In essentially every climate, good façade design begins with good glazing design. For the cold winters of the upper Midwest, it is particularly important to keep the overall façade insulating value (U-value) as low as possible to slow the transfer of heat through it. This starts with selecting the right amount of glazing. Limiting the amount of glazing is important because even the highest performing glazing has a much higher U-value (U = 0.2–0.3) than a typical wall assembly (U < 0.064). In addition to not insulating as well as a wall assembly, glazing adds solar heat to the space, contributing to the cooling load.

However, keeping building occupants happy and productive is crucial, so ample daylight and access to good outdoor views is important. Optimal glazing design, therefore, is a balancing act that provides adequate daylight, minimizes direct sun exposure and reduces energy use. Fully daylighting a space does not require a 75 percent glazed façade. Careful attention to glazing placement can provide plenty of daylight while minimizing the amount of glazing needed. Selecting the appropriate glazing product will minimize solar heat gain, keep the building well insulated, and allow natural daylight into the space. Then well-designed wall assemblies round out the façade for a well-insulated daylit building.

The building at 749 University Row is a highly energy efficient, multi-tenant office building constructed in Madison, Wisconsin in 2013. One of the main design considerations for this building was to give tenants access to natural daylight. To successfully daylight the building and ensure that the overall façade had an acceptable U-value meant paying attention to several design details. These included the window-to-wall ratio and building envelope properties (wall assembly, window frames and glazing).

The window-to-wall ratio (WWR) is important for both thermal and lighting reasons. Energy engineers modeled the energy ramifications of different WWRs and conducted a separate daylight analysis to determine the ideal window and skylight size and placement for the building. As shown in Figure 1, a WWR of about 30 to 40 percent is the sweet spot where energy cost remains low while keeping daylight autonomy high. Note how steeply energy cost rises as the WWR increases above 50 percent!

The original design of the building had a WWR of more than 45 percent. The building architects were able to lower it to 38 percent through effective window placement and by reducing the amount of glazing in transitional areas such as stairwells. While daylight is important in transitional areas, people do not spend much time in them so full glazing is not justified.

(continued on page 2)
The height to the top of the window is the primary driver of the depth that daylight will penetrate into the building, so windowsill height and total height were kept as high as possible while not obstructing occupants’ view out the windows. Placing wall assembly near the floor (as shown in Figure 2) instead of increasing window size reduces heating and cooling loads while providing ample daylighting. Once furniture is placed near the windows, occupants cannot tell that the façade is not fully glazed.

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The window to wall ratio energy and construction costs

<table>
<thead>
<tr>
<th>WWR reduction</th>
<th>Energy savings</th>
<th>Cost of glazing</th>
<th>Cost of wall</th>
<th>Material cost savings from WWR reduction</th>
<th>Percent façade cost savings</th>
<th>Payback period</th>
</tr>
</thead>
<tbody>
<tr>
<td>7%</td>
<td>$2,800</td>
<td>$38/sf</td>
<td>$25/sf</td>
<td>$27,000</td>
<td>2.9%</td>
<td>Immediate</td>
</tr>
</tbody>
</table>

Budget is always a consideration in building design, especially in a multi-tenant building like 749 University Row where costs needed to be low enough to keep rents competitive. Because window assemblies tend to cost more than do wall assemblies, this façade design actually reduced construction and energy cost.

Windows with good insulating properties require thoughtful selection of both frames and glass. Early in the design process, the energy consultants included the recommendation to use thermally broken, insulated frames. However, the window design process focused mainly on the center of glass U-value. The window vendor did not report an NFRC rating for the assembly: a U-value that would include both the glass and the frame. Although glass and frames typically come from different manufacturers, it is important for the vendor to conduct an analysis to see how they perform together as an assembly. Figure 3 shows the selected window properties as well as the annual energy savings achieved by going above energy code requirements. The importance of the assembly U-value is highlighted in energy codes as well, which only establish requirements for assembly U-value and not center of glass U-values.

Figure 3: Window properties and energy savings

<table>
<thead>
<tr>
<th>WINDOW</th>
<th>Baseline</th>
<th>Proposed</th>
<th>Annual energy savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>U assembly: 0.45</td>
<td>SHGC: 0.4</td>
<td>SHGC: 0.28</td>
<td>$5,300 59,000 kWh</td>
</tr>
<tr>
<td>VT: 54%</td>
<td>Visible transmittance: 54%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Relationship between visible transmittance and solar heat gain coefficient

(continued on page 3)
Seventhwave, one of the tenants at 749 University Row, included skylights in its space to bring daylight into interior rooms. Skylights alone will always result in increased energy consumption because they have a much higher U-value than the roof, but in conjunction with advanced daylighting, they can be energy neutral or even save energy if designed correctly. Engineers from Seventhwave conducted multiple iterations of both daylight and energy analyses to ensure that the skylight design would result in net energy savings.

With the amount of glazing incorporated in the façade at 749 University Row, it was also important to control glare. The daylight analysis showed that glare would be a problem on the southeast and southwest façade the majority of mid-afternoons in summer and mid-mornings in winter. Window overhangs on the exterior of the building between the transom window and vision window (see Figure 5) helped alleviate this problem.

The exterior walls for 749 University Row are steel framing at 16 inches on center with three inches of continuous mineral wool insulation. Mineral wool has a lower insulating property than typical fiberglass insulation (R-4.6/inch vs. R-5/inch), but is made from 75 percent postindustrial recycled content and is fire resistant. Continuous insulation is effective because it interferes with thermal bridging (when a more conductive material, such as steel framing, allows an easy pathway for heat flow across a thermal barrier). Insulation only in wall cavities compared to continuous insulation reduces the effective R-value of the wall (by more than 50 percent in steel framed walls). Rigid insulation was also used to avoid thermal bridging where the window and the wall section meet. Figure 6 shows the design wall assembly U-value as well as the annual energy savings achieved by going above energy code requirements.

<table>
<thead>
<tr>
<th>SKYLIGHT ENERGY ANALYSIS RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling energy from skylights</td>
</tr>
<tr>
<td>+140 kWh</td>
</tr>
</tbody>
</table>

**MAKING OPTIMAL GLAZING WORK**

- Conduct conceptual energy and daylight modeling as early as possible, even before schematic design, to optimize orientation, window-to-wall ratio, and façade properties.
- Analyze window assembly U-value not just glazing U-value because frames can vastly reduce the effectiveness of high performance glazing.
- Apply continuous insulation to minimize thermal bridging. Mineral wool is easier to install than fiberglass because it has more form, does not need to be stapled in place and leaves no air gaps.
- Pay attention to infiltration reduction in façade design. The building at 749 University Row used a liquid applied air barrier instead of the more standard adhered membrane. Liquid applied air barriers are easier to use in detailed areas, and generally will have fewer failures.

**OTHER RESOURCES**


COMFEN tool: windows.lbl.gov/software/comfen/comfen.html


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**Figure 5:** Daylight analysis of southwest façade A) without and B) with window overhang. Daylighting analysis done in AGI-32.

**Figure 6:** Wall properties and energy savings