# UNDERSTANDING INSULATION

## Considerations for PERSIST Assemblies

Alberta Infrastructure

DESIGN & TECHNOLOGY SERIES **06**

Modern insulation offers a wide range of material, budget, and performance options. From fossil-fuel derived foamed plastics, recycled glass, slag and newspaper, to agriculturally-sourced wool and cotton, choosing the best insulation for an application is more complex than merely selecting the product with the highest RSI value. *Design & Technology Series 06* compares the performance, health, and environmental characteristics of the three most commonly used options for Pressure Equalized Rainscreen Insulated Structure Technique (PERSIST) assemblies: extruded polystyrene (XPS), polyisocyanurate (polyiso), and mineral wool. *RSI* measures thermal resistance and is the metric equivalent to *R-value*; to convert to R-value, multiply the RSI by 5.68.

PERSIST assemblies locate insulation outside the air/vapour barrier and structural system in order to reduce thermal bridging and air/moisture movement through the building envelope. Reduction of thermal bridging is critical to insulation performance. Consider two similar steel stud walls with continuous exterior insulation rated at RSI 4.4. If Wall 1 is built with vertical z-girts fastened to conductive steel studs, thermal bridging will reduce the effective RSI to approximately RSI 2.1. Replacing the z-girts with intermittent clips at 915mm apart will increase the effective RSI of Wall 2 to approximately RSI 3.7[1].

The RSI values of XPS (RSI 0.88/inch), polyiso (RSI 0.88/inch*), and mineral wool (RSI 0.7/inch) are all very similar. Assuming that air leakage and thermal bridging are properly addressed in the envelope design, the choice of insulation may be a simple matter of cost if based solely on thermal performance. Considered from the additional perspectives of environmental impact and human health, the options become more distinct.

The environmental and human health impacts of insulation production are closely related. The foamed plastics XPS and polyiso are created from the combination of petroleum-based raw materials, blowing agents that create the cells within the foam and provide the insulating gas within, and flame retardants that protect the materials from combustion.

In XPS production, ethylene and benzene are combined to form ethylbenzene, which is dehydrogenated to form styrene, then polymerized to form polystyrene. The constituent, process, and byproduct chemicals of these reactions are toxic: benzene and ethylbenzene are known human carcinogens, styrene is a possible carcinogen, endocrine disruptor and hazardous air pollutant, and toluene is a developmental toxin. The flame retardant hexabromocyclododecane (HBCD) is commonly used in XPS insulation. Research has found that HBCD is a bioaccumulative toxin in humans, animals and the environment, and when exposed to fire, the resultant smoke is more toxic than that of untreated materials. HBCD use will be banned in Canada on January 1, 2017; it is unclear how the replacement chemicals will perform.[2]

Polyiso is produced by combining polyol and isocyanate, a blowing agent, and a flame retardant, typically TCPP. TCPP is chlorine and phosphorus based and believed to be less hazardous than the brominated flame retardants used in XPS. Isocyanate is highly toxic and requires strict safety standards for manufacturing, however the finished product is stable, with carbon monoxide and carbon dioxide being the primary off-gases[3].

Mineral wool is a fibrous insulation made from rock or recycled iron ore slag. It does not require blowing agents and is non-combustible (flame retardants are not needed, but sometimes added). The urea formaldehyde used to bind the fibres together largely dissipates during manufacturing. The International Living Future Institute has issued an exception to permit mineral wool in Living Building Challenge projects when installed

Chris the Sheep, Guinness Record Holder for Most Wool Sheared from a Sheep in a Single Shearing: 41.1kg
Photo credit: BBC.com

**Insulation Options for PERSIST Assemblies**

- **Extruded Polystyrene (XPS):** closed-cell petroleum-based foam. Thermoplastic (melts when heated). The brominated flame retardant HBCD used in XPS will be banned in Canada as of January 1, 2017[5]; polymeric flame retardant (PFR) has been identified as a replacement[2]. Excellent moisture resistance, with a good insulating value of RSI 0.88/inch.
- **Polyisocyanurate (Polyiso):** closed-cell petroleum-based foam. Thermoset (does not melt when heated); treated with chlorinated flame retardants. Typically faced with foil to reduce air and gas migration in and out of the foam. Absorbs moisture; below-grade application is not recommended. Use RSI 0.88/inch for cold climates (*see sidebar on following page).
- **Mineral Wool:** fibre-based batt or rigid boardstock spun from molten iron ore slag or natural rock. High recycled content 70-90%, RSI 0.7/inch, retains insulating qualities even when wet. Does not require flame retardants or blowing agents. Hydrophobic and vapour permeable; stable insulating value in all temperatures.

Photo Credit: BuildingGreen Inc.

**In-Service Insulation Performance**

The insulating value of new insulation is typically higher than that of aged material. To provide a more accurate indication of actual performance, the RSI is calculated using artifically aged samples. It is important to note that the overall insulating value of an assembly is dependant on the complete system. The RSI values of other materials, air leakage, and especially thermal bridging must be accounted for and addressed in the design. Energy modeling provides the most accurate means of estimating the performance of an assembly.

*Recent investigations have discovered that polyiso uniquely undergoes a loss of RSI in cold temperatures such as those common in Alberta. Generally accepted to have an RSI of 1.06/inch, polyiso should actually be considered to have an in-service RSI of 0.88/inch in cold climates[9]. This is due to the condensation of the insulating gas within the material at low temperatures. It is recommended that cold-stable insulation be used over polyiso to maintain its RSI 0.88/inch performance, or that the overall thickness of the insulation be increased to account for the loss in RSI value in cold conditions[10].

on the exterior of a building (e.g. PERSIST assemblies), as mineral wool poses less risk to human health and the ecosystem than foam-based alternatives[4].

Since 2010 all new insulation must be produced with zero Ozone Depletion Potential (ODP), yet damage due to the Global Warming Potential (GWP) of various insulation materials remains an issue. Although the ODP concerns have been addressed, some blowing agents now have worse GWP than the gases they replaced. For example, current third generation polyiso has a GWP of 7 while XPS has a GWP of 1430.

The table below[7] compares the energy and environmental impacts of XPS, polyiso, and mineral wool insulation. Polyiso has high embodied energy and carbon, but the lowest GWP. Mineral wool has the lowest RSI but also the lowest embodied energy and carbon, and it is free of blowing agents. XPS has the highest embodied energy, and the highest GWP due to the HFC blowing agent it contains.

| **Insulation Material** | **RSI/Inch (R/Inch)** | **Embodied Energy** MJ/kg | **Embodied Carbon** kgCO$^2$/kg | **Blowing Agent** | **Lifetime GWP/ m$^2$*RSI** |
|---|---|---|---|---|---|
| **XPS** | RSI 0.88 R-5 | 89 | 2.5 | HFC-134a GWP=1,430 | 3.350 |
| **Polyiso** | RSI 1.06* R-6* | 72 | 3.0 | Pentane GWP=7 | 0.060 |
| **Mineral Wool** | RSI 0.70 R-4 | 17 | 1.2 | None | 0.086 |

XPS, polyiso, and mineral wool each have unique and beneficial properties, however it is important to understand their health and environmental characteristics as well. When choosing insulation, consider low-impact, inert materials from abundant or recycled sources, and select insulation which best suits the application it will be used for (e.g. XPS works well in below-grade applications, while polyiso does not). The International Living Future Institute has developed a *Red List* of over 700 chemicals and compounds proven to be harmful to both the environment and humans. An updated list can be found at *http://living-future.org/redlist*.

Minimum effective RSI-values must comply with the National Energy Code for Buildings 2011. Insulation thicknesses and RSI may need to be adjusted at particular locations such as thermal bridges to prevent condensation on interior surfaces and to meet energy modeling and LEED energy performance credits[8]. Building airtightness may impact thermal performance as much as the insulation itself - see *Design & Technology Series 01*.

**Information Sourced From:**

1. http://www.engineering.com/Videos/LearningSeriesChannel/VideoId/2735/2-Rs-Wont-Make-Your-U.aspx
2. https://chemicalwatch.com/22250/countdown-begins-for-hbcd-phase-out
3. https://3sdwfb1xa06f3y7ie9255ali-wpengine.netdna-ssl.com/comm/wp-content/uploads/sites/7/2016/08/1911-MSDS-Insulation-IKOTherm-EN.pdf
4. https://living-future.org/sites/default/files/Declare%20Manufacturers%20Guide%20(2).pdf
5. http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=58F1CC80-1
6. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
7. Table and all other reference material from: *Insulation Choices: What You Need to Know About Performance, Cost, Health and Environmental Considerations* Published by BuildingGreen Inc., Battleboro, VT, 2013
8. http://www.infrastructure.alberta.ca/Content/docType486/Production/TechDesignRequirements.pdf
9. https://buildingscience.com/documents/information-sheets/info-502-temperature-dependent-r-value
10. Technical Services Branch: *Architectural Shared General Comments 2015*