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### Appendix A Summary of Energy Modelling



# 1 Introduction

The population of Canada's North is increasing significantly, creating a need for new housing and other facilities. Rising land costs and energy prices have made housing less affordable. Further, climate action goals require increasingly energy efficient building design.

Canada's North presents unique design conditions due to its extreme winter temperatures, low winter insolation, low solar angles, and access or transportation challenges for remote communities. While recent provide guidance on window and door (called 'fenestration') selection for Southern Canadian housing, to date there has not been a comprehensive study of fenestration design parameters specific to the Northern context.

The purpose of this guide is to provide designers, builders, and owners with guidance on energy efficient, comfortable, and cost-effective window design options in the North, collectively Yukon, Northwest Territories, and Nunavut.

Factors that currently influence the choice of window glazing options in the North include building codes, the Energy Star program, and use of the HOT2000 software from Natural Resources Canada to qualify homes for EnerGuide ratings. The report begins with a brief description of the relevant energy performance properties of windows and an overview of the regulatory factors that influence window selection today.

This is followed by a discussion of window products currently used in the North, based on interviews with fenestration manufacturers and builders who operate in this region. The key findings of the report arise from a parametric analysis performed using detailed energy simulations of a Northern house to identify the impact on winter heating costs of the following window-related design considerations:

- Available products and glass options
- Thermal performance
- Solar heat gain for energy efficiency and comfort
- Window to wall ratio
- Window orientation
- Use of insulating shutters

This guide focuses on design recommendations and associated cost implications, supported by a technical analysis in Appendix A.



## 2 Energy Performance Properties

There are four properties that describe the energy performance of windows, doors and skylights in Canada: U-value (also called U-factor), Solar Heat Gain Coefficient (SHGC), Energy Rating (ER) and Air Leakage (eg. L/s-m<sup>2</sup> at 75 Pa). Air leakage is technically an energy performance property, though it is usually left out of energy performance discussions.

These properties are defined in the Canadian standard CSA A440.2, *Fenestration Energy Performance*. Canadian building codes and the Canadian Energy Star program also recognize U-values determined according to American standards developed by the National Fenestration Rating Council: NFRC 100, *Procedure for Determining Fenestration Product U-factors*; and NFRC 200, *Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence*.

U-value, Solar Heat Gain Coefficient, and Energy Rating are defined with respect to specific window sizes for each operator type, as defined in CSA A440.2 or NFRC 100/200. Both the Canadian and American standards use the same reference sizes.

### U-value

U-value is a measure of the overall rate of heat transfer through the entire fenestration product under standardized winter conditions. The rate of heat transfer varies through the frame, the glass edge and the centre of glass; the U-value represents the overall rate of heat transfer through all of these components. The U-value is expressed in either metric units (W/m<sup>2</sup>·K) or imperial units (Btu/h-ft<sup>2</sup>·F). Lower U-values are always desirable in the North as they result in less heat transfer (primarily winter heat loss) and, therefore, less energy needed for heating. Window U-values are primarily influenced by the number of panes of glass, air/gas filled gaps, low-emissivity (low-e) coatings applied to the glazing surface(s), and the window frame type and material.

### Solar Heat Gain Coefficient

Solar Heat Gain Coefficient (SHGC) is the proportion of heat from the sun that is transferred through the product, and is a decimal fraction between 0.0 (totally opaque) and 1.0 (a hole in the wall). The SHGC of a window is primarily influenced by the type of low-e coating(s) applied to the glazing surfaces. SHGC is a measure of solar heat gain, not heat loss, thus it is not explicitly regulated in residential buildings in Canada. However the benefits of passive solar heat gain in winter are recognized in both the Energy Rating and in the software used to determine home EnerGuide ratings.

The merits of increasing or reducing the SHGC depend on building specific design parameters. In a suitably designed building, windows with high solar heat gain can reduce the need for heating in winter. However, in many Northern buildings, it is also beneficial to reduce solar heat gain in summer for comfort. This balance between summer and winter priorities mean the entire building design should be considered, including building orientation, exterior shading, window area, and glazing properties.

### Air Leakage

Air Leakage is a measure of the rate of air flow through a window system. It is considered an energy performance property as higher rates of air flow correlate with greater energy use for heating and cooling. Window air-leakage values are primarily influenced by the gaskets, seals, and hardware of operable

windows. In Canadian standards, specified air leakage rates must be achieved under both infiltration and exfiltration conditions. These requirements are generally more stringent than they are in American standards.

## **Energy Rating**

The Energy Rating (ER) is a Canadian measure of the energy performance of fully glazed windows and sliding doors. The higher the ER number, the more energy efficient the product.

The ER evaluates not only heating season heat loss (as measured by the U-value), but also the energy gained through passive solar heat gain. ER is a heating only rating, and therefore, achieving a good ER can sometimes result in situations where overheating is a problem. The energy benefit reflected in a better ER from passive solar heat gain must be balanced with thermal comfort and preventing overheating.



# 3 Current Energy Performance Regulations and Products

The Canadian territories adopt the National Building Code with some modifications and additions. The 2010 NBC was revised in 2012 to include new energy efficiency provisions for Part 9 buildings (Section 9.36), which include specific requirements for the thermal performance of windows. Whitehorse and Yellowknife have additional requirements for energy efficiency in buildings. These and other regulations are discussed further in the sections that follow.

## NBC 9.36 Window Energy Performance Requirements

Section 9.36 has prescriptive, climate zone-based energy performance requirements for windows specified with respect to U-value or Energy Rating (ER). Climate zones are based on heating degree days (HDD)<sup>1</sup>. These are summarized in Table 3.1. The territories are in climate zones 7B and 8, therefore the prescriptive Section 9.36 requirements for windows are a maximum U-value of 1.40 W/m<sup>2</sup>-K or a minimum Energy Rating (ER) of 29. Individual windows may exceed this value under the trade-off or performance paths of Section 9.36.

TABLE 3.1 NBC 9.36 THERMAL CHARACTERISTICS OF FENESTRATION AND DOORS							
Component	Thermal Characteristics	Heating Degree-Days at Building Location in Celsius Degree-Days					
		Zone 4 < 3000	Zone 5 3000 – 3999	Zone 6 4000 – 4999	Zone 7A 5000 – 5999	Zone 7B 6000 – 6999	Zone 8 ≥ 7000
Fenestration and Doors	Max. U-Value W/m <sup>2</sup> -K (Btu/h-ft <sup>2</sup> -F)	1.80 (0.32)		1.60 (0.28)		<b>1.40 (0.25)</b>	
	Min. Energy Rating	21		25		<b>29</b>	

## ENERGY STAR® Program

ENERGY STAR® is a marketing program, not a regulation. Its purpose is to encourage consumers to identify and select more energy efficient products. It helps consumers and builders to identify suppliers of window products that meet a high level of energy efficiency. Construction specifications sometimes indicate the desired level of performance with respect to the ENERGY STAR® zone criteria.

The ENERGY STAR® “Most Efficient” designation recognizes the most efficient products among those that qualify for ENERGY STAR®. These are products that exceed the requirements of the coldest zone in the program, and represent a level of performance that only a limited number of manufacturers can offer.

The ENERGY STAR® program underwent a significant change in February 2015, introducing a new three-zone map and more stringent energy performance requirements for the southern Canadian Zones. The

<sup>1</sup> Heating degree days (HDD) are a measurement of the relative demand for heating in a particular geographic location. Locations with higher HDD values reflect colder climates.



current and previous ENERGY STAR® qualification criteria for the Northern Zone are summarized in Table 3.2.

The Natural Resources Canada website lists all qualified window, door and skylight products in the Canadian ENERGY STAR® database. A search can be conducted on the basis of model, brand, product name, and specific energy performance criteria, including products with the Most Efficient designation. Listed products have certified energy performance characteristics.

TABLE 3.2 ENERGY STAR WINDOW PERFORMANCE REQUIREMENTS FOR THE NORTH FROM 2010 THROUGH 2015		
Program	U-value Path (Max.)	Energy Rating Path (Min.)
Energy Star 2010 Zone D	1.20 W/m <sup>2</sup> -K	ER 34
Energy Star 2015 Zone 3	1.20 W/m <sup>2</sup> -K and ER ≥ 24	ER 34
Energy Star 2015 "Most Efficient"	1.14 W/m <sup>2</sup> -K and ER ≥ 26	ER 36

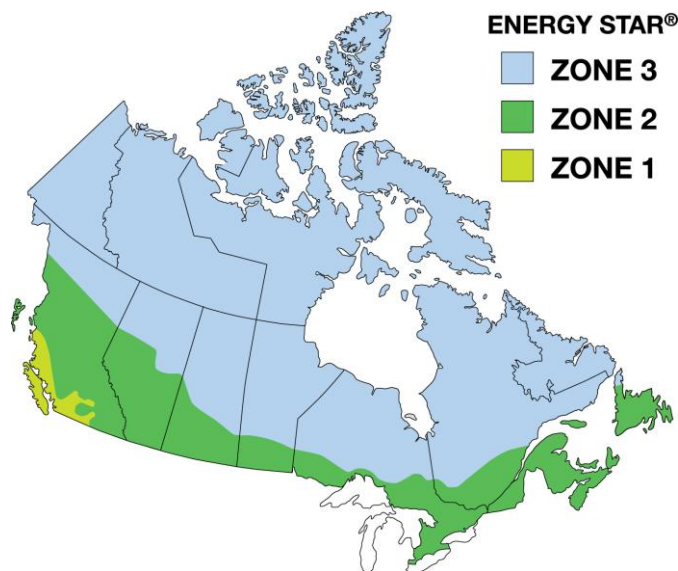


Figure 3.1 Energy Star Zone Map, Current as of February 2015

## Regulation in the Yukon

According to the NRC model code adoption website, NBC 9.36 energy performance requirements have been adopted in the Yukon effective April 2013<sup>2</sup>. There is building code enforcement in Whitehorse, but not throughout the rest of the territory.

The Whitehorse building department website refers builders to the New Green Building Standards which require an EnerGuide Rating System label of 82 or better for all new homes.

Whitehorse Building and Plumbing Bylaw 99-50<sup>3</sup> specifies minimum insulation values for the site built and factory built buildings and for additions to buildings. Doors without glazing must have a minimum thermal resistance of RSI-2.1 (R-12), and windows must have a maximum USI-value of 1.4 W/m<sup>2</sup>-K (U-0.25). There is no formal reference to NBC 9.36.

<sup>2</sup> Verified June 2015.

<sup>3</sup> Consolidated Bylaw 2014-24 passed June 9, 2014.

## Regulation in the Northwest Territories

According to the NRC model code adoption website<sup>4</sup>, the Northwest Territories have not yet adopted NBC 9.36. The City of Yellowknife building bylaw<sup>5</sup> regulates the energy performance of residential buildings, and requires all single family and two family homes to be designed and built to achieve an EnerGuide for New Homes rating of 80.

Builders are required to work with a Certified Energy Advisor (CEA). The CEA evaluates the proposed design and advises the builder on measures needed to achieve the EnerGuide rating, and performs on-site evaluations. A CEA from the Arctic Energy Alliance indicated that product U-values are not checked, but use of triple pane vinyl framed windows with argon fill and at least one low-e coating would be the normal choice for an EnerGuide 80 home. Windows are not typically evaluated based on a specific U-value, but based on the configuration as part of a whole home design that is evaluated by the CEA.<sup>6</sup>

There are no building code inspections outside of Yellowknife where the Office of the Fire Marshall simply advises builders to follow the National Building Code.

## Regulation in Nunavut

According to the NRC model code adoption website, Nunavut has not yet adopted any part of the National Building Code, however efforts are underway to develop building regulations modelled on the national code.<sup>7</sup> A Nunavut building code is under development and could be in place as early as 2016.

Most residential construction in Nunavut is public housing constructed by the Nunavut Housing Corporation (NHC), though local builders build some single family homes. Only Iqaluit requires permits and has a building bylaw. NHC specifications currently require windows to comply with 2010 ENERGY STAR® Zone D criteria, which are almost identical to 2015 ENERGY STAR® Zone 3. The ENERGY STAR® window performance criteria for the Territories is summarized in Table 3.2. These values can be achieved with vinyl framed triple pane windows with low-e coatings and argon gas fill, of the same type commonly used in the other territories.

The NHC now specifies the sizes and operator types of windows that can be used in their buildings and stocks glass for these sizes to facilitate glass replacement, as supplies can only be shipped economically by boat in the summer. Local companies make dual pane replacement insulating glass units (IGUs) for emergency repairs, but these fabricators currently lack the resources to fabricate energy efficient IGUs incorporating low-e coatings and argon gas fill.

Local builders order supplies from building supply centres who in turn order from southern manufacturers. Only one building supply store stocks windows.

## Window Products Currently Sold in the North

Vinyl-framed triple glazed windows are widely used in new construction throughout the North. While multiple low-e coatings, argon gas fill and warm edge spacers provide the lowest U-values, there is little awareness of U-value labeling, and triple-pane glass in vinyl or fiberglass window frames is believed to be sufficient for code compliance.

<sup>4</sup> Verified June 2015.

<sup>5</sup> Consolidated Bylaw 4469, amended January 27, 2014

<sup>6</sup> The Hot 2000 software used to generate the EnerGuide rating does not use U-values for window inputs.

<sup>7</sup> Verified June 2015.

Most products are imported from large southern suppliers, such as Ply Gem, All Weather, Kohltech, Jeld-Wen, Gentek, and others. Northerm is a Whitehorse manufacturer that makes triple and quad-pane products. Quad-pane products reportedly account for 20–25% of their local sales.

Sample window orders show that triple pane argon filled, dual low-e products are being used. One major supplier to the North commented that some homeowners building custom homes on view properties prefer to maximize the view through clear triple pane glass over maximizing energy performance with low-e coated windows.

While fixed, casement and awning are preferred for better air-tightness, triple-pane sliding windows are popular in some First Nations communities as they are easier to maintain than crank operated products.

Anecdotally, products with medium-low solar heat gain are preferred for greater occupant comfort during the warmer months (May – September). Several northern and southern manufacturers expressed doubt about the merits of passive solar gains in the North, and advocated low to medium solar gain glass options to prevent overheating discomfort.

Dual pane vinyl windows can achieve an Energy Ratings of 29 or greater when glazed with high solar gain glass with argon gas fill, which would qualify them for Zones 7B and 8 under NBC 9.36. Although such products technically qualify with the Part 9 energy requirements of the National Code, they are not optimal for energy performance in the North where the solar heat gain is not as abundant during the heating season. From both the comfort and energy performance viewpoints triple glazing is a better option.



# 4 Window Design Criteria for Energy Efficiency

Windows can have a big impact on how much heating energy a home needs; they typically account for 20% to 50% of heat loss from a house. This section highlights the key choices available to designers, and discusses how these can be optimized for houses in the North.

The plots shown in this section are based on energy modelling performed for a typical house in Northern Canada. A 1,000 s.f. archetype house with a 10% window-to-wall ratio was developed based on common design and construction practices in the territories for permafrost locations. In reality, a variety of house designs are constructed in the North; in particular, larger homes on grade with greater window areas will be constructed in cities like Whitehorse and Yellowknife. Based on previous research on modelling the impacts of windows<sup>8</sup>, this will not change the overall trends and recommendations, however cost savings would be higher for homes with greater window areas. Additional details of the archetype house model are shown in Appendix A.

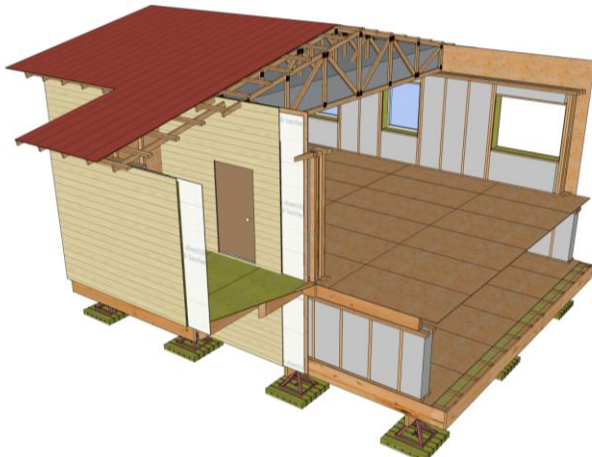


Figure 4.1 Illustration of the archetype house for energy modelling and parametric analysis of window design options.

The National Building Code divides Canada into six climate zones, as shown in Figure 4.2. Results are shown here for three Northern cities: Whitehorse (Zone 7B), Yellowknife (Zone 8), and Resolute (Zone 8). For houses in other locations, compare the results from the city in the same climate zone and nearest latitude. Table 4.1 shows climate data for the three locations used in this study. Figure 4.3 shows average monthly global solar radiation for these cities.

TABLE 4.1 2010 NBC CLIMATIC INFORMATION FOR NORTHERN LOCATIONS.			
	Whitehorse	Yellowknife	Resolute
Latitude	60.7 °N	62.4 °N	74.7 °N
Climate Zone	7B	8	8
Heating Degree Days (HDDs)	6580	8170	12360
January 2.5% Design Temperature	-41 °C	-41 °C	-42 °C

<sup>8</sup> Review of Window Energy Rating Procedure in Canada: Final Research Report, January 2013. Available online: <http://www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf>

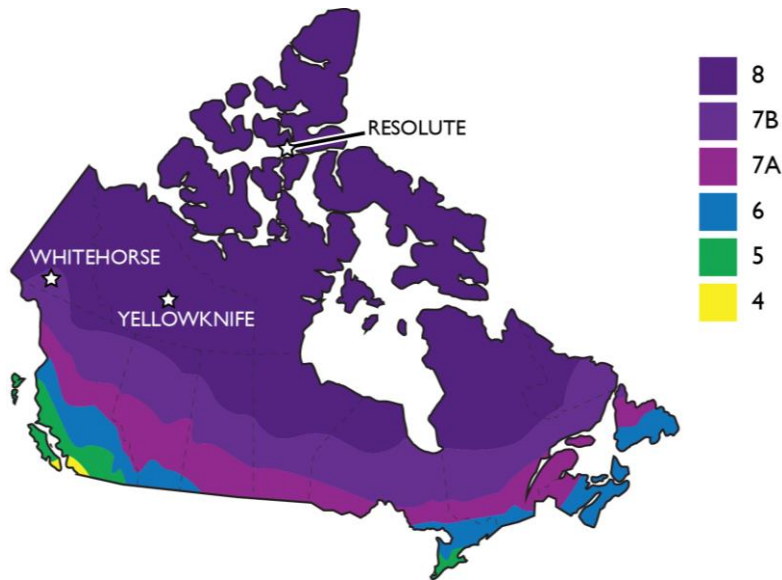


Figure 4.2 Climate zone map of Canada.

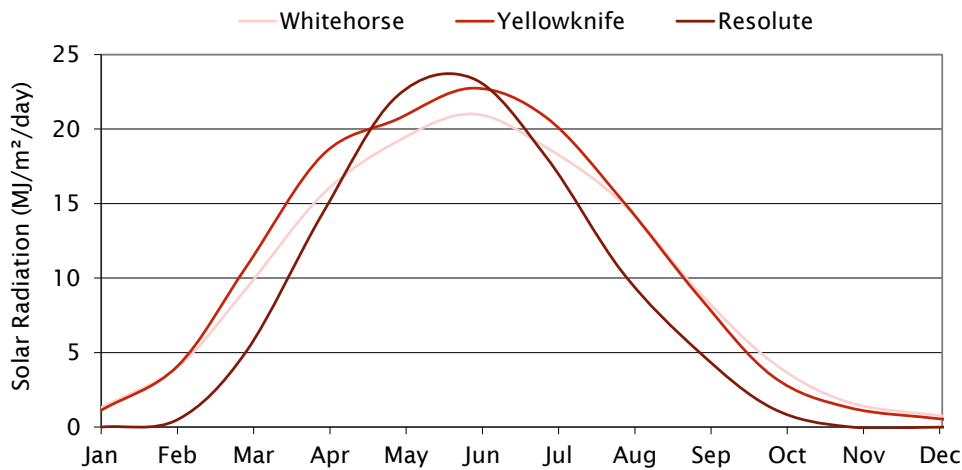


Figure 4.3 Average monthly global solar radiation for three Northern Canadian cities.<sup>9</sup>

Comparisons between product and design options are shown in this report for heating energy cost savings. While this is a metric that is easily understood and compared, it is also important to recall that actual cost savings will vary with several factors: the house design, window area, energy prices, location (climate), and other project-specific characteristics. In particular, energy costs can vary significantly across the North, which affects the savings resulting from energy efficient windows. The savings shown here should be taken only as guidelines or estimates for comparison. The following heating energy prices were used in this report:

→ Electric heating in Whitehorse: \$0.16/kWh<sup>10</sup>

<sup>9</sup> Data from HOT2000 program, <https://www.nrcan.gc.ca/energy/software-tools/7421>.

<sup>10</sup> Yukon Electrical Company Ltd., Residential Service >2,500 kWh including rate riders. Available online: [http://www.atcoelectricityukon.com/Documents/Regulatory/YECL\\_YEC\\_Rate\\_Schedules\\_Jul\\_01\\_2011\\_FINAL.pdf](http://www.atcoelectricityukon.com/Documents/Regulatory/YECL_YEC_Rate_Schedules_Jul_01_2011_FINAL.pdf)

→ Fuel oil heating in Yellowknife and Resolute: \$1.17/L (\$0.128/kWh)<sup>11</sup>

## Product Characteristics

Window energy performance is described with respect to U-value, Solar Heat Gain Coefficient (SHGC), and Energy Rating (ER). Each of these characteristics can affect heating savings. Energy modelling was used to analyze each of these characteristics separately for the Northern archetype home.

### U-value

U-value is the rate of heat flow through a window from the interior to the exterior; therefore, a lower U-value is better to reduce heating energy. A window U-value below 1.40 W/m<sup>2</sup>-K (0.25 Btu/hr-ft<sup>2</sup>-F) is recommended in Canada's territories, the maximum U-value permitted under the U-value compliance path of NBC 9.36. This corresponds to the performance of a triple glazed product (3 panes of glass), argon gas fill, and at least one low-e coating with a low conductivity frame made of vinyl, wood, or fibreglass.

Products with even lower U-values will further reduce heating costs, incorporating available features such as multiple low-e coatings, higher performance low-e selections, improved frame designs, or four glass layers. The energy modelling shows that lowering the U-value has a significant effect on reducing heating costs. Figure 4.4 shows the impact of lower U-values on heating cost savings for a typical house in three Northern Canadian cities.

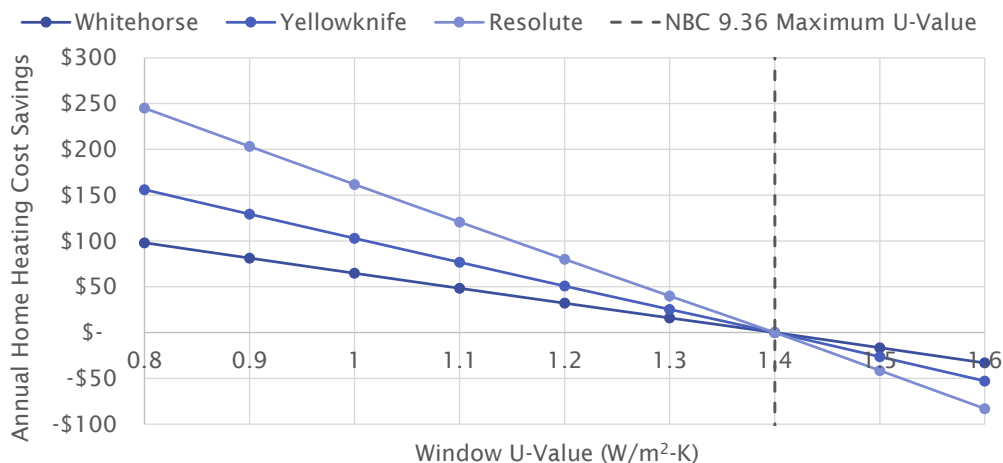


Figure 4.4 Typical home heating cost savings for various window U-values compared to the NBC 9.36 maximum U-value of 1.40 W/m<sup>2</sup>-K.

Windows with lower U-values tend to be more expensive due to the added features needed to improve performance, like more insulated frames, additional low-e coatings or additional panes of glass. However, the increased initial cost will be recovered over time through energy savings.

### SHGC

Increasing solar heat gain through windows also has a measurable effect on reducing heating costs for Northern homes. Figure 4.5 shows the impact of a range of SHGC values on heating cost savings for a typical house in the North.

<sup>11</sup> Statistics Canada five-month average for Yellowknife as at March 2015. Available online: <http://www.statcan.gc.ca/tables-tableaux/sum-som/I01/cst01/econ152r-eng.htm>

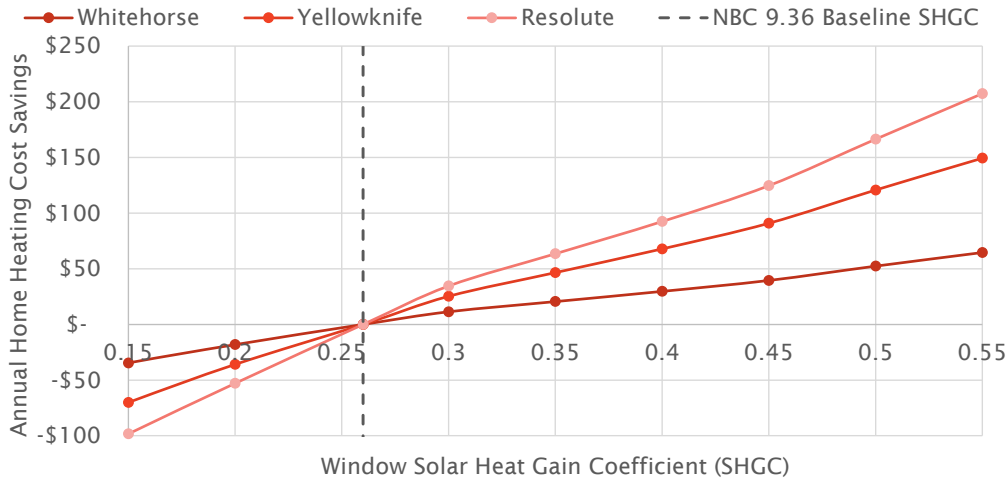


Figure 4.5 Typical house heating cost savings for various window SHGC values compared to a baseline value of 0.26.

While the benefits of passive solar heat gain are maximized when the primary window orientation is to the South, these results are based on the average solar heat gain benefit from all orientations. Orientation is discussed further under House Design.

Maximizing solar heat gain can be a low cost design strategy as there is little difference in price between low-e coatings with higher or lower SHGCs. However, it is also important to consider comfort and the risk of overheating. A higher window SHGC means that more heat from the sun will enter the house, which can offset heating needs during cold and sunny periods, but can also lead to occupant discomfort at certain times of year. Overheating can be a particular concern in the North since the region experiences low solar angles and long periods of daylight, increasing the risk of discomfort.

The benefits of choosing windows with SHGC should be evaluated carefully on a case-by-case basis. This is discussed in greater detail in Section 5.

## Energy Rating

Generally a higher ER will result in lower energy consumption based on studies conducted for Southern Canada<sup>12</sup>. However, because the ER formula includes both U-value and SHGC, two products could achieve the same ER with different design features, for instance one with a lower U-value (less heat loss), the other with a higher SGHC (more solar heat gain).

As Figure 4.6 shows, a higher ER value will generally result in more heating savings, but the results aren't as consistent as for U-value and SHGC shown previously. The variation is greatest for far North communities like Resolute. This occurs due to the shorter periods of daylight in the North; it is more beneficial to select windows on the basis of lower U-value, since solar heat gain does not provide as much benefit in the winter (with less hours of daylight) as in other parts of Canada. As a result, the ER is not as good of a predictor of low energy consumption in the North as it is in southern Canada.

<sup>12</sup> Review of Window Energy Rating Procedure in Canada: Final Research Report, January 2013. Available online: <http://www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf>

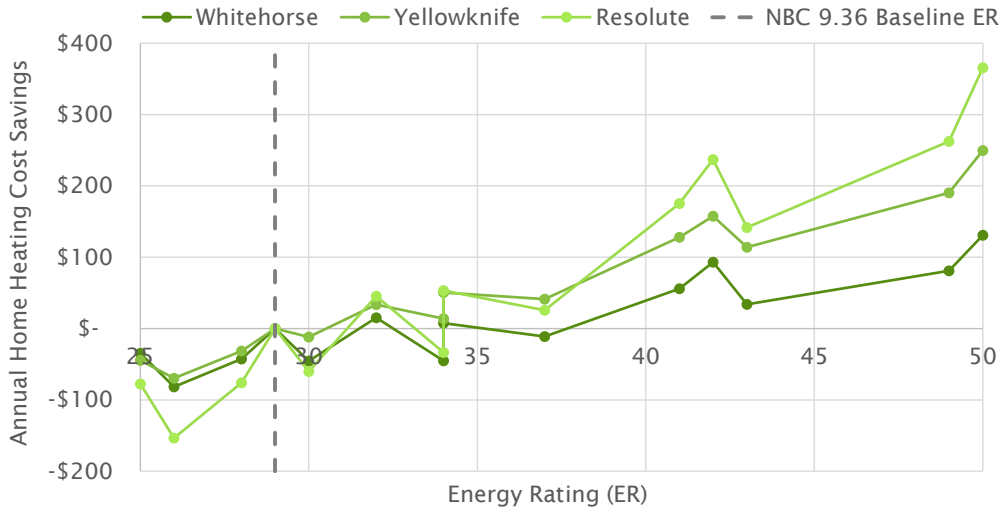


Figure 4.6 Typical house heating cost savings for various window ER values compared to the NBC 9.36 baseline value of ER 29. Note two different products with the same ER of 34 yield different heating energy consumption due to the differences in U-value and SHGC.

## House Design

The amount and orientation of windows can have a big impact on how much heating energy a house uses.

Window to wall ratio (WWR) is the percentage of total above grade exterior wall area of a house occupied by windows. Despite great improvements in the energy performance of modern windows, they still lose more heat than opaque walls. In the far North, a lower WWR will result in less heating energy use. Houses in Canada usually have WWRs in the range of 17% to 22%; however, in the far North, and in particular in remote communities, WWRs are typically lower to reduce heating costs and improve comfort inside the home.

Figure 4.7 shows the change in home heating energy for a variety of WWRs in a typical Northern house. Negative “cost savings” indicate an increase in heating bills. As the results show, greater window areas can significantly increase heating costs for a house.

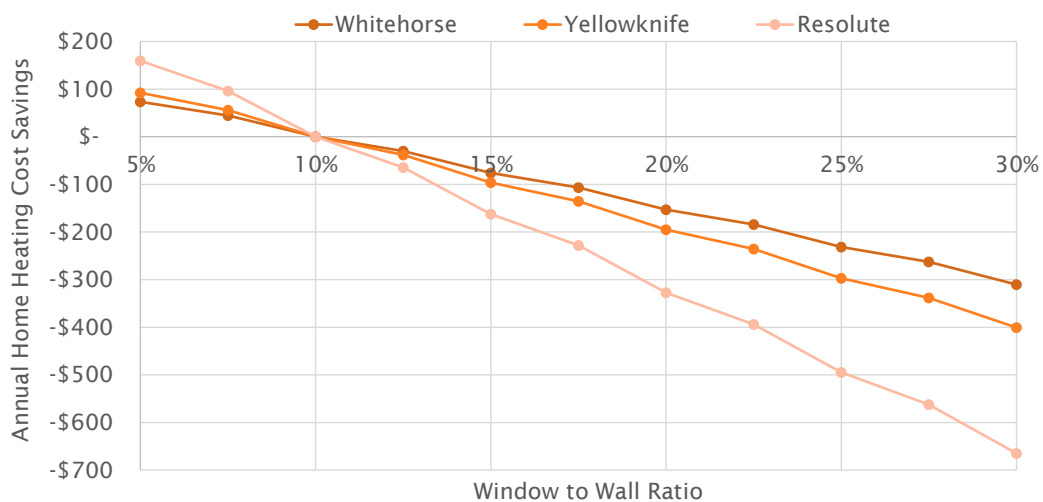


Figure 4.7 Typical change in home heating energy costs for various WWRs compared to a baseline value of 10% (USI-1.40, SHGC-0.26).



Orientation refers to the cardinal direction that the windows face. South-facing windows can help reduce energy consumption by allowing for more passive solar heating than windows facing East and West. Although there are less hours of daylight during the coldest winter months in the far North. South-facing windows still provide some passive solar heating and are the preferred orientation to reduce heating energy. In some cases, such as houses with views, compact lots, or multifamily buildings, it may not be possible to orient the windows optimally. However, when possible, South-facing windows can provide passive heating to offset energy consumption.

Figure 4.8 shows the change in heating costs with windows primarily oriented in different cardinal directions compared to a house with equal window orientation in all four directions (all with the same window area).<sup>13</sup> The results show that south-facing windows result in lower heating bills, while north-facing windows yield higher heating bills.

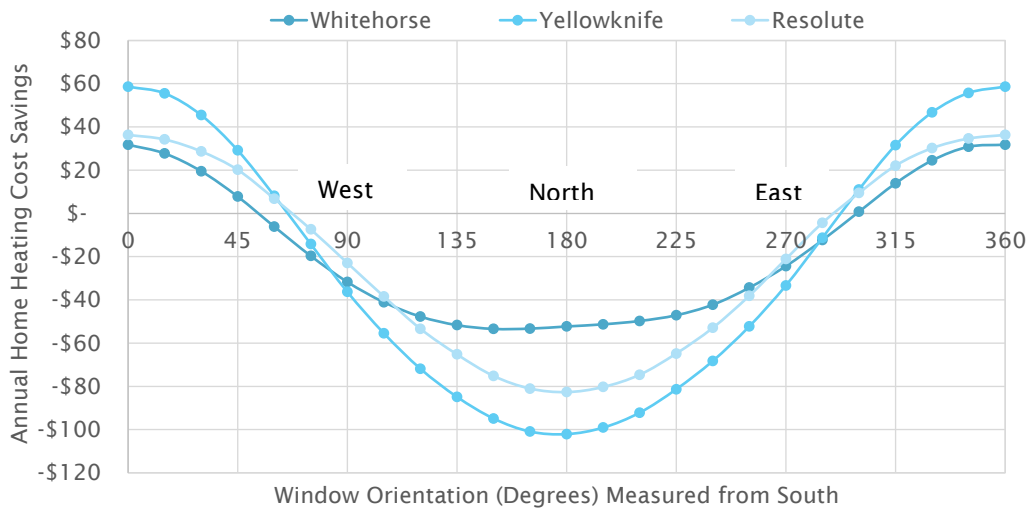


Figure 4.8 Typical change in home heating energy costs for windows facing various cardinal directions compared to a house with equal window area in all directions.

## Shading

Some Northern houses use temporary or permanent shutters installed outside the windows. This provides several benefits:

- Shutters can be closed to provide shading and prevent overheating, in addition to blocking the sun during extended periods of daylight.
- Shutters can be opened when views or passive solar heating are desired.
- Shutters can be closed during cold periods without sun to provide better insulation.

Compared with traditional shutters, insulated shutters can provide better insulation. To get the most out of the insulation, shutters should be as airtight as possible at the connection to the window or wall when closed. Air leakage around the shutter will lessen the insulation value of the shutter, though they will still provide some insulating benefit.

<sup>13</sup> These results were obtained by shifting the window area to one elevation and rotating the model through cardinal directions.



Figure 4.9 Typical heating energy savings for a house with various exterior shutter configurations compared to a house without exterior shutters. Insulated shutters (RSI-2 or R-11) versus uninsulated (RSI-0.2 or R-1) are shown. “Tight” installation refers to shutters that are installed as airtight as possible against the wall or window; “loose” installation refers to cases where outdoor air bypasses the shutters.

Note that there are several practical challenges with exterior shutters; for example, opening and closing shutters daily or during extreme winter conditions may be unrealistic. However, there may be some scenarios where shutters are practical, such as a window without views that can be shuttered for the entirety of the winter. Shutters should be evaluated based on occupants’ needs and practicalities.

# 5 Window Design Criteria for Comfort

Besides energy consumption, windows also affect how comfortable a space is. During cold periods, a well-insulated window will have warmer winter surface temperatures than a less insulated window, resulting in better comfort and less drafts. The choice of glazing also dictates how much heat from the sun gets into a space, which has an effect on comfort during the warmer months.

Many of the guidelines presented in Section 5 also result in more comfortable spaces during cold periods. For example, a lower U-value is better both for energy efficiency and for reducing cold window surfaces and drafts. However, when designing and selecting windows for a house, careful attention should be paid to ensure the windows do not increase the risk of overheating.

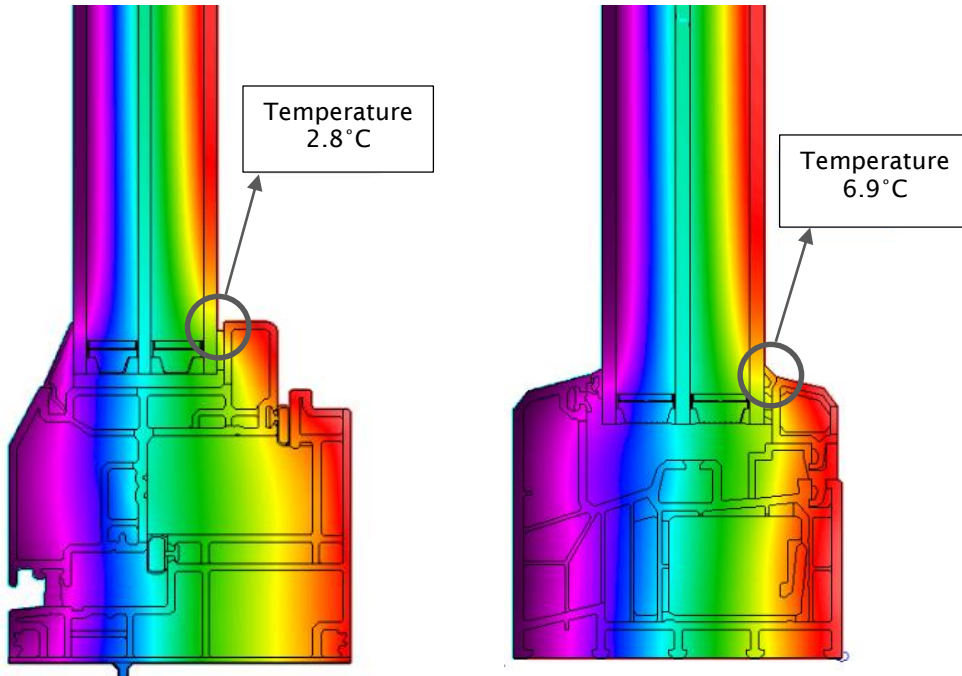
House design strategies such as the window-to-wall ratio, window orientation, and shading can be effective ways to control heat from the sun while still retaining benefits of this heat in the winter. Limit window area for East and West orientations, as these are more prone to overheating. Use exterior shading design strategies such as overhangs or shutters, or design landscaping features like trees and shrubs that can provide shade during the warmer and sunnier months.

Once the house design has been determined, glazing selection provides another opportunity to control heat from the sun. Several factors should be considered in choosing the right glazing in consideration of overheating:

- Are the windows shaded? Shading at the exterior, such as overhangs, shutters, or near-by trees or buildings, can all prevent overheating and excessive solar heat gain.
- What is the window orientation? West-facing windows typically cause the most risk of overheating, followed by East- and South-facing windows.
- What is the window-to-wall ratio? Houses with more window area will have greater chances of overheating.

Based on these factors, if the risk of overheating is judged to be high, select a window and glazing product that has a low SHGC, around 0.2 to 0.3. If the risk of overheating is judged to be low, choose a product with a high SHGC, 0.4 or higher, to reduce heating energy consumption.

Low U-value windows yield heating energy savings, and can also improve the thermal comfort of a space because the interior surfaces are warmer. For example, Figure 5.1 shows a thermal model of the heat transfer across two triple glazed window frames: the first a vinyl frame window typical of products currently sold in the North, and the second a Passive House vinyl frame window with a lower U-value. At an exterior temperature of  $-34\text{ }^{\circ}\text{C}$ , the first window has a cold point of  $2.8\text{ }^{\circ}\text{C}$ , while the lower U-value window has a cold point of  $6.9\text{ }^{\circ}\text{C}$ . The second window will feel more comfortable and less drafty for occupants because of the warmer surface temperature.



*Figure 5.1 Interior window surface temperatures during -34 °C exterior conditions for a triple glazed finyl frame window (left) and a triple glazed vinyl Passive House frame window (right).*

## 6 Product Selection

There is a wide range of window products available in Northern Canada, and selecting the best or optimal product will depend on various project-specific factors. Before choosing a product, consider the following key points highlighted in this guide:

- Window design (amount, orientation) and product selection can have a significant impact on the energy consumption and thermal comfort of homes in Canada’s North.
- Design a house with reasonable window-to-wall ratios (typically 15% or lower); orient glazing primarily to the South if possible, and include exterior shading (overhangs, shutters, trees).
- Ask manufacturers for their product’s **U-value** and **SHGC**.
- Select products with low U-values, at least below **1.4 W/m<sup>2</sup>-K**. Even lower values provide more energy savings and better comfort in the winter, particular for colder locations and houses with high window-to-wall ratios. Products with U-values below 1.4 W/m<sup>2</sup>-K typically include **triple glazing with insulated vinyl, fibreglass, or wood frames**.
- Assess the risk of overheating in the house, and choose glazing with an appropriate **SHGC**. Conditions that could lead to overheating include large areas of West, East, or South-facing glazing without exterior shading. If the house has a high risk of overheating select a low SHGC in the range of 0.15 to 0.3. If the house has a low risk of overheating, select a high SHGC of 0.4 or higher to maximize passive heating.

A variety of manufacturers’ products are available in the North. While the above guidelines can be used for any manufacturer’s product (simply request the U-value and SHGC for the product being considered), Table 6.1 provides a sample of a few products that are available in Canada’s North, and Figure 6.1 shows the relative heating energy savings compared to the product with the highest U-value. Results show that the highest performing product can yield annual savings of up to \$115 in Whitehorse and \$320 in Resolute, in the archetype house with a 10% window to wall ratio.

TABLE 6.1 SAMPLE WINDOW PRODUCTS SUITABLE FOR THE NORTH.				
Configuration*	Low-E Coatings**	Operable Unit Performance***		
		USI (W/m <sup>2</sup> -K)	U-Value (Btu/hr-ft <sup>2</sup> -F)	SHGC
Triple Glazed, Vinyl Frame, 1 Low-e Coating	LoE 180	1.25	0.22	0.38
	LoE 366	1.25	0.22	0.17
	LoE 270	1.25	0.22	0.22
Triple Glazed, Vinyl Frame, 2 Low-e Coatings	LoE 180/180	1.08	0.19	0.36
	LoE 366/180	1.02	0.18	0.16
Triple Glazed, Fibreglass Frame, 2 Low-e Coatings	LoE 180/180	1.19	0.21	0.28
	LoE 366/180	1.17	0.21	0.13
	LoE 270/180	1.19	0.21	0.17
	LoE 180/180	0.86	0.15	0.37

TABLE 6.1 SAMPLE WINDOW PRODUCTS SUITABLE FOR THE NORTH.				
Triple Glazed, Passive House Frame, 2 Low-e Coatings	LoE 366/180	0.84	0.15	0.17
Quad Glazed, Vinyl Frame, 2 Low-e Coatings	LoE 270/270	0.73	0.13	0.24

\*All configurations include argon gas fill and warm edge spacers.

\*\*Low-emissivity glass from Cardinal line of products shown as an example; other glass manufactures' products are available with similar performance characteristics.

\*\*\* Performance characteristics shown are values calculated in accordance with NFRC 100 and 200 for operable configurations of actual products. All products' operable units are casements, except Passive House units are tilt and turn.

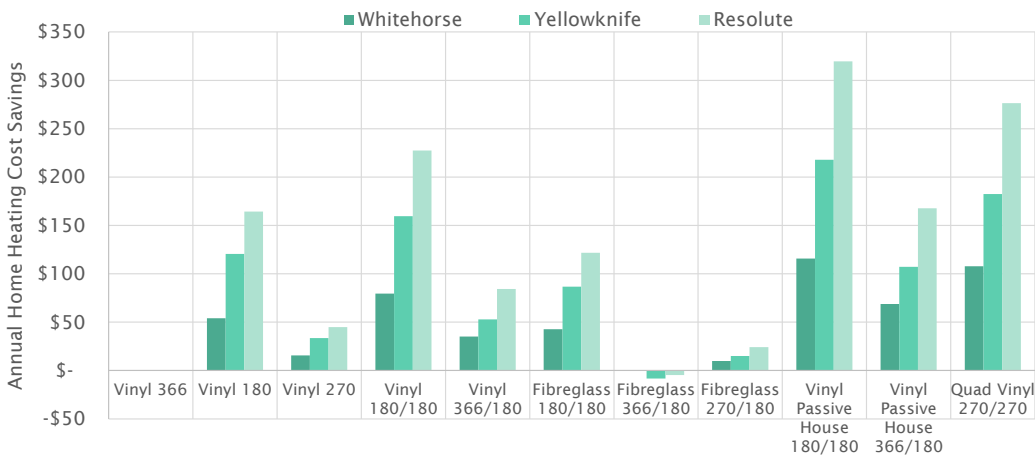


Figure 6.1 Typical house heating cost savings relative to the highest U-value product (Vinyl frame with LoE 366).

## Product Cost

While there are window manufacturers in Whitehorse and Yukon, most of the window products used in the North are supplied by southern manufacturers. In a market where triple pane windows containing at least one low-e coating and one argon gas fill are the norm for new construction, the incremental cost to add another coating and another fill is marginal. Larger southern suppliers are likely to offer argon fill in all gaps as standard.

There are four suppliers of low-e coated glass products to the window industry: Cardinal, Guardian, PPG and ACG. Each supplier has products that can be broadly characterized as having low, medium, and high solar heat gain properties. While there are minor cost differences between the low-e coatings available from any manufacturer, the choice of low-e coating is a very small part of the price of a window. Some manufacturers do not even charge for the difference, and cost and availability of particular coatings is a less a matter of cost and more a matter of stock levels based on inventory management and the buying habits of builders, factors that vary by region and by size of the manufacturer.

New house construction favors the lowest cost products available to builders, and the dominant frame type is unreinforced PVC (rigid vinyl) in residential windows. A typical house package from a large volume southern supplier shipping to Yellowknife will contain approximately twenty individual windows with an average area of 2 m<sup>2</sup> (20 s.f.), and an average cost of \$5/m<sup>2</sup> (\$50/s.f.). These windows typically have vinyl frames with casement/awning style sashes, triple glazing, two low-e coatings and argon gas fill.

The factors that have the greatest influence on window cost are the frame material, hardware, and the number of glass panes. Fiberglass framed products and commercial-grade vinyl products are more expensive than residential grade vinyl. Only one Northern manufacturer offers quad-pane windows for a significant premium in price.

Products will be sold through local dealers. Shipping to more remote locations will add cost, as will full box crating that would be required for products that are barged to remote locations.

## Window Performance in HOT2000 Software

As noted previously, both Yellowknife and Whitehorse refer to EnerGuide ratings to set new house energy efficiency requirements. These ratings are determined using HOT2000 software based on a review of the drawings accompanied by on-site blower door testing to measure air leakage. Window performance is incorporated into overall house energy efficiency as part of the HOT2000 model.

HOT2000 allows two alternatives for specifying the thermal performance of windows: by defining the construction, or by entering a U-value and SHGC. Most users will specify the window using the first method, identifying the frame material, number of glazing layers, number of coatings, gas fill, and other properties. HOT2000 then calculates a typical product U-value and SHGC based on the construction.

The construction definition method may provide a different U-value and SHGC than the actual product specified for a home.

For example, HOT2000 gives the following performance characteristics compared to manufacturers' NFRC certified values:

TABLE 6.2 SAMPLE U-VALUE AND SHGC: HOT2000 (H2K) VERSUS NFRC CERTIFIED VALUES FOR OPERABLE (CASEMENT) UNITS.					
Configuration*	Low-E Coatings**	USI (W/m <sup>2</sup> -K)		SHGC	
		NFRC	H2K	NFRC	H2K
Triple Glazed, Vinyl Frame, 1 Low-e Coating	LoE 180	1.25	1.52	0.38	0.41
	LoE 366	1.25	1.47	0.17	0.33
	LoE 270	1.25	1.47	0.22	0.33
Triple Glazed, Vinyl Frame, 2 Low-e Coatings	LoE 180/180	1.08	1.33	0.36	0.33
	LoE 366/180	1.02	1.28	0.16	0.20
Triple Glazed, Fibreglass Frame, 2 Low-e Coatings	LoE 180/180	1.19	1.11	0.28	0.32
	LoE 366/180	1.17	1.05	0.13	0.19
	LoE 270/180	1.19	1.05	0.17	0.19
Triple Glazed, Passive House Frame, 2 Low-e Coatings	LoE 180/180	0.86	1.33	0.37	0.33
	LoE 366/180	0.84	1.28	0.17	0.20
Quad Glazed, Vinyl Frame, 2 Low-e Coatings	LoE 270/270	0.73	1.16	0.24	0.25





# **Appendix A**

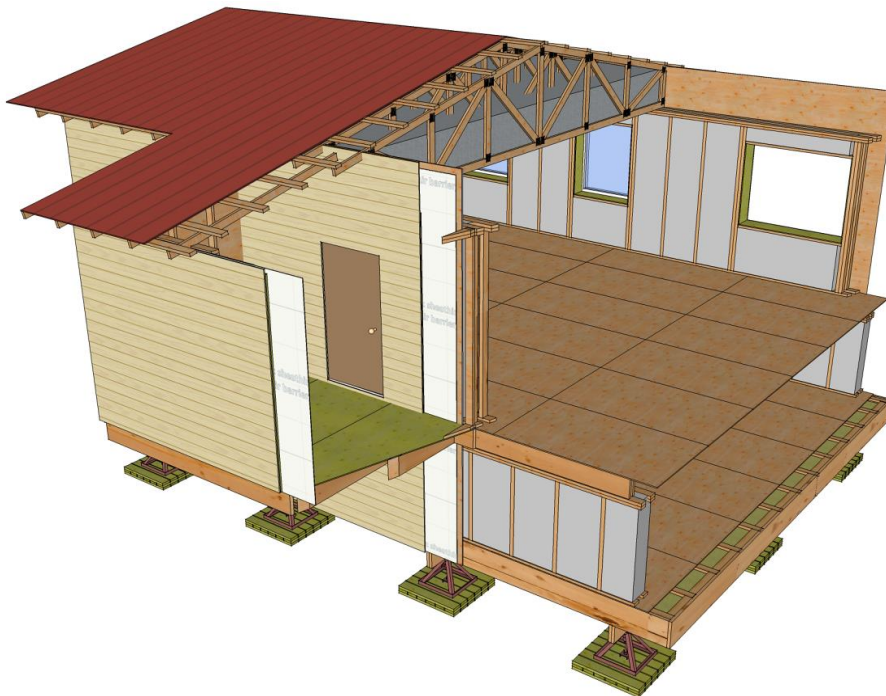
## **Summary of Energy Modelling**

## Archetype House and Model Inputs

The archetype house was developed based on common design and construction practices in Canada's territories for permafrost locations. It is understood that in cities like Whitehorse or Yellowknife larger homes on grade may be constructed. However based on previous research on modelling the impacts of windows<sup>14</sup>, this will not change the overall trends and recommendations.

The archetype house has 1,000 sf of living area over a heated crawlspace and an unheated enclosed porch. The assemblies and mechanical systems were developed based on previous work with CMHC and NRCan in the Yukon and Northwest Territories. A window to wall ratio of 10% was selected similar to the low ratios of much of the North; however, it is important to note that many houses in cities like Whitehorse and Yellowknife will have higher window-to-wall ratios. In these cases, recommendations and trends remain the same, though energy cost savings from high performance windows would be higher.

Figure A.1 illustrates the archetype house used for this analysis, and Figure A.2 shows a screen shot of the energy model geometry.



*Figure A.1 Illustration of the archetype house for energy modelling and parametric analysis of window design options.*

<sup>14</sup> Review of Window Energy Rating Procedure in Canada: Final Research Report, January 2013. Available online: <http://www.hpo.bc.ca/files/download/Report/Window-ER-Full-Report.pdf>

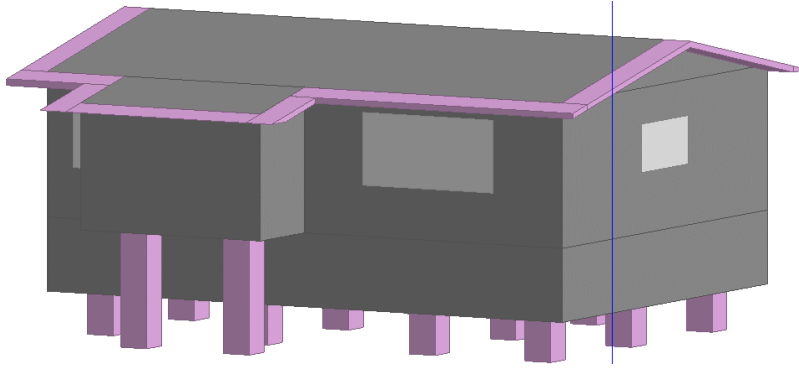


Figure A.2 Energy model geometry of the archetype house.

Table A.1 summarizes the key energy model inputs. Inputs were based primarily on common construction and systems in the territories. As noted in the table below, some inputs were based on NBC Section 9.36, and, where necessary, the 2011 National Energy Code for Buildings (NECB). Although the NBC Section 9.36 is the appropriate modelling reference for houses in Canada, certain inputs necessary for hourly energy modelling programs (such as schedules and lighting/equipment densities) are not explicitly provided in 9.36; values from the NECB were referenced in these cases.

While a variety of space heating fuels may be found across the North, the most common heating fuels were selected for this modeling: electricity in the Yukon (Whitehorse), and heating oil in Northwest Territories and Nunavut. The fuel type affects heating energy savings reported in this study due to the different fuel costs by type and region, however the general trends and recommendations remain consistent for different conditions.

TABLE A.1 KEY MODEL INPUTS FOR THE BASELINE ARCHETYPE NORTHERN HOUSE.			
	Units	Value	Notes and References
<i>Space Use</i>			
Occupancy	people	4	
Occupant Schedule			NECB Table A-8.4.3.2.(1) Schedule G
Heating Set Point	°C	21	NBC 9.36.5.4. (5)
Heating Set Back	°C	18	NEBC A-8.4.3.2.(1) Schedule G
Crawlspace Heating Set Point	°C	15	NBC 9.36.5.4. (5)
Appliances & Plug Loads	W/m <sup>2</sup>	5	NEBC Table A-8.4.3.3 (1) A.
Appliances & Plug Loads Schedule			NEBC Table A-8.4.3.2. (1)G.
Lighting Energy	W/m <sup>2</sup>	6.5	NEBC Table 4.2.1.5.
Schedule			NECB Table A-8.4.3.2.(1) Schedule G
<i>Building Enclosure</i>			
External Wall R-Value	m <sup>2</sup> -K/W	7.04	R-40 overall effective; may be achieved using a variety of assemblies and materials
Attic R-value	m <sup>2</sup> -K/W	10.57	R-60 overall effective; may be achieved using a variety of assemblies and materials
External floor	m <sup>2</sup> -K/W	7.04	R-40 overall effective; may be achieved using a variety of assemblies and materials

TABLE A.1 KEY MODEL INPUTS FOR THE BASELINE ARCHETYPE NORTHERN HOUSE.			
	Units	Value	Notes and References
External door	m <sup>2</sup> -K/W	1.41	R-8 overall effective
Infiltration rate	ACH50	1.5	Typical construction practice
Window U-Value	W/m <sup>2</sup> -K	1.4	NBC Table 9.36.2.7.A.
Window SHGC		0.26	NBC 9.36.5.14.2c
Window to Wall Ratio		10%	
<i>Mechanical Systems</i>			
Heating System	YU: Electric baseboards and electric water heater NWT & NU: Oil-fired furnace and oil-fired water heater Heat recovery ventilator (HRV) stand-alone (YU) or ducted through furnace (NWT & NU)		
Cooling System	None		
Outdoor Air	L/s	27	NBC Table 9.32.3.3 (2)
HRV Efficiency	@ 0°C	60%	NBC 9.36.3.9.3b
Oil Furnace and Water Heater Efficiency		80%	NBC Table 9.36.3.10
Elec. Baseboard Efficiency		100%	
DHW Consumption	L/day	225	NBC 9.36.5.8

## Archetype House Model Results and Checks

Energy modelling for this study was performed using the program DesignBuilder, an interface for EnergyPlus. While modeling of Canadian houses is usually performed using HOT2000, DesignBuilder/EnergyPlus was selected for this work as it performs hourly calculations to estimate energy consumption. This type of program more accurately accounts for the effects of solar radiation and solar angles, which is critical for this study of window design parameters for Canada's North.

The baseline archetype model results were compared to statistical data as a check to ensure the model results are reasonable.

### Energy Consumption by Household and Energy Use Intensity

The total simulated energy consumption for the baseline archetype house in Yellowknife is 32,800 kWh per year. By comparison, NRCan's 2007 Survey of Household Energy Use (SHEU) gives an average household energy consumption of 29,000 kWh per year nation-wide. While there is no consumption provided for Canada's territories in this survey, the province with the highest consumption is Alberta with an average of 36,000 kWh per household. Based on this, the modelled value for Yellowknife appears reasonable. The archetype house is small and well-insulated with a low window-to-wall ratio, and so is expected to have lower consumption than an average house in the Northwest Territories.

Building energy consumption is often reported as an Energy Use Intensity, normalized per square metre of conditioned floor area. Using only the living floor area gives an EUI of 360 kWh/m<sup>2</sup>. However, to account for the heated crawlspace, normalizing heating to the living space and crawlspace area gives an EUI of 230 kWh/m<sup>2</sup>.

Modelling the archetype house in Whitehorse (with electric heating), total annual consumption is 14,900 kWh per year, with an EUI of 162 kWh/m<sup>2</sup> (or 124 kWh/m<sup>2</sup> with heating normalized to include the crawlspace area). This represents a very energy efficient new house, with lower than average energy consumption.

## Energy Consumption by End-Use

Figure A.3 shows the modelled breakdown of energy consumption by end-use for the baseline archetype house in Yellowknife and Whitehorse. A significant proportion of consumption is for heating, as expected given the cold climate. Heating proportions in Canada's provinces typically range from 40% to 80% of household energy consumption.

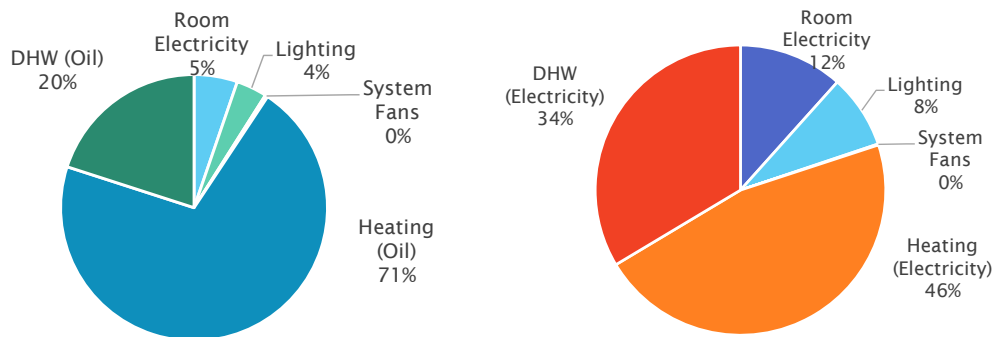


Figure A.3: Distribution of energy consumption by end-use for the archetype house in Yellowknife, NT [left] and Whitehorse, YT [right].

## Fuel Costs

Fuel costs for the baseline archetype houses were computed as an additional means to verify the model results. For the archetype in Yellowknife, an electricity price of \$0.2853/kWh<sup>15</sup> and a heating oil price of \$1.20/litre<sup>16</sup> gives the following annual costs:

- Electricity \$900
- Heating oil \$3,900
- Total \$4,800

For the archetype in Whitehorse, an electricity price of \$0.16/kWh<sup>17</sup> gives annual energy costs of \$2,400 (all electricity). Costs are lower due to less heating consumption (less extreme climate and 100% efficient electric baseboard heating) and lower cost fuel.

Note that this archetype represents a very efficient house with well insulated enclosure assemblies, a small footprint, low window to wall ratio, and low internal uses. Many existing houses, particularly in Whitehorse and Yellowknife (where houses tend to be larger) likely have higher consumption.

<sup>15</sup> Northwest Territories Power Corporation residential electricity rates effective September 1, 2014; available online at <https://www.ntpc.com/customer-service/residential-service/what-is-my-power-rate>

<sup>16</sup> Statistics Canada five-month average for Yellowknife as at March 2015. Available online: <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ152r-eng.htm>

<sup>17</sup> Yukon Electrical Company Ltd., Residential Service >2,500 kWh including rate riders. Available online: [http://www.atcoelectricityukon.com/Documents/Regulatory/YECL\\_YEC\\_Rate\\_Schedules\\_Jul\\_01\\_2011\\_FINAL.pdf](http://www.atcoelectricityukon.com/Documents/Regulatory/YECL_YEC_Rate_Schedules_Jul_01_2011_FINAL.pdf)