The Emerging Role of Electronically Tintable Glass for Energy Codes and Standards

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One of the core missions for today's building codes is to progressively reduce the total energy consumption of modern buildings with each revision. Current three-year revisions of ASHRAE Standard 90.1 and IECC respectively target additional reductions of 20 and 30% over their earlier versions[1]. Designing attractive, cost effective buildings with such aggressive energy targets requires that all of the core systems of the building be improved, including the building façade. In addition to enabling the reduction of electric lighting with additional natural daylight, the properties (and behavior) and thermal performance of the façade affect the load that the heating and cooling systems see. All three taken together account for over 50% of the building's energy consumption so must take first priority in efficient building design[2].

When one considers modern efficient facades, especially with regard to daylighting integration, the material class of tintable or dynamic glazing must be included. Dynamic glazing is an important advance in building materials whose that needs to be rapidly incorporated into today's codes and standards. With the culmination of decades of research and refinements to the technology, the 2012 construction market will see multiple manufacturers release fully commercialized dynamic glazing products[3]. The availability these market ready products will provide architects with a cost effective façade system that can expand design possibilities and enable the creation of exceptionally energy efficient and comfortable daylit spaces that would otherwise not be possible[4].

Unfortunately building codes and policy for the built environment have not kept pace with that of building materials technology. The current versions of the most important of these standards have yet to recognize the product category in any meaningful way. Because of this lag, our efficiency driven codes are creating an unforeseen barrier for tintable glazing. Without guidance on their preferred application or even their ultimate allowance, designers will be reluctant to dimming facades in their building designs. This paper will review the current state of the regulatory bodies with regard to dynamic glass and suggest a reasonable path forward.

Standards and Codes

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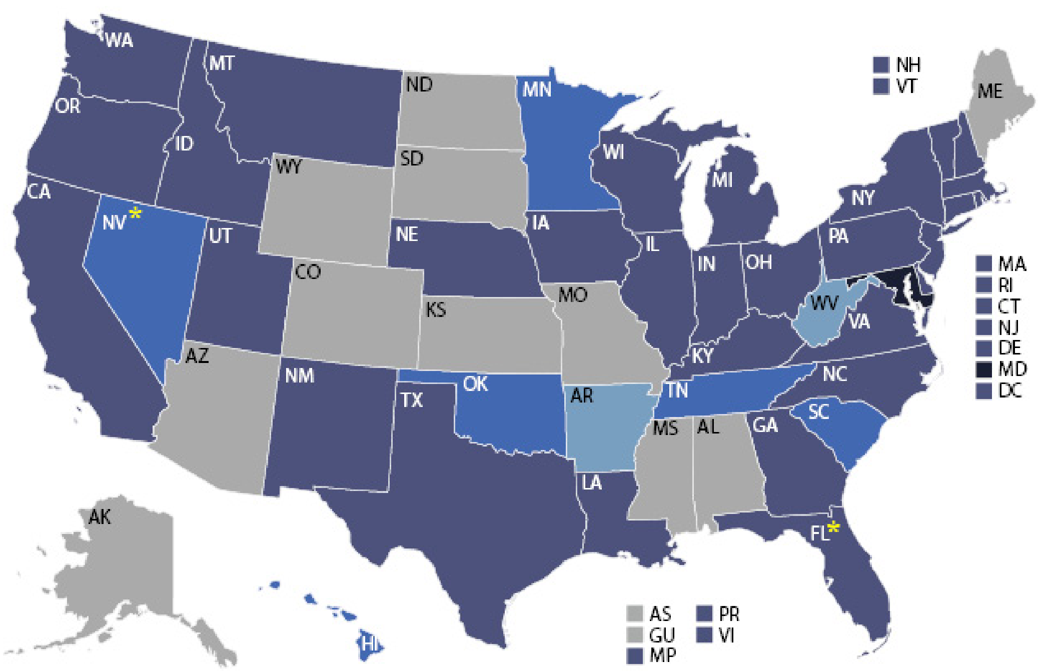
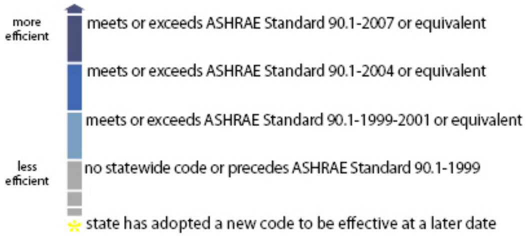
[1] US Department of Energy, Buildings Technology Program," Building Regulatory Programs Multi-Year Program Plan," (2010).
[2] Environmental Information Administration, "EIA Annual Energy Outlook," (2008)
[3] At the time of this writing SAGE Electrochromics Inc., Soladigm, and Research Frontiers all have commercial product for 2012
[4] Arasteh, D., Selkowitz, S., Apte, J., LaFrance, M., "Zero Energy Windows," Proceedings of the 2006 ACEEE Summer Study on Energy Efficiency in Buildings (2006).

Today, primary guidance around the type and quantity of glazing used in commercial buildings is driven by the International Energy Conservation Code (IECC) and the affiliated document, ASHRAE Standard 90.1. The commercial chapter of the IECC sets energy efficiency requirements for non-residential buildings and for residential buildings with more than three stories. ASHRAE is a model building standard specifying the design of all buildings except low rise residential. It is worth noting that although both documents are written in code language, the IECC and ASHRAE revision processes vary significantly. The IECC proposals are introduced and decided in a public-hearing, and floor amendments are considered during the hearing, whereas ASHRAE Standard 90.1 is developed in an open forum through work with technical committees.

As a result, IECC is enforced as a national model code adopted or referenced by state energy codes. As a compliance alternative, this IECC references ASHRAE Standard 90.1. In addition to being used for code compliance, Standard 90.1 is often used as a baseline for energy efficient and green building programs. It is in these two documents where building materials and their properties are incorporated into allowable building designs. As of February 1, 2012, just one state, Maryland, has adopted the most current version of these two documents as part of their statewide code. 39 US states have adopted an earlier revision (2009 IECC or 2007 ASHRAE 90.1)[5].



[5] Per the Commercial Windows website:
http://www.commercialwindows.org/codesstandards_ashrae90_1_more.php referenced in January 2012.



Prescriptive path compliance

Within these documents, there are two options for compliance – the prescriptive and the performance based design. The with regard to vertical fenestration, the prescriptive approach sets discrete limits for glass type and coverage for buildings. The requirements are concise, but often unacceptably limiting to designers. For example, the prescriptive path limits vertical fenestration of any performance or type to 40% of the total wall area[6]. Similarly limiting in nature, glass performance is specified exclusively by static u-factor and SHGC. The prescriptive requirements for the 2012 IECC code are given below.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7&8**
2010 ASHRAE 90.1 Max SHGC	0.25	0.25	0.25	0.40	0.40	0.40	0.45
2012 IECC w/ no shading Max SHGC	0.25	0.25	0.25	0.40	0.40	0.40	0.45

Dynamic glazing is dealt with in the 2012 code by the requirement that it be modeled in its fully darkened state, at all times during the year. This is remarkable in that it takes todays newest, highly variable materials and inaccurately treats them as older, static materials. The affiliated ASHRAE standard, 90.1-2010 has no language regarding dynamic glazing.

The California Building Energy Standard, commonly referred to as Title 24, has also adopted similar language for treatment of dynamic glass into its 2013 revision[7].

Performance path compliance

Alternately, a building design team may choose the prescriptive path of a presenting the energy performance of the building as intended to be compared to a baseline code compliant building of similar form an function. It appears that performance-based compliance is a two-part process. First, the applicant must show that dynamic glass meets (is capable of meeting) the minimum prescriptive requirements of the code (u-factor and SHGC). Note that again, SHGC is considered the lowest state only

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[6] 40% window to wall area is allowed by IECC 2012 only when automatic daylighting controls impact 50% of the conditioned floor area. 40% is allowed without provision by ASHRAE 90.1-2010.

[7] As of this writing it is included in the California code public draft document "*45-day 2013 Standard Consolidated 2_22_12 copy*" available on the California Code website, http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/current/Express_Terms/

for dynamic glazing. Second, the applicant then must show that glass meets minimum performance requirements using fixed, unshaded glazing meeting prescriptive requirements. Such performance shall include:

- Specific site conditions
- Consideration of adjacent buildings, including specification of alternate operating scenarios in the future event of adjacent building removal
- Specification of operating sequences (how and when glazing optical properties change and definition of response criteria)
- Inclusion of annual heating, cooling, and daylighting performance

In the code the applicant always has exceptional calculation process to follow, but to this author's knowledge, this is rarely used in the industry.

The intent of the energy codes is to the intent of the code is to maximize the annual energy savings via a compromise of the summer and winter conditioning loads. It is obvious from the table values and the simple treatment of dynamic glazing that their strict control of the SHGC across all regions is meant to limit the summer solar gain ad expensive electric cooling. The strategy is sound for static materials, but for the case of dynamic glass, misses the base purpose of the glass and undermines the potential annual savings. In its dark state dynamic glazing can minimize expensive summer cooling, but setting such a smart surface to always dark (without regard to actual solar intensity) falsely eliminates the benefits of natural daylighting on temperate or overcast days. More important still, during the winter months dynamic glazing in its transparent state can allow passive solar gain to minimize winter heating demands. Ignoring the intrinsic energy and comfort benefits of dynamic glazing is an unacceptable flaw in the upcoming revisions. The stated purpose of the IECC is to is to minimize total building energy consumption, and that aim should be accomplished by acknowledging dynamic glazing potential savings particular to annual seasons and by reflecting to representative performance of the materials and systems. In the code's history, there is precedent from other building systems that should serve to justify improved treatment of dynamic glazing going forward.

Precedents for Dynamic Glazing - Control

One of the main arguments over acceptance of dynamic glazing as a recognized energy saving system is the requirement of a control strategy, At the most basic level, there is truth in the fact that some automated control program is required for the surfaces to operate in an efficient manner without human intervention. Those reluctant to fully embrace dynamic glazing as a code recognized efficiency approach argue against it for two main reasons 1) since the system is also intended to improve human comfort, their (the occupants) will significantly undermine the system; and 2) without a standard or well described control method, code cannot predict and therefore recognize the benefits. These objections do not pass muster.

Building efficiency systems dependent upon control logic for their operation have existed for many decades. Further, systems designed for occupant comfort and thus allowing for human control have also existed and been recognized – the simplest example is the common thermostat. Of course thermostats are recognized by code in a representative form. The reason is likewise simple and common to current dynamic glazing control systems. Though a user may change the automated settings on a thermostat (or dynamic glazing façade), the manual control is temporary. After a predetermined time (from minutes to hours) the system then reverts back to its automated state. In the cases where this does not occur, the building is operating outside of its commissioned state, which is beyond the scope of the codes. Given the precedent of thermostats (and their mix of occupant and automatic control, dynamic glazing should be immediately recognized by code as a similar technology and be updated for its consideration as a realistically dynamic surface.

One Example Approach
One thoughtful approach to incorporating and modeling dynamic glazing exists in the latest version of the "Commercial Buildings Energy Modeling Guidelines & Procedures " (MGP) as developed by COMNET[8]. In the "*Advanced Modeling Tips / Design Features*" section of the MGP, they treat dynamic glazing as follows:

> In modeling switchable glazing that includes an automatic control such as a heat sensor, a control set-point, usually in Btu/h, will be used in the model. The basic window will be modeled with the U-Factor, SHGC and VT (visible transmittance) of the glazing with no tinting applied. The energy model will then include modifiers to each of these values when the control set-point has been reached. Thus, the energy model will reduce the energy gain through the windows in response to solar gains on the particular window.
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> Another approach is to apply the same modifiers on an hourly basis using a series of schedules. This approach might be used in a circumstance where the glazing is being controlled with a building energy management system and would be applied at a consistent time of day, or seasonally. In this case, the hourly schedule would dictate the multiplier to be applied to the U-Factor, SHGC and/or visible transmittance.

In the modeling approach described by the first paragraph of the relevant MGP section, modeling with automated controls is explicitly recognized without limiting or describing the control strategy. The second paragraph also gives great latitude to the modeling approach when using dynamic glazing, but it does suggest that an hourly or season strategy be used during evaluation. Both of these approaches better reflect the variable properties of dynamic glazing but yet also involve language that is compatible with that of current building codes and standards. The MGP should be considered as a template for future improvements to the IECC and ASHRAE 90.1 requirements.

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[8] Per the COMNET website: http://www.comnet.org/mgp/content/721-switchable-glazing referenced in January 2012.

Conclusion

With every revision, the model building energy codes and affiliated standards continue to improve and continue to drive building designs that reduce the energy required to operate. In fact, the 2010 revision of ASHRAE 90.1 has been calculated to reduce building energy consumption by 18.2 percent on a national basis[9]. However, the latest code and standards revisions fall short with regard to their treatment of property changing materials and systems such as dynamic glass. Instead of simplifying their operation to that of traditional static glass systems, today's guidance documents should model their behavior across their range of operation and a basic control strategy. With simple, automatic dynamic control of their facades, buildings seeking code compliance could potentially save more than the 18.2 percent achieved in the current version.

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[9] M. Halverson, M., Rosenberg, M., Liu, B., "ANSI/ASHRAE/IESNA Standard 90.1-2010 Preliminary Determination Quantitative Analysis", Pacific Northwest National Laboratory (2010).