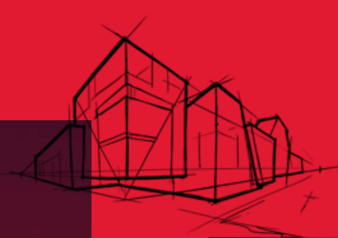
Commercial Retrofit Solutions Guide



Why retrofit?

Deep energy renovation of buildings is critical if cities want to tackle their climate emissions on a large scale. Energy renovation could provide up to 55% of the GHG emissions reductions needed to meet the 2030 targets and align cities with a 1.5°C trajectory.

Globally, existing buildings account for approximately 30% of final energy demand and CO_2 emissions
Typical renovation rates are 1-2% of the building stock per year, with an average energy use intensity (EUI) reduction of less than 15%. However, to reach sustainable development and climate targets, EUI reductions should be between 30-50%. To achieve this, energy codes require intensification of measures to strengthen energy reduction while not raising resultant emissions, policy development on energy retrofits need to deepen, and the adoption of high performance, Net Zero buildings needs to be accelerated. In addition, access to financing from government to project teams and investments in R&D to enhance building technologies and materials is required.

Throughout North America, model energy codes are evolving for higher energy efficiency. Local code adoption and policy development have also strengthened their position to increase energy reduction targets with the inclusion of building retrofit requirements. For example, in 2019 New York City passed the Climate Mobilization Act, housing a series of bills setting specific retrofit requirements and emissions limits (Bill 1253, Local Law 97 of 2019) and supplementary financing for sustainable retrofits (Bill 12520).

In addition to energy and emissions conservations, building retrofits improve occupant health and comfort. In many cases, existing buildings are poorly insulated and leaky, resulting in excess heat loss and reduced thermal comfort. Mechanical systems are oftentimes outdated and inefficient, requiring consistent maintenance. With spending most of our times indoors, improvement of indoor health and comfort can be a priceless attribute that can be a key driver for building renewal investment.

Retrofit Planning

Building retrofits come with their unique conditions and challenges, thus requiring a holistic and long-term planning approach to ensure overall goals and targets are achieved. Items for planning include auditing the existing conditions of the building, assessing potential energy conservation measures (ECM's) that will be applied, analysing cost and long-term capital requirements, and understanding the social and economic effects on the building occupants (current and future).

ECM's include passive strategies such as envelope improvements and active strategies such as mechanical systems upgrades. The ECMs applied to a retrofit project will vary and will be building and site dependent but will typically consist of both passive and active strategies used to complement each other to achieve a desired performance and indoor environmental condition. Cost for implementation and return on investment is often addressed by assessing the overall energy demand savings of the different ECMs. For these reasons it is important to consider the members of the project team and ensure an interdisciplinary approach during assessment.

Saving a kWh through stone wool insulation is much less carbon intensive than producing a kWh, even when using renewable energy.

The building envelope affects approximately 50% of the energy demand of typical buildings, therefore, implementing envelope related ECM's are an effective way to reduce energy demand and operational carbon emissions of a building. When deciding on enclosure specific ECMs, consideration for thermal efficiency, durability, structural capacity, and constructability, among others, is necessary. Therefore, understanding the unique challenges of different enclosure retrofit options is key to ensure appropriate solutions are applied.

Thermal Efficiency

Existing buildings will typically have little to no insulation within the envelope, resulting in excess heat loss and increased energy consumption. More importantly, they typically also have poorly installed or non-existent air barriers, making them very leaky and further increasing energy losses. The addition of insulation in exterior walls and roofs, in combination with an appropriate air barrier system, is integral to improve building performance, reduce leaks and create more comfortable indoor environments. When it comes to thermal efficiency of assemblies, the overall effective thermal performance of the system must be considered, not simply the nominal thermal resistance of the insulation layer. This means accounting for the thermal resistance of all applicable layers within the assembly, and calculating reductions caused by thermal bridges.

Durability

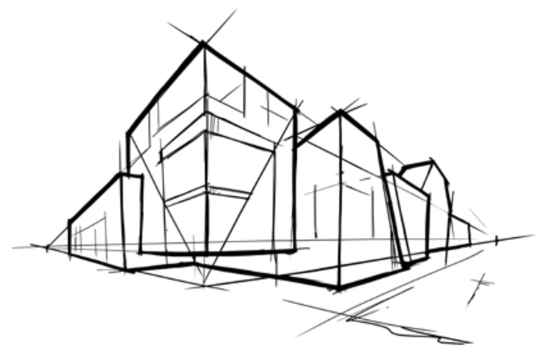
One of the critical benefits of retrofitting buildings is that we can increase their lifespan. The added longevity and durability of an enclosure and the energy savings they create are a way to justify the upfront costs. Considerations for an enclosure's durability include assessing the primary control layers, in particular, those related to water and moisture management. It is critical to ensure that appropriate drainage and drying measures, and vapor diffusion control considerations are in place, as poorly designed retrofits may lead to unintended moisture damage.

Constructability

The constructability of a retrofit relates to the ease at which the retrofit strategy is installed and executed. With that, it also encompasses the total cost of implementation and the amount of occupant disturbance. Therefore, upgrading the building enclosure can bring different constructability challenges, depending on the building site and existing condition and the strategies applied will vary and cannot necessarily be applied on all projects in the same manner.

Aesthetics

While very subjective, the aesthetics of a building is often the primary concern from an architectural, building owner and occupant desire. For existing buildings, the retrofit strategy may require the aesthetics of the façade to either be improved or left untouched. Depending on the scenario, materials will be selected accordingly. With that, versatility of the strategy is an important attribute.



Thermal Bridge Definition:

A thermal bridge is a localised area or component of the building enclosure with a higher thermal conductivity than the surrounding materials, creating a path for heat transfer. Thermal bridges result in an overall thermal resistance reduction leading to cold spots on the interior side of the assembly and risks of condensation within the enclosure. There are three types of thermal bridges: repeated, linear and point thermal bridges.

- Within the enclosure's structural component, you will often find a repeating thermal bridge. When performing an overall U-Value calculation, be sure to consider these thermal bridges—for example, wood studs and steel studs.
- A linear thermal bridge, expressed as a Psi Value (Ψ), is found along the length of the enclosure occurring mainly at component joints, edges and transitions within the building enclosure. For example, a window to wall connection or slab edge are considered linear thermal bridges. Linear thermal bridges are calculated separately using 2D thermal modelling software.
- A point thermal bridge uses Chi Value (X) for expression and occurs at isolated points within the enclosure—for example, insulation attachments and fasteners. Calculate the impacts of point thermal bridges separately using 3D thermal modeling software.

Exterior Insulation Retrofits

Thermal Efficiency

For exterior insulation systems, thermal reductions caused by the cladding attachment system are critical. There are numerous generic and proprietary cladding support systems designed for use with exterior insulation. The materials that make up these systems vary and can include galvanized steel, stainless steel, aluminum, fiberglass, and plastic. While each system is different, the approach often has continuous framing, intermittent clip and rail, direct fastening with screws, or other engineered systems. The thermal efficiency of the various methods is dependent on the material and spacing requirements.

For a full list of cladding attachment solutions, visit

rockwool.com/north-america/resources-and-tools/documentation

There are often structural capacity constraints for retrofit projects. Examples include how much the existing wall substrate can carry, and if cladding attachments need to span from floor to floor. In these cases, the cladding attachment is typically more robust, causing significant thermal bridging. When accounting for both linear and point thermal bridges, specialized detailing with more strong attachments may be necessary and require 2D or 3D thermal bridge calculations to assess thermal performance appropriately.

For optimal performance, windows should align with the exterior insulation. If upgrading windows is not part of the enclosure retrofit, or if it is impossible to move a window's placement, wrapping the frame and ledge with insulation can improve performance.

Durability

Working on the exterior side of the enclosure allows for new water control strategies to be applied, such as appropriate cladding and overhand design to ensure proper water deflection, and the inclusion of a water-resistant barrier to act as a drainage plane. The addition of exterior insulation also serves as a supplementary drainage plane for the enclosure, inherently limiting the moisture amount that passes through the insulation. Exterior insulation also improves the enclosure's temperature gradient, pushing the dew point temperature within the wall towards the outerboard side of the assembly. In turn, the new insulation strategy increases the interior surface temperatures and reduces the potential for vapor diffusion and air leakage-related interstitial condensation at critical layers of the assembly. However, the type of exterior insulation will play a role in the overall performance of this system. A vapor impermeable insulation may reduce the drying potential of the wall assembly, causing moisture-related concerns. In these cases, take extreme caution to add enough exterior insulation to avoid these problems. When using vapor permeable exterior insulation, increased drying potential, and outward drying is possible as the insulation will not trap moisture within the assembly.

Get in contact with our ROCKWOOL building science team for support on retrofit energy modeling.

rockwool.com/north-america/resources-and-tools/building-science-support/

Constructability

The constructability of the strategy will vary depending on the technology. For exterior insulation, standard attachment strategies such as continuous girts, or clip and rail systems, are usually the easiest to install. They don't require new training for contractors, and there is a perceived lower risk of failure. More modern attachment strategies, such as thermally broken clip systems or direct fastening, while gaining traction, may require additional analysis and contractor training. Other site considerations are also necessary. For example, in densely populated areas, an exterior retrofit may bring more execution challenges than a building located in a less dense area, due to the proximity to other facilities, access to the site, and the potential for increased pedestrian disturbance and safety measures.

Rainscreen Overcladding System using ROCKWOOL Stone Wool

Exterior insulation retrofit using ROCKWOOL Cavityrock® or Comfortboard® in combination with a ventilated cladding.

A rainscreen overcladding system using stone wool insulation can use various substrates, providing versatility and design freedom for architects and designers. Depending on the cladding type and weight, the overall desired insulation performance, and thickness, they can be accommodated with either thermally broken intermittent clip and girt systems or directly fastened through the stone wool insulation.

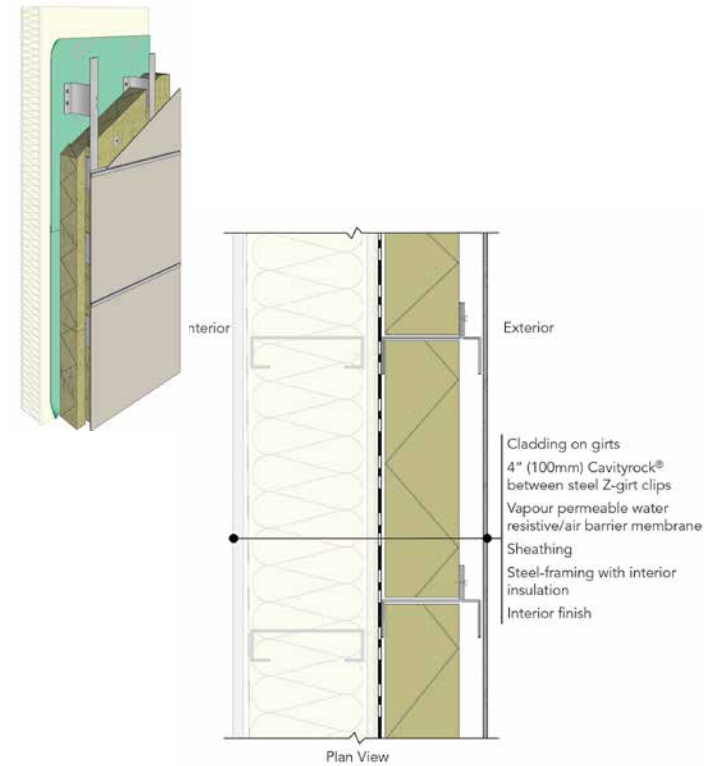


Figure 1: ROCKWOOL Cavityrock between a Z-girt clip system, installed over an existing steel stud wall

For more information on ROCKWOOL Cavityrock, visit rockwool.com/north-america/products-and-applications/products/cavityrock/

Clip and girt systems can use ROCKWOOL Cavityrock, a semi-rigid, non-combustible board. This combination can easily accommodate a single insulation layer up to 6" (152 mm) of insulation with a nominal R-value of R4.3 per inch (RSI 0.76 per 25.4 mm). For assemblies that require higher thermal performance, Cavityrock insulation boards can be layered to achieve the desired performance. A clip and girt system using Cavityrock is ideal for most cladding types, including metal panels and terracotta. Overall, the substrate's load-bearing capacity and the cladding weight will dictate the cladding attachment spacing, with heavy-weight claddings often requiring more connections for support.

If the clear wall cannot hold the additional weight and cladding attachments must span from floor to floor, a clip and girt system may be more effective and more manageable from a constructability standpoint. These cases will often require 2D or 3D thermal bridge calculations to assess the thermal performance appropriately.

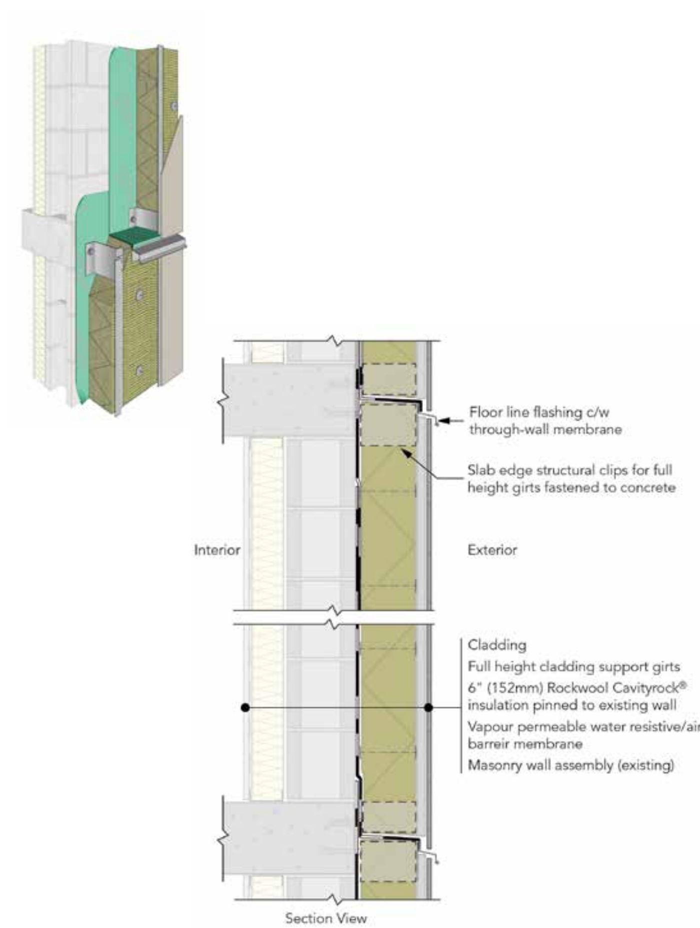


Figure 2: ROCKWOOL Cavityrock between a Z-girt clip system, installed over an existing CMU structure, attached through the concrete slab

Overcladding solutions using stone wool insulation provide versatility in design and cladding options along with additional fire resistance. Non-combustible stone wool insulation has a flame spread index and smoke development index of 0. It does not trigger assembly testing, such as NFPA 285, even near other buildings, such as in dense metropolitan markets.

Construct direct-fastened systems with ROCKWOOL Comfortboard 80 and Comfortboard 110, rigid continuous insulation boards-install up to 3" (76 mm) of insulation in a single layer system with a nominal R-value of R4.2 per inch (RSI 0.74 per 25.4 mm) for Comfortboard 80 and R4.0 per inch (RSI 0.70 per 25.4 mm) for Comfortboard 110.

The long screw fastener approach is thermally efficient. It can accommodate most substrates and different cladding types and is ideal for light- to medium-weight claddings less than 5 to 15 lbs/ft2 (49-73 kg/m2), such as metal and fiber cement panels. The fasteners' thermal losses range between 5-10 percent depending on the type and their spacing, with heavier cladding requiring a tighter tributary area per fastener and a higher number of fasteners.

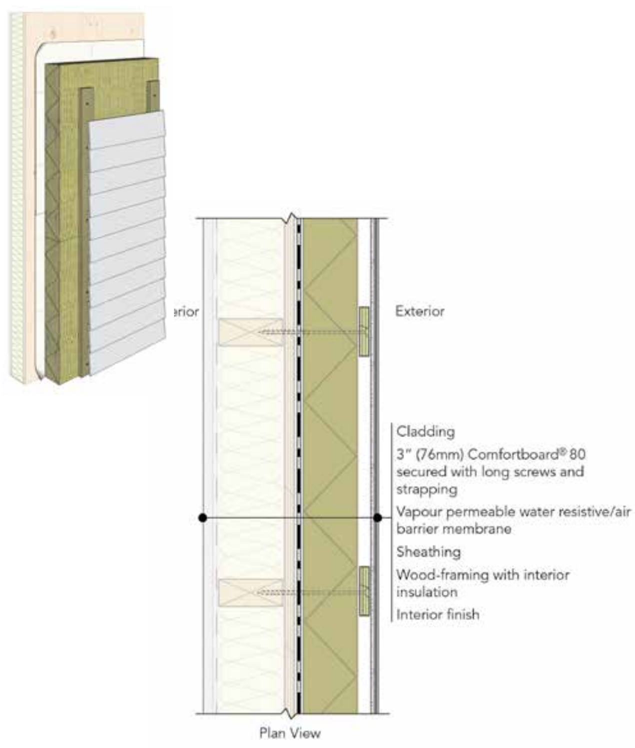


Figure 3: ROCKWOOL Comfortboard fastened to an existing wood framed wall

Figure 4: ROCKWOOL Comfortboard installed around a window over an existing wood frame wall. 1" thick plywood extension buck is installed to align window with exterior insulation

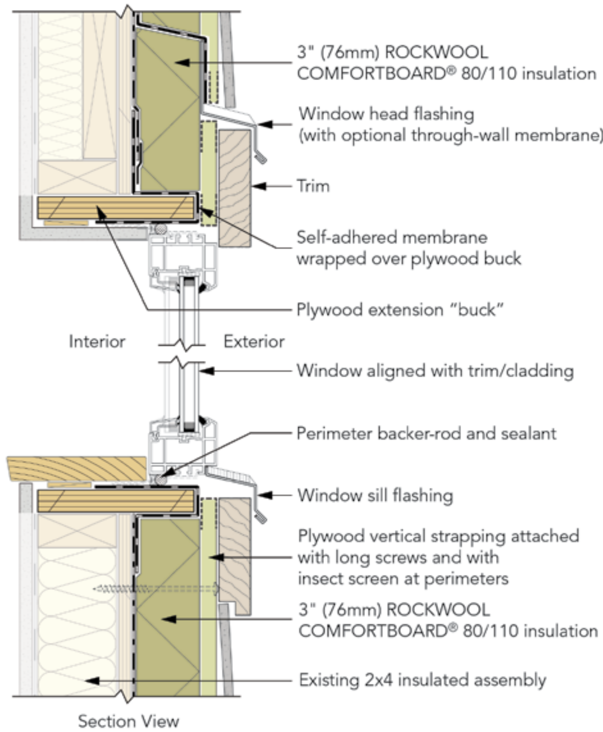
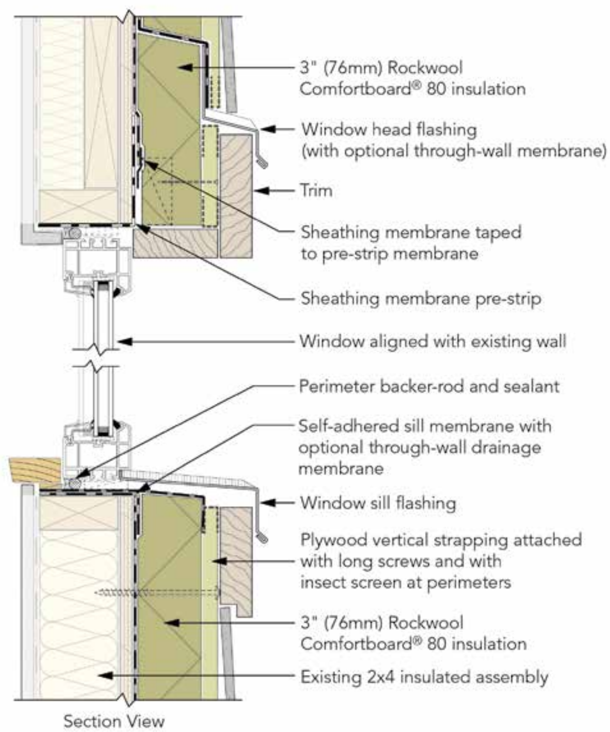


Figure 5: ROCKWOOL Comfortboard installed around a window over an existing wood frame wall. Window is aligned with the existing wall



To see our Structural Testing of Screws through Thick Exterior Insulation technical guide, visit rockwool.com/north-america/resources-and-tools/documentation

ROCKWOOL Stone Wool Insulation for EIFS

ROCKWOOL Frontrock™ is a semi-rigid stone wool board for mechanically fastened, non-combustible exterior insulation finish systems.

Suitable as an overcladding solution in retrofit applications, mechanically fastened stone wool in exterior insulation finishing systems (EIFS) allows for up to 6" of insulation in a single-layer system, with an overall nominal thermal resistance value of R-24 (RSI-4.23) and limited thermal bridging. The spacing of mechanical fasteners is dependent on system holder specifications. Stone wool insulation is dimensionally stable and is not subject to expansion and contraction, critical to ensure long-term thermal efficiency,system durability, and aesthetics of the EIFS system.

To allow for appropriate drainage, EIFS incorporates a small drainage gap behind the insulation, created by adding adhesive ribbons or a geometrically defined drainage cavity (GDDC) on the back of the insulation board, depending on the system provider. The vapor permeability of stone wool insulation also enhances drainage properties and allows for increased drying potential.

EIFS offers a range of finish render options allowing for design flexibility and aesthetics.

The substrate of an existing building is not always flat, which may create challenges in ensuring the insulation can be installed flush to the substrate. The dual-density characteristic of ROCKWOOL Frontrock insulation boards allows the installer to leverage the softer backside of the boards to level the exterior surface, in order to install the finish render appropriately. Meanwhile, the higher density outerside provides a robust exterior for fastening and helps reduce base coat consumption during installation.

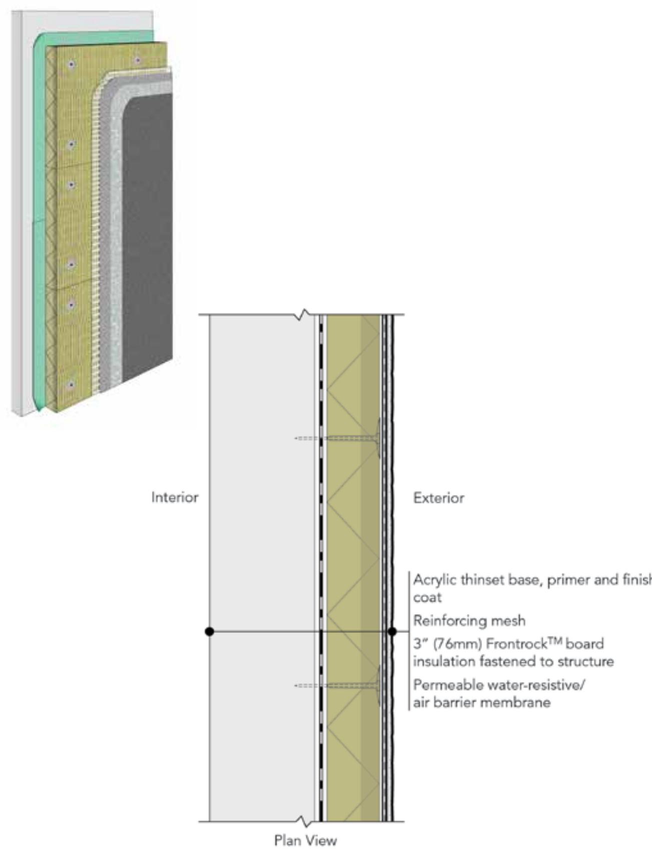


Figure 6: ROCKWOOL Frontrock installed as part of an EIFS system over the existing structure, attached using adhesive ribbons for use as a drainage gap, and additional mechanical fasteners

Visit rockwool.com/products/frontrock for more information

Project Highlight:

Ken Soble Tower Project
500 MacNabb Street
Hamilton, ON

The Ken Soble Tower project sought to rehabilitate a post-war apartment building in Hamilton, Ontario. The building was completely upgraded, inside and out, to achieve Passive House standard. The building overhaul would include nearly every facet of the building from the building envelope, mechanical systems, electrical, plumbing, and safety systems to interior upgrades to its 146 units to support aging in place, accessibility, comfort, and overall improvement of the occupant experience.

The cladding design includes a six-inch thick stone wool EIFS system. Architects chose this EIFS system due to the non-combustibility (important given the vulnerability of the senior-aged occupants), the excellent moisture control offered by both the stone wool and the unique, built-in drainage layer cut into the back side of the insulation, as well as the liquid applied water resistive barrier used in the EIFS system.

In all, 50,000 sq. ft. of ROCKWOOL stone wool insulation was incorporated into the new façade, helping to realize the R-38 effective R-value required to achieve EnerPHIT Passive house certification, while reducing greenhouse gas emissions by an impressive 94%.

Interior Insulation Retrofits

Thermal efficiency
The potential for thermal bridging increases when choosing to use an interior insulated retrofit strategy rather than insulating on the exterior. Interior insulation strategies can either include direct-fastening insulation, adding insulation between wood or steel studs, or a combination. However, this strategy does not mitigate large thermal bridges such as floor slabs, and often increases the thermal bridge. To account for these large thermal bridges, consider floor and roof insulation around the walls' perimeter, although these are not as effective as an exterior insulation solution. When working on the enclosure's interior side, ensuring continuity of the materials and their transitions is more complex, requiring attention to assembly detailing.

Durability
Interior retrofits are often a solution for buildings with limited lot lines or where the exterior aesthetic requires preservation for historical reasoning or client requests. However, an interior retrofit comes with additional performance and durability considerations due to the insulation's location and the potential for interstitial condensation. In these cases, airtightness is crucial to reducing the transfer of moist air through the assembly. Even with an interior retrofit strategy, exterior work still may be required; for example, ensuri there are appropriate overhangs and drip edges to limit water exposure, fixing the existing cladding if applicable, or updating windows and doors.

Constructability
Typically, an interior retrofit can be considered a more straightforward installation than exterior retrofits. The additional insulation weight is carried by the internal floor structure and held in place with non-structural elements, making structural considerations and lightening external safety requirements. However, interior retrofits will have a level of occupant disturbance. If residents live in the building, there may be associated costs to ensure their health and safety.

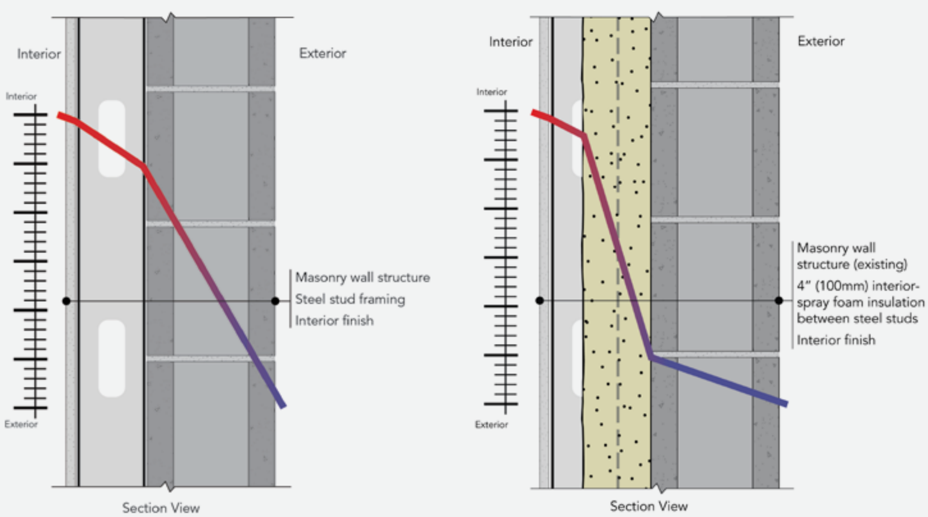


Figure 7: Temperature gradients of a masonry wall with interior steel studs

Figure 7 shows the temperature gradient through a non-insulated wall (left), and a retrofitted wall with interior insulation (right). The addition of insulation on the interior side of the existing masonry wall has for effect to reduce the temperature of the interior surface of the masonry during the cold months of the year. If it decreases below the dew point, there is a risk for condensation to occur within the wall. In order to control the risk for air leakage condensation or condensation due to vapor diffusion, water vapor impermeable and air impermeable insulation such as close-cell spray foam can be used to block any inward or outward moisture movements.

Masonry Wall Interior Insulation Retrofits Using ROCKWOOL Stone Wool Insulation

Applicable products include Cavityrock, Comfortboard 80 and Comfortbatt

Existing masonry buildings are often a target for interior retrofits due to façade preservation requirements. Historically, masonry walls vary in thickness, consisting of multiple wythes (layers) of brick that range in quality—the exterior wythes will be of higher quality than the interior wythes. Masonry walls are heavy and porous, allowing them to store moisture. Because older masonry walls often do not have insulation, the wall's energy transfer makes them dry inefficiently. Therefore, adding interior insulation will change the wall assembly's temperature gradient, which can be detrimental in winter conditions. For example, internal insulation layers will create a sizeable temperature drop, cooling the brick and potentially causing freeze-thaw damage. Also, masonry walls often do not have a dedicated air barrier system and can be very leaky. Therefore, airtightness is vital for the retrofit design, especially since interior air leakage can condense on the cold brick and cause potential moisture concerns and mold on the newly created interior finishes. Similar conditions apply to other mass-type walls such as pre-cast concrete, tilt-up, or concrete masonry unit (CMU) where there is no existing insulation.

Use ROCKWOOL Cavityrock for a continuous interior layer of insulation up to 6" (150 mm) with a nominal R-value of 4.3 per inch (RSI 0.76 per 25.4 mm). The dual-density characteristic of Cavityrock (available in greater than 2.5" thicknesses) provides a soft backside enabling an easier install against uneven surfaces and a higher-density exterior surface for a more robust exterior finish. The insulation can be installed using an attachment system or held in place using mechanically fastened impaling pins. The assembly is typically finished with a thin stud frame adjacent to the insulation to aid as a service cavity and substrate for the interior wall finish.

Alternatively, install a continuous layer of ROCKWOOL Comfortboard 80 rigid stone wool insulation. Comfortboard 80 is available in a single layer up to 3" (76 mm) with a nominal R-value of R4.2 per inch (RSI 0.74 per 25.4 mm). This strategy enables direct fastening into the substrate through furring strips/hat channel or install using impaling pins and a stud frame wall to help keep the insulation in place and flush with the existing exterior wall.

When retrofitting mass walls on the interior with stone wool insulation, use in combination with a capillary break between the masonry and insulation, in addition to an interior smart vapor retarder. Create a capillary break using a vapor permeable, liquid-applied, water-resistive barrier, or a gap up to 10 mm between the insulation and the substrate. For interior vapor control, a smart membrane is best. A smart vapor retarder is a membrane that transitions in vapor permeability depending on the surrounding relative humidity. In this case, it will assist with inward drying when necessary. For airtightness, the water-resistive barrier (WRB) or interior membrane, taped and sealed, can serve as the primary and secondary air barrier system critical to ensure airtightness requirements to limit moisture-related risks.

Challenges with the constructability of interior insulation systems on masonry walls are often design related. The enclosure is usually required to be thinner, to not take up more than necessary interior space. It may require the ability to be easily disassembled without damages to the existing substrate.

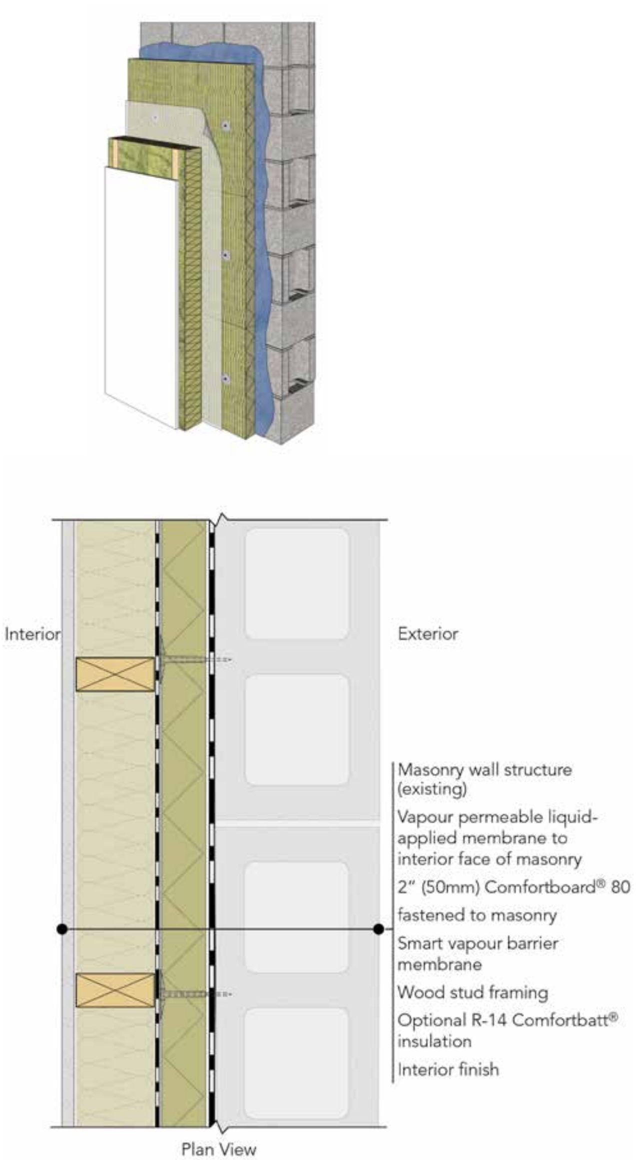


Figure 9: ROCKWOOL Comfortboard installed on the interior of an existing CMU construction, with optional batt insulation installed between a wood frame

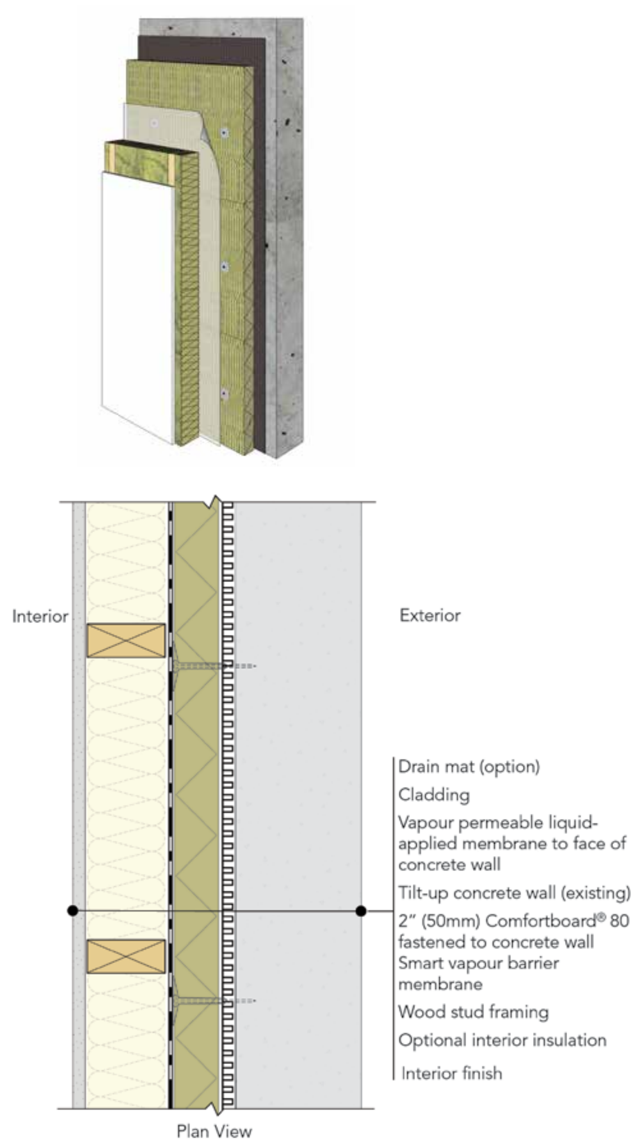


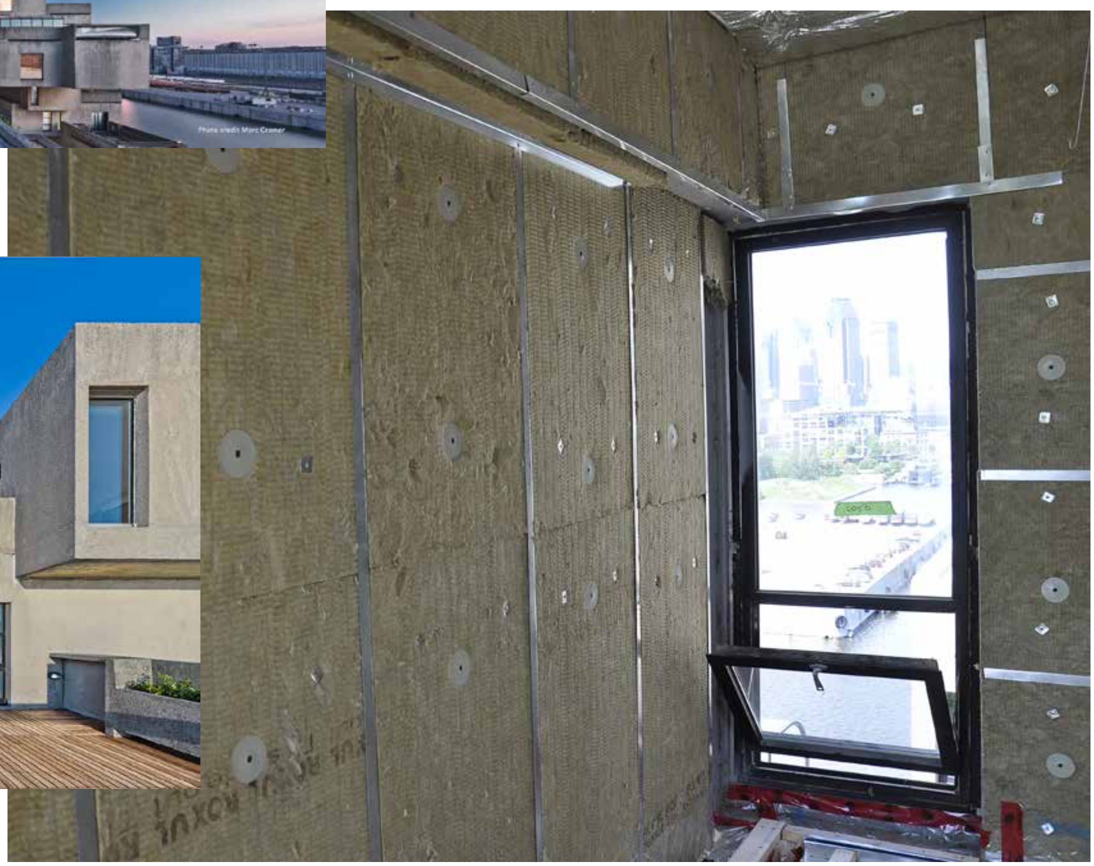
Figure 8: ROCKWOOL Comfortboard installed on the interior of an existing concrete tilt-up construction, with optional batt insulation installed between a wood frame

For more information on ROCKWOOL exterior wall products, visit

rockwool.com/north-america/products-and-applications/external-wall-insulation/

Project Highlight:

Iconic heritage building, Habitat 67, necessitates creative restoration solutions



Perched on the banks of Montreal's riverfront, Habitat 67 is a historical landmark, a building commissioned as part of Canada's Expo 67 centennial celebrations. The goal of the renovation was to increase its energy efficiency while respecting the building's heritage designation. ROCKWOOL insulation was installed on the interior of the structure as a continuous layer, providing improved comfort, energy efficiency, safety and durability. Residents will benefit from more stable and homogenous indoor temperatures, as well as passive fire protection due to the buildings non-combustible stone wool insulation, all while maintaining the historic landmark aesthetic.

For the full case study, visit
rockwool.com/north-america/advice-and-inspiration/case-studies/habitat-67/

Flat Roof System Retrofits

Thermal efficiency

Most existing buildings that are ready for a roof retrofit have insulation levels below current energy standards. Although increasing the thermal performance to current standards may not be necessary when conducting roof renovations, it can be critical for energy savings. Depending on the retrofit strategy, this may be achieved by adding a few additional inches of insulation over the existing roof, or it may require a full re-roof (tear-off). From a thermal efficiency standpoint, different roofing systems will encounter other thermal effects depending on the application, type of insulation, temperature exposures, number of fasteners, and material properties. Insulation boards used in roofing applications are fastened into place using screws with varying densities and lengths, causing thermal bridging. Roof systems are subject to higher and larger temperature fluctuations, meaning their membranes and insulation materials are subject to expansion. For example, foam plastics are at more significant risk to thermal deficiencies caused by gaps and holes caused by thermal expansion and contraction, along with their in-situ climate-dependent thermal performance.

For more information on the affect of temperature on insulation, visit www.rockwool.com/north-america/resources-and-tools documentation for a complete collection of ROCKWOOL research studies

In some cases, insulations like polyisocyanurate will be susceptible to lower thermal performance at cold temperatures, affecting overall performance, especially in cold climates. To reduce the effects of expansion and contraction, double layers with offset seams are necessary. A design solution to limit the impact of climate-dependent thermal performance includes using a dimensionally stable insulation board (such as stone wool) as the second insulation layer or as the system coverboard.

Durability

From a durability perspective, the primary goal of a roof retrofit is typically water management and improvement in drainage. When energy is the driver for the retrofit, adding insulation to increase thermal performance will ensure durability. The retrofit strategy applied will be dependent on the existing conditions of the roof and the desired performance. Methods include installing crickets and tapered insulation for improved drainage, roof remediation, and adding insulation or a full tear-off and re-roof. The appropriate retrofit solution is dependent on the age of the building, drainage, and condition of the existing roof membrane.

In roof remediation, the existing roof insulation is often in good condition, but the roof membrane may be damaged, or there may still be a need for improved drainage. And even though the condition of the insulation may be good, it’s likely there isn’t enough. This is an excellent opportunity to enhance the roof's thermal performance. The remediation process commonly includes corrective treatment of roof penetrations and other failure conditions, the addition of a new drainage pattern, and a new membrane. The existing roof membrane is usually cut at the seams and around parapets and penetrations to avoid tearing, and the new membrane is then re-sealed. When adding insulation, the new layer should be installed over the existing membrane to serve as a coverboard(also referred to as a divorce layer)and the substrate for a new roof membrane and drainage if applicable.

A full re-roof involves removing all the existing roofing components and replacing them with a new roof assembly starting from the roof deck up. In this situation, the new roof assembly would need to meet current energy code requirements.

Constructability

In the case of recovery or full re-roof, consider the existing roof's parapet heights to ensure there is enough space to add the desired thickness of insulation. Installing crickets to modify drainage is a simple solution, mainly when the parapets' roof edge is low and does not allow for increased depths. Most Importantly, the roof's structural capacity requires engineering evaluation to ensure it can handle the weight of the new or added layers and confirm the existing deck is compliant with structural requirements, determined by a pull-through test.

Flat Roof Retrofits Using Stone Wool Insulation

Applicable products include ROCKWOOL Toprock® DD, Toprock® DD Plus and Multifix™

Retrofitting with stone wool rigid insulation provides added moisture management, drying capacity, and superior fire and acoustics performance. ROCKWOOL Toprock DD, ROCKWOOL Toprock DD Plus, and ROCKWOOL Multifix roof insulation starts at 2" thick and increases to 6" in ½" increments with a nominal R-value of R-3.8 per inch (RSI 0.67 per inch). Toprock DD is un-coated, while Toprock DD Plus has a bitumen coating for modified bitumen roofs. Multifix has an embedded glass facer compatible with multiple attachment methods, including torched hot-mopped, self-adhered, cold-adhered, and liquid systems. Fabricated stone wool products (crickets and tapers) are available via a third-party.

Roof Remediation

For roof remediation systems incorporating additional insulation, choices will vary depending on the new membrane type. Adding stone wool insulation in a recovery system helps improve the roof's overall durability and thermal efficiency if the existing insulation (typically polyisocyanurate) is in poor condition and gaps are evident. Placing a 2" (52 mm) layer of rigid stone wool insulation with a total added R-value of R-7.6 (RSI 1.34) is a cost-effective measure to improve thermal performance, fire safety, and sound attenuation.

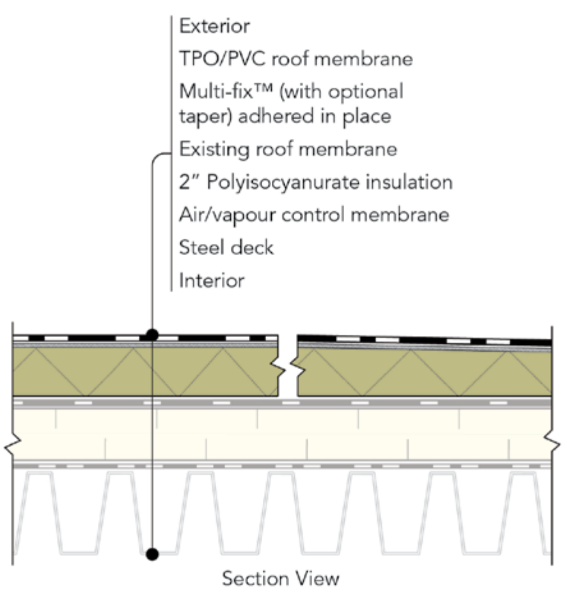


Figure 10: ROCKWOOL Multifix installed on top of an existing roof structure, using a TPO/PVC roof membrane

for more information on ROCKWOOL roofing products, visit https://www.rockwool.com/north-america/products-and-applications/roof-insulation/

Full Re-roof System

In a full re-roof application, the new insulation system can be either full-depth stone wool or a hybrid roof design, incorporating a layer of stone wool insulation over a base layer of polyisocyanurate insulation. This solution also enables compliance with updated wind load and fire testing requirements. Full re-roofing is optimal for buildings with a high roof-to-wall ratio where most of the heat loss occurs through the top, and there is a favorable cost-benefit.

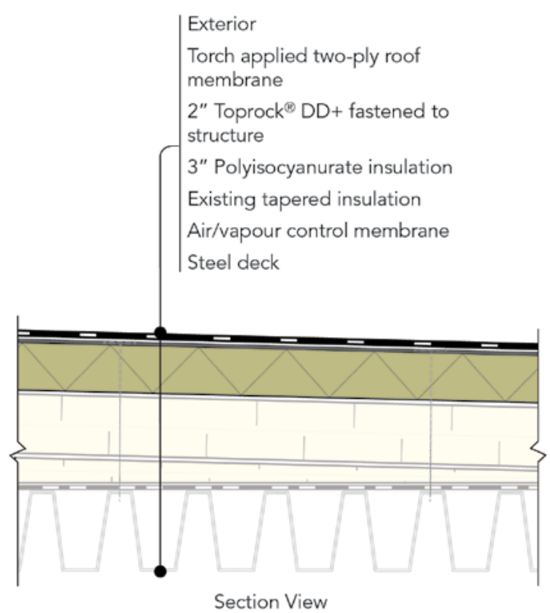


Figure 11: ROCKWOOL Toprock DD Plus installed on top of an existing roof structure, using a torch applied roof membrane

At the ROCKWOOL Group, we are committed to enriching the lives of everyone who comes into contact with our solutions. Our expertise is perfectly suited to tackle many of today's biggest sustainability and development challenges, from energy consumption and noise pollution to fire resilience, water scarcity and flooding. Our range of products reflects the diversity of the world's needs, while supporting our stakeholders in reducing their own carbon footprint.

Stone wool is a versatile material and forms the basis of all our businesses. With more than 11,000 employees in 39 countries, we are the world leader in stone wool solutions, from building insulation to acoustic ceilings, external cladding systems to horticultural solutions, engineered fibres for industrial use to insulation for the process industry and marine and offshore.

Publication date -edition: 03/2021

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