Transforming the Window and Glazing Markets in BC through Energy Efficiency Standards and Regulations

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ABSTRACT

This paper provides an overview of a collaborative market transformation strategy led by the Ministry of Energy, Mines, and Petroleum Resources to promote and improve the energy efficiency of windows and glazing assemblies for new and existing buildings in British Columbia (BC). This included regulations under the BC *Energy Efficiency Act*, applying to products for new and existing buildings, and a reference to the ASHRAE standard 90.1-2004 in the BC Building Code, applying to new high-rise and large building construction.

Analytical work illustrated the energy impacts of the regulations for various window product types and percentage of building glazing for high-rise, multi-unit residential buildings. The estimated energy savings from the *Energy Efficiency Act* standards for metal-framed windows in the sample building is about 2.2% of the total building energy demand. This can increase to 4.4% if non-metal framed windows are installed.

The paper presents findings from surveys of window manufacturers and building officials on the effectiveness of the market transformation strategy to improve energy efficiency of windows and glazing assemblies. The results of the surveys confirm success of the adopted strategy, while also identifying the need for further improvements around overall compliance and testing costs for small manufacturers.

INTRODUCTION

The purpose of this paper is to summarize, evaluate and describe the benefits of the market transformation strategy of the British Columbia (BC) Ministry of Energy, Mines and Petroleum Resources (MEMPR) to promote energy efficient fenestration products. MEMPR is responsible for programs and policies pertaining to energy efficiency, including regulations under the *Energy Efficiency Act* for equipment and manufactured building components such as windows and glazing assemblies. These regulations apply to products destined for both new construction and existing buildings in the province. The BC Building Code references ASHRAE Standard 90.1-2004, administered by the Office of Housing and Construction Standards, applying primarily to new construction. The combined impact of the *Energy Efficiency Act* and BC Building Code ensures that all manufactured windows and glazing assemblies have energy efficiency requirements, regardless of application, effectively mandating a low-emissivity coating for all products sold. Estimated energy savings from the regulations for a typical multi-unit residential building are presented in this paper.

BC's market transformation strategy included consumer information, industry training, market stimulus, voluntary commitments and regulatory measures introduced between 2005 and 2010, largely based on ENERGY STAR® standards (NRCan 2005). This paper provides an overview of those measures, established by the provincial and federal governments, electric utilities and the Window and Door Manufacturers' Association of BC (WDMA-BC). The government policy context

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was set by two generations of an "Energy Efficiency Building Strategy" that include aggressive energy efficiency and greenhouse gas emission reduction targets for new and existing buildings, such as a 20% reduction in energy use per household by 2020 and a 1.8 million tonne emission reduction for all sectors in 2020 (BC MEMPR 2008). The strategy is the topic of a separate ASHRAE conference paper (Pape-Salmon et.al. 2010a).

The evaluation of energy efficiency measures is based on market statistics and results from two surveys that sought input from window manufacturers and local building officials on the effectiveness of governments' and utilities' efforts. Further evaluation of BC's efforts is presented in Pape-Salmon et.al. (2010b), including a comparison against practices in other jurisdictions.

OVERVIEW OF ENERGY EFFICIENCY MEASURES

In 2004, the BC Ministry of Energy, Mines and Petroleum Resources (MEMPR) announced a goal to permanently transform the market for windows, glazing assemblies and doors, such that 100% of those products sold in BC are energy efficient by 2010. Significant progress was made through the introduction of ten policy and market measures (several summarized below, see Pape-Salmon et.al. 2010b for a comprehensive list) by a number of parties, coordinated by MEMPR. The measures were broadly designed to address market barriers to energy efficiency by increasing awareness, acceptance, availability and affordability of ENERGY STAR products, followed by regulations to solidify the transformation.

Natural Resources Canada ENERGY STAR® Program

ENERGY STAR sets standards for windows based on a maximum U-value, an "Energy Rating" (ER) alternative and a maximum air leakage rate. MEMPR based its market transformation program on the ENERGY STAR U-value standard for Zone A (coastal BC), equivalent to 0.35 BTU/(h·ft²·°F) (USI 2.0 W/(m^2·K)). As of October 2010, the standards were revised to a more stringent level of U-0.32 (USI-1.8) (NRCan 2009), partly in response to BC's window regulations. At this time, there are no ENERGY STAR criteria for glazing assemblies for large buildings.

In addition to branding energy efficiency standards that simplify consumer choice, the ENERGY STAR program provides an online database of qualified products, hosts and co-chairs the Energy Efficient Fenestration Steering Committee to provide advice on a variety of technical and programmatic issues, undertakes national advertising and defines protocols for product labeling.

MEMPR Programs and Incentives

In 2006 and 2007, MEMPR retained a "Capacity Building Coordinator" to provide information and advice to BC-based manufacturers on the process to test products, certify manufacturing and apply for ENERGY STAR qualification. The Coordinator also provided confidential feedback on product designs. The relationships established through these efforts opened new channels for MEMPR to effectively communicate its energy efficiency vision to the industry. The Coordinator also helped increase the credibility of WDMA-BC as an industry representative, including the interests of small manufacturers, as many barriers raised by manufacturers were passed on to WDMA-BC for follow-up (Jaugelis 2010).

All ENERGY STAR qualified and listed windows and doors were exempt from the provincial sales tax (7%) between 2007 and 2010, valued at several million dollars per year in foregone revenue to the BC Government. In addition, MEMPR invested $200,000 to subsidize product testing for 35 BC-based manufacturers at Standards Council of Canada or National Fenestration Rating Council (NFRC) accredited laboratories. This helped to defray their cost to qualify products for ENERGY STAR, particularly important for small production manufacturers, given that their testing costs per product line are comparable to those of large manufacturers, thus having a greater proportionate impact on their bottom line.

Since 2008, rebates of $20-$40 have been provided for each ENERGY STAR qualified product installed in existing houses under the LiveSmart BC: Efficiency Incentive Program. This whole-house, energy efficiency program includes assessments by Certified Energy Advisors, advice on appropriate energy efficiency upgrades, rebates for energy efficiency improvements and an "EnerGuide for Houses" label with a performance rating between 0 and 100. Two tiers of rebates are

provided for windows – for those qualified within the ENERGY STAR zone where they are installed, and a higher rebate for those qualified for one zone higher. The rebates amounts were based on the estimated greenhouse gas emissions reductions over 12 years multiplied by a $25 per metric tonne emission abatement value.

Energy Utility Demand-Side Management Programs

BC's two major electric utilities, BC Hydro and FortisBC, have been instrumental in promoting and driving acceptance of ENERGY STAR labelled windows through their demand-side management programs. On the consumer side, this includes information materials such as leaflets enclosed with power bills, along with promotions and incentives such as a $\$1/ft^2$ rebate offered in conjunction with MEMPR until 2007 and a "win your windows contest". On the industry side, they share costs with manufacturers to promote ENERGY STAR products, including point-of-purchase displays and media campaigns. BC Hydro also publishes an energy efficiency newsletter for manufacturers. Finally, both utilities support the WDMA-BC's meetings and events, and promote ENERGY STAR products among builders, developers and property managers.

BC Hydro's Power Smart New Construction program promotes "whole building design" for large buildings early in their construction phase, including rebates for energy studies and capital incentives for energy efficiency improvements such as the use of higher performance glazing assemblies. The energy studies define the baseline which needs to be at least better than the building code requirements (ASHRAE 90.1). The capital incentives are tiered, based on the percentage of electricity savings achieved in proportion to the baseline.

Energy Efficiency Act standards for new construction and replacement products

The following standards were set in regulation in 2006 and revised in 2008 and 2009 (Queens Printer 2009).

Table 1. BC Energy Efficiency Act Standards for Windows and Glazing Assemblies

Product	U-value Requirement (USI)	Effective Date
Non-metal windows in small buildings (residential buildings with less than 5 stories and other buildings with less than 6,458 ft^2 / 600 m^2 of floor space)	0.35 (2.0)	Mar 1, 2009
Metal framed windows in small buildings – interim standard	0.45 (2.57)	Jun 1, 2009
Metal framed windows in small buildings – final standard	0.35 (2.0)	Jan 1, 2011
Wood windows in small buildings	0.35 (2.0)	Jan 1, 2011
Skylights in all buildings	0.54 (3.1)	Mar 1, 2009
Metal framed windows, sliding glass doors, curtain walls, window walls or storefront windows for large buildings (residential buildings with 5+ stories and other buildings with 6,458 ft^2 / 600 m^2 of floor space or higher)	0.45 (2.57)	Jan 1, 2011
Non-metal products for large buildings	0.35 (2.0)	Jan 1, 2011

Test standards for windows and glazing assemblies include either Canadian Standards Association (CSA) A440.2 (2004) or NFRC 100 (2004), both applying to the overall assembly. Exemptions apply to products installed in designated heritage buildings and large buildings that are compliant with ASHRAE Standard 90.1. The multitude of effective dates was designed to address varying degrees of market readiness for different product types.

Two levels of labelling are required: (1) a permanent label, word mark, trademark or symbol from a Canadian Standards Council accredited certification organization or an NFRC accredited Inspection Agency that verifies that the product complies with the requirements, and (2) a temporary label setting out the U-value in metric units. The latter is designed to educate consumers and encourage energy performance beyond the regulated levels, and can be removed by the end consumer.

Flexibility is provided for windows designed for unique structural support purposes in a specific building, where the design falls outside the scope of existing certification programs. This allows for some products to be less energy efficient

(e.g., large structural windows), provided that the area weighted average U-value is meets the regulated standard performance requirements.

BC Building Code and Vancouver Building Bylaw

The BC Building Code (BCBC) (BCOHCS 2008) applies to new construction and major renovations, and is generally enforced by municipal building inspectors. Effective September 2008, residential buildings of 5+ stories, or non-residential buildings with 4+ stories or 6,458 ft^2 (600 m^2) of floor space are required to meet the ASHRAE Standard 90.1-2004 (hereby referred to as 90.1). Prior to 2008, the BCBC didn't include any energy efficiency provisions for large/high-rise buildings. Also, the 90.1 standard doesn't apply to low-rise/small commercial buildings, but instead the BCBC has prescriptive insulation tables that are based on 90.1. The aforementioned *Energy Efficiency Act* window standards apply to all building types.

The City of Vancouver has its own Building Bylaw that references 90.1-2007. The City has a long history regulating the energy performance of large buildings, previously referencing 90.1-2001 in its Energy Utilization Bylaw.

In March 2010, the BC Office of Housing and Construction announced a proposal to introduce new performance targets for houses (low-rise) in the Building Code with an effective date of October 2011. These would set standards for the overall thermal resistance and air leakage of the building envelope, including windows. For large buildings, MEMPR will propose reference to the 2011 National Energy Code for Buildings being developed by the Canada Commission on Fire and Building Codes. Unlike ASHRAE 90.1, the performance path of this standard is based on energy performance, not energy cost.

POTENTIAL FOR ENERGY SAVINGS WITH IMPROVEMENTS TO GLAZING ASSEMBLIES

The following sections illustrate the need for heat transfer improvements in window products and whole building designs. In order to meet the energy efficiency and greenhouse gas emission targets, an integrated systems approach based on in-service data is needed for the design and construction of sustainable buildings (Knowles et.al. 2010). Effective regulations must recognize this need.

Energy consumption in a building occurs through a variety of different systems and appliances. A recent study of the energy consumption of existing high-rise residential buildings (RDH 2010) allowed for the calibration of energy consumption models with actual consumption data, before and after major building enclosure renovations of 11 buildings, and before renovations of two buildings. Based on this data, a model (i.e., DOE2 engine with interface developed by Enersys Analytics Inc.) of a typical, non combustible building was created in order to estimate the impact of the *Energy Efficiency Act* window/glazing assembly regulations and the adoption of 90.1-2004, 90.1-2007 and ASHRAE 189.1 prescriptive building enclosure requirements.

Figure 1 illustrates the breakdown of energy consumption for this sample high-rise residential building in Vancouver, BC. The largest portion of energy consumption is related to space heating, even in Vancouver's relatively mild climate. Only one building in the 39 cases had space cooling.

Space heating in the model building was found to be primarily related to conduction heat loss and air leakage through the building enclosure and pre-heating for the mechanical ventilation. Figure 2 illustrates three different space heat breakdown scenarios at different air leakage rates. The enclosure air leakage was assumed to be 0.15 cfm/ft^2 (0.76 $l/s/m^2$) at average operating pressures, based on the

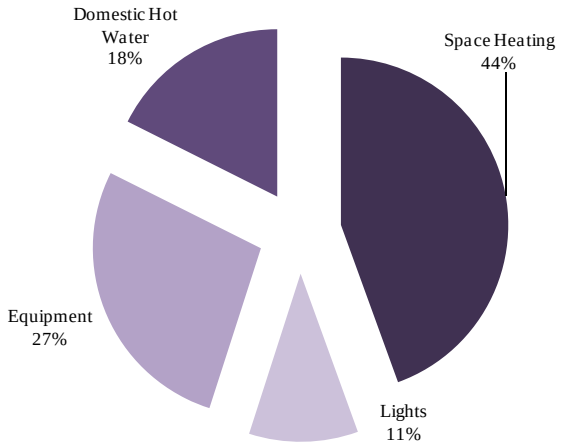

Figure 1 *Distribution of energy consumption in a sample building*

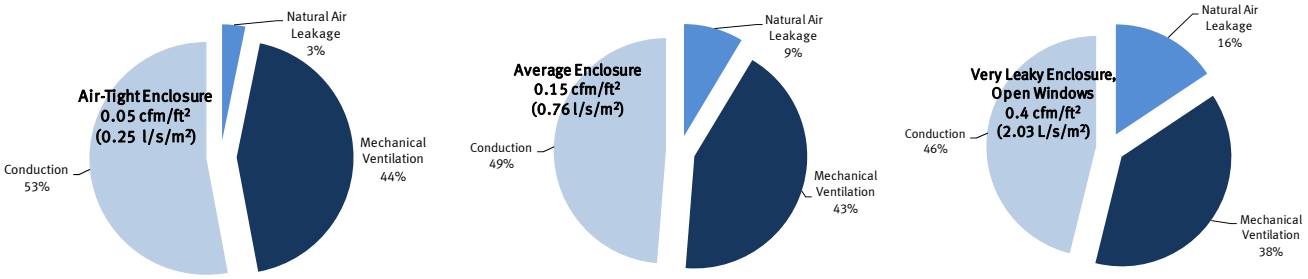

Figure 2 *Means of space heat loss through a sample building at different air leakage rates*

study of in-service buildings. The "compliant enclosure" in the figure refers to the R-value resulting from the minimum wall and window prescriptive requirements under 90.1-2004.

As part of the assessment of potential improvements to building products, the components of the building enclosure and their relative impact on energy conservation were considered. This is particularly important given that standards in the BC Building Code for building air leakage are limited. Figure 3 illustrates the impact of increased building envelope glazing assemblies (as a percentage of total wall area) on the overall building R-value for six different levels of window energy performance. These R-values are based on the prescriptive requirements of 90.1 for steel framed wall assemblies in Climate Zone 5 (R-13 + R-7.4 ci), an effective value of approximately R-15.6 (h·ft^2/Btu) (RSI-2.75 m^2·K/W).

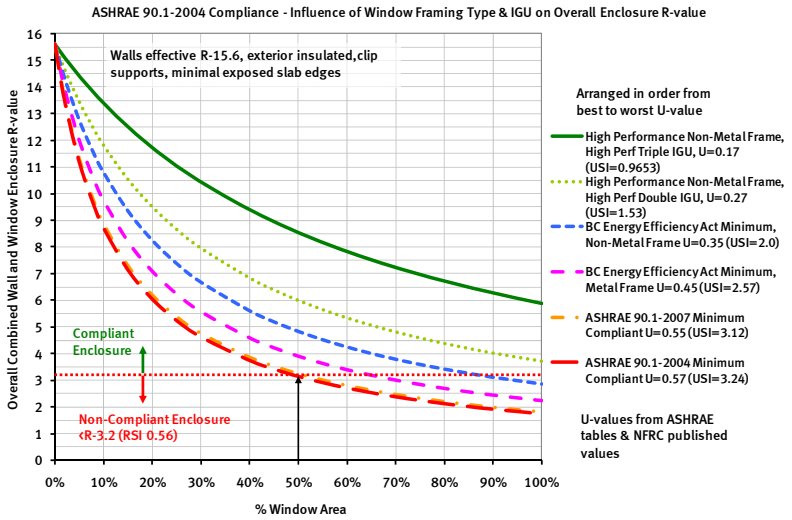

Figure 3 *Relationship of glazing percentage on overall building R-value*

The impacts of different window performance characteristics on the total building energy consumption was modelled based on the sample building. These results are provided in Table 2 below. It is estimated that the *Energy Efficiency Act* window requirements will result in a 2.2% reduction in total energy consumption for metal-framed windows, and 4.4% reduction in energy consumption when non metal frames (e.g., vinyl, fibreglass, etc.) are installed into an existing high-rise residential building in coastal BC. Most of these savings are from in-suite space heating. The effect on overall building energy consumption as a result of the currently regulated, prescriptive glazing assembly requirements referenced in the 90.1-2004 standard are comparable to the energy performance of the sample existing building (due to greater solar heat gain in the sample building compared to 90.1, offsetting space heat consumption). By comparison, improvements to lighting systems to meet the ASHRAE 90.1-2007 and ASHRAE 189.1 requirements would result in reductions of 0.9% and 1.4% respectively. While these results are specific to high-rise residential buildings, it is conceivable that other building types will yield similar results due to similarities in construction. This is the topic for future research and analysis.

The research study (RDH, 2010) found that further savings could be achieved through an integrated approach to whole building system improvement, rather than just individual components. For example, preliminary findings from the sample building model found that changes to wall and glazing assemblies during building renovations, combined with improved ventilation strategies (e.g., heat recovery, compartmentalization of residential units, individual suite make-up air, make-up air set point temperature, etc.) could potentially reduce space heat energy consumption to approximately 30% of the current levels (a 70% reduction).

Table 2. Comparison of Different Window Performance Criteria on Total Building Energy Consumption

Case	Performance Standard (effective values)	Overall Product Performance Characteristics	Total Heating [kWh/m^2] (kWh/ft^2)	Total Bldg Energy [kWh/m^2] (kWh/ft^2)	% Total Savings
Existing Building Baseline	Wall R-3.6 (RSI-0.63), Roof R-12.7 (RSI-2.22), Glazing percentage: 46%	U-0.70 (USI-4.0), SHGC-0.67	83.2 (7.7)	187.1 (17.4)	0.0%
Changes to Sample Building					
Window	ASHRAE 90.1-2004	U-0.57 (USI-3.26), SHGC-0.4	83.3 (7.7)	187.2 (17.4)	-0.1%
	ASHRAE 90.1-2007	U-0.55 (USI-3.14), SHGC-0.4	82.7 (7.7)	186.6 (17.3)	0.3%
	ASHRAE 189.1-2009	U-0.45 (USI-2.57), SHGC-0.4	79.1 (7.4)	183.0 (17.0)	2.2%
	BC EEA metal frame	U-0.45 (USI-2.57), SHGC-0.4	79.1 (7.4)	183.0 (17.0)	2.2%
	BC EEA non-metal frame	U-0.35 (USI-2.0), SHGC-0.4	75.0 (7.0)	178.8 (16.6)	4.4%
	Non metal frame, low-e, argon fill, triple glazed	U-0.17 (USI-0.97), SHGC-0.3	67.6 (6.3)	171.5 (15.9)	8.4%
Lighting	ASHRAE 90.1-2007	0.7 W/ft^2 (7.53 W/m^2)	83.7 (7.8)	185.5 (17.2)	0.9%
	ASHRAE 189.1-2009	0.63 W/ft^2 (6.78 W/m^2)	84.1 (7.8)	184.4 (17.1)	1.4%

EFFECTIVENESS OF MEASURES

The evaluation of BC's energy efficiency measures for windows and glazing assemblies included a literature review of approaches taken in other jurisdictions and two surveys of industry players conducted in 2010. Results from the literature review are summarized in Pape-Salmon et.al. (2010b), highlighting that BC's efforts are among the most comprehensive taken, compared to initiatives in several jurisdictions in the United States.

Window Manufacturer Survey

The first survey was conducted by a University of Victoria researcher, Dian Ross. It targeted window manufacturers and sought their evaluation of the relative impact of ten energy efficiency measures on increasing consumer demand for ENERGY STAR windows and motivating manufacturers to introduce new energy efficient product lines. It also included questions about the average energy performance of product lines, changes in ENERGY STAR market share, implementation costs to meet the regulations and impacts on their staffing and manufacturing locations. The 17 respondents (a 19% response rate) were primarily manufacturers of windows for houses, rather than glazing assemblies for large buildings.

Manufacturers rated the ENERGY STAR program as the most impactful measure, followed by the *Energy Efficiency Act* regulations and the provincial sales tax (PST) exemption. The ENERGY STAR brand was ideally suited to increasing customer awareness on energy efficiency, due to its universality and simplicity. It established manufacturer support for energy efficiency by providing third-party branding, access to rebates and incentives and an opportunity for differentiation in a competitive market. Finally, it enabled product research and innovation by creating a space for increased profit margins (Ibid., 9), particularly those manufacturers that were first on the market with ENERGY STAR qualified products. The survey identified that the average ENERGY STAR market share among respondents has increased from 38% to 60% of sales between 2006 and 2009 (Ibid., 7) , confirming the benefits of market transformation. On the other hand, it identified that the regulations may have had a disproportionate financial impact on smaller businesses, indicated by high costs for product testing and plant certification as a percentage of total costs (Ibid., 8).

Building Official Survey

A survey of the building officials was conducted to evaluate the industry compliance with the new energy efficiency regulations for buildings and glazing assemblies across BC, and to provide input on regional market transformation indicators such as awareness and acceptance of the standards and product availability and affordability. The survey results also helped identify challenges with the implementation of these regulations as a basis for future improvements. A total of 28 officials responded to the survey, a response rate of about 5%, but the geographic distribution of the responses was good.

Local building inspectors are responsible for enforcing the BC Building Code (BCBC), including the ASHRAE 90.1-2004 standard (90.1) for new large buildings and major retrofits. It was estimated that 70% of commercial window sales in BC are for new construction (Hood 2007, 8), thus 90.1 would be triggered for the majority window and glazing assembly sales. Building inspectors are not required to enforce the *Energy Efficiency Act* (EEA) standards and thus, are less familiar with the associated energy performance requirements of windows for low-rise buildings.

The respondents to the survey estimated a 65% average rate of compliance with the 90.1 requirements for large buildings, well below ideal levels. Publicly owned buildings, particularly in the health and education sectors, had an estimated compliance rate of 80%. In comparison, the survey respondents estimated a compliance rate of 75% with the *Energy Efficiency Act* requirements for houses and small commercial buildings. The higher rate is likely due to better industry readiness to meet the regulation due to MEMPR's comprehensive strategy to encourage market transformation.

The survey results confirmed reliance on site inspections and Letters of Assurance from design professionals as the primary means of determining compliance with 90.1 requirements. A few of the respondents also identified other means of checking for compliance, including undertaking their own analysis. Given that compliance with 90.1 requirements cannot be confirmed with site inspections alone, it is anticipated that the reliance on Architectural, Mechanical and Building Enclosure Letters of Assurance will increase with upcoming code changes and increased awareness. However, Letters of Assurance do not currently indicate the 90.1 compliance path (i.e., prescriptive, Building Envelope Tradeoff Method, Energy Cost Budget) used or the average energy performance of the glazing assembly and building envelope. Therefore, there are benefits to window product labeling to complement these measures.

Improved glazing assembly components such as low-e coatings, argon gas fill, and alternate frame materials to metal were commonly identified by the respondents as being adopted to comply with both sets of regulations. The use of vinyl windows with low-e coatings was identified as the most common means to meet the EEA requirements. In addition, approximately two thirds of the respondents felt that the removable U-value label requirements on window assemblies was useful. It is anticipated that the labeling requirements will make it easier for contractors, consumers, and building officials to confirm compliance of window performance criteria in the future as these labels become more widely recognized.

A high proportion of building officials indicated that there is now widespread public and industry awareness of the 90.1 and EEA requirements, along with acceptance of these requirements on their technical merits. However, many of the respondents confirmed that the market transformation is not yet complete, as well as other challenges including affordability and cost effectiveness of products, and product availability in some regions.

CONCLUSIONS

This paper evaluated the impact of a market transformation program that led to energy efficiency regulations for windows and glazing assemblies in British Columbia. Results of surveys of window manufacturers and local building inspectors indicated strong market readiness for, and an estimated 75% compliance rate with *Energy Efficiency Act* regulations for windows and glazing assemblies. On the other hand, the lower compliance rate of 65% with ASHRAE 90.1 for high-rise and large buildings and concerns around product affordability and availability indicates a need for further market transformation efforts. Other conclusions drawn from the building official survey included an anticipated shift toward greater reliance on Letters of Assurance from professionals to complement site inspections. The estimated energy savings from the *Energy Efficiency Act* standards for metal-framed windows in high-rise, residential buildings in coastal BC are about 2.2% of the total building energy demand. This increases to 4.4% with compliant, non-metal framed windows.

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REFERENCES

[ASHRAE] American Society of Heating, Refrigeration and Air Conditioning Engineers. 2010. Standard 189.1-2009 Standard for the Design of High-Performance Green Buildings, Except Low-Rise Residential Buildings.

ASHRAE. 2004 and 2007. Standard 90.1 Energy Standard for Buildings, Except Low-Rise Residential Buildings.

[BC MEMPR] BC Ministry of Energy, Mines and Petroleum Resources. 2008. Energy Efficient Buildings Strategy: More Action, Less Energy. http://www.energyplan.gov.bc.ca/efficiency/.

[BCOHCS] BC Office of Housing and Construction Standards. 2008. Revisions to the 2006 BC Building Code and 2006 Fire Code. http://www.housing.gov.bc.ca/building/regs/codes/BCBC_Revision_2_20080408.pdf.

[BCUC] British Columbia Utilities Commission. 2009. Annual Report 2008/09.

Finch, Graham, Dave Ricketts and Warren Knowles. 2010. The Path towards Net Zero High-Rise Residential Buildings: Lessons Learned from Current Practice. ASHRAE Transactions (2010, vol 116, part 2).

Hood, Innes, Sampson Research. 2007. Commercial Window Market Assessment. Includes a Residential Window Market Update. Prepared for BC Hydro.

Jaugelis, Al (former WDMA-BC president). 2010. Personal communication.

Knowles, Warren, Brian Hubbs, Paul Kernan, and Graham Finch. 2010. A New Paradigm for the Design of Sustainable Buildings, Best 2 Conference

[NRCan] Natural Resources Canada. 2009. ENERGY STAR® Initiative for Residential Windows, Doors and Skylights. New Technical Specification Announcement.

Pape-Salmon, Andrew, Katherine Muncaster and Erik Kaye. 2010a. British Columbia's Energy Efficient Buildings Strategy. Presented at ASHRAE 2011 Winter Conference.

Pape-Salmon, Andrew and Dian Ross. 2010b. Market Transformation Strategy for Windows and Doors in British Columbia. Presented at 2010 American Council for an Energy Efficient Economy (ACEEE) conference – Summer Study for Energy Efficiency in Buildings.

Queens Printer. 2009. Energy Efficiency Standards Regulation under the *Energy Efficiency Act*. http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/10_389_93.

RDH Building Engineering Ltd. 2010. Research Study: Energy Consumption and Conservation in Mid and High Rise Residential Buildings in British Columbia (draft).