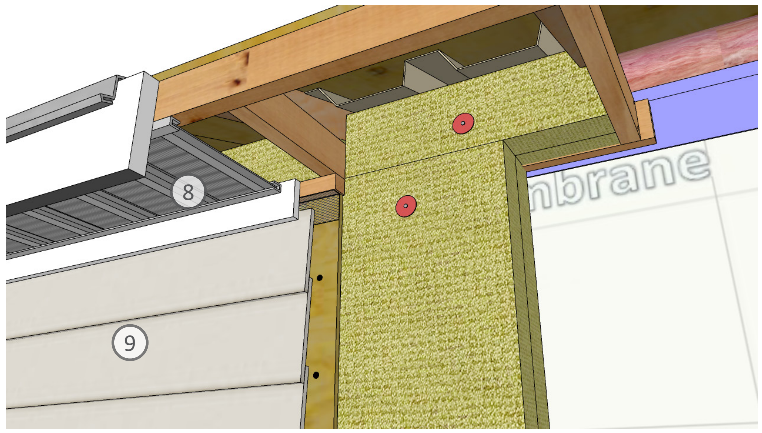
Retrofit Steps Continued:

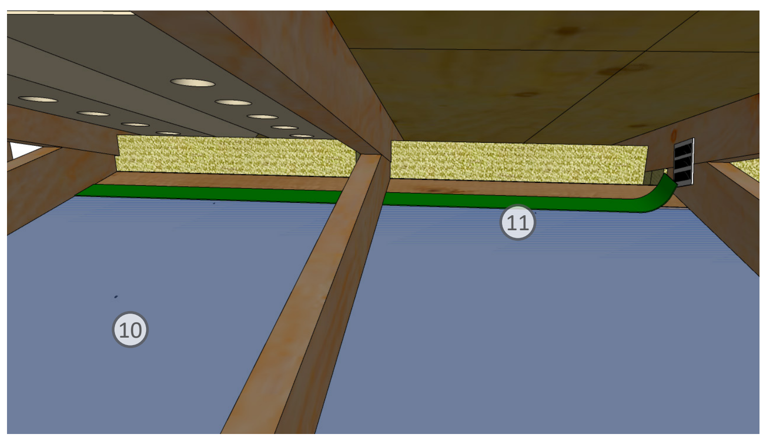
5. Install new soffit ladder framing.
6. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Insulation in the soffit may also be secured with insulation retention fasteners.
7. Install framing at underside of ladder framing to support cladding trim. Framing should extend 1" beyond depth of finished cladding to allow for ventilation of the wall cavity. Install bug screen between planes of strapping and framing.
8. Install new vented soffit material.
9. Reinstall existing cladding where possible or install new cladding. Leave the cladding 1” short of the soffit material to allow for cavity ventilation.
10. Complete exterior insulation work in conjunction with air sealing and insulation work at ceiling plane.
11. Install air sealing tape between the top plate and ceiling polyethylene sheet to transition air barrier. Tape over butt joints located at the top plate.

Key Considerations:

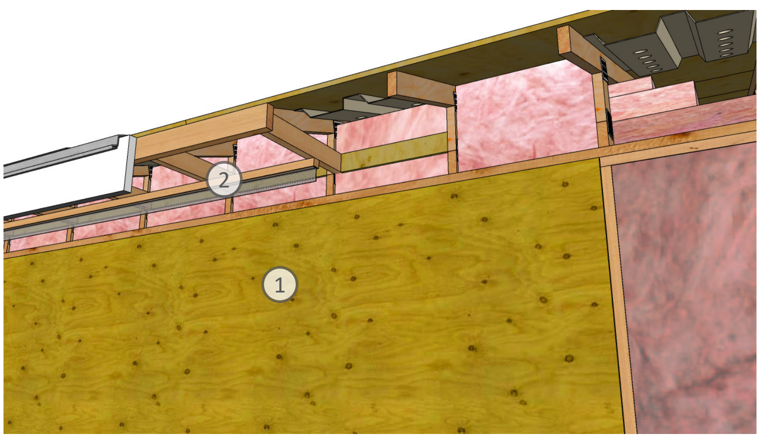
- Ensure insulation at the roof-to-wall interface is continuous and does not have gaps or areas of reduced insulation thickness.
- Ensure attic space is provided with adequate ventilation and that the correct size and number of baffles are installed.
- New vented soffit panels can be installed directly to the underside of the truss top chord tail. Wall vented cavity should remain isolated from roof vent in this configuration. See Detail 25 Chainsaw Retrofit — Blown-in Insulation for reference.

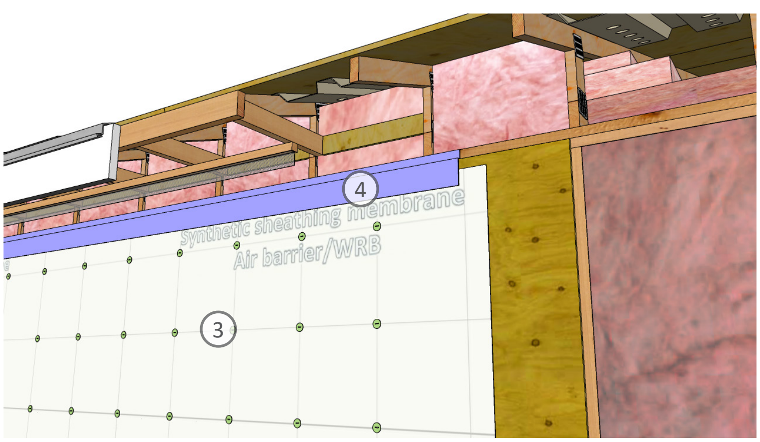






Detail 17 Above Grade Wall to Pitched Roof — Raised Heel Truss





Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary.

2. Remove existing roof soffit material and repair any soffit framing (lookouts and sub-fascia) as required. Remove the wall sheathing as needed to expose the upper top plate (double top plate) if not already exposed. Install strapping to retain batt insulation within interior portion of roof assembly.

3. Install vapour-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity. Install sheathing membrane, leaving a 1.5” gap below the top of the wall sheathing.

4. Seal the leading edge of the sheathing membrane to the wall sheathing and the upper top plate (double top plate) with a 6” strip of self-adhered membrane. Make sure primer is applied prior to the self-adhered membrane to ensure a good bond.

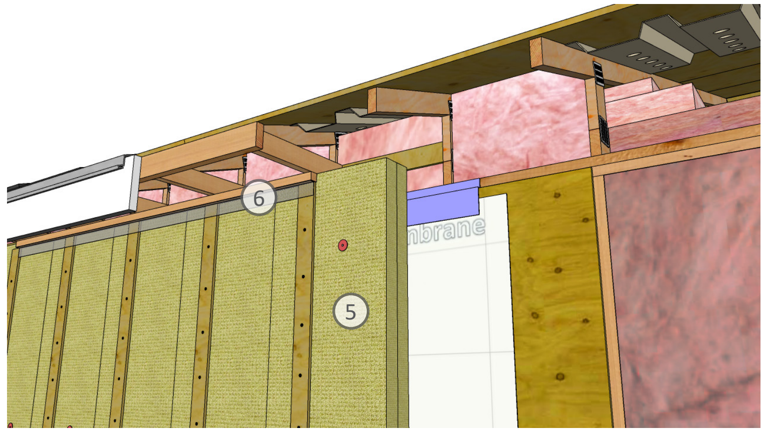
(Continued on next page)

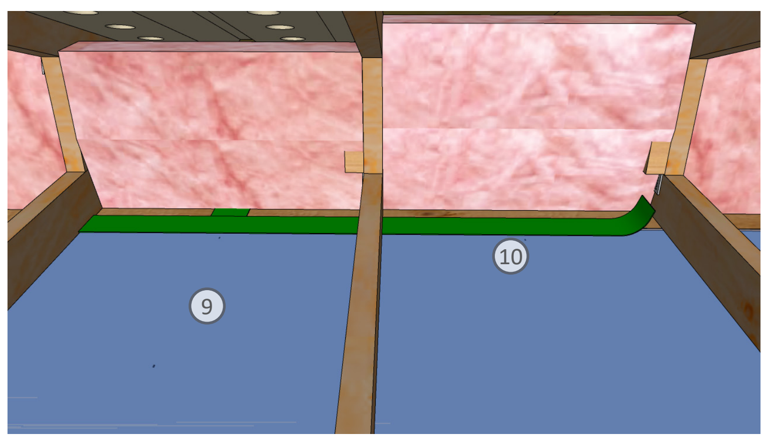
Retrofit Steps Continued:

5. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Insulation in the soffit may also be secured with insulation retention fasteners.
6. Install framing at underside of ladder framing to support cladding trim. Framing should extend 1" beyond depth of finished cladding to allow for ventilation of the wall cavity. Install bug screen between planes of strapping and framing.
7. Install new vented soffit material.
8. Reinstall existing cladding where possible or install new cladding. Leave the cladding 1” short of the soffit material to allow for ventilation of the wall cavity.
9. Complete exterior insulation work in conjunction with air sealing and insulation work at ceiling plane.
10. Install air sealing tape between the top plate and ceiling polyethylene sheet to transition air barrier. Tape over butt joints located at the top plate.

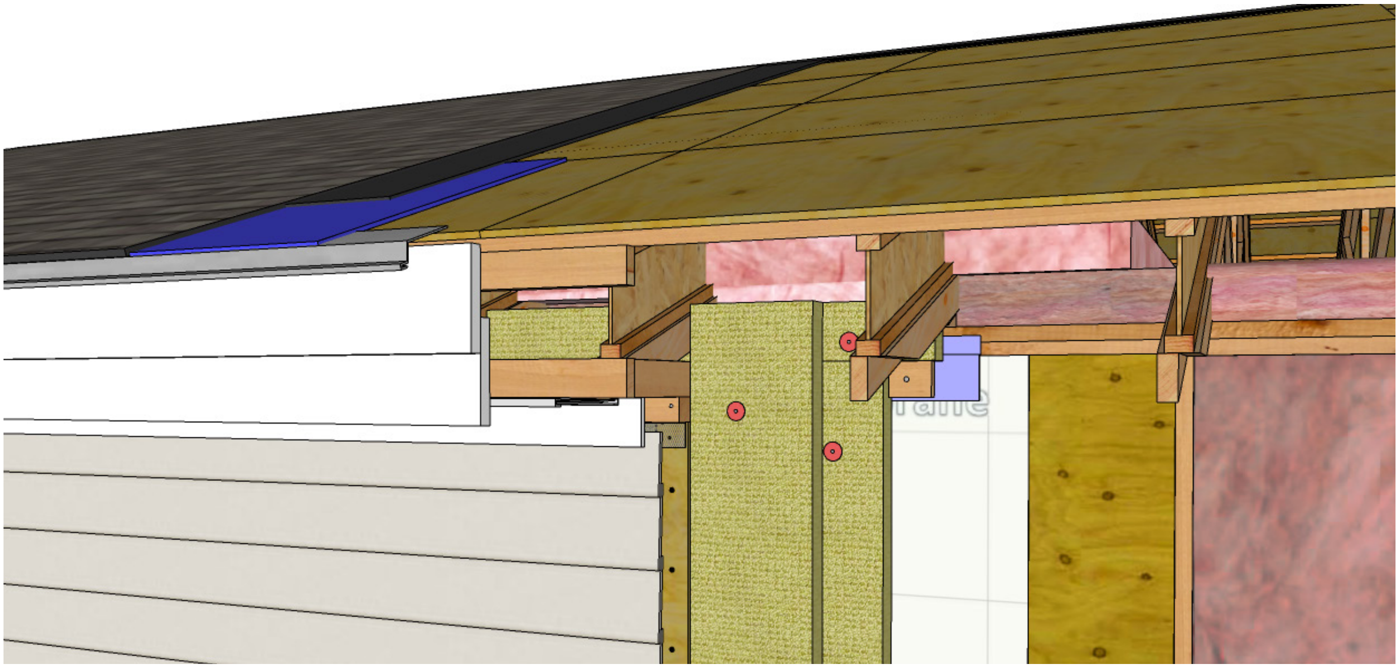
Key Considerations:

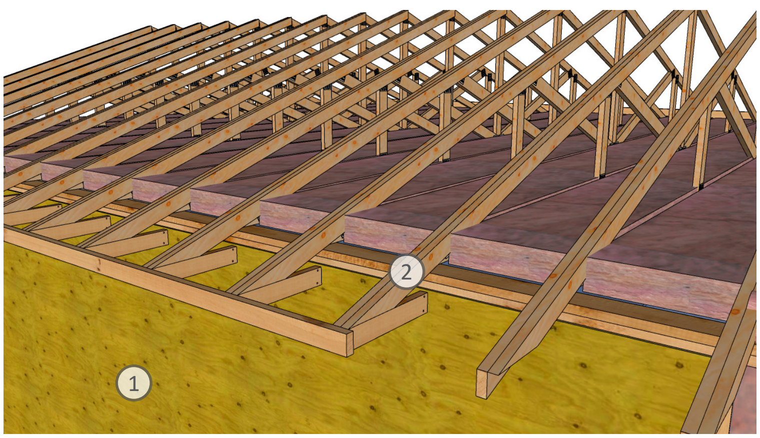
- Ensure insulation at the roof-to-wall interface is continuous and does not have gaps or areas of reduced insulation thickness.
- Ensure attic space is provided with adequate ventilation and that the correct size and number of baffles are installed.

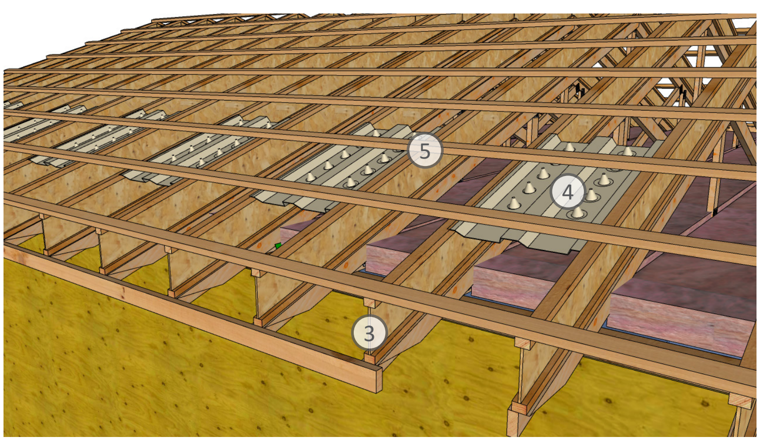




Detail 18   Additional Roof Structure







Retrofit Steps:

1. Remove existing roofing and plywood sheathing to expose the trusses beneath. Remove existing cladding and building paper to expose exterior wall assembly. Remove the wall sheathing as needed to expose the upper top plate (double top plate) if not already exposed. Inspect and repair sheathing and framing as necessary.
2. Sister on new 2x4 dimensional lumber parallel to the top chord of the roof truss.
3. Install TJI joists parallel to roof slope on outer face of roof truss.
4. Install new baffles/rafter vents as required by Code.
5. Install 2x3 dimensional lumber cross strapping above the TJIs to provide cross-vented roof cavity.

(Continued on next page)

Retrofit Steps Continued:

6. Install new roof sheathing.
7. Install vapor-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity.
8. Seal the leading edge of the sheathing membrane to the wall sheathing and the upper top plate (double top plate) with a 6” strip of self-adhered membrane. Apply primer prior to installation of the self-adhered membrane to ensure an aggressive bond with the substrate.
9. Install new soffit ladder framing.
10. Install exterior insulation to wall and plywood blocking and secure with strapping. Extend insulation through soffit ladder framing. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity.
11. Install framing at underside of ladder framing to support cladding trim. Framing should extend 1" beyond depth of finished cladding to allow for ventilation of the wall cavity. Install bug screen between planes of strapping and framing.
12. Install new fascia at ends of TJI joists.
13. Install roof new roofing underlayment, edge flashing with drip edge, and asphalt shingles.

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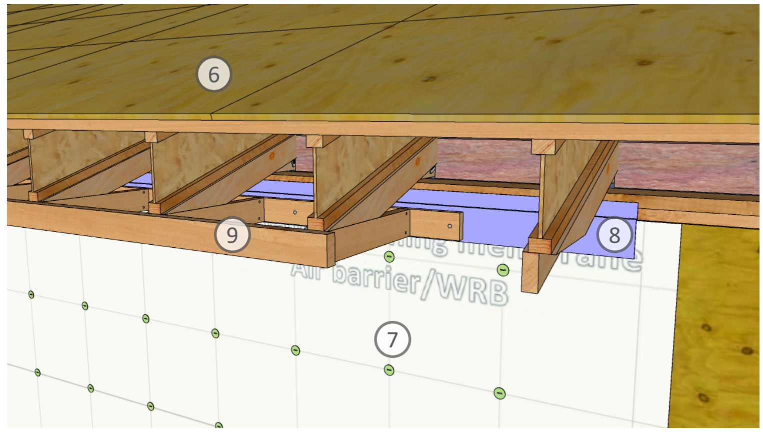
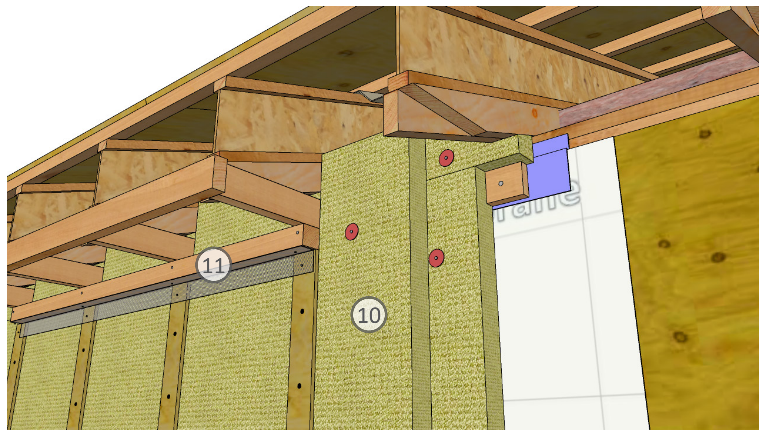
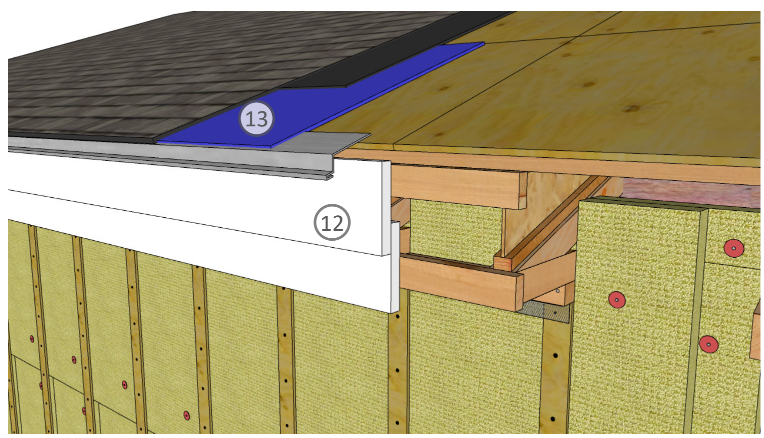




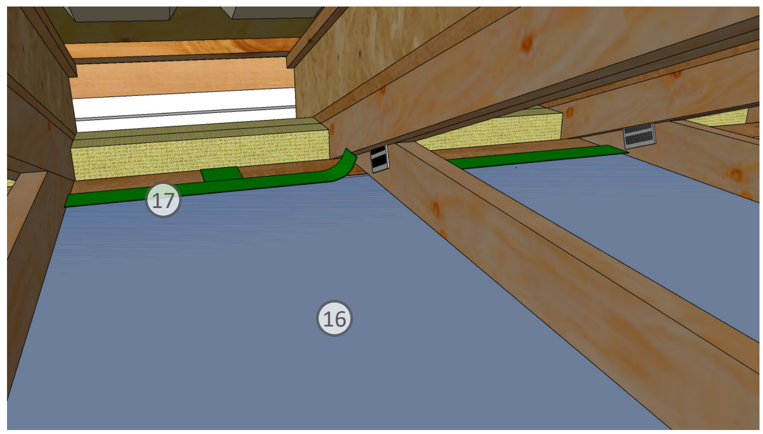


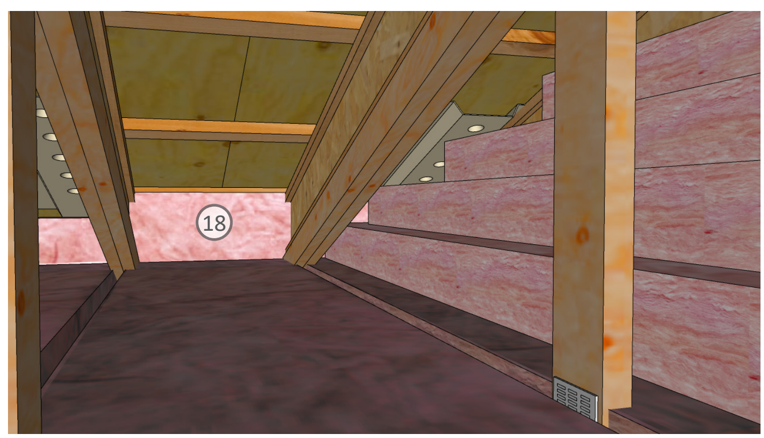
Retrofit Steps Continued:

14. Install new vented soffit panel.
15. Reinstall existing cladding where possible or install new cladding. Leave the cladding 1" short of the soffit material to allow for ventilation of the wall cavity.
16. Complete exterior insulation work in conjunction with air sealing and insulation work at ceiling plane.
17. Install air sealing tape between the top plate and ceiling polyethylene sheet to transition air barrier. Tape over butt joints located at the top plate.
18. Install new attic insulation

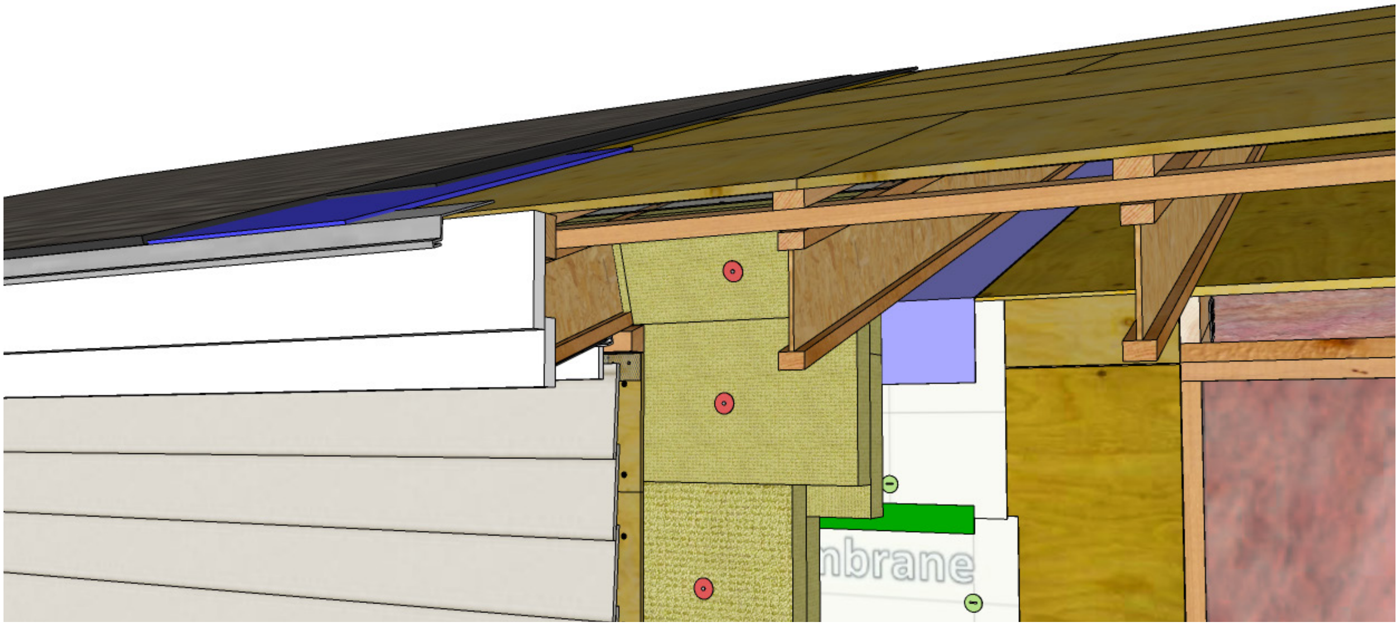
Key Considerations:

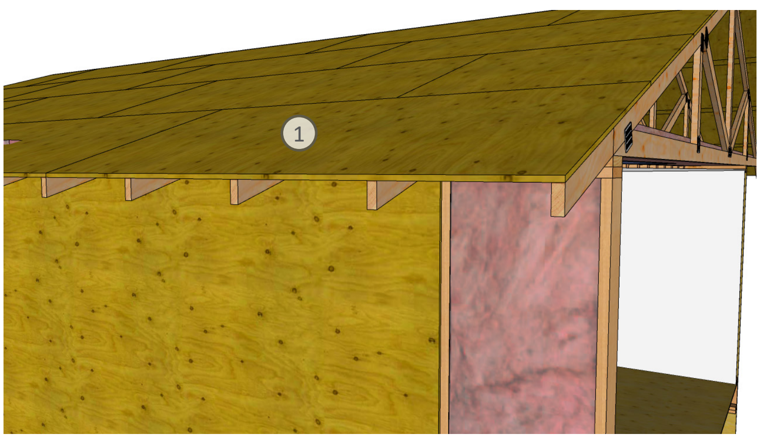
- Ensure insulation at the roof-to-wall interface is continuous and does not have gaps or areas of reduced insulation thickness.
- Ensure attic space is provided with adequate ventilation and that the correct size and number of baffles are installed.
- In a highly insulated attic, the ceiling may require 1x4 strapping at 16" on centre to support the weight of insulation.





Detail 19 Chainsaw Retrofit — Blown-in Insulation





Retrofit Steps:

1. Remove existing roofing, cladding, and sheathing membrane as required to expose the exterior wall and roof sheathing. Inspect and repair sheathing and framing as necessary.
2. Cut back roof sheathing and overhanging truss top chord to the plane of exterior wall framing.
3. Install ½" plywood sheathing over the exposed truss heel.
4. Install vapor-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity.
5. Install vapour-impermeable self-adhered membrane on roof sheathing, lapping onto exterior wall sheathing membrane by minimum 6". Apply primer to plywood sheathing prior to installing the self-adhered membrane as required to ensure aggressive adhesion.

(Continued on next page)

Retrofit Steps Continued:

6. Install TJI joists parallel to roof slope and fasten to the trusses beneath. Deeper TJI's may be used to increase the depth of the installed insulation.

7. Install blocking between TJIs at plane of wall to retain dense-pack insulation. Install new vented soffit material.

8. Install dense-pack insulation netting over TJI flanges. Ensure netting is installed taut to minimize bulges that may block roof venting.

9. Install exterior insulation on wall and plywood blocking and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity.

10. Install framing at underside of TJIs to support cladding trim. Framing should extend 1" beyond depth of finished cladding to allow for ventilation of the wall cavity. Install bug screen between planes of strapping and framing.

11. Install 2x3 dimensional lumber cross strapping above the TJIs to provide venting and minimize bulging of insulation.

12. Install dense pack insulation.

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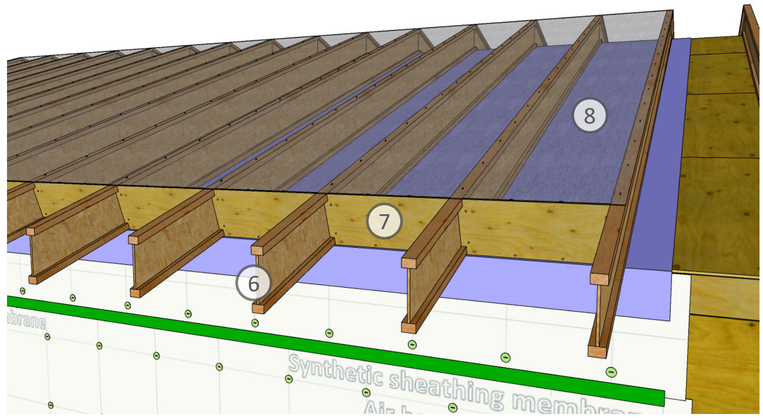
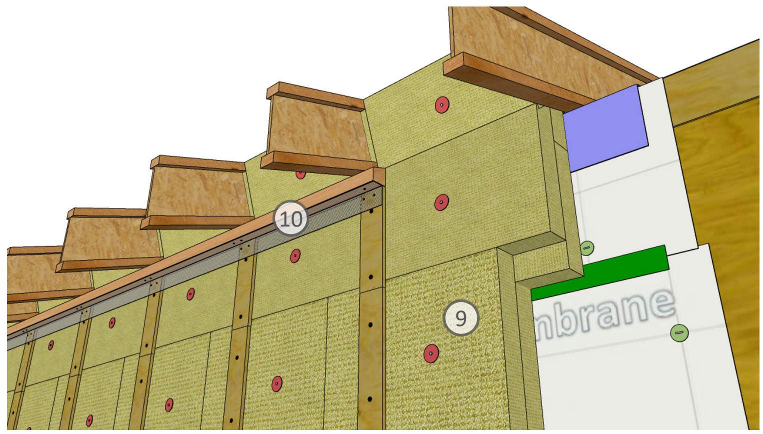
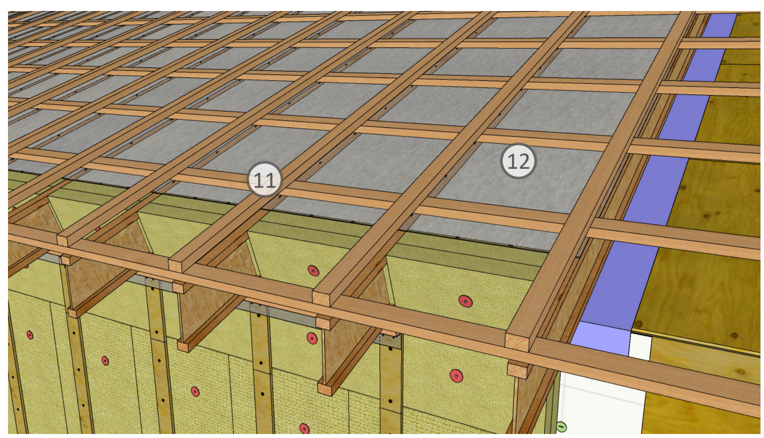




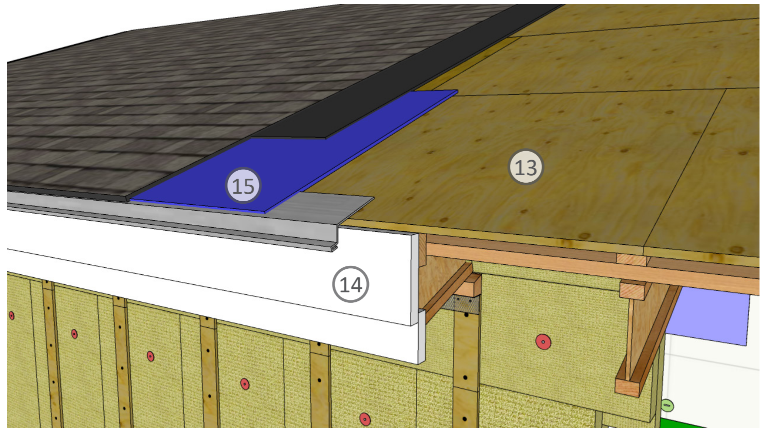


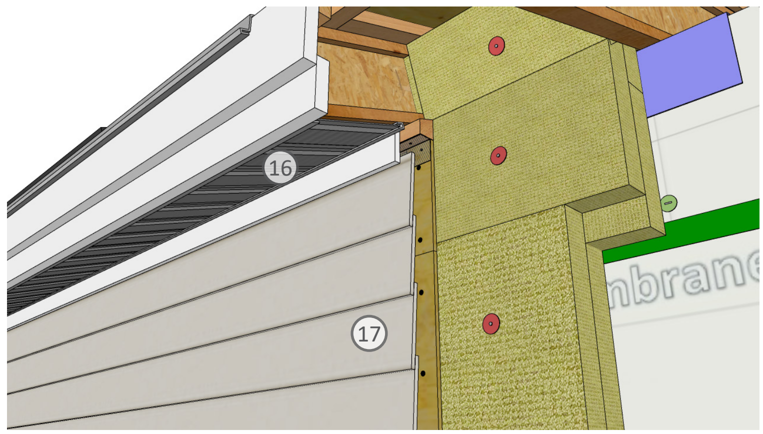
Retrofit Steps Continued:

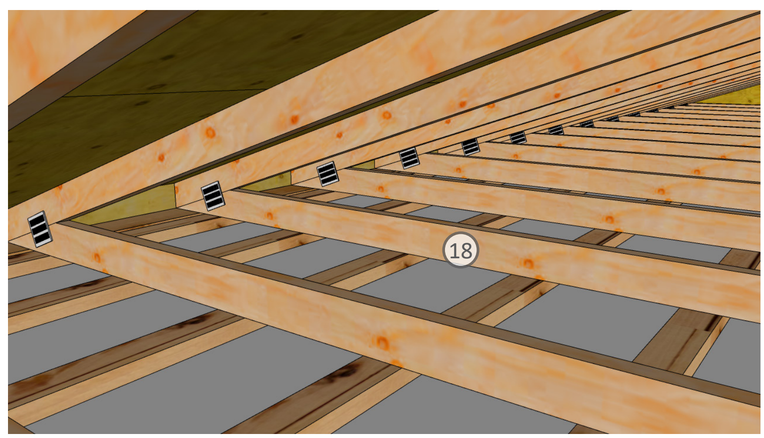
13. Install new plywood roof sheathing
14. Install painted fascia board.
15. Install roofing underlayment, ice and water shield, edge flashing with drip edge, and asphalt shingles.
16. Install vented soffit panels to underside of TJI joist.
17. Reinstall existing cladding where possible or install new cladding. Leave the cladding 1” short of the soffit material to allow for ventilation of the wall cavity.
18. Attic insulation and ceiling polyethylene sheet may be removed to convert the attic into usable space.

Key Considerations:

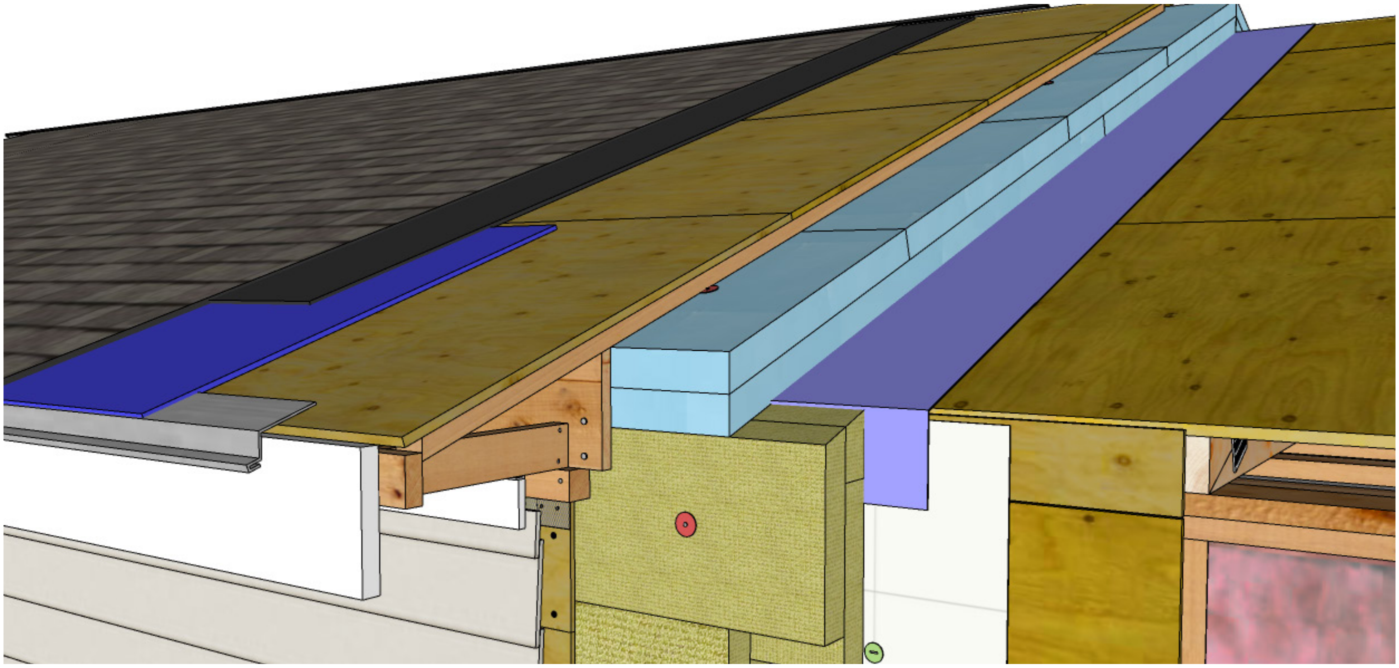
- Ensure soffit insulation at the roof-to-wall interface is continuous and does not have gaps or areas of reduced insulation thickness.
- Ensure dense-pack insulation does not bulge and block vented space created by cross-strapping.

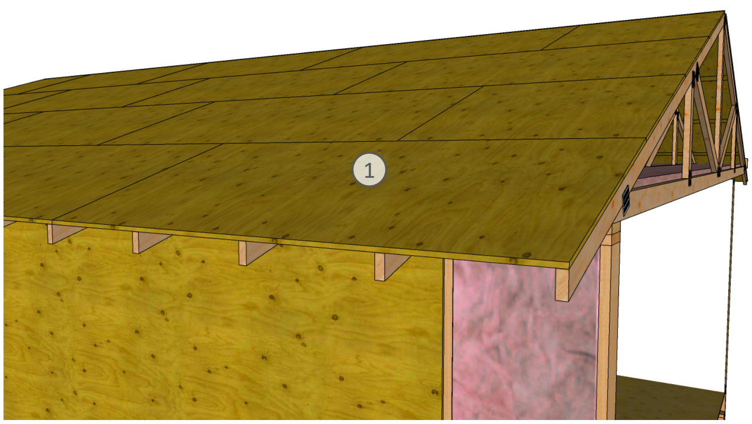


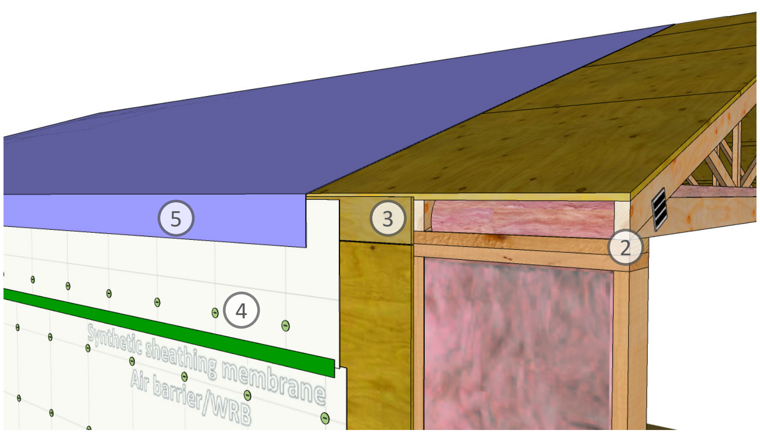




Detail 20 Chainsaw Retrofit — Rigid Foam Board Insulation







Retrofit Steps:

1. Remove existing roofing, cladding, and sheathing membrane as required to expose the exterior wall and roof sheathing. Inspect and repair sheathing and framing as necessary.
2. Cut back roof sheathing and overhanging truss top chord to the plane of exterior wall framing.
3. Install ½" plywood sheathing over the exposed truss heel.
4. Install vapor-permeable air barrier membrane (sheathing membrane). Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity.
5. Install vapour-impermeable self-adhered membrane on roof sheathing, lapping onto exterior wall sheathing membrane by minimum 6". Apply primer to plywood sheathing prior to installing the self-adhered membrane as required to ensure aggressive adhesion.

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Retrofit Steps Continued:

6. Install exterior insulation on wall and plywood blocking and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity.
7. Install rigid foam board insulation on new roof membrane. Ensure there are no gaps in the insulation and the insulation board joints as with wall insulation. Run roof insulation over edge of wall insulation to improve thermal continuity.
8. Install new soffit ladder framing. Fasten ledger board to plywood sheathing using long screws through wall insulation.
9. Install 2x3 dimensional lumber strapping over roof insulation. Fasten directly to roof trusses using long screws.
10. Install new plywood roof sheathing
11. Install painted fascia board.
12. Install roofing underlayment, ice and water shield, edge flashing with drip edge, and asphalt shingles.

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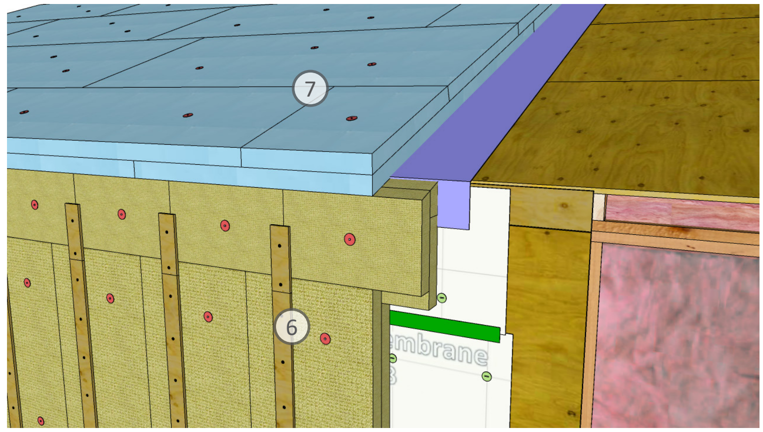
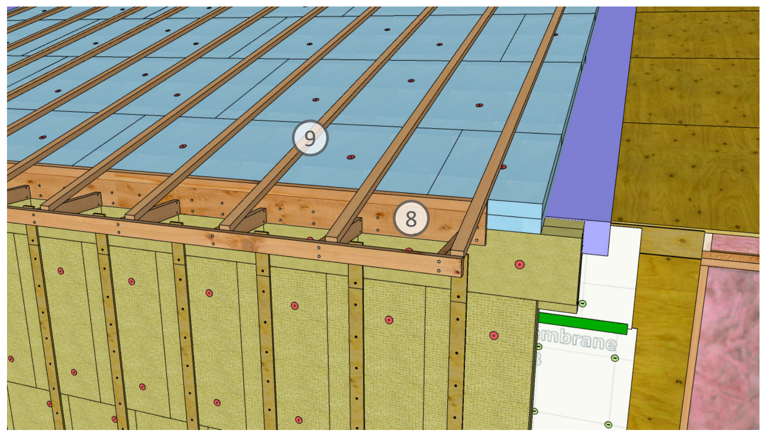
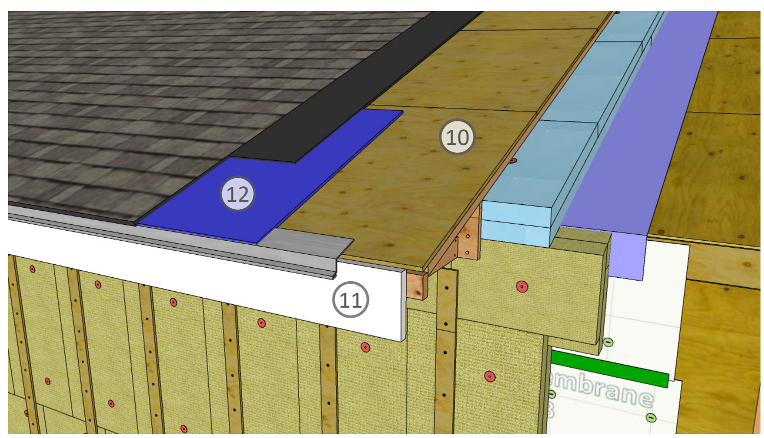






Retrofit Steps Continued:

14. Install framing at underside of TJIs to support cladding trim. Framing should extend 1" beyond depth of finished cladding to allow for ventilation of the wall cavity. Install bug screen between planes of strapping and framing.

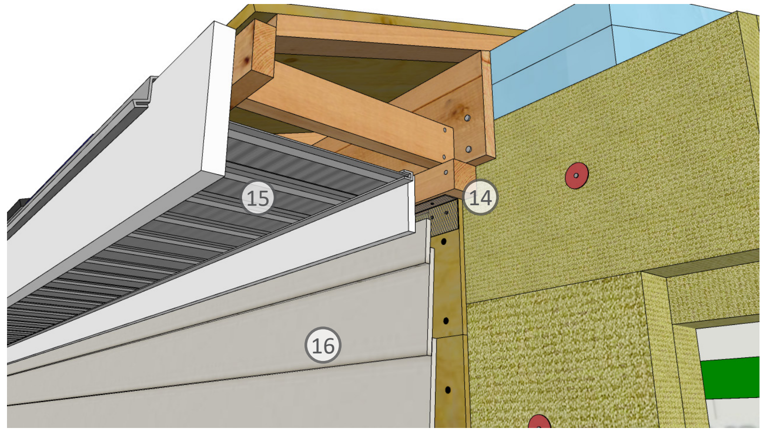
15. Install vented soffit panels.

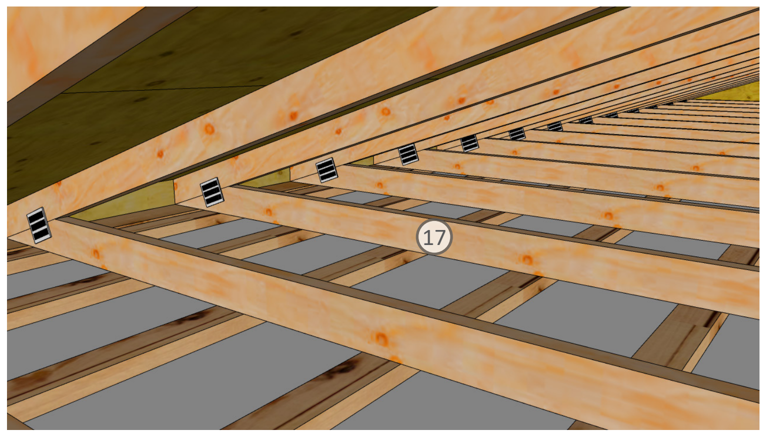
16. Reinstall existing cladding where possible or install new cladding. Leave the cladding 1” short of the soffit material to allow for ventilation of the wall cavity.

17. Attic insulation and ceiling polyethylene sheet may be removed to convert the attic into useable space.

Key Considerations:

- Ensure soffit insulation at the roof-to-wall interface is continuous and does not have gaps or areas of reduced insulation thickness.





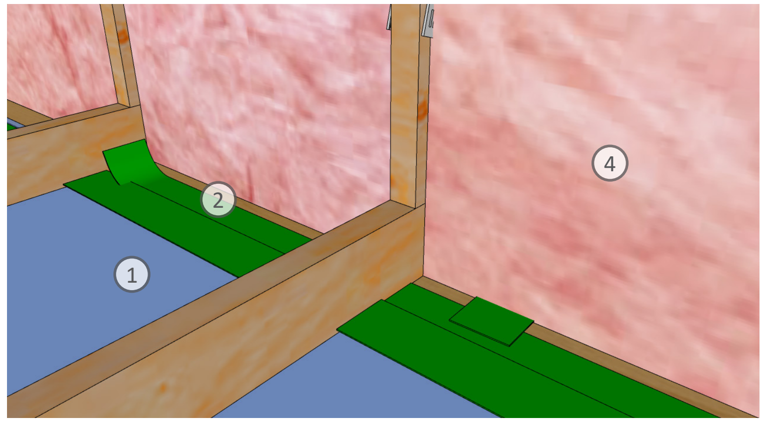
Detail 21 Attic Insulation

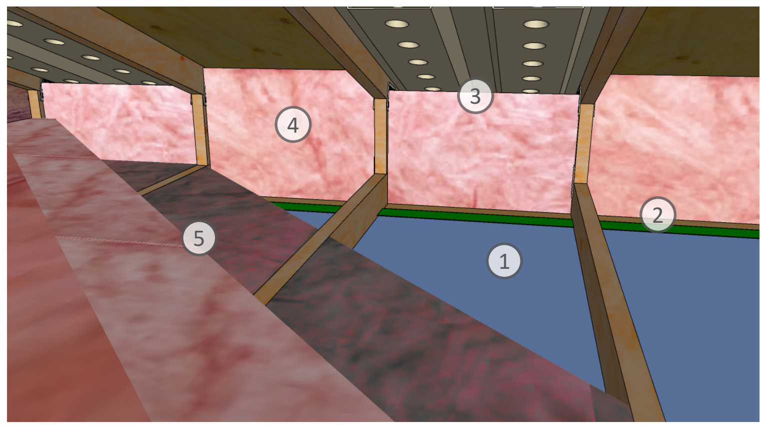
Retrofit Steps:

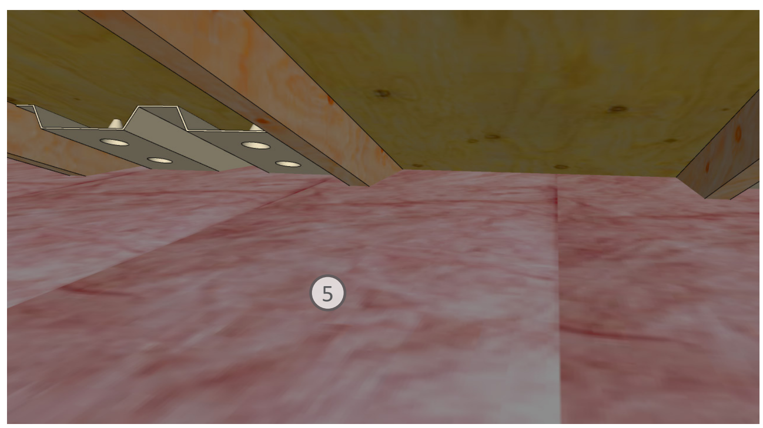
1. Move existing insulation as required to expose penetrations and top plates of exterior and interior walls.
2. Seal all penetrations that go through the ceiling polyethylene into the attic. Seal exterior and interior top plates to the polyethylene sheet with appropriate tape. Insulate and air seal all heat sources including plumbing, electrical, and HVAC components.
3. Install insulation baffles as required along the roof edge, or above each soffit ventilation port if it is not a continuous soffit vent.
4. Install batt insulation into every empty rafter space.
5. Add new insulation per the manufacturer's instructions. Ensure each layer of batt insulation is placed perpendicular to the previous layer.
6. Refer to the following details around plumbing stacks and chimney penetration.

Key Considerations:

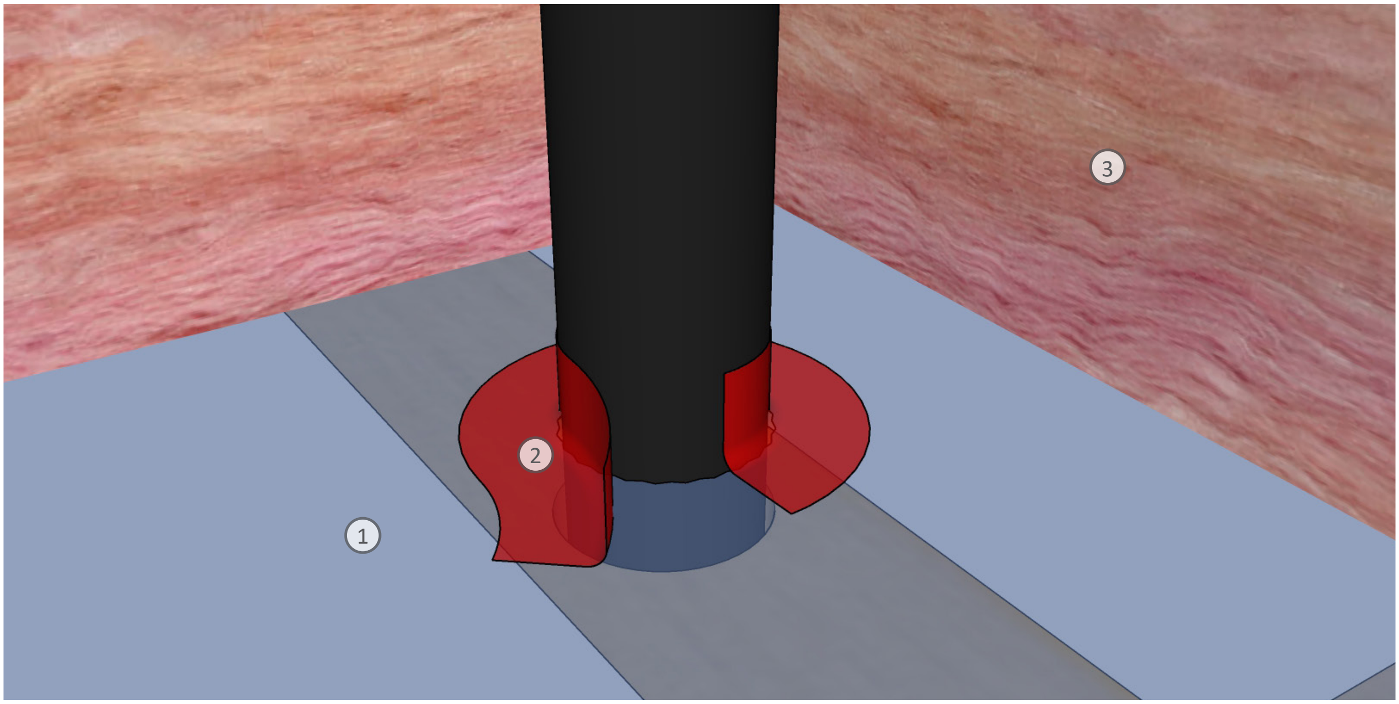
- Air sealing throughout the attic space must be completed prior to adding new insulation to ensure an airtight ceiling plane.
- Batt insulation should form a continuous, non-compressed blanket of insulation when installed properly.
- To minimize ice damming risks, ensure insulation at the roof-to-wall interface is continuous and does not have areas of reduced insulation thickness.
- Ensure attic space is provided with adequate ventilation and that the correct size and number of baffles are installed. Increased attic ventilation can keep the roof sheathing closer to outside temperatures, limiting snow melt and subsequent ice damming.
- Blown in cellulose can be used as an alternative to batt insulation.







Detail 22 Plumbing Vent Stack — Attic



Retrofit Steps:

1. Expose the ceiling polyethylene air barrier around the vent stack. Remove dirt and debris from the surrounding polyethylene and the vent stack.
2. Install high-performance tape around the plumbing vent stack, sealing it to the ceiling polyethylene.
3. Reinstall existing insulation around the vent stack and add new insulation per the manufacturer's instructions. Ensure each layer of batt insulation is placed perpendicularly to the previous layer.

Key Considerations:

- Ensure all ceiling penetrations are air sealed from the attic using a similar approach, being sure to maintain continuity of the air barrier at the polyethylene sheet.
- Plumbing vent stacks are prone to movement, usually caused by settlement or thermal expansion/contraction. Ensure that the seal between the plumbing vent stack and the ceiling polyethylene allows for some movement and is flexible.
- Blown in cellulose can be used as an alternative to batt insulation to maintain an effective R-Value. It can also be used in addition to batt insulation to fill gaps.

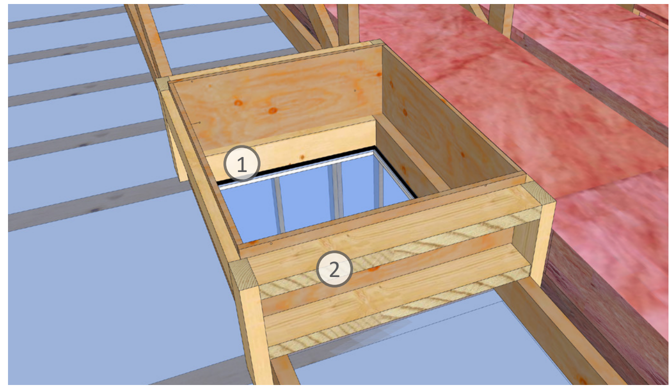
Detail 23 Attic Hatch

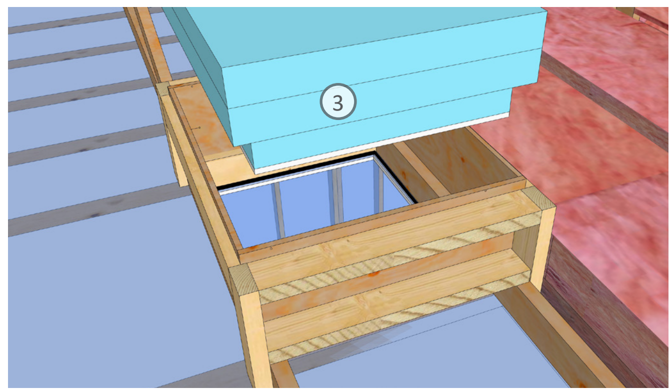
Retrofit Steps:

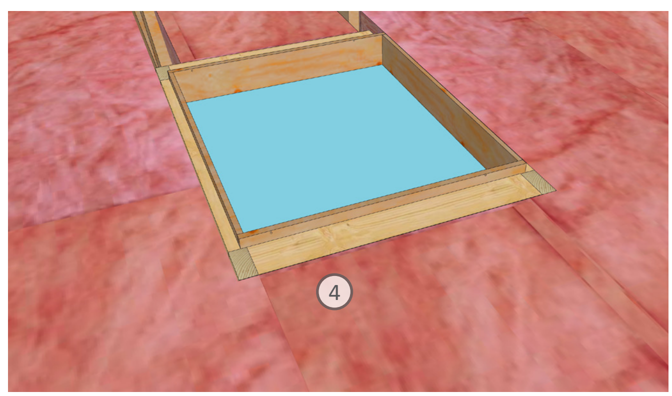
1. Seal ceiling polyethylene sheet to underside of attic hatch box framing. Adhere weather stripping to the access cover ledge on all sides and over the polyethylene end lap.
2. Install plywood box around the access opening. Ensure the plywood is sized to be above the final layer of fiberglass insulation. Install additional framing around the plywood box.
3. Cut two or more pieces of rigid foam board and adhere to attic hatch cover. Ensure the bottom layer adhered to the access cover fits within the joist opening. Ensure the remaining layers of rigid foam board fit within the plywood frame.
4. Place existing insulation back into all rafter spaces. Install additional fiberglass insulation ensuring joints are overlapped.
5. Use latches on interior side of access cover to ensure full air seal.

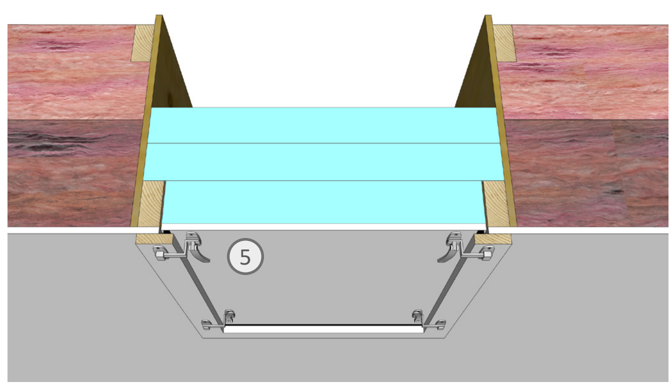
Key Considerations:

- Ensure ceiling polyethylene is fully sealed on all sides of access cover ledge.
- Ensure adhesive used to bond rigid foam boards and access cover can withstand varying temperatures that may be experienced in the attic.









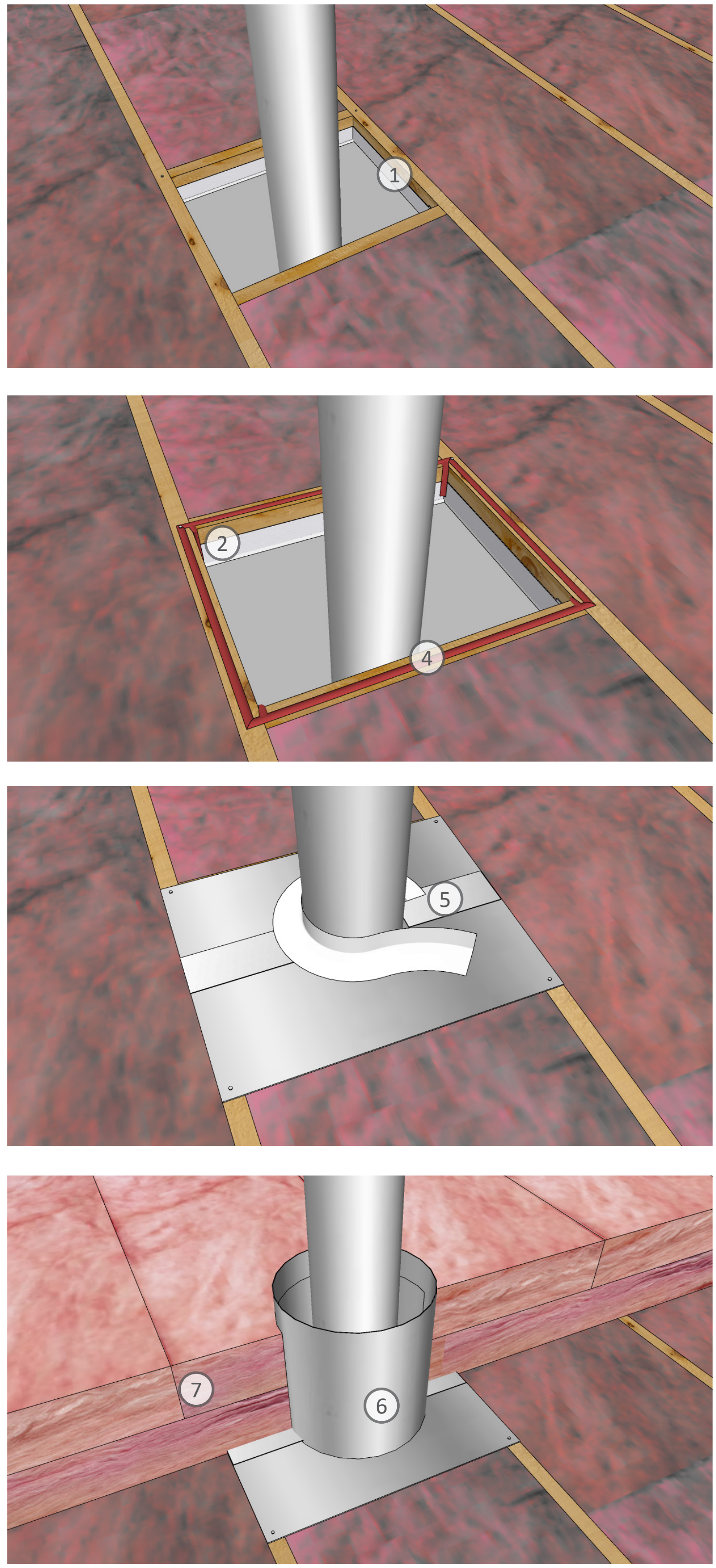
Detail 24 Chimney Penetration — Attic

Retrofit Steps:

1. Seal ceiling polyethylene to chimney box-out with appropriate tape.
2. Install fire-resistant silicone sealant at framing and blocking corners.
3. Cut sheet metal closure to fit over the chimney opening tight to the metal chimney, with overlap at each joint (not shown).
4. Apply fire-resistant silicone sealant onto the wood framing where the metal closures will be placed.
5. Secure the metal closures to the wood framing with screws and seal the metal closure to the chimney and at each joint with fire-resistant flue tape.
6. Install an insulation guard around chimney. Cut and fold tabs to keep the insulation guard spaced 3” from the chimney on the top and bottom. Size it so that the top edge is above the insulation level, including any additional insulation that may be added.
7. Reinstall existing insulation and add new insulation as recommended around the chimney insulation guard. Ensure each layer of batt insulation is placed perpendicularly to the previous layer.

Key Considerations:

- Ensure there is a minimum 3” insulation clearance around the combustion appliance vent, both at the interior ceiling space and in the attic.
- A cap above the insulation guard may be required to prevent combustible debris falling between the guard and the chimney. Consult the insulation guard manufacturer's installation requirements.



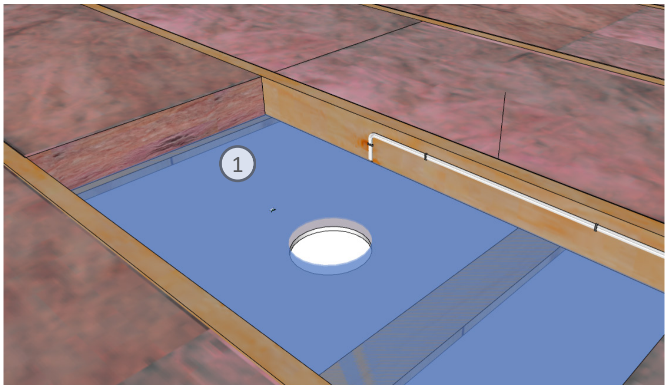
Detail 25 Electrical Penetration — Attic

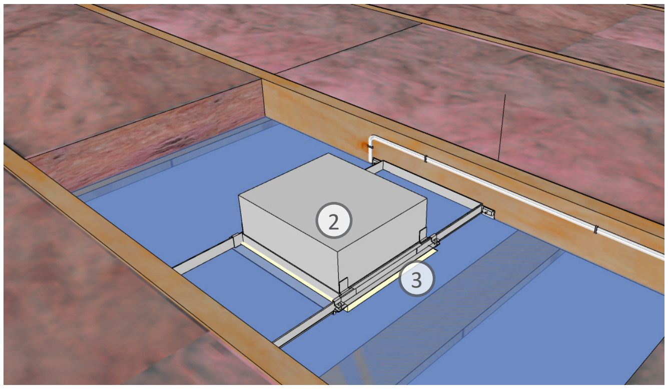
Retrofit Steps:

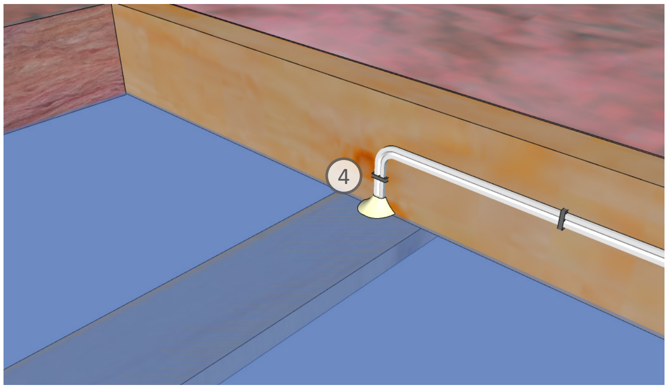
1. Remove existing insulation around the area of work. Disconnect and remove existing non-IC-rated pot light. Cut or repair the ceiling as needed if the diameter of the new pot light is different.
2. Install new IC/AT-rated pot light. (IC/AT-rated replacement housing is shown.)
3. An IC/AT-rated pot light may come with gaskets to provide a seal between the housing and the drywall. Seal around housing if gaskets are not provided.
4. Seal conduit penetrations with sealant.
5. Replace the insulation and add new insulation as desired.

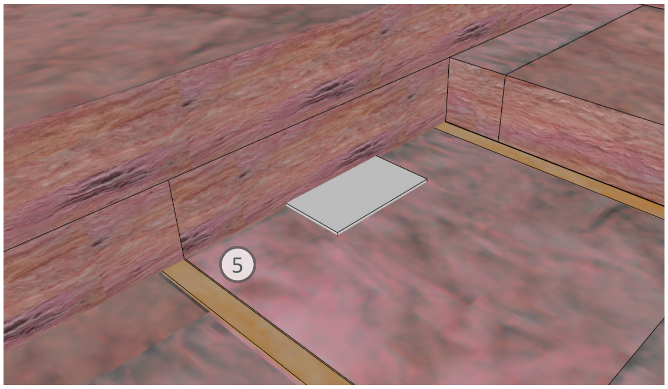
Key Considerations:

- Do not use spray foam directly in contact with electrical fixtures or uninsulated wires.
- Ensure all electrical wires are properly attached to the fixture and secured to the framing, and that the penetrations through the box are sealed. The use of an electrician is recommended for replacing any light fixtures.

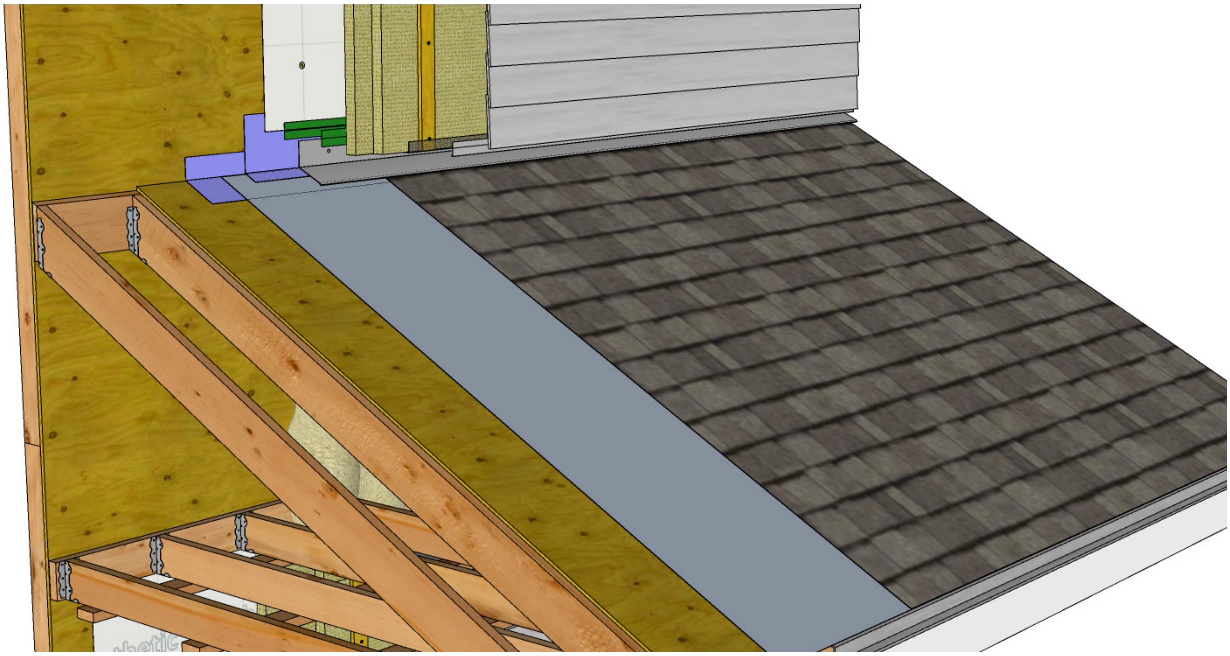


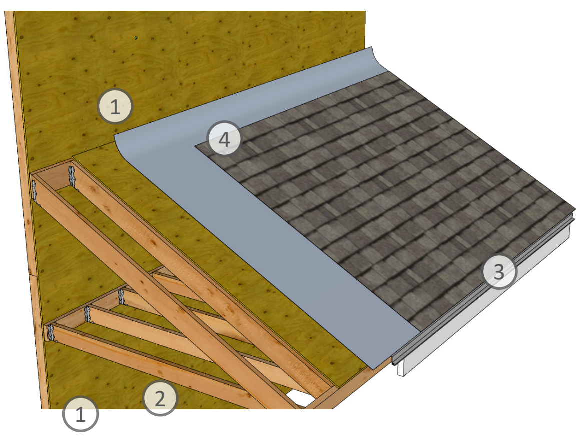


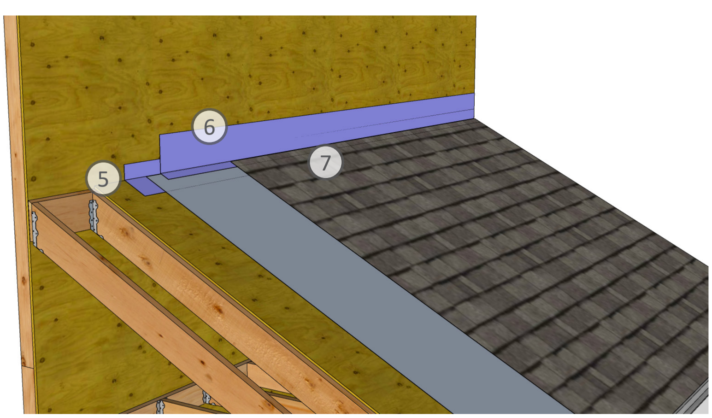




Detail 26 Exterior Canopy







Retrofit Steps:

1. Remove existing cladding and building paper to expose exterior wall assembly above and below canopy. Inspect and repair sheathing and framing as necessary.
2. Remove existing canopy soffit material to expose framing (ledgers, rafters, lookouts, furring, and sub-fascia). Inspect and repair sheathing and framing as necessary.
3. Inspect and repair existing shingles, drip-edge flashing, and fascia.
4. Remove top section of canopy shingles. Peel up leading edge of existing canopy underlayment at wall-to-canopy sheathing interface.
5. Install strip of self-adhered membrane beneath existing canopy underlayment, between wall sheathing and canopy. Return leading edge of existing canopy underlayment to original position.
6. Install strip of self-adhered membrane from wall sheathing to canopy sheathing, lapping onto the existing canopy underlayment.
7. Reinstall top section of canopy shingles.

(Continued on next page)

Retrofit Steps Continued:

8. Install vapour-permeable air barrier membrane (sheathing membrane). Lap the membrane over the self-adhered membrane below and seal the leading edge with sheathing tape to maintain air barrier continuity.

9. Install pre-finished metal closure flashing and seal the leading edge with sheathing tape.

10. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.

11. Reinstall cladding where possible or install new cladding.

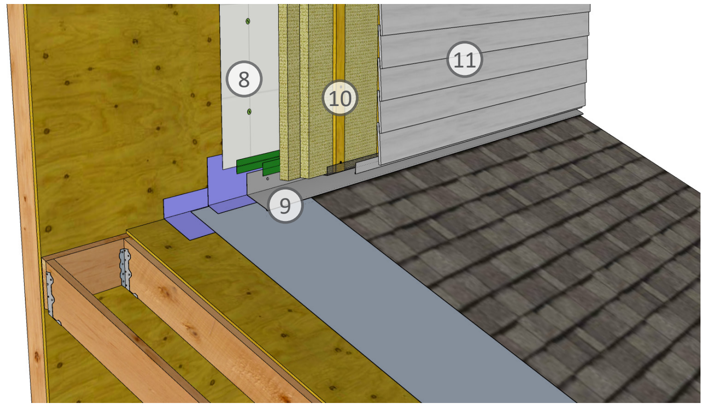
12. Install sheathing membrane below the canopy. Ensure the membrane terminates with a bead of sealant directly under the canopy's lower ledger board. Seal all membrane laps with sheathing tape for air barrier continuity.

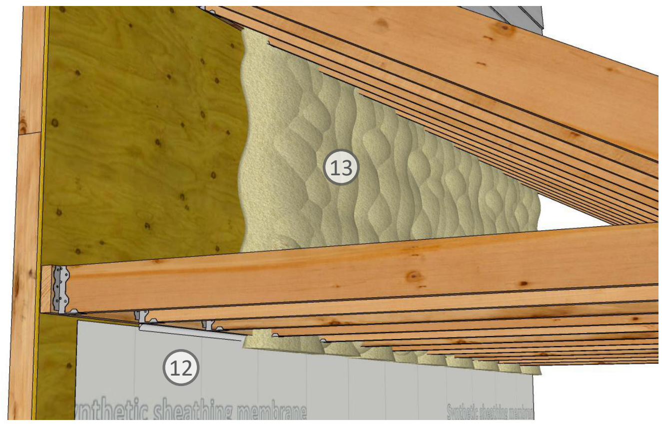
13. Apply spray foam insulation with a uniform thickness and ensure no voids are created. The spray foam should extend from the underside of the canopy sheathing to the sheathing membrane below the canopy (min. 6" overlap).

14. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide bug screens at the top and bottom of the strapping.

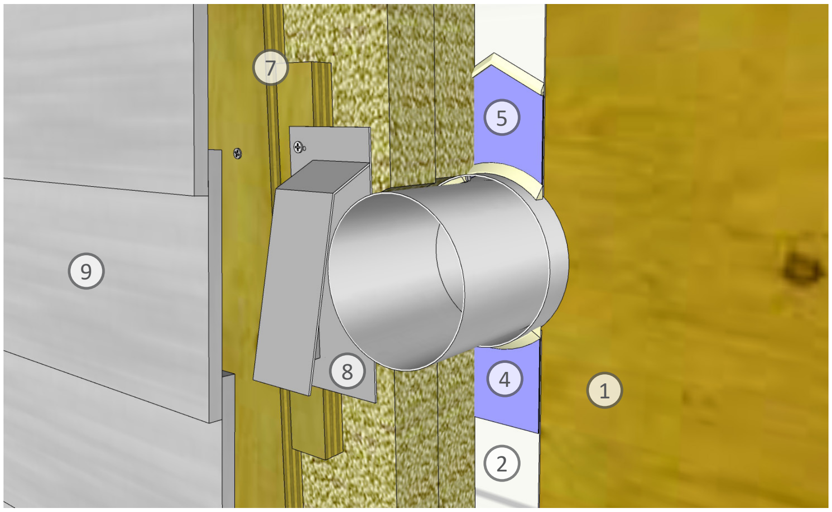
15. Install new vented soffit material.

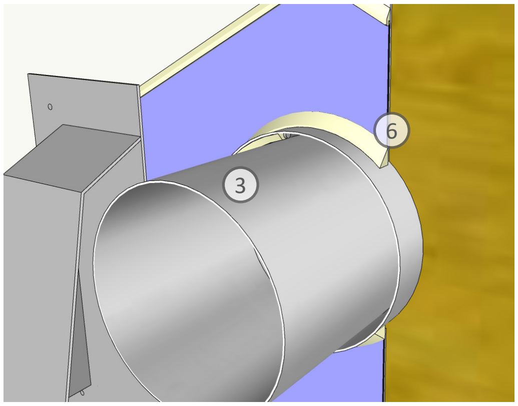
16. Reinstall existing cladding where possible or install new cladding.





Detail 27   Exhaust Vent — Wall

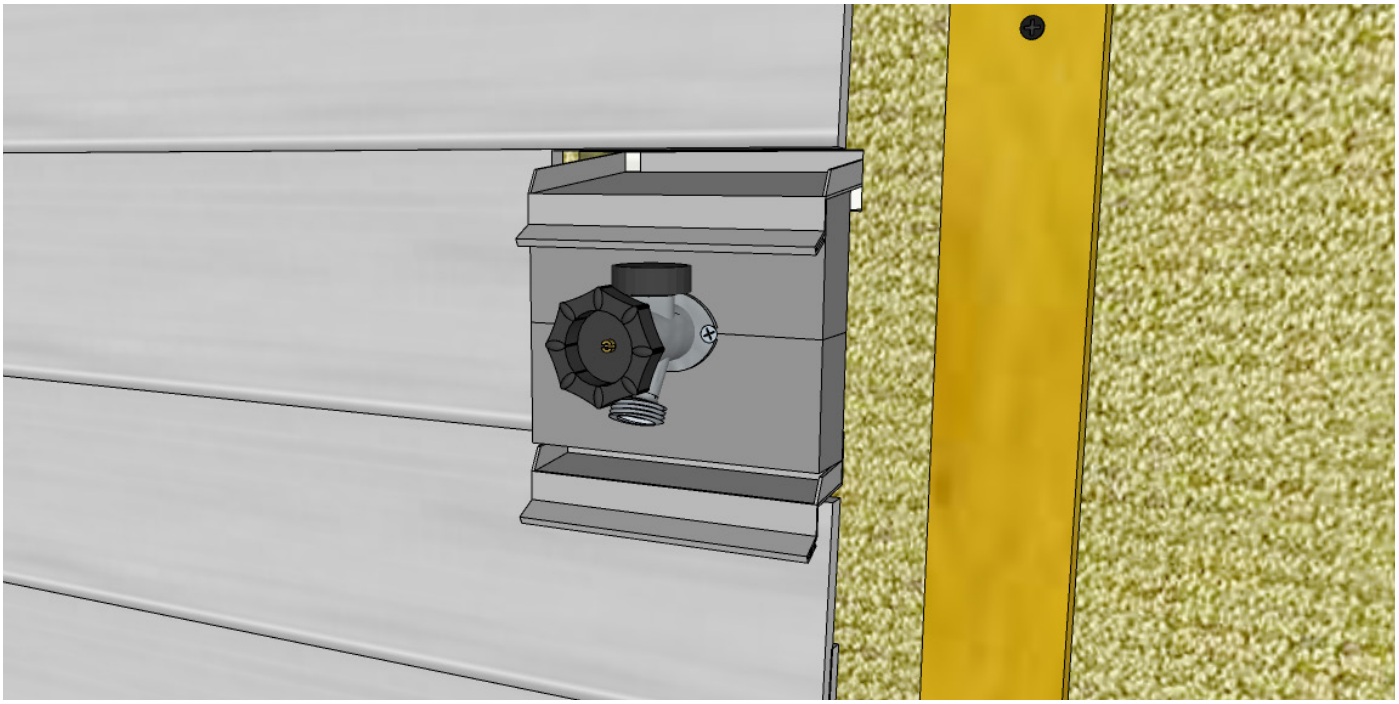


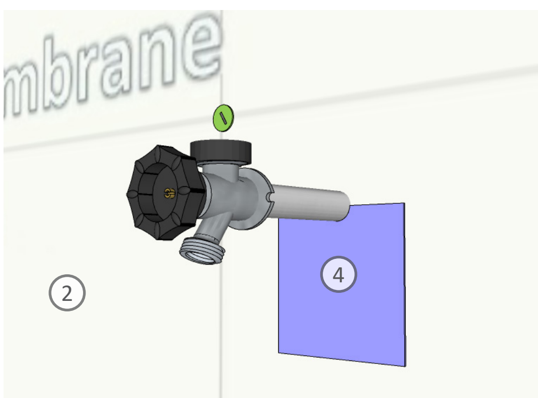


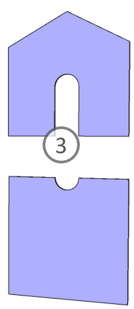
Retrofit Steps:

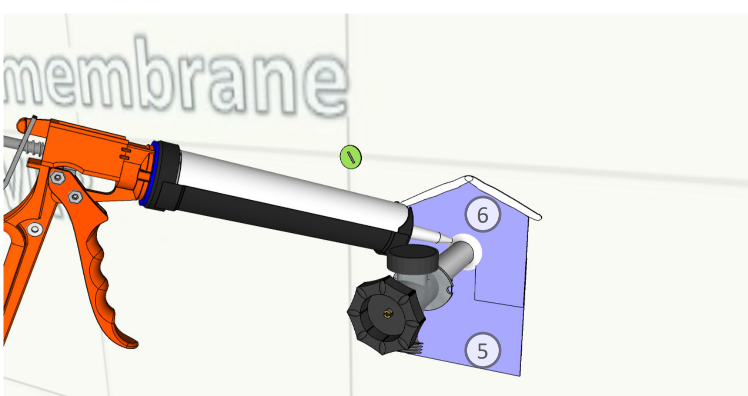
1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary.
2. Install vapour-permeable air barrier membrane (sheathing membrane) at exhaust vent. Seal all membrane laps with sheathing tape for air barrier continuity.
3. Install a one-piece duct extension with vent hood and seal to existing vent with backer rod and sealant so that the vent hood flange terminates at the outside face of the future exterior strapping.
4. Install horseshoe-shaped self-adhered membrane (SAM) below the exhaust vent.
5. Install horseshoe-shaped SAM above the exhaust vent. Taper the top of the membrane to facilitate water drainage. Seal the leading edge of the SAM with compatible sealant.
6. Apply sealant between the existing exhaust vent and the SAM.
7. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide additional strapping around the penetration to support the vent hood flange. Take care to not allow the vent hood to shift when installing insulation and strapping as it may damage the seal.
8. Secure flange of vent hood to the support strapping.
9. Reinstall existing cladding where possible or install new cladding.
10. Apply a bead of sealant between the exhaust vent hood and cladding on the top and sides (not shown).

Detail 28 Hose Bib









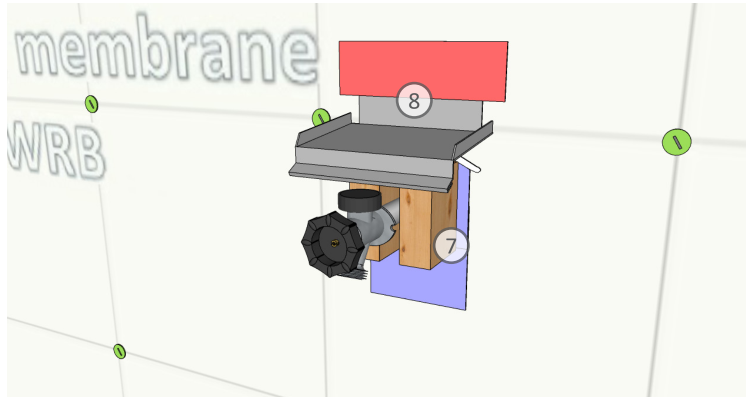
Retrofit Steps:

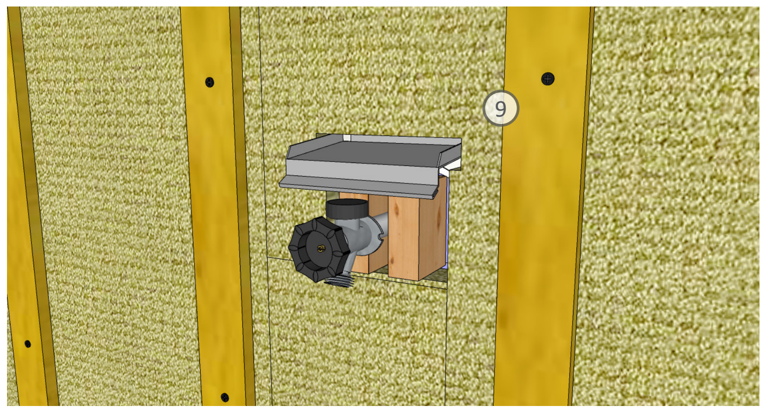
1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary (not shown). It is recommended to install new frost-proof hose bib (shown). Ensure hose bib flange terminates at the out side of the future cladding.
2. Install vapour-permeable air barrier membrane (sheathing membrane) at hose bib location. Make a small cut (hole) in the sheathing membrane to allow for it to be installed over the hose bib. Ensure the hole is small enough that it can be covered by the self-adhered membrane (SAM).
3. Prepare two pieces of SAM as shown.
4. Install the bottom piece of SAM, ensuring a tight fit to the underside of the hose bib.
5. Install top piece of SAM, positively lap the top piece over the bottom sheet a minimum 2". Apply compatible silicone sealant at the leading edge of the SAM.
6. Apply a bead of sealant around the perimeter of the hose bib, ensuring good adhesion to the SAM to maintain air barrier continuity.

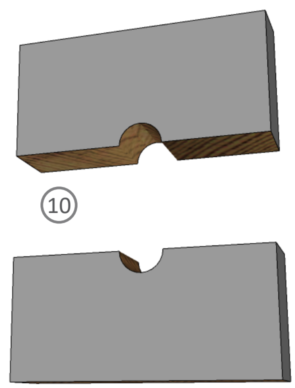
(Continued on next page)

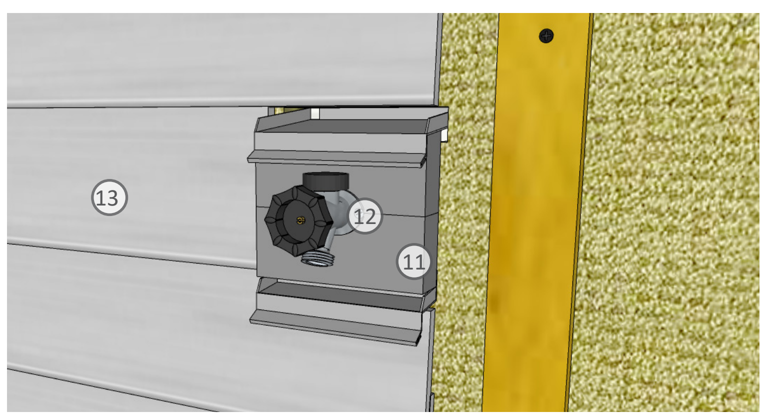
Retrofit Steps Continued:

7. Install pressure treated blocking on both sides of the hose bib to the depth of the insulation to be installed.
8. Install flashing above the hose bib and tape the leading edge.
9. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide void in insulation at hose bib location.
10. Construct two-piece pressure treated blocking as shown.
11. Install the blocking around the hose bib and secure it to the previously installed blocking with appropriate fasteners.
12. Apply a bead of sealant around the perimeter of the hose bib, sealing it to the blocking. Seal the joint between the two pieces of blocking.
13. Reinstall existing cladding where possible or install new cladding.





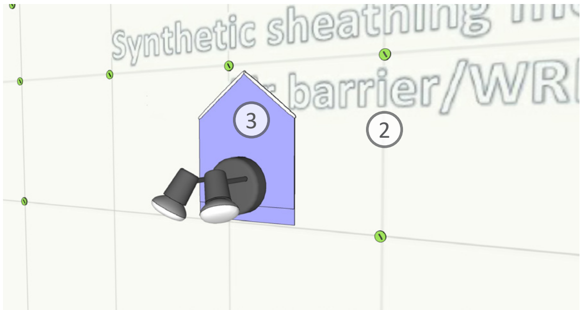


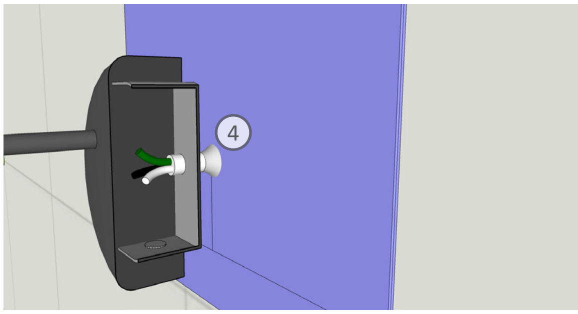


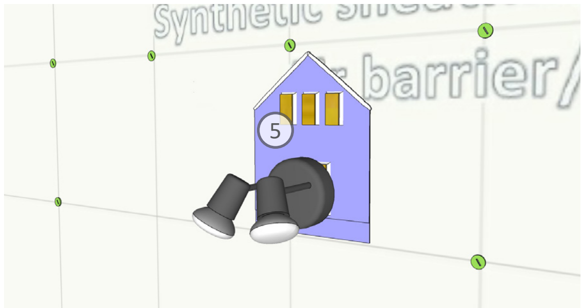
Detail 29 Exterior Light Fixture

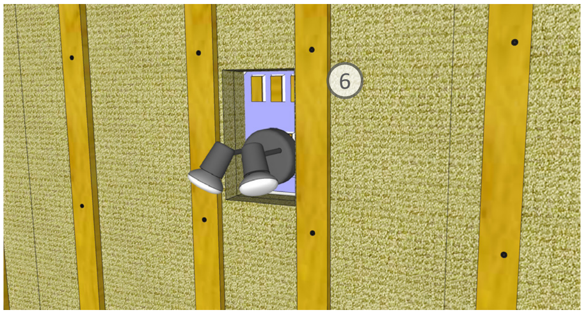
Retrofit Steps:

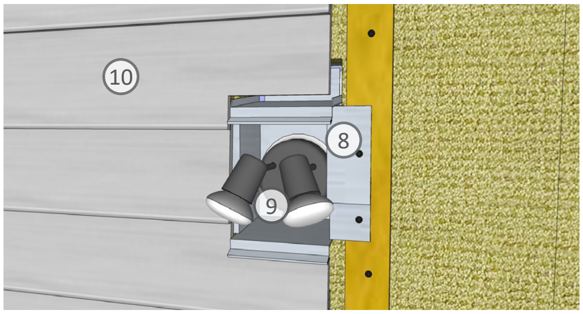
1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary (not shown).
2. Install vapour-permeable air barrier membrane (sheathing membrane) at existing exterior light fixture location. Ensure positive laps and seal all membrane laps with sheathing tape for air barrier continuity.
3. Construct and install two-piece SAM detail over the sheathing membrane, with tapered top edge to facilitate drainage. Ensure a tight fit around electrical cable when installing the SAM. Refer to the hose bib retrofit steps for more detail. Seal the leading edge of the foil-faced membrane with compatible sealant.
4. Apply a bead of sealant around the perimeter of the electrical cable, ensuring good adhesion to the SAM to maintain air barrier continuity.
5. Install pressure treated shims above the exterior light fixture box. Seal the shims at the top and sides to the sheathing membrane.
6. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide void in insulation at exterior light fixture location.
7. Construct a three-piece pre-finished metal flashing exterior light fixture box (not shown). Ensure the exterior light fixture box is large enough to not interfere with the function of the light.
8. Install the pre-finished metal flashing box.
9. Seal the existing exterior light fixture at its perimeter to the pre-finished metal flashing box.
10. Reinstall existing cladding where possible or install new cladding.







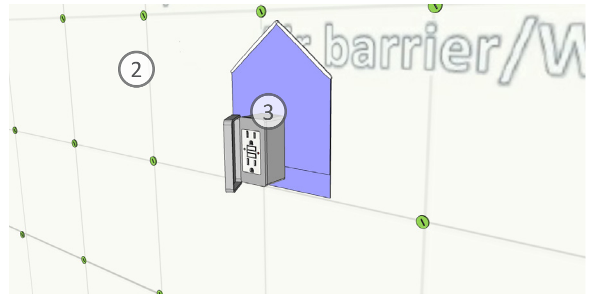


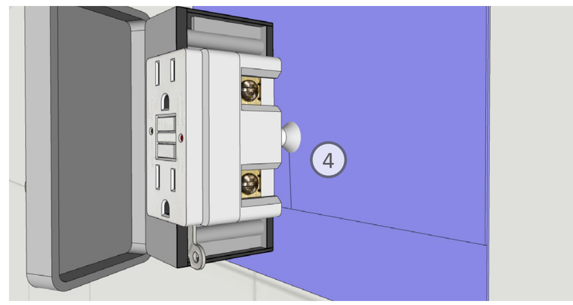


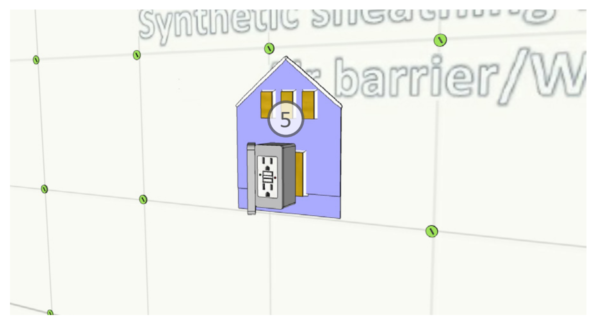
Detail 30   Exterior Electrical Outlet

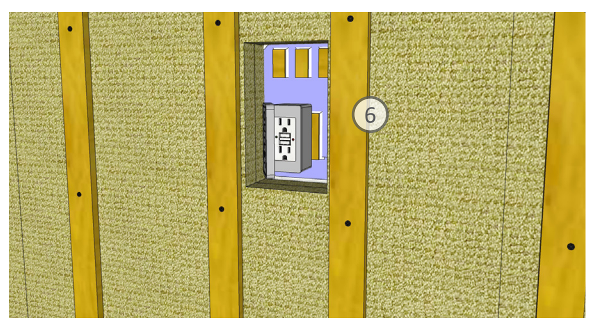
Retrofit Steps:

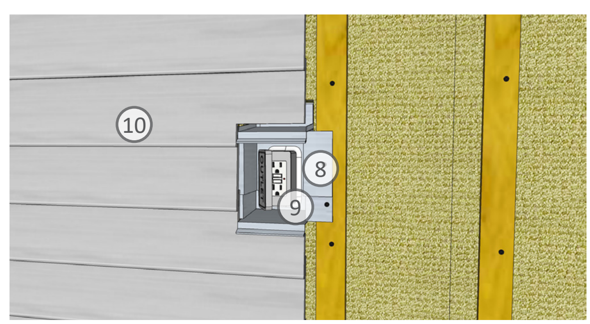
1. Remove existing cladding and building paper to expose exterior wall assembly. Inspect and repair sheathing and framing as necessary (not shown).
2. Install vapour-permeable air barrier membrane (sheathing membrane) at existing exterior electrical outlet location.
3. Construct and install two-piece SAM detail over the sheathing membrane, with tapered top edge to facilitate drainage. Ensure a tight fit around electrical cable when installing the SAM. Refer to the hose bib retrofit steps for more detail. Seal the leading edge of the foil-faced membrane with compatible sealant.
4. Apply a bead of sealant around the perimeter of the electrical cable, ensuring good adhesion to the SAM to maintain air barrier continuity.
5. Install pressure treated shims above the exterior electrical outlet box. Seal the shims at the top and sides to the sheathing membrane.
6. Install exterior insulation and secure with strapping. Ensure there are no gaps in the insulation and that it is installed tight to the sheathing. Stagger the insulation board joints to improve thermal continuity. Provide void in insulation at exterior electrical outlet location.
7. Construct a three-piece pre-finished metal flashing exterior electrical outlet box (not shown). Ensure the exterior electrical outlet box is large enough to not interfere with the function of the outlet.
8. Install the pre-finished metal flashing box, refer to the hose bib retrofit steps.
9. Seal the existing exterior electrical outlet at its perimeter to the pre-finished metal flashing box.
10. Reinstall existing cladding where possible or install new cladding.



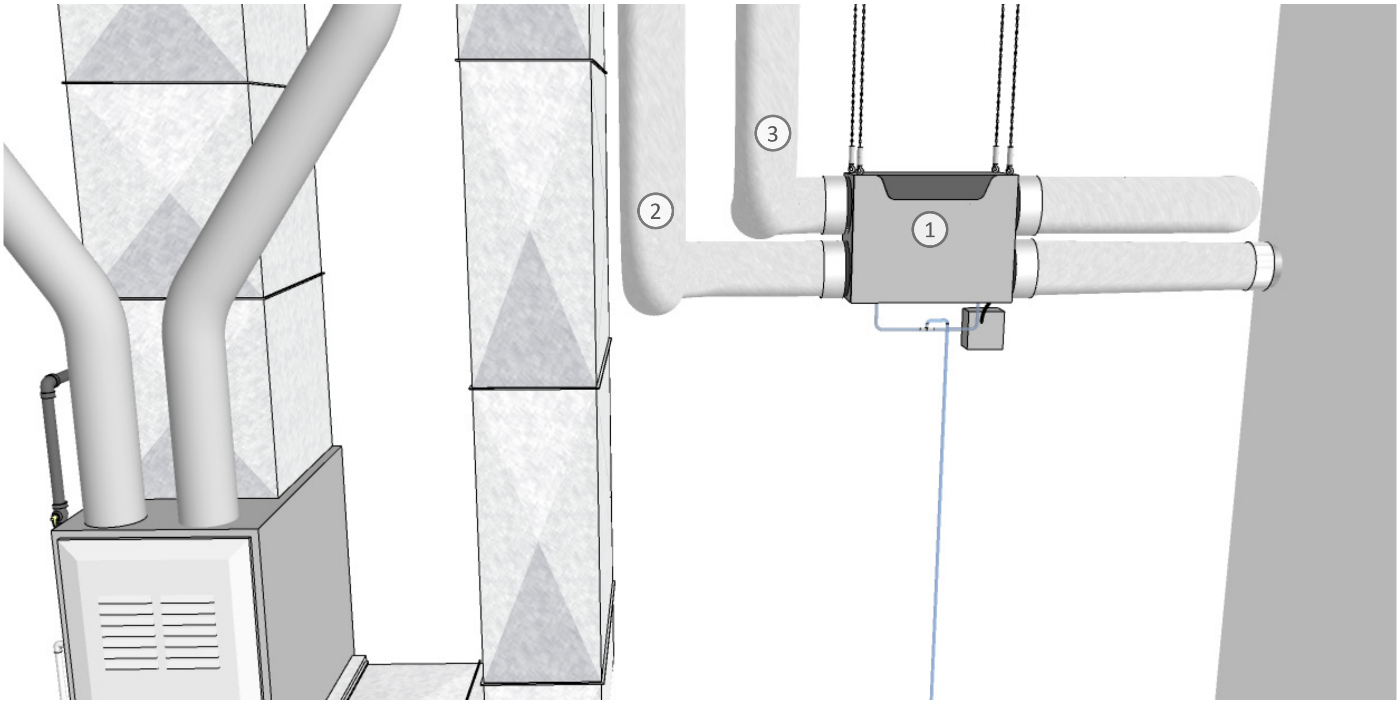


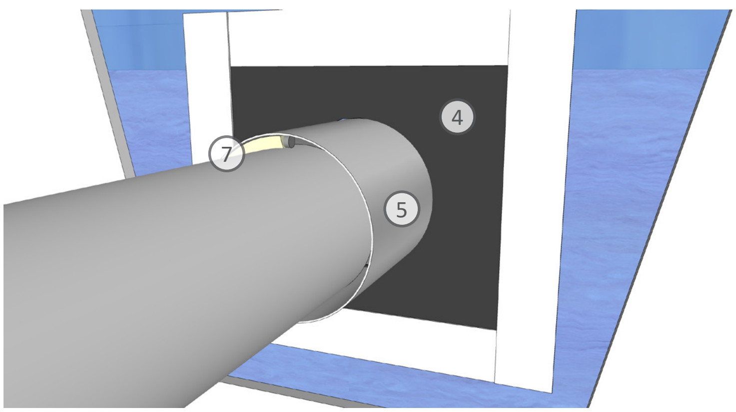


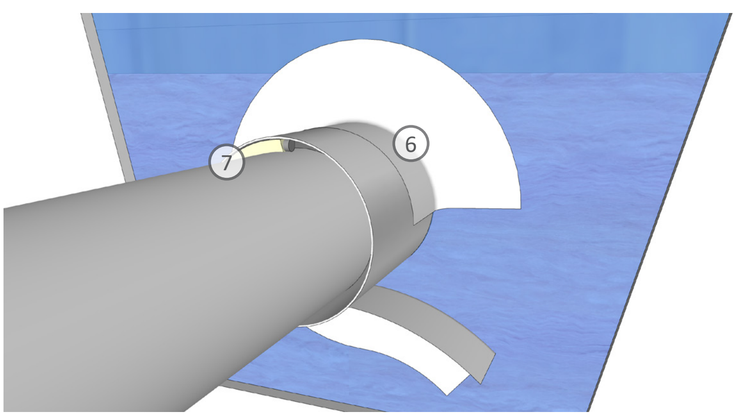




Detail 31 Heat-Recovery Ventilator Installation — No Exterior Retrofit







Retrofit Steps:

1. Install the HRV unit in mechanical room, following the manufacturer's instructions
2. Connect the HRV supply duct to the central return duct a minimum of 10' from the furnace.
3. Connect the HRV exhaust duct to central return duct a minimum of 3' upstream of HRV supply duct.
4. Install sheet of unreinforced EPDM with hole undersized for exhaust/intake pipe sleeve diameter as required to provided tight seal to pipe sleeve. Tape all sides of EPDM to polyethylene sheet.
5. Insert exhaust/intake pipe sleeve through EPDM gasket or;
6. Omit step 4 and 5 and install exhaust/intake pipe sleeve and tape sleeve to polyethylene sheeting air/vapour retarder.
7. Seal gap between sleeve and exhaust/intake pipe with backer rod and sealant.

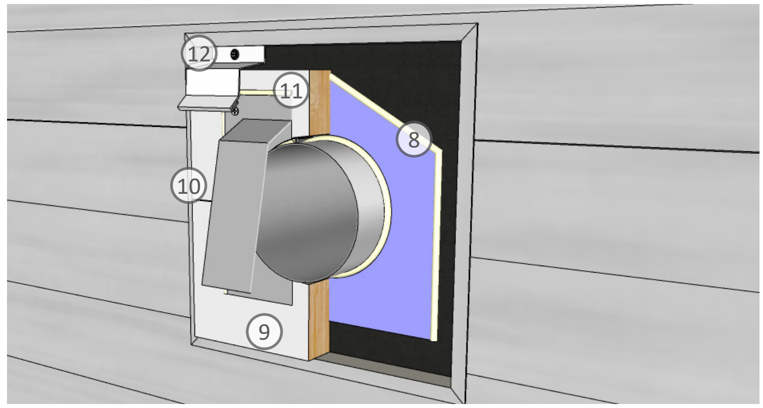
(Continued on next page)

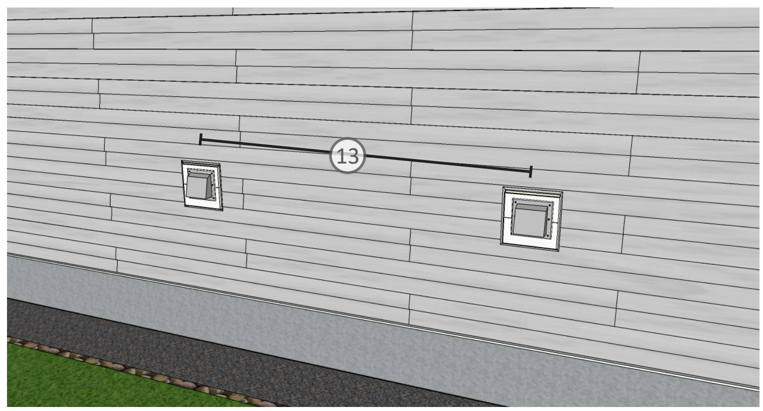
Retrofit Steps Continued:

8. Install self-adhered membrane (SAM) with a tapered leading edge to facilitate drainage. Use primer as required. Seal the leading edge of SAM and between the vent and SAM with compatible sealant.
9. Install pressure treated blocking painted to match exterior cladding.
10. Seal between jamb J-channel trim and blocking. Leave sill and head unsealed.
11. Install vent hood and seal leading edge and sides.
12. Install metal head flashing complete with end dams. Tuck flashing back leg behind J-trim and fasten to wall sheathing.
13. Ensure a minimum 6 feet of clearance is provided between exhaust vent and intake vent or operable windows.

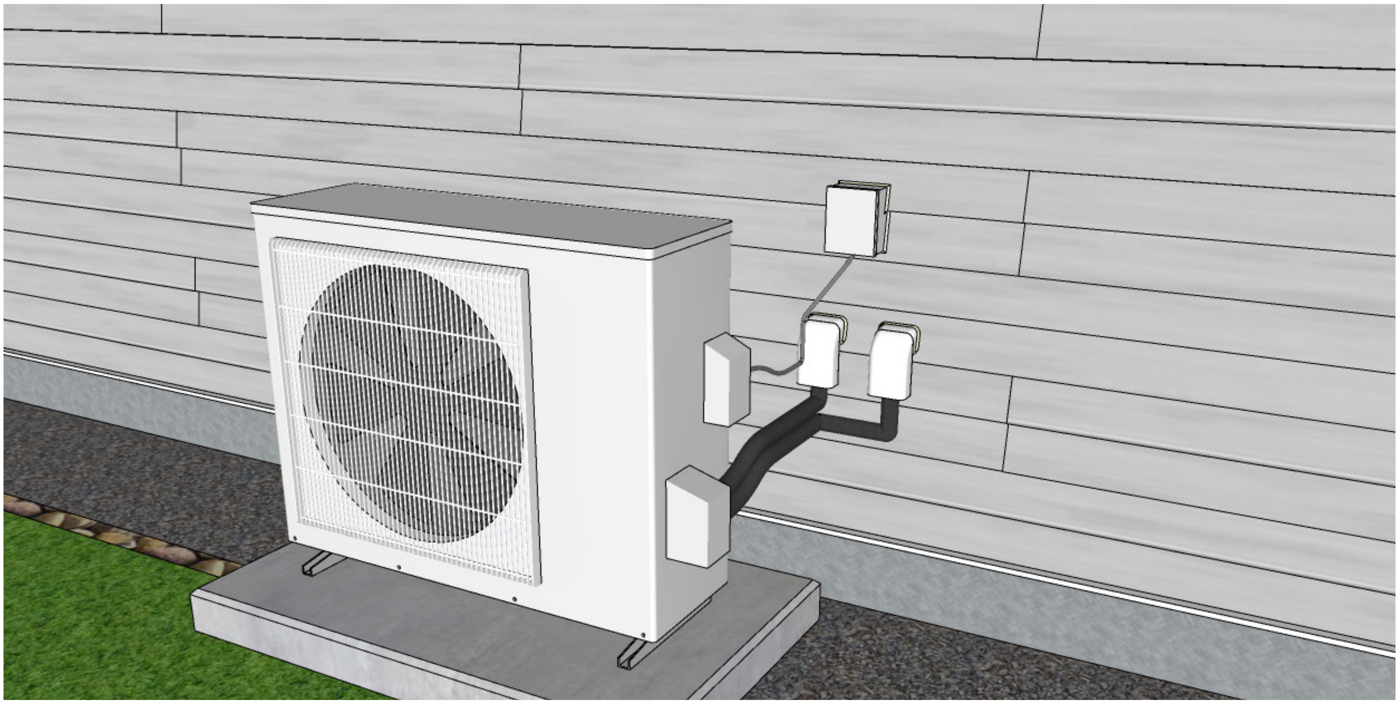
Key Considerations:

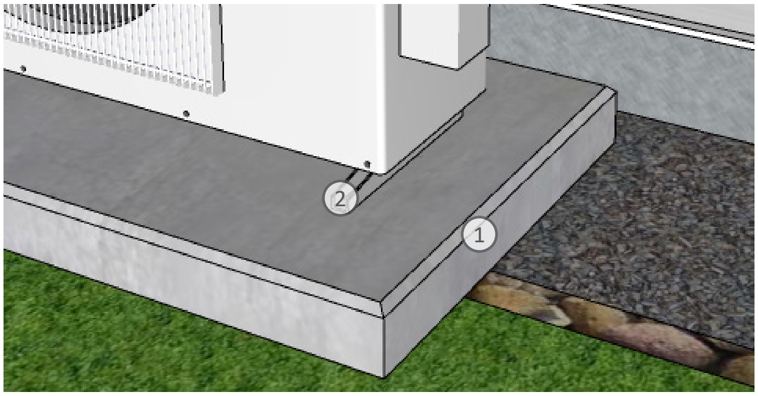
- Ensure pipe is rigidly secured to reduce the risk of movement damaging seals.
- Shingle head J-channel over jamb J-channels to prevent water running behind the cladding.
- Furnace fan must be interlocked with the HRV to avoid air flow short circuiting within the return air duct.
- Ensure pipe is sloped to the exterior to allow drainage of any condensate.

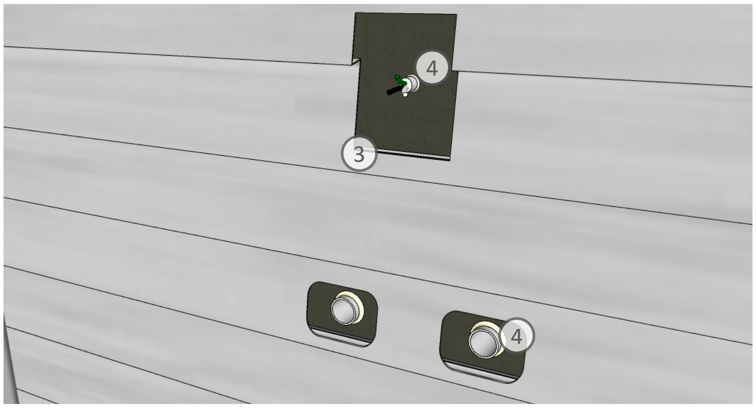




Detail 32   Air-Source Heat Pump Installation — No Exterior Retrofit







Retrofit Steps:

1. Provide a secure pad with cast in place or a single piece of pre-cast concrete or composite slab.
2. Fasten unit to pad with proprietary footings to provide clearance under unit. Ensure units have an unobstructed space 2' from the front, sides, and top. Provide a minimum 1' of clearance between the back of the unit and house.
3. Locally cut out siding as required for installation of electrical box and separated refrigerant lines.
4. Insert pipe sleeves for refrigerant lines and conduit for electrical connection. Seal penetrations to building paper with silicone sealant.

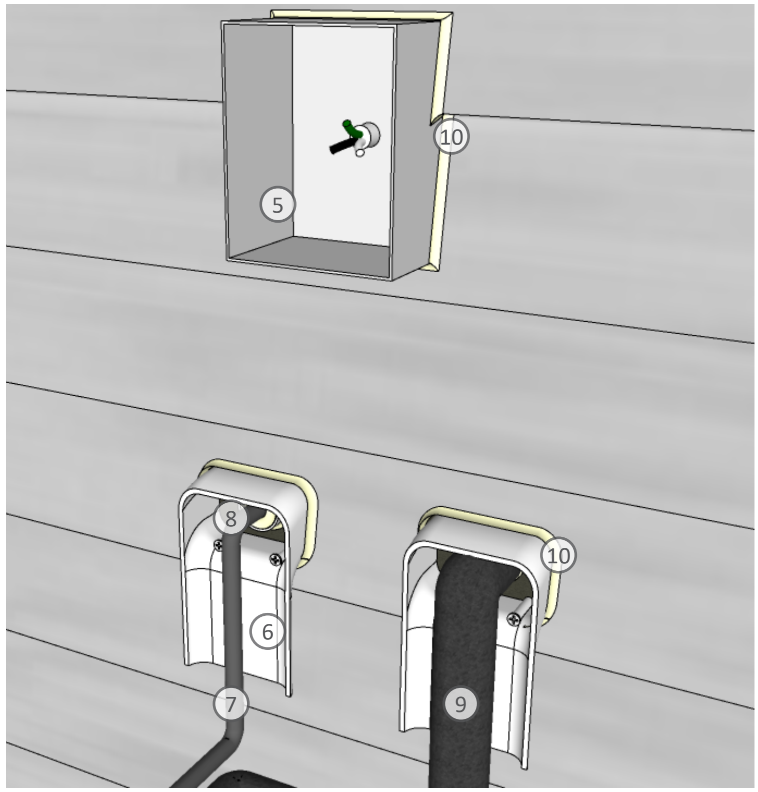
(Continued on next page)

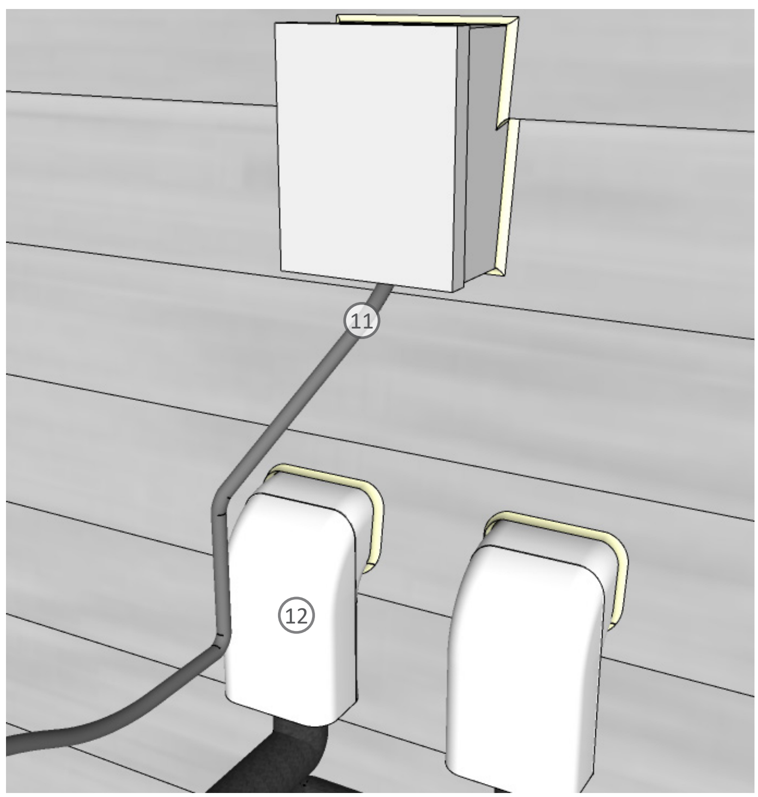
Retrofit Steps Continued:

5. Install 240 volt electrical box for housing power connection.
6. Install refrigerant line covers. Fasten them securely to the wall sheathing.
7. Install refrigerant line and secure it to line cover.
8. Install spray foam within pipe sheath. Ensure it is continuous for entire depth of pipe. Seal end with silicone sealant.
9. Install refrigerant line insulation appropriate for exterior environments.
10. Seal around electrical box and refrigerant line covers.
11. Connect heat pump to circuit and energize when ready to operate.
12. Install refrigerant line cover caps.

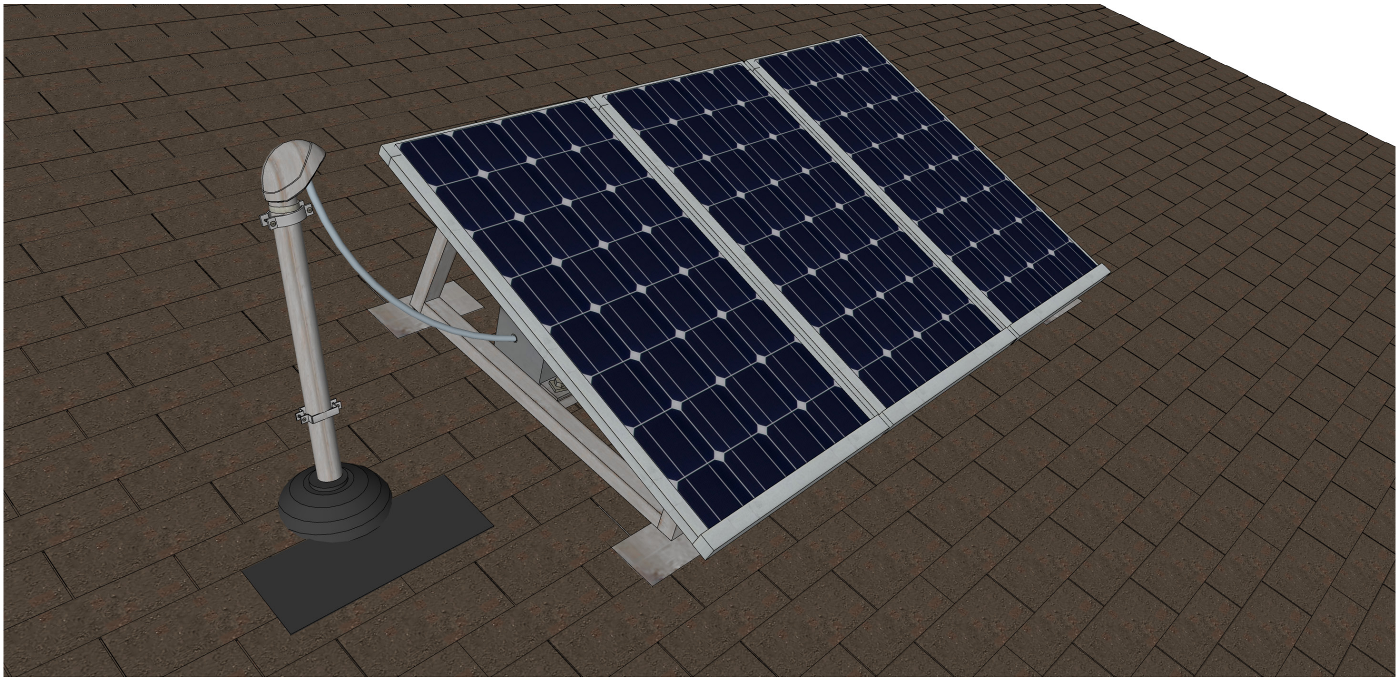
Key Considerations:

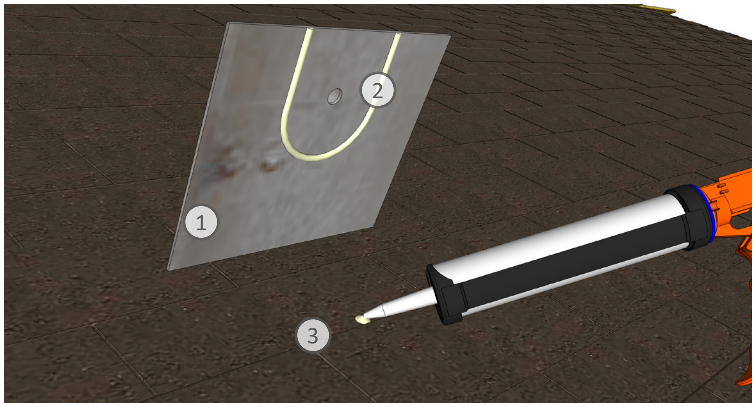
- Positions that get full sun in the winter are preferable.
- Ensure easy drainage of condensate. Watch for ice build up on adjacent walking surfaces. If possible, install the ASHP on taller footings with clearance to allow for a catch bucket (such as a plastic toboggan) that can be pulled out and dumped to remove the ice build-up.
- Protect from winter winds using vegetation, wind baffles, or the positioning relative to the home.
- Units should be located above the anticipated snow level and a taller pad may be required. Clear any snow that accumulates around the unit.

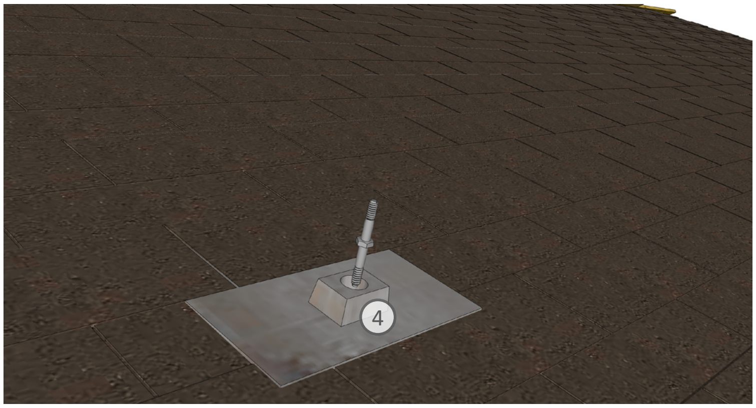




Detail 33 Photovoltaic Panel Installation







Retrofit Steps:

1. Layout proprietary roof anchor flashing for PV rack per the manufacturers requirements. Pre-drill holes for required fastener penetrations.
2. Add horseshoe bead of roof-compatible sealant to underside of flashing. Profile should encompass all roof penetrations.
3. Add roof-compatible sealant to penetration(s) before installing fastener(s).
4. Install roof anchor flashing as per manufacturers requirements.

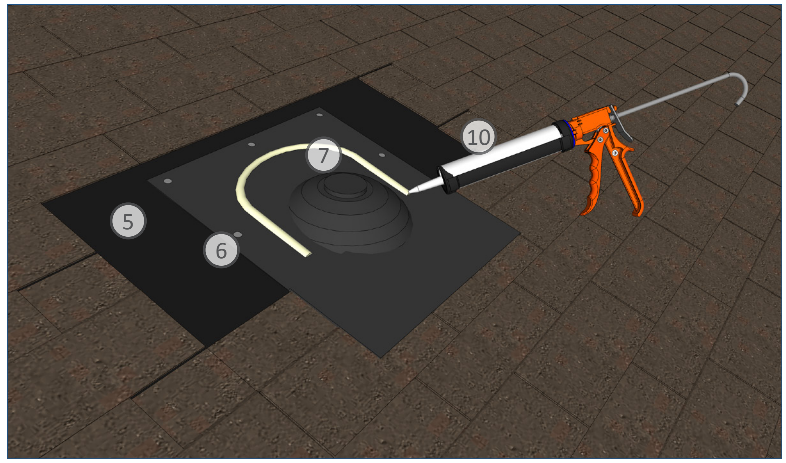
(Continued on next page)

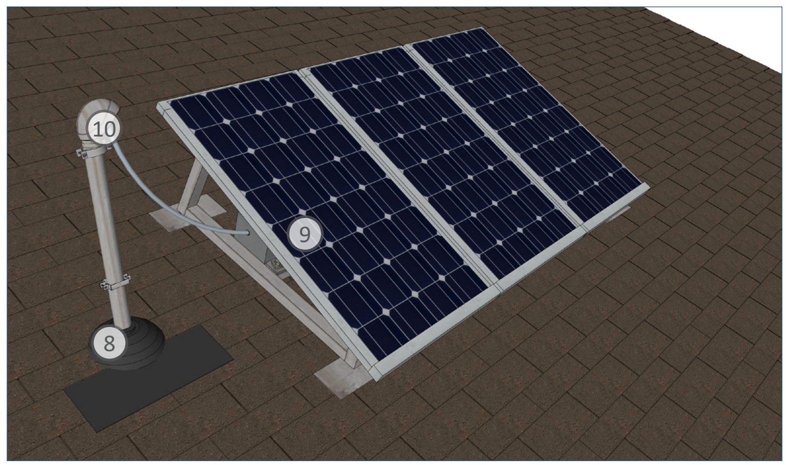
Retrofit Steps Continued:

5. Locally remove existing asphalt shingles to expose roofing underlayment. Leave a first course of shingles to shingle over with rubber boot. Be careful not to damage shingles that will stay in place.
6. Install fasteners as per manufacturer's requirements.
7. Add horseshoe of compatible sealant to secure shingles that will run over boot.
8. Cut boot to size and insert weather head as per manufacturer's requirements. Ensure head extends a minimum 3' above the finished roof surface.
9. Install PV frame and panels as per manufacture's requirements.
10. Feed conduit into weather head. Seal conduit within weather head/gooseneck and seal within the conduit, between the wiring and conduit.
11. Air seal penetration at ceiling plane per previously provided attic details.

Key Considerations:

- Ensure weather head is secured with blocking within the attic space. Additional guide wire support may be required depending on height of weather head above the roof surface.
- Existing shingles that have been pulled up require additional adhesive sealant to prevent uplift from wind.
- Snow Guards are recommended to protect other roofing penetrations, gutters, and walkways below.
- It is generally recommended to have a qualified installer complete the installation.





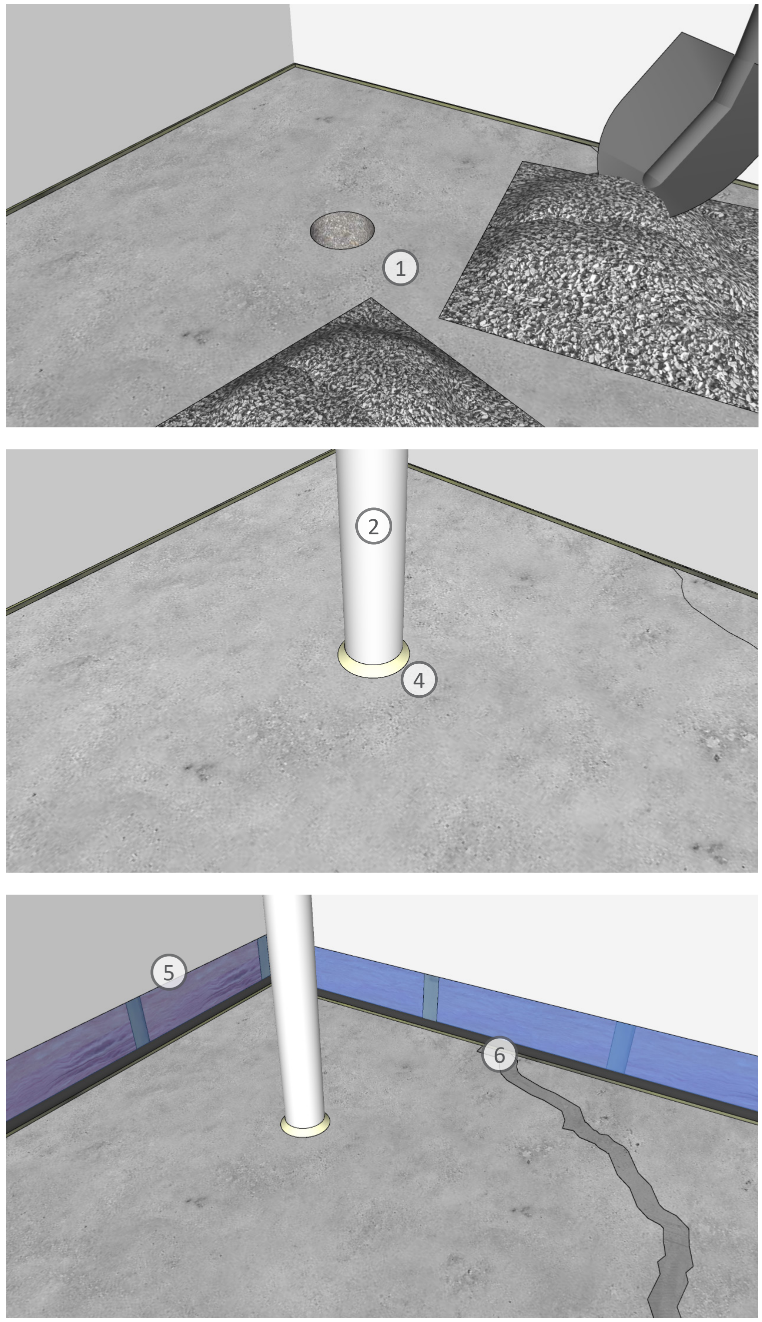
Detail 34 Radon Retrofit — Active Soil Depressurization

Retrofit Steps:

1. Cut 5" hole in concrete slab near exterior wall, at least 1' away from pressure-treated wood foundation. If there is no drainage gravel beneath slab, or it is contaminated with fine debris, remove as much existing under-slab fill as possible by hand and fill with washed 3/4" gravel.
2. Install 4" diameter PVC pipe into the hole.
3. Seal PVC pipe to the under-slab polyethylene with appropriate sealant (not shown).
4. Seal PVC to concrete slab using backer rod and appropriate sealant.
5. At base of PWF wall, remove roughly 6" of existing wall finishes (gypsum board). Install sealant continuously between slab and polyethylene sheet.
6. Seal between the slab edge and wall polyethylene sheet, seal cracks in the slab, and seal around all other slab penetrations. This can be done with spray polyethylene sealant, polyurethane sealant, or crack fill kits.

Key Considerations:

- Radon testing should be conducted prior to this retrofit to assess radon exposure in the home. Re-testing after completing the installation is recommended to ensure the mitigation effort was successful.
- An alternative to installing a PVC pipe into the slab is to seal and depressurize the basement sump pit or foundation drain tile. Consult a certified radon mitigation professional if this alternative is feasible.
- The radon vent should be labelled so that it is not confused with a plumbing vent. The vent pipe must be kept airtight to avoid accidental venting of radon into the home.



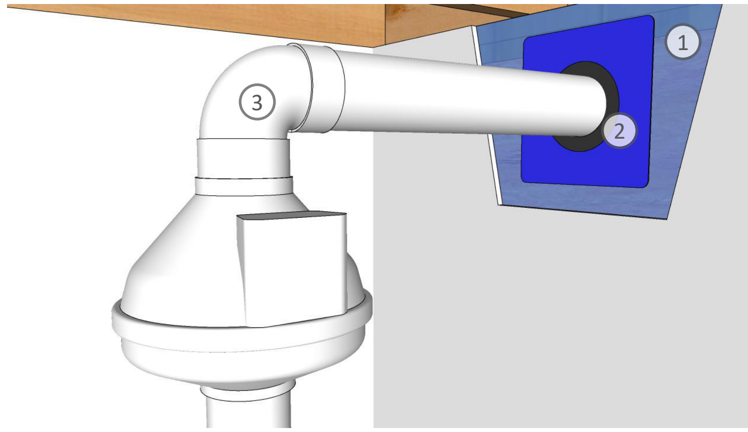
Detail 35 Radon Retrofit — Radon Vent

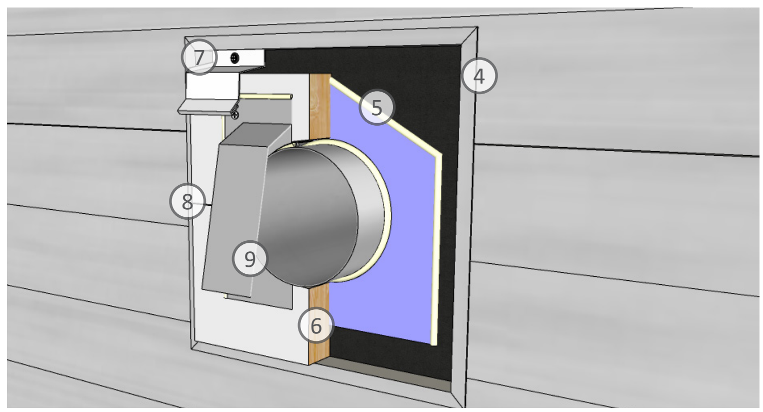
Retrofit Steps:

1. Remove interior finishes (gypsum board) to expose interior polyethylene sheet.
2. Cut hole in exterior wall using hole saw. Push PVC radon vent pipe through exterior wall, ensuring pipe is sloped to the exterior to allow drainage of any condensate. Seal PVC to polyethelyne using EPDM gasket to provide air sealing. Refer to Detail 31 for additional reference.
3. Connect vent pipe to radon fan, ensuring PVC pipe joints are well sealed with appropriate sealant.
4. Remove siding 10" x 10" around pipe vent.
5. Install self-adhered membrane (SAM) with a tapered leading edge to facilitate drainage. Seal the leading edge of SAM and between the vent and SAM with compatible sealant.
6. Install pressure treated blocking painted to match exterior cladding.
7. Install metal head flashing complete with end dams. Tuck flashing back leg behind J-trim and fasten to wall sheathing.
8. Seal between jamb J-channel trim and blocking. Leave sill and head unsealed.
9. Install vent hood and seal leading edge and sides.

Key Considerations:

- Radon testing should be conducted prior to this retrofit to assess radon exposure in the home. Re-testing after completing the installation is recommended to ensure the mitigation effort was successful.
- The radon vent should be labelled so that it is not confused with a plumbing vent. The vent pipe must be well sealed to avoid accidental venting of radon into the home.
- Radon vent penetration can be installed through rim joist to allow running radon vent through joist space. Interior penetration should be sealed with spray foam to ensure air barrier continuity.





9.0 Additional Resources

Energy Retrofit Considerations for Yukon

Ice Damming

Building Science Digest 135, Ice Dams, 2006. Building Science Corporation. Available online:
https://www.buildingscience.com/documents/digests/bsd-135-ice-dams

Soil Freezing and Frost Heave

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