EF 3: LIMIT HEAT LOSS THROUGH EXTERIOR WALLS

ANSI/ASHRAE/IESNA 90.1 (2007) and the Energy Conservation Construction Code of New York State
Proposal developed by Energy & Ventilation Committee

Summary

Issue: Building envelope design has a major impact on both heat loss in winter and solar gain in summer. Using the flexibility in current energy codes, designers can meet energy-efficiency requirements by trading off the efficiency of mechanical and lighting equipment against the thermal integrity of the envelope. Since the building envelope will be in use for a century or more, this trade-off is short-sighted.

Recommendation: Establish fixed performance requirements for building envelopes with respect to heat loss, independent of mechanical and lighting equipment choices.

Proposed Legislation, Rule or Study

Amendments to ANSI/ASHRAE/IESNA 90.1 (2007), as incorporated in Chapter 13 of the New York City Building Code:

1. Add a new Section 5.4.4 as follows:

5.4.4 Maximum Exterior Building Envelope Heat Transfer.

5.4.4.1 Exterior building envelopes shall comply either with the prescriptive option of subsection 5.4.4.2 or the performance option of subsection 5.4.4.3 notwithstanding whether the overall building design complies with the requirements of the Energy Cost Budget Method of Section 11. In addition to the foregoing, if the energy cost budget trade off option as set forth in Section 11 is chosen as a compliance path and requires a lower average U-factor than .25 Btu/hr-sf°F, then that lower value must be utilized in the proposed design.

Exception: Any building with a peak design rate of energy usage less than 3.4 Btu/hr-sf or 1.0 watt/sf of floor area for space conditioning purposes.

5.4.4.2 Exterior building envelopes excluding the roof but including skylight area in excess of 5% of roof area shall have a maximum average U-factor of 0.25 Btu/hr-sf°F for buildings receiving permits before July 1, 2016, 0.20 Btu/hr-sf°F for buildings receiving permits after July 1, 2016 but before July 1, 2022, or 0.16 Btu/hr-sf°F for buildings receiving permits after July 1, 2022, notwithstanding whether the exterior building envelope has a sufficiently high envelope performance factor as set forth in Section 5.6, except as permitted in subsection 5.4.4.3. The maximum average U-factor shall be calculated by averaging the U-factor of each component of the exterior building envelope excluding roof but including skylights over the entire above-ground wall and fenestration areas that enclose heated spaces but excluding semiheated spaces. The average U-factor shall be calculated as follows:

\[
\text{Average U-factor} = \frac{UA_1 + UA_2 + \ldots UA_n}{Atotal}
\]

where

\[UA = \text{the U-factor for each individual exterior building envelope component excluding the roof but including skylights (except those over semiheated spaces)} \times \text{the total area of such component incorporated in the exterior building envelope. The U-factor for each component shall be calculated by taking into account thermal bridging at metal studs and members, shelf angles, floor edges, projecting balconies, window frames, and other components passing through the thermal barrier. U-factors can be determined using test results as required by this standard, tabulations provided by this standard, Standard NFRC-100-2004 methods, or two-dimensional or three-dimensional heat flow modeling, provided that three-dimensional heat flow modeling shall not be used to determine the U-value for standard wall-types listed in the above referenced tables. For residential construction with exposed slab edges, the following table must be used for U-factors.} \]
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U_{\text{ref}} = \text{the sum of all of the UAs for the exterior building envelope components excluding roof but including skylights; and}

A_{\text{total}} = \text{the total area of the exterior building envelope excluding roof but including skylights.}

(RESIDENTIAL SLAB-EDGE TABLE TO BE PROVIDED HERE DURING IMPLEMENTATION).

5.4.4.3 A building may comply with this section by employing the building envelope trade-off option in Section 5.6 to demonstrate that the proposed envelope performance factor is 10% less than the base envelope performance factor, where the base building complies with subsection 5.4.4.2 and for which all fenestration has an SHGC of 0.40 or less. In no case shall the average U-factor of the proposed building exceed 0.28 Btu/hr-sf°F for buildings receiving permits before July 1, 2016, 0.23 Btu/hr-sf°F for buildings receiving permits after July 1, 2016 but before July 1, 2022, or 0.18 Btu/hr-sf°F for buildings receiving permits after July 1, 2022.

Amendments to the Energy Conservation Construction Code of New York State, as incorporated in Chapter 13 of the New York City Building Code:

1. Add a new Section 402.1.5 as follows:

402.1.5 Maximum Building Envelope Heat Transfer. Notwithstanding any provision of Section 402 to the contrary, building envelopes excluding roof but including skylights shall have a maximum average U-factor of 0.25 Btu/hr-sf°F for buildings receiving permits before July 1, 2016, 0.20 Btu/hr-sf°F for buildings receiving permits after July 1, 2016 but before July 1, 2022, or 0.16 Btu/hr-sf°F for buildings receiving permits after July 1, 2022.

The maximum average U-factor shall be calculated by averaging the U-factor of each component of the building envelope over the entire above-ground wall and fenestration areas that enclose heated spaces but excluding semiheated spaces. For the purposes of this Section 402.1.5, the definitions of "wall", "fenestration" and "semiheated spaces" shall have the meanings set forth in ANSI/ASHRAE/IESNA Standard 90.1(2007). The average U-factor shall be calculated as follows:

\[
\text{Average U-factor} = \frac{U_{\text{ref}}}{A_{\text{total}}} = \frac{U_{A_1} + U_{A_2} + \ldots + U_{A_n}}{A_{\text{total}}}
\]

where

\[
UA = \text{the U-factor for each individual building envelope component excluding roof but including skylights (except for those over semiheated spaces) multiplied by the total area of such component incorporated in the building envelope. The U-factor for each component shall be calculated by taking into account thermal bridging at metal studs and members, shelf angles, floor edges, projecting balconies, window frames, and other components passing through the thermal barrier. U-factors can be determined using test results as required by ANSI/ASHRAE/IESNA Standard 90.1(2007), ANSI/ASHRAE/IESNA Standard 90.1(2007) tabulations, Standard NFRC-100-2004 methods, or three-dimensional heat flow modeling;}
\]

\[
U_{\text{ref}} = \text{the sum of all of the UAs for the building envelope components excluding roof but including skylights; and}
\]

\[
A_{\text{total}} = \text{the total area of the building envelope excluding roof but including skylights.}
\]

Supporting Information

Issue – Expanded

Many buildings being constructed today – particularly the large ones – have poorly performing exterior envelopes. This is because the energy code allows a “performance path”, wherein the thermal efficiency of the envelope can be diminished if other systems, such as lighting or the mechanical system, are made more efficient to compensate, as documented using an energy model. Many builders decide to utilize this trade-off because it is the least expensive way to meet the code and provide highly glazed facades or simply built brick high-rise buildings. But the price for this trade-off is a generation of buildings with poorly performing facades that will far outlast their efficient lighting and mechanical systems, which are changed out within 15 to 25 year cycles. Building envelopes will typically survive for the life of the building, which can easily exceed 100 years, so their impact on fuel and electric use and carbon emissions is substantial. This proposal aims to improve the long-term efficiency of the building stock by requiring that all building envelopes achieve a minimum thermal performance that is independent of the other trade-offs pursued.

How will this proposal impact the way the way buildings are built? There has been concern that this proposal will make it impossible to build all-glass buildings, which is not the case. Many trade-offs are available to the designer of a façade, including not just the amount of glazing, but the amount of glazing that is actually clear (i.e. the vision glazing), the amount of insulation used in the spandrel panels, the thermal properties of the glass, the properties of the mullions, and
the inclusion of shading devices, double walls, or glass with well-tuned solar heat gain factors. As the Cost / Savings section shows, some of these strategies will result in increased cost, but that is not inevitable, as there are no-cost ways to comply.

Nonetheless, the proposal will increase the cost of buildings that have clear floor-to-ceiling glass, at least in the near term. It should be noted such floor-to-ceiling glass is not a benefit from the point of view of day-lighting; there is no gain in daylighting advantages (reduction in lighting electric use) from more than 40% vision glazing, since when the sun is out the additional glare usually leads occupants to draw the blinds or erect shades. And there is a serious thermal penalty for such glass when built utilizing the current generation of mullions and double glazed panels, a fact that is well known in the industry.

Still, looking out of floor-to-ceiling glazing is unarguably a striking experience, and many developers find this effect to be sought by tenants. In such cases, many existing technologies can bring a highly glazed facade into compliance—see the Cost and Market Availability sections below.

It should be noted that this proposal only impacts the insulating value of the glass. Considerable time was spent trying to construct a meaningful overall limit on solar heat gain factor, but due to the complexity of the issue and fact that New York City buildings are either heating dominated or, if cooling dominated, driven largely by internal loads, this component was dropped from the measure. Improved solar heat gain performance can be incorporated by using the trade-off option, 5.4.4.3.

The result of adoption of this proposal will be a generation of buildings that out-perform many of today’s buildings both immediately (for buildings that follow the prescriptive path) and over the long haul for all buildings, since their performance will be much less subject to compromise should a future owner decide to replace the original mechanical equipment with less efficient substitutes at the time of failure. If owners continue to use the best available equipment, savings will be even greater. The task force expects this measure to generate a new level of common practice, much as the NYS ECCC resulted in the adaptation of double-glazed windows, which became relatively low-cost items as industry adopted them as the standard.

EF04 and EF03 are intended to work together in order to ensure significant improvements in the energy efficiency of exterior walls in New York City and consequently lead to substantial energy savings over time. The two proposals will transform the industry by pushing it to adopt new technology and design exterior walls that will outperform comparable existing walls by a substantial margin. The phased approach to new maximum U-values makes the transition feasible and allows for flexibility as developers, building owners and designers will be able to follow either the performance or prescriptive path in many ways as long as they meet the prescribed criteria. The performance path in particular will give more flexibility to designers to use dynamic systems (shading, double walls, glass that responds to light conditions, etc.) and other new strategies to meet the requirements.

Section 5.6 of and Appendix C of ASHRAE 90.1 have been used as the basis of the trade-off option. An alternative, possibly superior, approach would be to use the building modeling constraints of EPAct 2005 – the system used for Federal tax credits. This would not affect the criteria presented here, only the details of how the modeling will be carried out, and can be incorporated into the legislation if appropriate.

Further development may be needed for the case of roofs with large areas of skylights. Also, since ASHRAE 90.1 does not provide adequate tables for effective R and U values for exposed slab edges, the Task Force will provide such tables. They have not yet been prepared, so a place-holder has been inserted in the code language above.

**Environmental & Health Benefits**

Adaptation of this measure will result in substantially lowered fuel and electric use in large buildings, with associated reductions in pollutants and CO2 emissions.

This proposal was found to have a high, positive environmental impact per building and to impact a large number of buildings. It was thus given an environmental score of 3.

This proposal was found to have a positive, indirect health impact.

**Cost & Savings**

Capital cost impact will vary widely with building type and alternative designs. For buildings with less than 40% vision glass, current good design practice can meet these criteria at no additional cost. Construction with more than 60% vision glass would be more expensive under this proposal, since triple or quadruple glazing and/or high performance mullions would be required. Between 40 and 60% vision glass there may or may not be an increase in cost depending on the particular design. The minimum U-factor of 0.25 Btu/sf·°F was chosen because it can be reached (at some additional expense) with a facade incorporating a high percentage of vision glass.

Typical construction utilizes double-glazing with moderately thermally broken aluminum mullions. Typical overall U-values for this vision glass are around 0.5 Btu/ft²·°F, or R-2. Improvements are commonly made using low emissivity coatings, improved mullions, and argon or krypton fill. (There is ongoing uncertainty about the long-term integrity of
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the gas fills.) The following table shows the whole window U-value required to meet the criterion of $U_{ave} = 0.25 \text{ Btu/ft}^2\cdot\text{F}$ if the non-vision glass parts are insulated to R-12, easily achieved with continuous insulation. (The table is exemplary and does not take many details of construction into account.)

<table>
<thead>
<tr>
<th>Vision glass fraction:</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole-window U-value (Btu/ft²·°F):</td>
<td>0.50</td>
<td>0.42</td>
<td>0.36</td>
<td>0.32</td>
</tr>
</tbody>
</table>

However, it is possible to do considerably better even with materials readily available today. A prominent mid-town skyscraper currently under construction has achieved an overall U-value of 0.28 Btu/sf·°F with floor-to-ceiling vision glass on 60% of the envelope by selecting high quality materials based on double-glazing at costs well within the budget of a building of this class. Utilization of higher quality mullions, low-e coatings, and finally triple glazing do lead to somewhat higher costs, but these will normally be repaid through fuel savings.

As described in the Executive Summary, Bovis Lend Lease prepared cost estimates for each Task Force proposal in the context of well-defined construction projects in specific buildings. Where possible, members of the Technical Committees prepared savings estimates for some of these projects and buildings. These cost and savings estimates are presented in the February 1st draft version of Appendix A. The innate uncertainty in how construction and operation will vary from one building to another, the complexity of the Task Force proposals, and the wide range of applications in which the proposals may be realized mean these figures are truly estimates.

For this proposal, costs were developed for many different combinations of building type and vision glass, and are summarized in Appendix A. For the large scale commercial building with a curtain wall, the type perhaps of most concern to New York City business, there was no increase in overall building construction cost at the 40% vision wall level, a 0.7% increase for 52.5% vision wall, and a more significant 1.3% increase for 65% vision wall. Fuel savings were estimated for this building type, and were sufficient to pay for the increased cost in twelve years for the 52.5% vision glass case, and slightly over twenty years in the case of 65% glazing.

For the other building types, the cost increases range from zero (for 40% vision glass) to values higher than for the large commercial building. Savings were not estimated for these buildings, but should be comparable, since the improvement in envelope is roughly the same. For masonry buildings, Bovis found cost increases in all cases, but the task force believes this stemmed from a misunderstanding about the base case, which should have been chosen to meet the new criterion without improvements in the case of 40% vision glass.

All these cost estimates were based on current pricing for widely used and standard materials. Newer multi-glazed window materials, based on internal polymer films rather than a third layer of vitreous glazing, are available at substantially lower cost. The primary obstacle to their use appears to be lack of familiarity and experience, but as they become better known, the capital cost increments will shrink, drawing the payback periods down with them.

**Precedents**

All energy codes seem to include limits on building thermal losses, often this stringent, but they also permit performance trade-offs so that better mechanical equipment can offset a poor façade. No codes were found with a similar absolute limit on thermal performance.

**LEED**

Current LEED prerequisites for Minimum Energy Performance under the Energy & Atmosphere sections of almost all of the rating systems require that the scope of work complies with ANSI/ASHRAE/IESNA standard 90.1-2004. This proposed code requires compliance with measures exceeding ASHRAE 90.1-2007. Since LEED 2009 prerequisites for Minimum Energy Performance also reference ASHRAE 90.1-2007, the measures outlined in this proposal will be correlated with the next generation of LEED.

However, LEED qualifies that a more stringent local code requirement becomes the LEED prerequisite requirement as well. Therefore, this proposal will change the baseline criteria that registered projects must meet for LEED certification.

**Implementation & Market Availability**

Given the significance of this proposal, members of the Steering Committee and real estate members of the Industry Advisory Committee held several meetings to discuss its content and implementation. These discussions provided valuable input and are reflected in revisions to the proposal content (shifting the first trigger date from 2013 to 2016) and in the discussion that follows.

All alternative façade options are mature. Thermally improved and broken mullions are widely available and currently in use in select buildings. Triple glazing is widely used in Europe and provides the envelope for a 15 story building in Calgary, Alberta. Manufacturers assured that although triple glazing has not been widely used in the US, it is readily
available should demand arise. Although concerns were raised about the increased weight of vitreous triple glazing, other knowledgeable engineers asserted that the additional weight could be readily incorporated into standard design practice, and that steps taken to incorporate blast resistance into critical buildings already had a greater impact.

Concerns were raised that visual distortion, which can be a modest problem with large double glazed panels, would be exacerbated in triple-glazed products. Others thought the effect would be minimal or could be countered through quality control, and cited the availability of European technology that minimizes this effect.

Manufacturers of products with a central polymer layer\(^4\) offer vision glass that will allow construction of buildings with high vision glass fractions that meet the proposed thermal criteria at substantially lower cost than standard triple glazing. Serious Materials, for example, offers multiply glazed panels for curtain walls up to twelve feet high and six feet wide. The polymer layer will not produce any distortion of transmitted light, even if it is not quite flat, due to its thinness. These newer products have not been used widely in New York City high-rise buildings, so dealers, architects, and contractors will have to develop confidence in the products and production may have to ramp up.

Notes

The section for the NYS ECCC is included to apply to additions and alterations of existing buildings, since new low rise construction is covered by our Energy Star requirement. An exemption is granted by NYS ECCC 101.5.2.1 for low energy buildings with design load of less than 3.4 Btu/hr-sf. The Task Force has used this criterion as an exception for the high rise/commercial case also.

**ENDNOTES:**


