NUMBER 9

Builder Insight

Fenestration Energy Performance:

A Roadmap for Understanding Requirements for Residential Buildings in British Columbia

Homeowner Protection Office
Branch of BC Housing

Overview

Energy performance requirements for windows, doors and skylights (collectively referred to as fenestration) have become more stringent in recent years.

Energy performance is now regulated through building codes as well as the *BC Energy Efficiency Act* (EEA). Incentive programs such as LiveSmart BC encourage homeowners to renovate with ENERGY STAR qualified products. Some of the requirements are directed at registered professionals and others at manufacturers. This bulletin clarifies the energy performance requirements for windows, glazed doors and skylights used in residential buildings, and provides a roadmap for compliance.

Overall Window U-factor Calculation

Overall window U-factor =

Frame U-factor x % frame area +
Centre of glass U-factor x % glass area +
Edge of glass U-factor x % edge of glass area

Overall window R-value = 1 / U-factor

Energy Performance Properties

There are two properties that describe the energy performance of windows, doors and skylights: U-factor (also called U-value) and Solar Heat Gain Coefficient (SHGC).

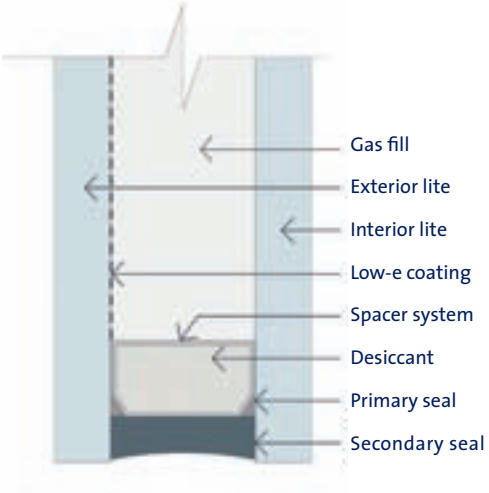
U-factor is a measure of the overall rate of heat transfer through the entire fenestration product under standardized winter conditions. The rate of heat transfer varies through the frame, the glass edge and the centre of glass; the U-factor represents the overall rate of heat transfer through all of these components. The U-factor is expressed in either metric units (W/(m²•°K)) or IP units (Btu/h•ft²•°F).

This bulletin clarifies the energy performance requirements for windows, glazed doors and skylights used in residential buildings, and provides a roadmap for compliance.

Builder Insight is a series of bulletins designed to provide practical information on new technologies, research results, good building practices and emerging technical issues in residential construction to Licensed Residential Builders and others in the industry.

This bulletin is produced by the Homeowner Protection Office (HPO), a branch of BC Housing, and was prepared by RDH Building Engineering Ltd. in cooperation with industry organizations.

Insulating Glazing Unit (IGU) Components



Solar Heat Gain Coefficient (SHGC) is the proportion of incident solar radiation transferred through the product, and is a decimal fraction between 0.0 (totally opaque) and 1.0 (a hole in the wall).

Lower U-factors are always desirable as they represent less heat transfer (primarily winter heat loss) and, therefore, less energy needed for heating and cooling. The merits of increasing or reducing the SHGC depends on building specific design parameters. In a suitably designed building, fenestration with high solar heat gain can reduce the need for heating in winter. However, in many buildings, it is also beneficial to reduce solar heat gain in summer for comfort or to reduce the need for cooling. This balance between summer and winter priorities requires consideration of the entire building design, including building orientation, exterior shading, window area and glazing properties.

Energy Performance Regulations: Building Codes and the *Energy Efficiency Act*

In British Columbia, the energy performance of fenestration is regulated through building codes as well as the *Energy Efficiency Act* (EEA). The 2006 British Columbia Building Code (BCBC), revised in 2008 for energy requirements, and the 2007 Vancouver Building By-law (VBBL) establish the energy performance requirements for fenestration used in new high-rise construction (five-storeys or more), as well as for some renovation projects. The EEA further regulates manufacturers and establishes minimum energy performance requirements for fenestration products. In general, the EEA fenestration energy performance requirements will apply for:

- Part 9 residential buildings
- Part 3 residential buildings of four-storeys or less in building height
- Windows used in replacement or rehabilitation projects, and
- More generally for building types where fenestration energy performance is not specifically addressed by the building codes.

The Roadmap for Fenestration Energy Performance Requirements (Roadmap) illustrates the interrelationship between the BCBC, VBBL and the EEA for various size buildings.

The BCBC, VBBL and EEA each rely on supporting standards to provide specific methodology for determining and reporting energy performance values. These standards or programs include:

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings (City of Vancouver).
- ASHRAE 90.1-2004 (Remainder of British Columbia).
- National Fenestration Rating Council (NFRC) 100-2004 Procedure for Determining Fenestration Product U-factors.
- NFRC 200-2010 Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence.
- NFRC 100-2010 Procedure for Determining Fenestration Products U-factors.
- Canadian Standards Association (CSA) A440.2-04 Energy Performance of Windows and Other Fenestration Systems.

British Columbia Building Code (BCBC)

The BCBC is administered by the BC Ministry of Energy and Mines, Office of Housing and Construction Standards, with enforcement by local municipal authorities. BCBC Section 9.7 deals specifically with windows in Part 9 buildings and references CSA A440.0 for structural, water penetration and airtightness performance requirements. However, the related energy performance standard CSA A440.2-04, Energy Performance of Windows and Other Fenestration Systems, is not referenced and, therefore, does not form part of the BCBC requirements.

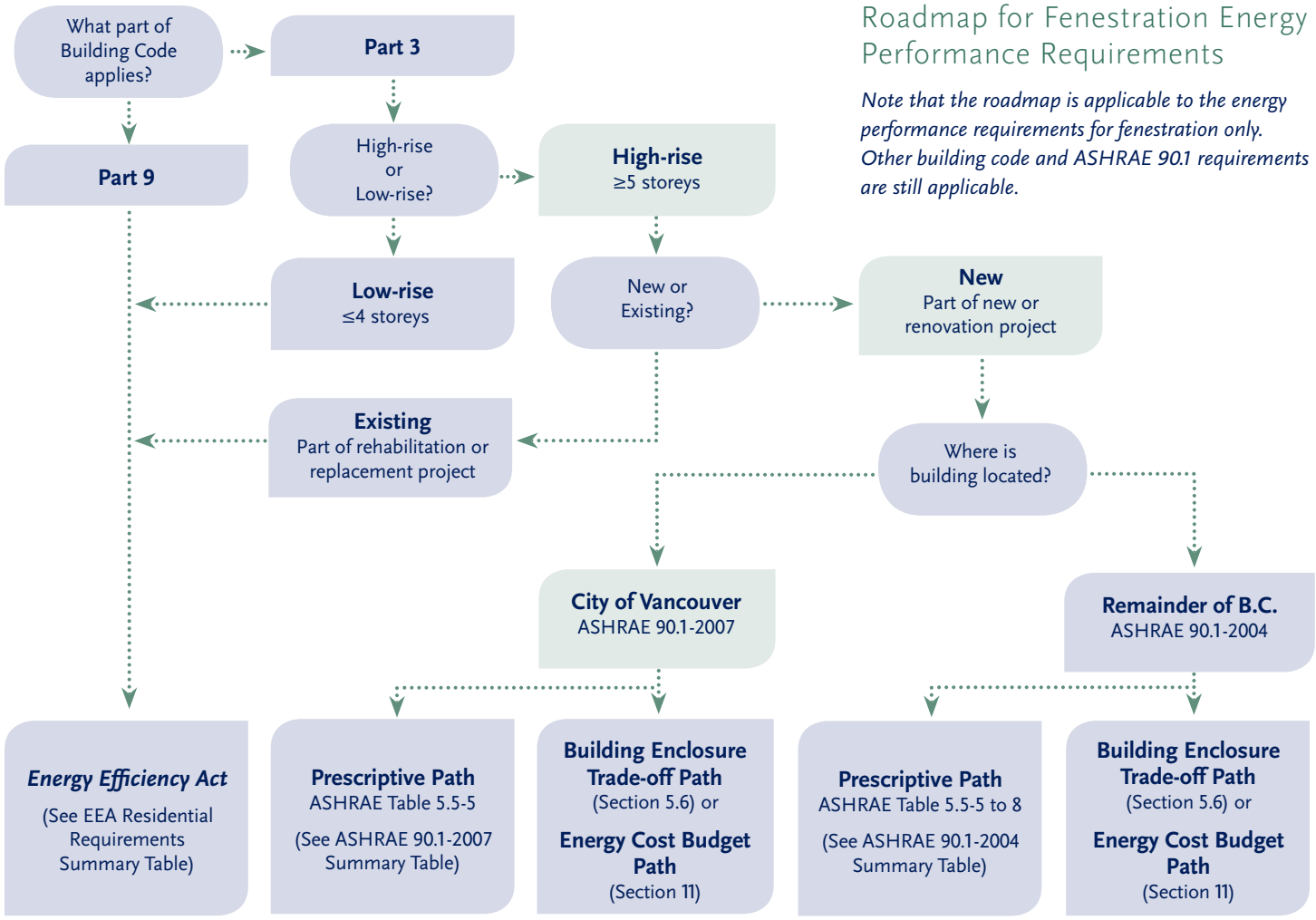
BCBC Part 10 requires that all new Part 3 residential buildings of five-storeys or more in building height comply with the requirements of ASHRAE 90.1-2004 which includes the energy performance of fenestration. The energy performance requirements for fenestration in other buildings, including Part 9 buildings and buildings of four-storeys or less, are addressed by the EEA.

Vancouver Building By-Law (VBBL)

The VBBL requires that all new Part 3 buildings of five-storeys or more in building height comply with the requirements of ASHRAE Standard 90.1-2007. Similar to the BCBC, fenestration for VBBL Part 9 buildings and buildings of four-storeys or less must comply with the EEA. Windows in one and two family dwellings must also comply with the City of Vancouver's Green Homes Program (U ≤2.0 W/ m^2•°K, consistent with the EEA).

Roadmap for Fenestration Energy Performance Requirements

Note that the roadmap is applicable to the energy performance requirements for fenestration only. Other building code and ASHRAE 90.1 requirements are still applicable.



Energy Efficiency Act (EEA)

The EEA is not part of the BCBC or the VBBL and is administered and enforced by the BC Ministry of Energy and Mines, Energy Efficiency Branch. The EEA was amended in 2008, 2009 and 2011 to include minimum energy performance requirements for fenestration products sold in British Columbia, regardless of where they are manufactured.

The EEA sets out prescriptive energy performance requirements for fenestration used in residential buildings of four-storeys or less. Fenestration used within residential buildings that are five-storeys or more must comply either with the EEA, or be used in buildings that comply with ASHRAE 90.1-2004, 2007 or 2010. The EEA exempts products that are installed in an ASHRAE 90.1 compliant building.

The EEA requires that the energy performance of all windows be determined using the procedures of CSA A440.2-04 or NFRC 100. Most fenestration products must also be labelled under the supervision of an energy certification practitioner or an organization accredited by the Standards Council of Canada (SCC) or NFRC. Products must bear both a permanent label identifying the certification organization as well as a temporary label showing the U-factor in metric units. Other performance information can be included on the temporary label but is optional.

For larger buildings (five-storeys or more), label certificates may be used in lieu of temporary and permanent labels applied to windows.

The EEA also provides for products that fall outside of the scope of certification programs (e.g. commercial glazing products like curtainwall or storefront that are used both on residential and commercial buildings). In these instances, professional engineers or architects are permitted to certify compliance on a project specific basis. The calculations performed are based on an area weighted average U-factor for all products that are not certified. A certification letter bearing the professional's seal is issued at the beginning of the project. A sealed verification letter is also submitted upon completion of the project.

BC Energy Efficiency Act – Residential Requirements

Four-storeys or Less		Five-storeys or More	
Windows and Glazed Doors Frame Types	**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)	**Windows and Glazed** Doors Frame Types	**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)
Vinyl and fibreglass	0.35 (2.0)		
Wood	0.35 (2.0)	Non-metal	0.35 (2.0)
Metal	0.35 (2.0)	Metal	0.45 (2.57)
Skylights	0.55 (3.1)	**Skylights**	0.55 (3.1)
Exemptions • Decorative – stained glass, inserts and blinds inside the insulated glazing unit (IGU) • Products installed in designated heritage buildings and buildings included in local or provincial heritage registers • IGU replacements in an existing sash and frame • Products used in non-heated buildings • Products exported from B.C.		**Exemptions** • Buildings compliant with ASHRAE 90.1 (2004, 2007 or 2010) • Products installed in designated heritage buildings and buildings included in local or provincial heritage registers • IGU replacements in an existing sash and frame • Products used in non-heated buildings • Products exported from B.C.	

ASHRAE 90.1

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is a research and standards writing organization based in the United States. The BCBC references ASHRAE 90.1-2004 while the VBBL references ASHRAE 90.1-2007. Both standards provide energy performance requirements based on climate zones. The climate zones are determined based on Heating Degree-Days (HDD) resulting in four distinct zones within British Columbia. A HDD is a measure of how cold a location is over a one-year period relative to a base temperature of 18°C.

There are two key differences between the 2004 and 2007 versions of ASHRAE 90.1 with respect to fenestration energy performance requirements. The 2007 standard differentiates maximum U-factor requirements based on the frame material type, whereas the 2004 standard requires the same performance levels for all frame types. In addition, the 2007 standard limits the window area to 40% of the wall area when using the *Prescriptive* compliance path. The 2004 standard allows 50% window area when using the *Prescriptive* compliance path. Buildings with greater than these window areas can comply using the *Building Envelope Trade-off Method* or *Energy Cost Budget* compliance paths.

ASHRAE 90.1 Climate Zones for British Columbia. Actual Heating Degree-Days (HDD) for most municipalities in British Columbia can be found in Appendix C, Division B of the BC Building Code. The map above is intended to provide a general representation of the ASHRAE 90.1 Climate Zones; the actual BCBC tabulated values for HDD should be used to determine ASHRAE Climate Zones. There is one exception to this rule. BCBC tabulated HDD values place some Lower Mainland and Vancouver Island municipalities in Climate Zone 4. However, the ASHRAE 90.1 HDD data set is slightly different and locates these municipalities in Climate Zone 5. As a result, there is currently no Zone 4 area within British Columbia for the purpose of AHSRAE 90.1 energy performance compliance.

ASHRAE 90.1 – 2007 Fenestration U-factors and SHGC Summary – City of Vancouver

	VBBL – ASHRAE 90.1-2007 Climate Zone 5	
Windows and Glazed Doors	**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)	**Assembly Maximum SHGC** All Orientations
Non-metal frames (Vinyl, fibreglass and wood)	0.35 (2.0)	0.40
Metal framed (aluminum)	0.55 (3.1)	0.40
Metal frames (Curtainwall and storefront)	0.45 (2.57)	0.40
Skylights		
Glass with curb		
Area (% of roof): 0-2.0%	1.17 (6.64)	0.49
Area (% of roof): 2.1-5.0%	1.17 (6.64)	0.39
Plastic with curb		
Area (% of roof): 0-2.0%	1.10 (6.25)	0.77
Area (% of roof): 2.1-5.0%	1.10 (6.25)	0.62
Plastic and glass without curb		
Area (% of roof): 0-2.0%	0.69 (3.92)	0.49
Area (% of roof): 2.1-5.0%	0.69 (3.92)	0.39

Notes: 40% maximum window area for Prescriptive path, 5% maximum skylight area for Prescriptive path.

Both ASHRAE 90.1 standards require that U-factors be determined through an accredited organization such as the National Fenestration Rating Council (NFRC), and that NFRC 100 procedures be followed to determine the U-factors. SCC accredited organizations are not acceptable for ASHRAE 90.1 compliance. NFRC has a comprehensive training and evaluation program for test labs and simulators and requires physical testing to verify results obtained through simulation. Uniform procedures are followed by all parties involved in energy performance measurement. Both ASHRAE 90.1 standards require that manufactured windows have permanent labels that list the U-factor, SHGC and air leakage rate. Doors only require U-factor and air leakage rate to be listed.

NFRC U-factors are based on standard window sizes, and are not representative of the actual window sizes and configurations installed in a building. In order to use either the *Building Envelope Trade-off Method* or *Energy Cost Budget* compliance paths, additional simulation work will be required. Effective U-values must consider actual sizes, configurations, corner posts, couplers, integral flashing components, internal reinforcing, hardware and anchors.

Non-Residential Buildings

This bulletin focuses on requirements for residential buildings.

The EEA also addresses non-residential buildings. The only difference for non-residential buildings is that the low-rise requirements apply to buildings of 600 m² or less, rather than four-storeys or less.

ASHRAE 90.1-2004, 2007 and 2010 standards have a distinct category and performance requirements for non-residential buildings. These performance values may vary from those shown in this bulletin for residential buildings.

NFRC has a comprehensive training and evaluation program for test labs and simulators and requires physical testing to verify results obtained through simulation.

ASHRAE 90.1 – 2004 Fenestration U-factors and SHGC Summary – Remainder of B.C.

		ASHRAE 90.1-2004 Climate Zone 5		ASHRAE 90.1-2004 Climate Zone 6		ASHRAE 90.1-2004 Climate Zone 7		ASHRAE 90.1-2004 Climate Zone 8	
Windows and Glazed Doors (all frame types) **Area** (% of wall)		**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)	**Assembly Maximum SHGC** All (North)	**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)	**Assembly Maximum SHGC** All (North)	**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)	**Assembly Maximum SHGC** All (North)	**Maximum U-factor** Btu/h•ft²•°F (W/m²•°K)	**Assembly Maximum SHGC** All (North)
0-10%	Fixed	0.57 (3.24)	0.49	0.57 (3.24)	0.49	0.57 (3.24)	0.49	0.46 (2.61)	NR
	Operable	0.67 (3.80)	(0.49)	0.67 (3.80)	(0.64)	0.67 (3.80)	(0.64)	0.47 (2.67)	NR
10.1-20%	Fixed	0.57 (3.24)	0.39	0.57 (3.24)	0.39	0.57 (3.24)	0.49	0.46 (2.61)	NR
	Operable	0.67 (3.80)	(0.49)	0.67 (3.80)	(0.49)	0.67 (3.80)	(0.64)	0.47 (2.67)	NR
20.1-30%	Fixed	0.57 (3.24)	0.39	0.57 (3.24)	0.39	0.57 (3.24)	0.49	0.46 (2.61)	NR
	Operable	0.67 (3.80)	(0.49)	0.67 (3.80)	(0.49)	0.67 (3.80)	(0.64)	0.47 (2.67)	NR
30.1-40%	Fixed	0.46 (2.61)	0.39	0.57 (3.24)	0.39	0.57 (3.24)	0.49	0.46 (2.61)	NR
	Operable	0.47 (2.67)	(0.49)	0.67 (3.80)	(0.49)	0.67 (3.80)	(0.64)	0.47 (2.67)	NR
40.1-50%	Fixed	0.57 (3.24)	0.26	0.46 (2.61)	0.26	0.46 (2.61)	0.36	0.35 (2.00)	NR
	Operable	0.67 (3.80)	(0.49)	0.47 (2.67)	(0.49)	0.47 (2.67)	(0.64)	0.39 (2.21)	NR
Skylight Area (% of roof)									
Glass	0–2.0%	1.17 (6.64)	0.49	0.98 (5.56)	0.49	1.17 (6.64)	0.64	0.98 (5.56)	NR
With curb	2.1–5.0%	1.17 (6.64)	0.39	0.98 (5.56)	0.39	1.17 (6.64)	0.64	0.98 (5.56)	NR
Plastic	0–2.0%	1.10 (6.25)	0.77	0.74 (4.20)	0.65	1.17 (6.64)	0.77	0.61 (3.46)	NR
With curb	2.1–5.0%	1.10 (6.25)	0.62	0.74 (4.20)	0.55	1.17 (6.64)	0.77	0.61 (3.46)	NR
Plastic and glass	0–2.0%	0.69 (3.92)	0.49	0.58 (3.29)	0.49	0.58 (3.29)	0.64	0.58 (3.29)	NR
Without curb	2.1–5.0%	0.69 (3.92)	0.39	0.58 (3.29)	0.39	0.58 (3.29)	0.64	0.58 (3.29)	NR

Notes: 5% maximum skylight area for prescriptive path, 50% maximum window area for Prescriptive path, NR = not required.

ENERGY STAR Program

ENERGY STAR in Canada is administered by Natural Resources Canada's (NRCan's) Office of Energy Efficiency. It is a voluntary program that qualifies windows and doors in different climate zones based on U-factor and Energy Rating (ER). Three zones have been defined for British Columbia. The calculation protocol must conform to either CSA A440.2-04 or NFRC 100 procedures. The ER is calculated as specified in CSA A440.2-04.

The ENERGY STAR U-factors are lower (more stringent) than those required by the *BC Energy Efficiency Act* and ASHRAE 90.1. As a voluntary program, it is not part of energy performance regulation in B.C. However, ENERGY STAR product labels are valid for reporting a product's U-factor for compliance with the EEA.

Additional information regarding ENERGY STAR program requirements, available products and ratings can be found on the ENERGY STAR Canada website at www.oee.nrcan.gc.ca.

National Fenestration Rating Council Standards (NFRC – 100 and 200)

The National Fenestration Rating Council (NFRC) is a U.S. based non-profit organization that administers a voluntary, uniform rating, labelling and certification system for the energy performance of windows, doors, curtain walls, skylights and other fenestration products. NFRC standards are used to determine U-factor (NFRC–100), Solar Heat Gain Coefficient (NFRC–200), visible transmittance and condensation resistance properties. The NFRC certification program is administered through accredited independent certification and inspection agencies, and includes certification of testing and simulation labs, simulators and approved calculation entities.

The primary purpose of NFRC energy performance certification is to compare the energy performance of various fenestration products at specified sizes and environmental conditions. NFRC U-factors do not represent actual performance under local

environmental conditions, or for sizes different from those specified in NFRC documents. NFRC ratings are recognized by ASHRAE because they are the only independently validated source of fenestration energy performance in the U.S. NFRC U-factors are also recognized by the EEA in British Columbia and by the Canadian ENERGY STAR program. NFRC requires the energy performance of certified products to be labelled. Factory glazed products are labelled by manufacturers under the supervision of an Inspection and Certification Agency (IA). Each product must bear a permanent label identifying the manufacturer and product line indentification number (CPD), and one or more temporary labels showing the energy performance ratings for each operator type (at standard sizes) within each overall assembled unit. A combination window would have separate labels for the fixed glazing and for the operable sash. NFRC temporary labels will always display the product U-factor, SHGC and visible transmittance, and may also display additional performance information. On large projects a single label certificate may be used for this purpose. Field-glazed 'commercial' products can also be rated and labelled on a project basis by an NFRC recognized Approved Calculation Entity (ACE).

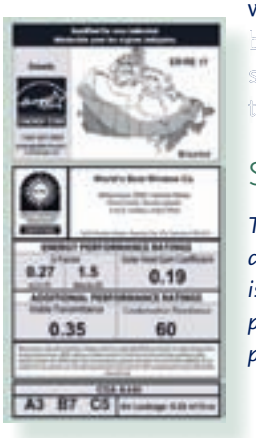
Canadian Standards Association (CSA) A440.2-04

The Canadian Standards Association is a non-profit, membership-based association serving business, industry, government and consumers in Canada.

CSA A440.2-04, Fenestration Energy Performance, is the Canadian standard for determining the energy performance of fenestration products. The 2009 edition harmonizes the energy property calculations with those of NFRC.

U-factors determined by CSA A440.2-04 are recognized by the EEA in British Columbia, and by the Canadian ENERGY STAR program. They are not recognized by ASHRAE.

CSA A440.2-04 defines a unique Canadian energy performance property, the Energy Rating (ER). In addition to heat loss as measured by the U-factor, the ER considers heat lost through the product due to air leakage as well as energy captured 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 the impact on cooling.



Sample Temporary Window Label

The top portion represents the ENERGY STAR component of the label. The middle section is the NFRC portion, while the bottom portion provides additional optional labelling performance criteria specified by A440.0.

Project Accountability and Verifying Compliance

Letters of Assurance

The BCBC uses Letters of Assurance (LOA) as the primary accountability tool for registered professionals on Part 3 buildings. The format and content of LOA changed significantly in September 2010. For additional information, consult the *Guide to the Letters of Assurance in the BC Building Code 2006 December, 2010 Edition 5*, published by Building and Safety Standards Branch, Ministry of Housing and Social Development (www.bccodes.ca).

The new LOA explicitly identifies energy performance for architectural, electrical and mechanical disciplines. Specifically, item 1.24 of the architectural portion of the LOA states: *Building envelope, Part 10/ASHRAE requirements*. The architect is, therefore, taking responsibility for the design of the energy performance aspects of the building enclosure, including the fenestration. The architect may rely upon other registered professionals and information in taking responsibility for energy performance. For example, another architect, a building enclosure engineer, mechanical engineer or an engineer working for the window manufacturer may provide specific modeling and analysis services to support the energy performance values that are provided and used. In these instances, where another registered professional is providing support services, the use of Schedule S (for supporting registered professionals) which is endorsed by the Architectural Institute of BC (AIBC) and the Association of Professional Engineers and Geoscientists of BC (APEGBC), is the appropriate accountability document to be provided to the architect. The following should be noted with respect to the use of supporting registered professionals and Schedule S:

- Schedule S is not part of the BCBC LOA and, therefore, is not submitted to the authorities having jurisdiction.
- The use of a supporting registered professional and Schedule S for any part of the LOA is not mandatory, and its use is solely at the discretion of the registered professional of record.
- The architect for a building not required to have LOA (smaller buildings) may still utilize supporting registered professionals and Schedule S, if desired.

Schedule S should be completed to suit the scope of services provided and can include design support services, field review services or a combination of both services. The City of Vancouver has not updated its LOA in a similar manner to the BCBC. The VBBL LOA does not explicitly identify energy performance of fenestration. However, signing of the architectural LOA does cover all performance aspects of windows mandated by the VBBL, including energy performance. As with the BCBC, the use of Schedule S is appropriate when receiving support from another registered professional with respect to energy performance.

Specifications

As the *Roadmap* illustrates, there are several paths that will facilitate compliance with the applicable building codes and the EEA. For larger new construction projects, registered professionals are required and are responsible for determining which of these compliance paths will be followed. The effective documentation of the intended compliance paths and required performance criteria for the window manufacturer is essential. Manufacturers should generally be aware of the requirements of the EEA, however, the EEA exempts windows installed in buildings that are compliant with ASHRAE 90.1 (2004 or 2007). A statement should be included in the windows specification section noting whether or not the EEA prescriptive requirements apply to the project. In addition, the required U-factors and SHGC should be included, along with the other performance requirements for the windows (water penetration resistance, airtightness, condensation resistance, structural, visible light transmittance etc.), as is appropriate.

When specifying the energy performance requirements for a project, keep in mind that there are often compromises made during the bid review process or during construction that may impact the final energy performance values of the installed fenestration products. Some allowance should be made at the design stage for the potential erosion of the design intent at later stages of the project.

Construction Stage

It is common to request shop drawings and possibly samples of window and door products to be submitted for projects. As part of these submissions, the manufacturers should be requested to provide confirmation of the energy performance attributes of their products. If an ASHRAE 90.1 compliance path is utilized then project specific configurations, window areas, and the impact of ancillary elements of the window system on the overall U-factor (corner posts, integral flashing anchors etc.) will need to be considered. Field review can confirm that the installed window assembly complies with the material specifications and project specific shop drawings.

Key Points

- The architect is responsible for the design of the energy performance aspects of fenestration through Letters of Assurance.
- Fenestration energy performance compliance requirements include three alternate paths within the ASHRAE 90.1 standard, as well as the EEA. Only one set of fenestration energy performance requirements will govern a particular building project.
- For fenestration rehabilitation or replacement programs, the EEA is often the only practical approach for determining fenestration energy performance requirements, although the BCBC or VBBL (through reference to ASHRAE 90.1) may also theoretically apply.
- There are two key differences between the 2004 and 2007 versions of ASHRAE 90.1 with respect to fenestration performance requirements: maximum window to wall ratios, and U-factors based on frame material type.
- ASHRAE 90.1 (2004 and 2007) standards require that U-factors be determined through an NFRC accredited organization. ASHRAE 90.1 standards do not recognize U-factors obtained by CSA A440.2.
- Effective U-factors used in either of the ASHRAE 90.1 trade-off compliance paths must consider actual sizes and configurations, corner posts, couplers, integral flashing components and anchors.
- U-factors generally must be certified and visibly confirmed through product labelling. Alternative letter certification is permitted in some circumstances.
- Fenestration is usually one of the best opportunities to improve energy performance of the building enclosure.

For More Information

- *ASHRAE Standard 90.1-2004 and 90.1-2007*, Energy Standard for Buildings Except Low-Rise Residential Buildings, www.ashrae.org.
- *2009 ASHRAE Handbook* – Fundamentals (I-P) or Fundamentals (SI), www.ashrae.org.
- *National Fenestration Rating Council (NFRC)*, www.nfrc.org.
- *Building Enclosure Design Guide – Wood-Frame Multi-Unit Residential Buildings*, Homeowner Protection Office, 2011, www.hpo.bc.ca.
- *Builder Insight#7 ASHRAE 90.1 Requirements for the Building Enclosure: Understanding the Compliance Path for Multi-Unit Residential Buildings*, Homeowner Protection Office, 2010, www.hpo.bc.ca.

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