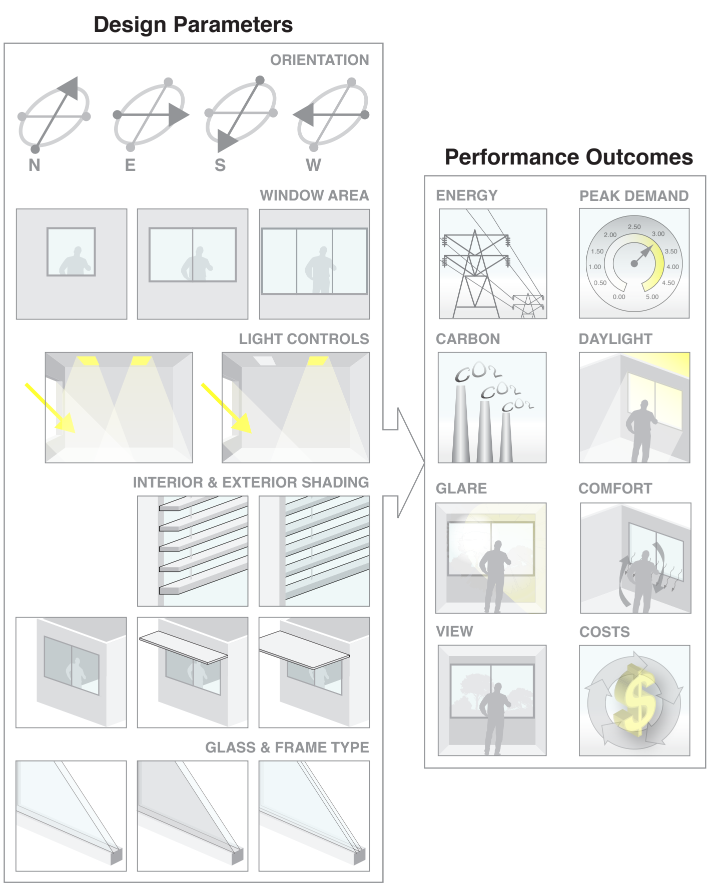
Design Guidance for Schools in Phoenix, Arizona

Introduction

The energy use of a perimeter zone in a school depends on several design decisions—window orientation, window area, shading conditions, glazing type, and whether lighting controls are used in the space. Designers need to know the answers to the following questions. What is the best orientation, window area, and glazing to reduce energy use in a particular location? Are shading devices and lighting controls effective in saving energy?

Unfortunately, the answers to these questions are not quite as simple as they seem. For example, there is a general perception that spaces with larger window areas use more energy than spaces with smaller window areas. This may be true for conventional clear glazing, however, with high performance glazing, a space with a large window area can use the same amount of energy or even less energy than a space with a small window area. The best option is not always obvious, so it is important for designers to be aware of these advanced technologies and to use calculation tools to optimize design choices for energy efficient performance.

To provide guidance to designers, the following pages examine the energy use impacts for perimeter school (classroom) zones in Phoenix, Arizona. The energy use has been calculated for many window design variations including four orientations, six glazing areas, twelve glazing types, nine shading conditions, and two light control options. The assumptions are shown on the next page. All simulations were performed using COMFEN4 and analysis was done using the Facade Design Tool. To determine actual impact of window design variations on a specific project, use the Facade Design Tool.



Key Findings

Orientation: With conventional high-SHGC clear glazings, north- and south-facing spaces use much less energy than east- and west-facing spaces. With high performance glazings, these differences can be much less.

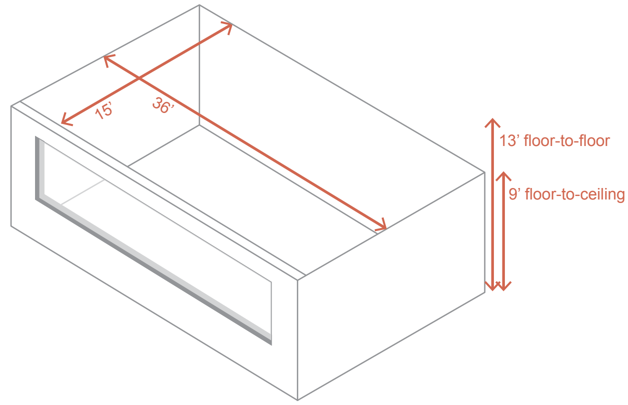
Window Area: Energy use increases with window area using conventional high-SHGC clear glazings. With high performance glazings, energy use may increase only slightly as window area increases.

Lighting Controls: Lighting controls that dim electric lights when there is sufficient daylight almost always reduce energy use in perimeter spaces. The only exception is when glazings with very low visible transmittance are used resulting in insufficient daylight.

Shading Condition: On north-facing orientations, shading devices have little impact. On south-facing orientations, shading devices such as overhangs and exterior blinds are effective with high-SHGC clear glazings. Shading devices have less impact when high performance glazings with low SHGC are used. On east- and west-facing orientations, shading devices such as fixed exterior blinds are most effective with high-SHGC clear glazings. Overhangs are less effective than on the south. Shading devices in general are less effective when high performance glazings (low SHGC) are used.

Assumptions

The following assumptions are used in the Facade Design Tool for all energy use calculations presented in this design guide.



The Building

The school (classroom) type was modeled with a zone width of 36 feet, height of 9 feet, and depth of 15 feet. Lighting was assumed to be 1.4 W/sf and equipment was 0.9 W/sf. The occupancy load of 12.53 persons per zone.

Zone Orientation

Orientation of the perimeter zone is available in each of the four cardinal directions: north, east, south and west.

Window-to-Wall Ratio (WWR)

Flush-mounted, non-operable windows were modeled in the exterior wall of each perimeter zone. Window sizes were modeled with a fenestration window-to-wall area ratio (which includes the area of the whole window with frame) where the wall area was defined as the floor-to-floor exterior wall area and the COMFEN simulations were conducted using the floor-to-ceiling exterior wall area. Window-to-wall ratios modeled include 10%, 20%, 30%, 40%, 50% and 60%.

Building Projections and Shades

Overhangs were mounted directly above the window frame with either a 2- or 4-foot projection. The overhang extends the entire width of the zone. Interior and exterior Venetian blinds were simulated so that the slats would be at 45 degrees and fixed in the "always on" state. The optical properties of the blinds were set to the defaults in COMFEN.

Lighting Controls

Electric Lighting System: Recessed fluorescent lighting systems were modeled with a lighting power density of 1.4 Watt per square foot throughout the zone. Heat from the lighting system was apportioned to the school zone (60%) and to the unconditioned plenum (40%). If no daylighting controls were specified, the lighting was assumed to be at 100% power, and governed, as in the daylighting case, by the occupancy schedule.

Continuous Dimming Electric Lighting Controls: For continuous dimming, the overhead lights dim continuously and linearly from (maximum electric power, maximum light output) to (minimum electric power, minimum light output) as the daylight illuminance increases. The lights stay on at the minimum point with further increase in the daylight illuminance. The lowest power the lighting system can dim down to is expressed as a fraction of maximum input power.

Glazing System

There are hundreds of glazing systems available in the market today, with varying combinations of glass panes, special coatings, and tints. The Facade Design Tool models the performance of ten glazing systems and two retrofit films, representative of the breadth of options available. For ease of comparing the performance of glass features, all high-performance glazing systems in the Facade Design Tool are modeled with an argon fill. In general, energy performance from similar windows with an air fill will be about 2–5% poorer. Aluminum frames were used in all of the simulations. Single-layered systems use a non-thermal frame, double-layered systems use a thermally broken frame, and triple-layered systems use a high performance frame.

Window Types Used in Energy Calculations

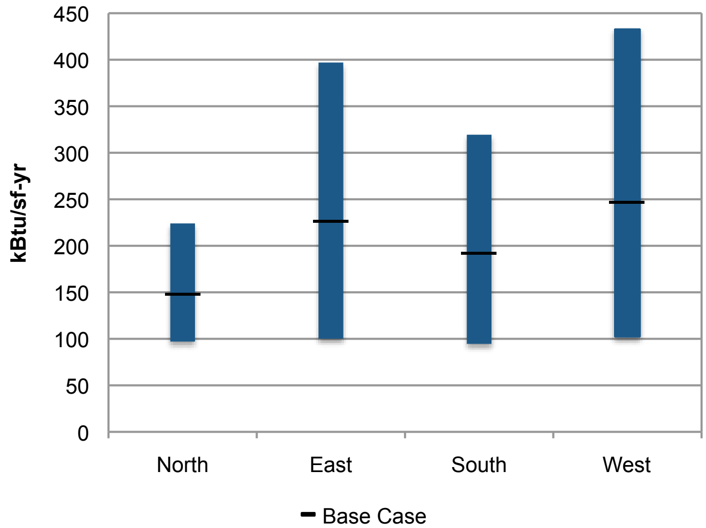
Products Simulated			Center of Glass			2.5″ Alum Frame	
ID	Layers	Description	U-factor	SHGC	Tvis	Type	U-factor
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88	Non-thermal	1.00
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79	Thermally-broken	0.85
C	2	Tint, moderate VT, moderate SHGC	0.47	0.50	0.48	Thermally-broken	0.85
D	2	Reflective, low VT, low SHGC	0.44	0.18	0.10	Thermally-broken	0.85
E	2	Low-E tint, moderate VT, moderate SHGC, argon	0.24	0.29	0.52	Thermally-broken	0.85
F	2	Low-E, low VT, low SHGC, argon	0.25	0.24	0.37	Thermally-broken	0.85
G	2	Low-E, high VT, moderate SHGC, argon	0.24	0.38	0.70	Thermally-broken	0.85
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64	Thermally-broken	0.85
I	3	Low-E, high VT, moderate SHGC, argon	0.13	0.32	0.60	High-performance	0.35
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34	High-performance	0.35
K	1	Clear, applied film	0.99	0.48	0.60	Non-thermal	1.00
L	2	Clear, applied film	0.47	0.55	0.54	Thermally-broken	0.85

School Perimeter Zone—Phoenix, AZ
Orientation

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations including four orientations, six glazing areas, twelve glazing types, nine shading conditions, and two light control options. The bars in Figure 1 show the range of possible energy use for these variations grouped by orientation. The base case window is clear double-glazing (Window B), unshaded, 30% WWR, with no lighting controls.

- The impact of orientation on energy use is not the same for all glazings.
- The lower ends of the bars show that under certain conditions, very low energy use can be achieved with any orientation.
- For the base case, north-facing spaces use the least energy followed by south-facing spaces. East- and west-facing spaces use the most energy.

Figure 1: Energy Use in Schools - Phoenix, AZ
Orientation - Range of Performance

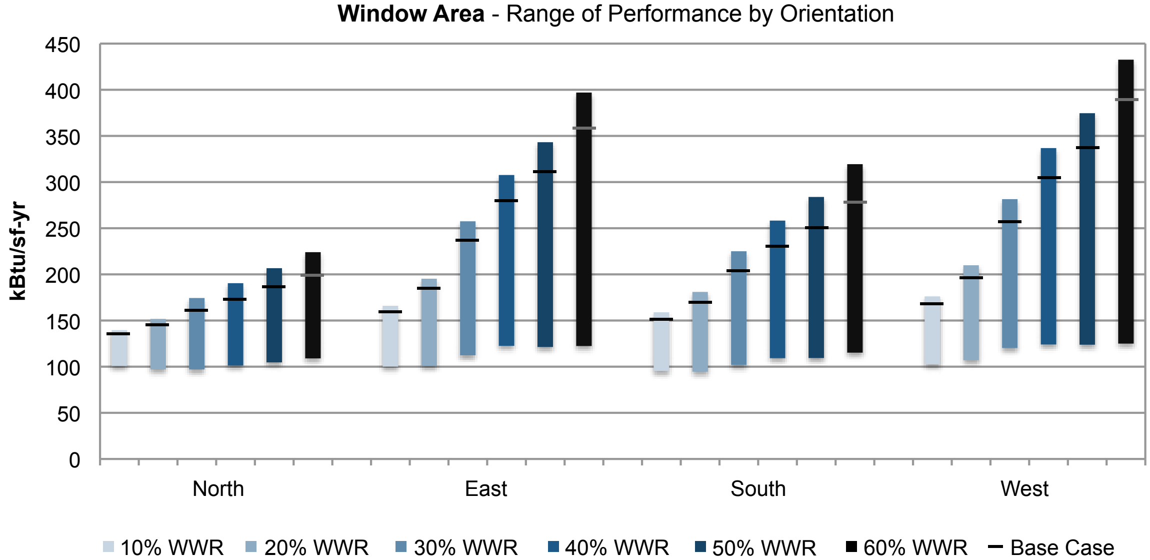


Window Area

The bars in Figure 2 below show the range of possible energy use for these variations grouped by window area for each orientation. The base case window is clear double-glazing (Window B), unshaded, with no lighting controls.

- The impact of window area on energy use is not the same for all orientations.
- The lower ends of the bars show that under certain conditions, very low energy use can be achieved with any window area on any orientation.
- The higher ends of the bars show that on east- and west-facing orientations, larger window areas can have much worse performance than larger window areas on north- and south-facing orientations.
- For the base case, energy use increases with window area on all orientations but at different rates. It increases least in north-facing spaces, and most in east- and west-facing spaces.

Figure 2: Energy Use in Schools - Phoenix, AZ
Window Area - Range of Performance by Orientation

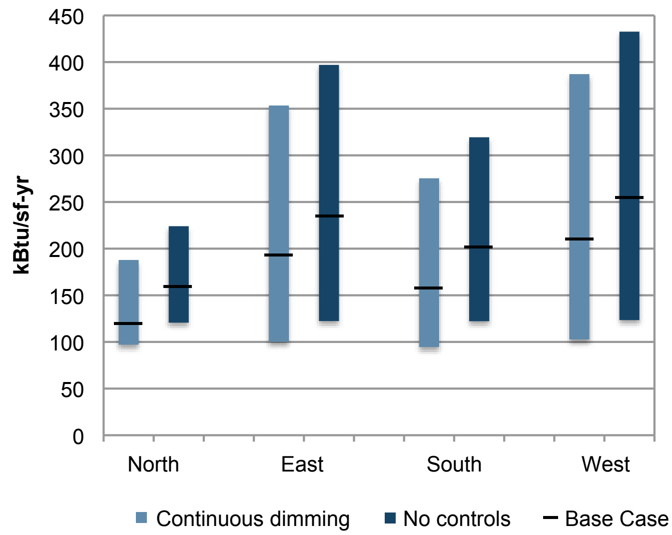


School Perimeter Zone—Phoenix, AZ
Lighting Controls

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figure 3 show the range of possible energy performance for these variations grouped by light control option for each orientation. The base case window is clear double-glazing (Window B), unshaded, and 30% WWR.

- Lighting controls that dim electric lights when there is sufficient daylight almost always reduce energy use in perimeter spaces.
- For the base case, the energy use with continuous dimming light controls is significantly lower than without light controls regardless of orientation.

Figure 3: Energy Use in Schools - Phoenix, AZ
Daylight controls - Range of Performance by Orientation

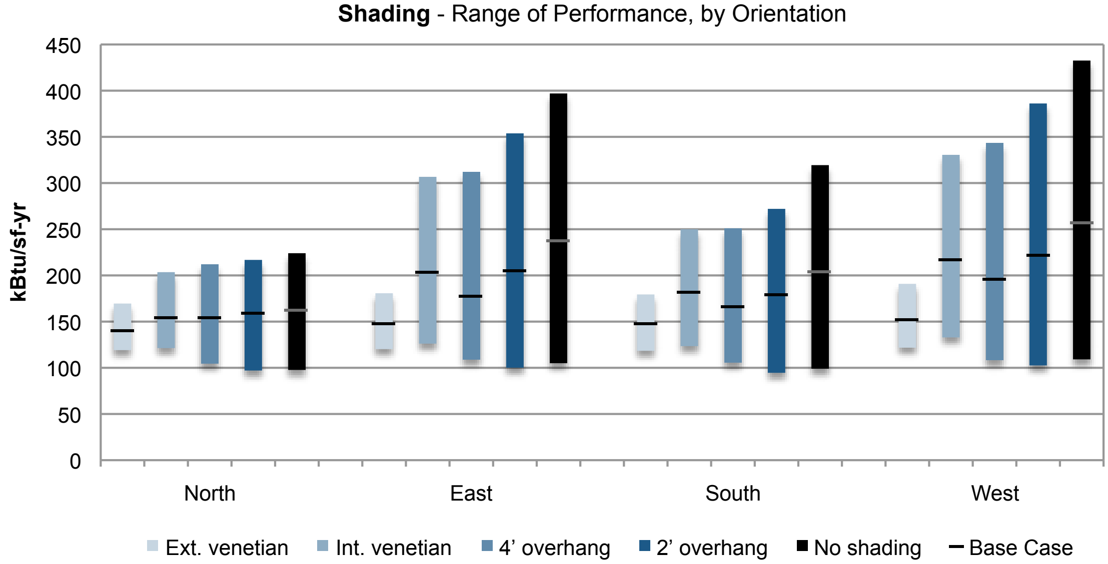


Shading

The bars in Figure 4 show the range of possible energy performance for these variations grouped by shading condition for each orientation. The base case window is clear double-glazing (Window B), 30% WWR, with no lighting controls.

- The impact of shading conditions on energy use is not the same for all orientations.
- The lower ends of the bars show that under certain conditions, very low energy use can be achieved with or without shading on any orientation.
- The higher ends of the bars show that on east- and west-facing orientations, some unshaded windows can have much worse performance than unshaded windows on the north or south.
- For the base case, shading devices have little impact on north-facing orientations. On south-facing orientations, exterior blinds perform very well on the south but these are fixed in place at all times blocking view and daylight to some extent. Shading devices such as overhangs and fixed interior blinds are also effective. For the base case on east- and west-facing orientations, shading devices such as fixed exterior blinds are most effective. Deeper 4-foot overhangs are more effective on the east and west compared to shallower overhangs and interior blinds.

Figure 4: Energy Use in Schools - Phoenix, AZ
Shading - Range of Performance, by Orientation

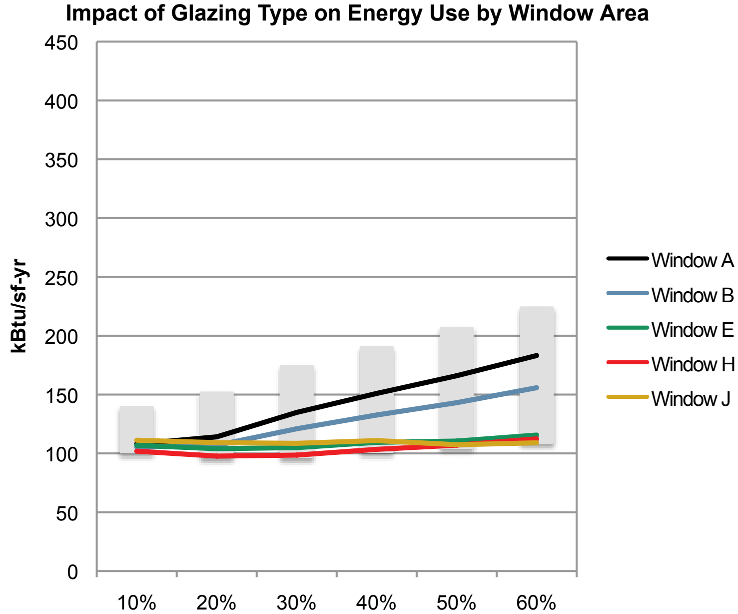


North-Facing School—Phoenix, AZ
Glazing Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figure 5 show the range of possible energy use for these variations grouped by window area for the north-facing orientation. Superimposed on the bars is the performance of five glazing types with light controls and no shading.

- The impact of window area on energy use is not the same for all glazings.
- Energy use increases somewhat for poorer performing clear single- and double-glazing (Windows A and B) as the percentage of window area increases.
- Window area has almost no effect with higher performing double- and triple-glazings with low-E coatings (Windows E, H and J).

Figure 5: North-Facing School Zones - Phoenix, AZ
Impact of Glazing Type on Energy Use by Window Area



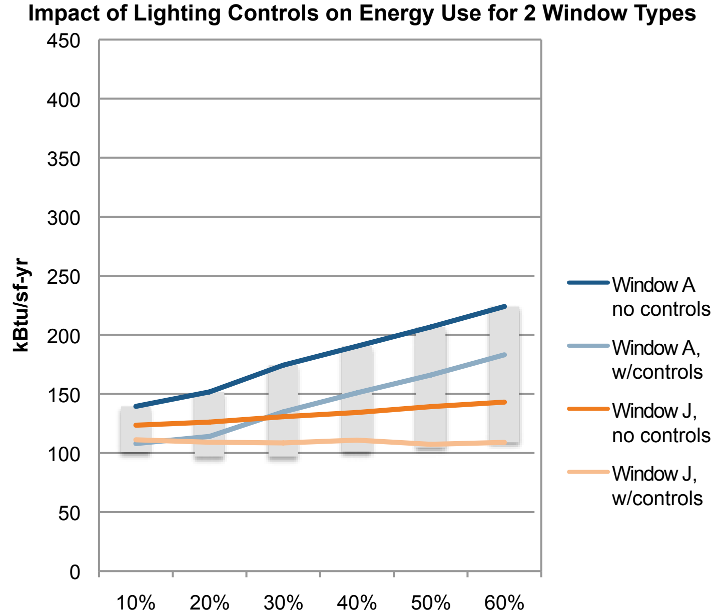
Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Lighting Controls and Window Area

The bars in Figure 6 show the range of possible energy use for these variations grouped by window area for the north-facing orientation. Superimposed on the bars is the performance of two unshaded glazing types with and without daylighting controls. The two types represent very poor performing and very high-performing glazing (Window A: clear single-glazing and Window J: low-E triple-glazing).

- Daylighting controls reduce energy use for both types of glazing. The amount of energy savings is greater with clear single-glazing (Window A) because it has a higher visible transmittance than low-E triple-glazing (Window J). For clear single-glazing (Window A), increases in window area do not significantly impact the energy savings offered by lighting controls. For low-E triple-glazing (Window J), there is a slight increase in energy savings from light controls as window area increases.

Figure 6: North-Facing School Zones - Phoenix, AZ
Impact of Lighting Controls on Energy Use for 2 Window Types



North-Facing School—Phoenix, AZ
Shading Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figures 7, 8 and 9 show the range of possible energy performance for these variations grouped by window area for the north-facing orientation. Each of the three figures represents a different type of glazing with the performance of five shading types superimposed. All cases have light controls.

- For clear double-glazing (Window B), fixed exterior shading devices and overhangs either have little impact or increase energy use in some cases. Fixed interior shades perform worse than no shading at all.
- For low-E double- and triple-glazing (Windows E and J), all types of shading either have little impact or they actually increase energy use slightly in some cases.

Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Figure 7: North-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window B: Clear Double Glazing

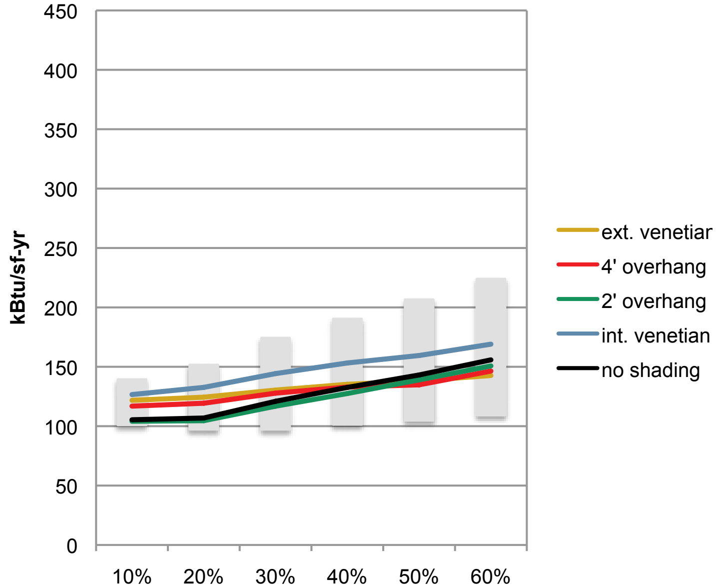


Figure 8: North-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window E: Low-E Tinted Double Glazing

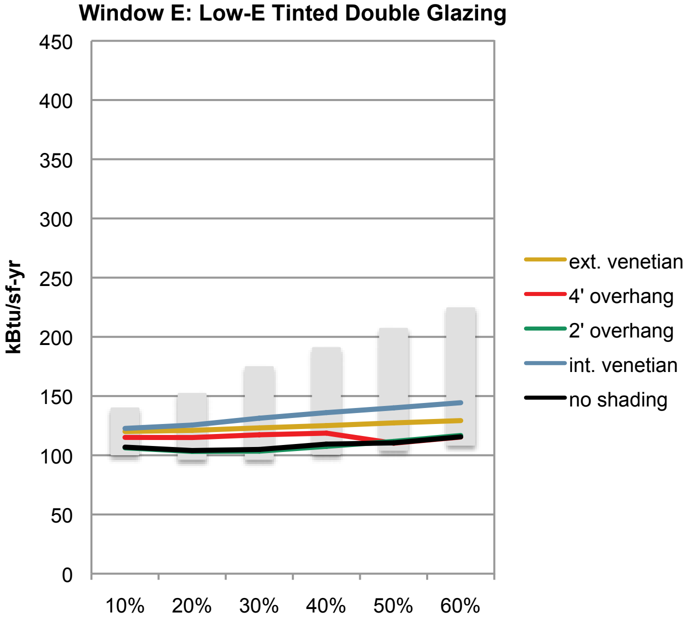
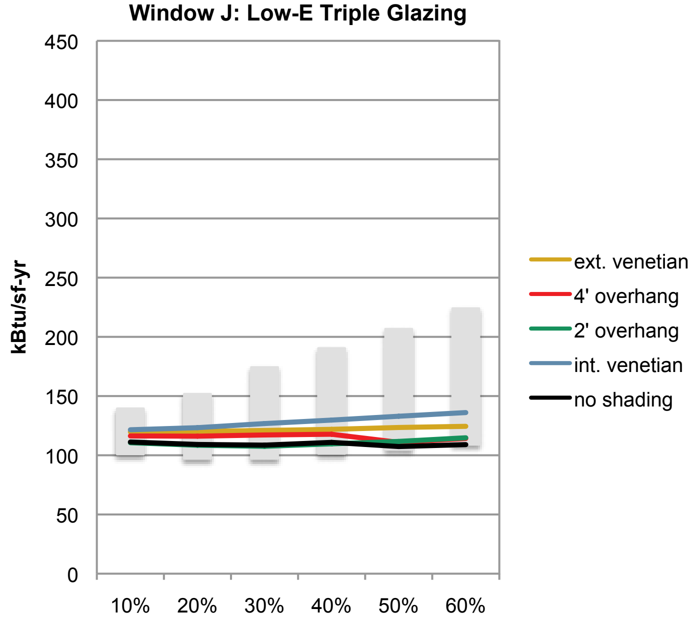


Figure 9: North-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window J: Low-E Triple Glazing

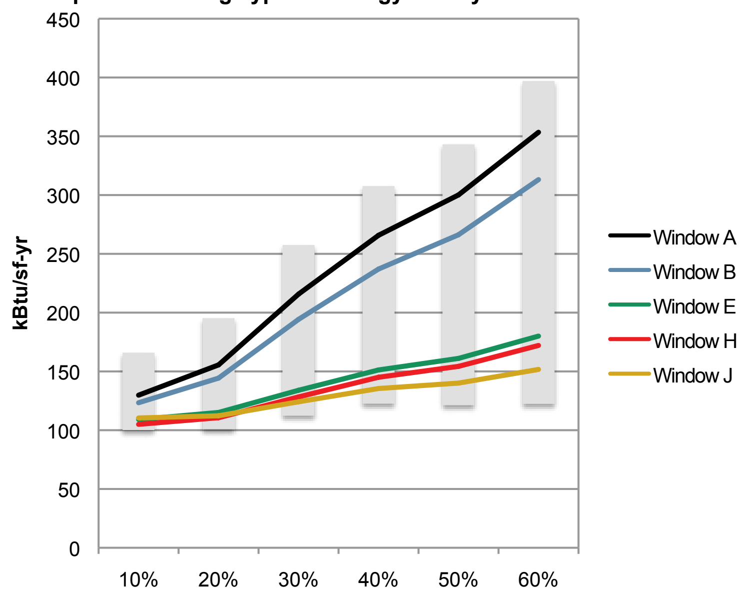


East-Facing School—Phoenix, AZ
Glazing Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figure 10 show the range of possible energy use for these variations grouped by window area for the east-facing orientation. Superimposed on the bars is the performance of five glazing types with light controls and no shading.

- The impact of window area on energy use is not the same for all glazings.
- Energy use increases substantially for poorer performing clear single- and double-glazing (Windows A and B) as the percentage of window area increases.
- Energy use increases at a lower rate as the percentage of window area increases with higher performing double- and triple-glazings with low-E coatings (Windows E, H and J).

Figure 10: East-Facing School Zones - Phoenix, AZ
Impact of Glazing Type on Energy Use by Window Area



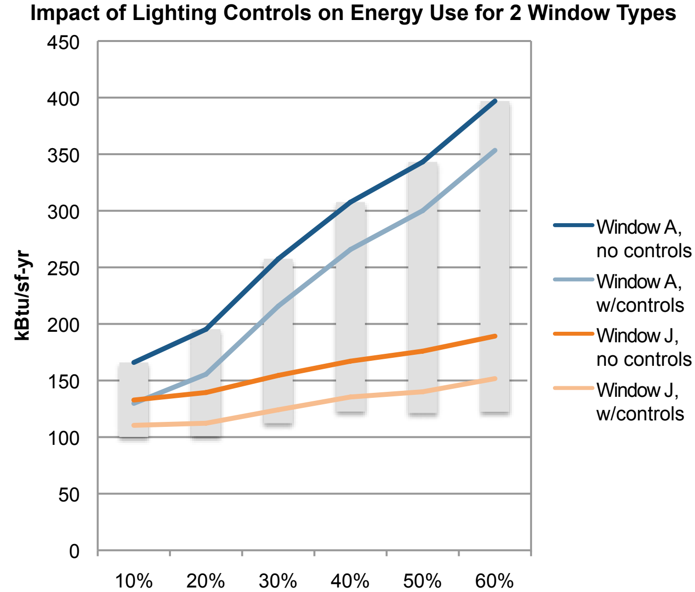
Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Lighting Controls and Window Area

The bars in Figure 11 show the range of possible energy use for these variations grouped by window area for the east-facing orientation. Superimposed on the bars is the performance of two unshaded glazing types with and without daylighting controls. The two types represent very poor performing and very high-performing glazing (Window A: clear single-glazing and Window J: low-E triple-glazing).

- Daylighting controls reduce energy use similar amounts for both types of glazing. Increases in window area do not significantly impact the energy savings offered by lighting controls.

Figure 11: East-Facing School Zones - Phoenix, AZ
Impact of Lighting Controls on Energy Use for 2 Window Types

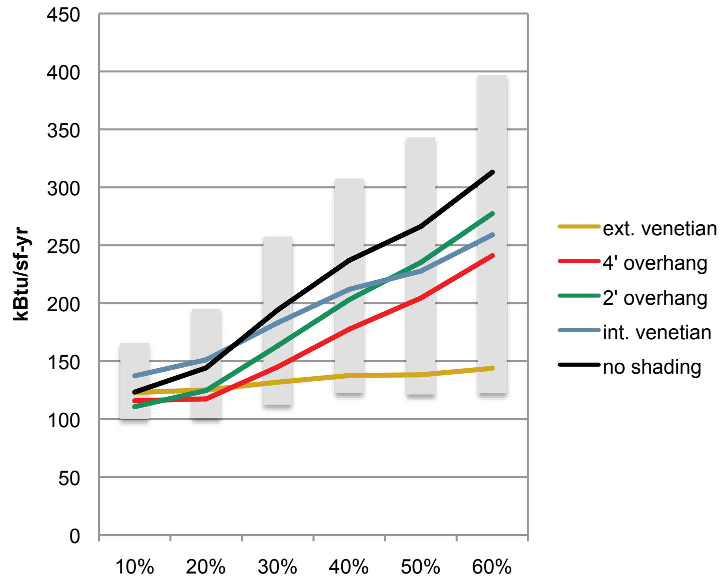


East-Facing School—Phoenix, AZ
Shading Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figures 12, 13 and 14 show the range of possible energy performance for these variations grouped by window area for the east-facing orientation. Each of the three figures represents a different type of glazing with the performance of five shading types superimposed. All cases have light controls.

- For clear double-glazing (Window B), fixed exterior blinds lower energy use significantly especially as window area increases. Overhangs provide smaller but still substantial energy savings. Fixed interior blinds also provide savings above 30% window area.
- For low-E double-glazing (Window E), fixed exterior blinds lower energy use significantly above 20% WWR. The next best case for energy savings is the 4-foot overhang (above 20% WWR) while 2-foot overhangs have a smaller effect. Fixed vertical interior shading devices perform worse than no shading at all.
- For low-E triple-glazing (Window J), fixed vertical exterior blinds save energy above 30% WWR. There are small savings with 4-foot overhangs at WWR above 30% while 2-foot overhangs have a smaller effect. Fixed vertical interior shading devices perform worse than no shading at all.

Figure 12: East-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window B: Clear Double Glazing



Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Figure 13: East-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window E: Low-E Tinted Double Glazing

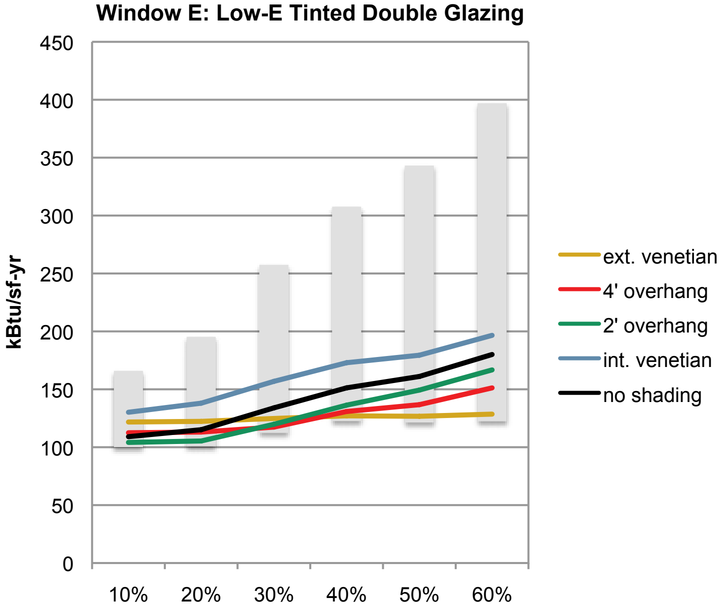
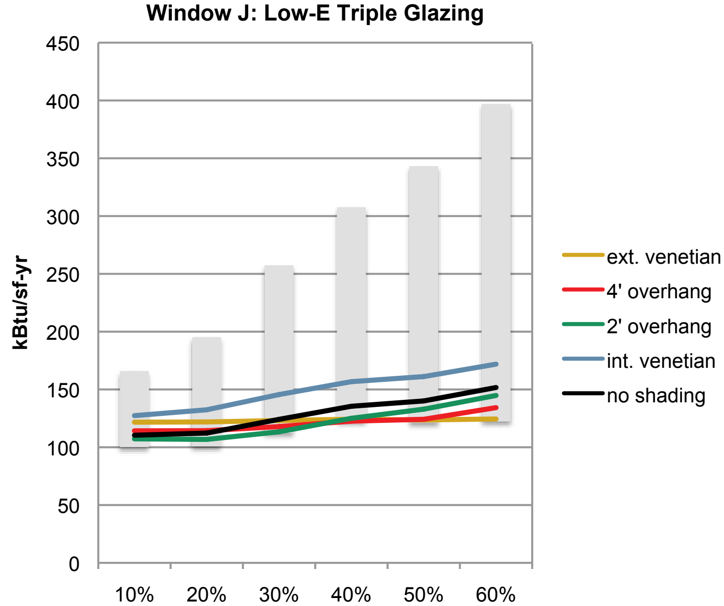


Figure 14: East-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window J: Low-E Triple Glazing

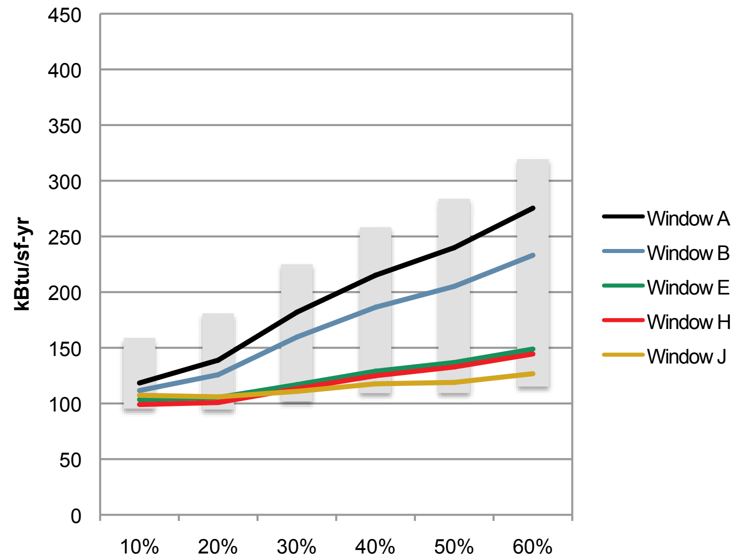


South-Facing School—Phoenix, AZ
Glazing Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figure 15 show the range of possible energy use for these variations grouped by window area for the south-facing orientation. Superimposed on the bars is the performance of five glazing types with light controls and no shading.

- The impact of window area on energy use is not the same for all glazings.
- Energy use increases substantially for poorer performing clear single- and double-glazing (Windows A and B) as the percentage of window area increases.
- For higher performing double- and triple-glazings with low-E coatings (Windows E, H and J), energy use increases at a lower rate as the window area increases.

Figure 15: South-Facing School Zones - Phoenix, AZ
Impact of Glazing Type on Energy Use by Window Area



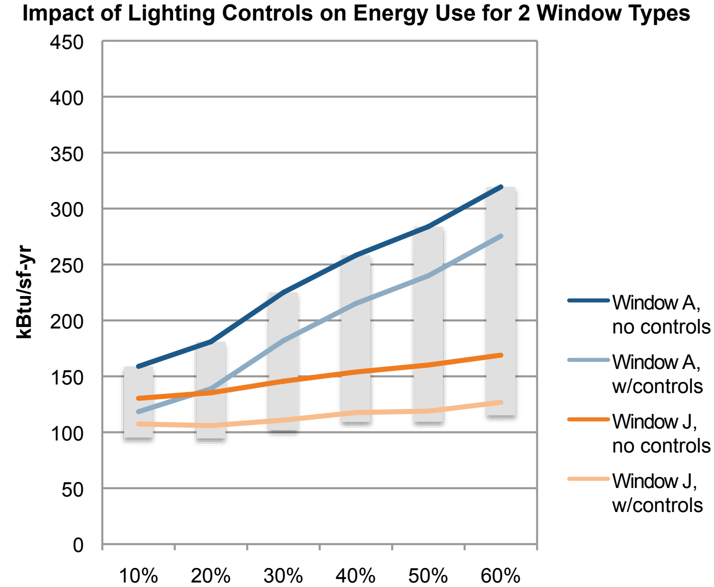
Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Lighting Controls and Window Area

The bars in Figure 6 show the range of possible energy use for these variations grouped by window area for the south-facing orientation. Superimposed on the bars is the performance of two unshaded glazing types with and without daylighting controls. The two types represent very poor performing and very high-performing glazing (Window A: clear single-glazing and Window J: low-E triple-glazing).

- Daylighting controls reduce energy use similar amounts for both types of glazing. Increases in window area do not significantly impact the energy savings offered by lighting controls.

Figure 16: South-Facing School Zones - Phoenix, AZ
Impact of Lighting Controls on Energy Use for 2 Window Types

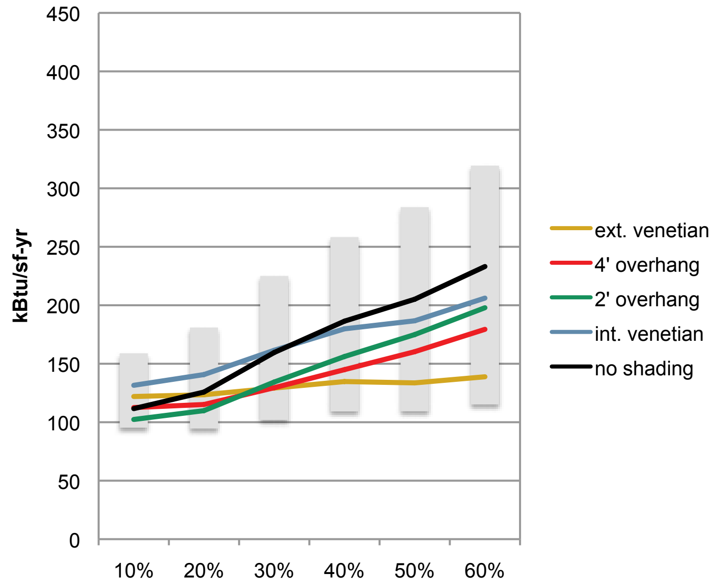


South-Facing School—Phoenix, AZ
Shading Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figures 17, 18 and 19 show the range of possible energy performance for these variations grouped by window area for the south-facing orientation. Each of the three figures represents a different type of glazing with the performance of five shading types superimposed. All cases have light controls.

- For clear double-glazing (Window B), fixed exterior blinds lower energy use significantly especially as the percentage of window area increases above 20% WWR. Overhangs (2 and 4 feet) reduce energy use as window area increases. Fixed interior shades have less impact than overhangs and are worse than no shading at all below 30% WWR.
- For low-E double-glazing (Window E), fixed vertical exterior blinds and overhangs (2 and 4 feet) reduce energy use somewhat as window area increases above 30% WWR. Fixed vertical interior blinds perform worse than no shading at all.
- For low-E triple-glazing (Window J), fixed vertical exterior blinds and overhangs (2 and 4 feet) have little or no impact on energy savings. Fixed vertical interior blinds perform worse than no shading at all.

Figure 17: South-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window B: Clear Double Glazing



Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Figure 18: South-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window E: Low-E Tinted Double Glazing

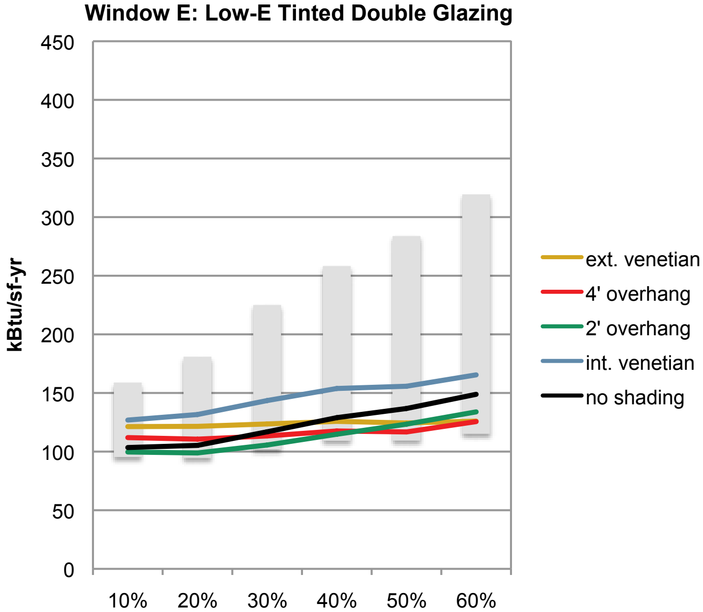
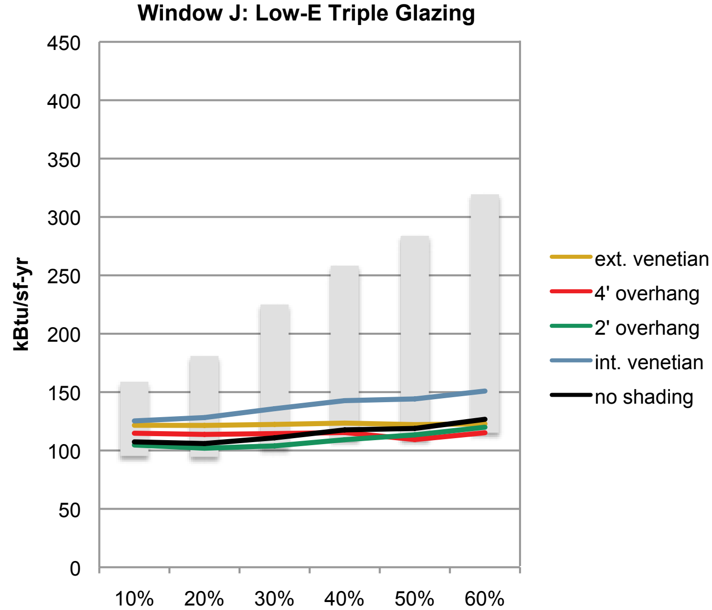


Figure 19: South-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window J: Low-E Triple Glazing

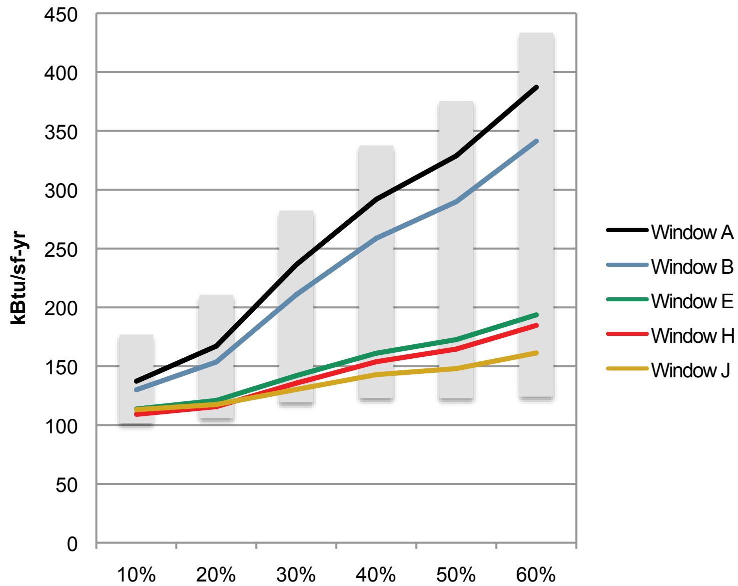


West-Facing School—Phoenix, AZ
Glazing Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figure 20 show the range of possible energy use for these variations grouped by window area for the west-facing orientation. Superimposed on the bars is the performance of five glazing types with light controls and no shading.

- The impact of window area on energy use is not the same for all glazings.
- Energy use increases substantially for poorer performing clear single- and double-glazing (Windows A and B) as the percentage of window area increases.
- Energy use increases at a lower rate as the percentage of window area increases with higher performing double- and triple-glazings with low-E coatings (Windows E, H and J).

Figure 20: West-Facing School Zones - Phoenix, AZ Impact of Glazing Type on Energy Use by Window Area



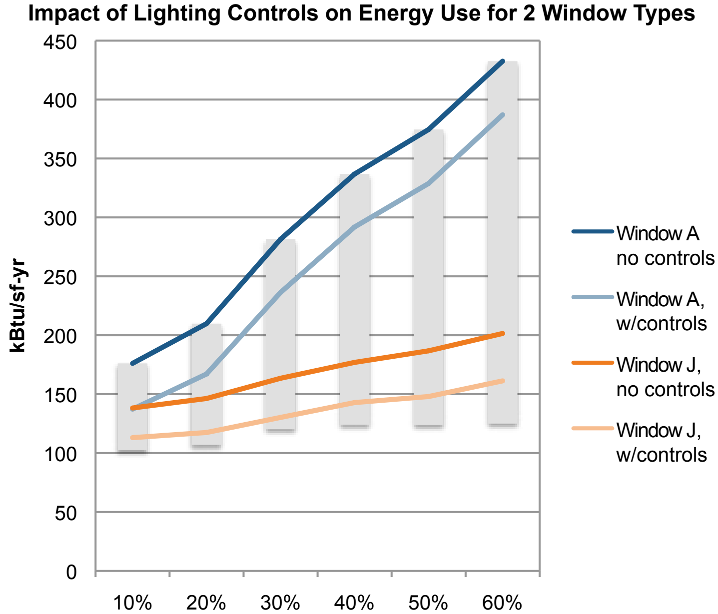
Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Lighting Controls and Window Area

The bars in Figure 21 show the range of possible energy use for these variations grouped by window area for the west-facing orientation. Superimposed on the bars is the performance of two unshaded glazing types with and without daylighting controls. The two types represent very poor performing and very high-performing glazing (Window A: clear single-glazing and Window J: low-E triple-glazing).

- Daylighting controls reduce energy use similar amounts for both types of glazing. Increases in window area do not significantly impact the energy savings offered by lighting controls.

Figure 21: West-Facing School Zones - Phoenix, AZ Impact of Lighting Controls on Energy Use for 2 Window Types

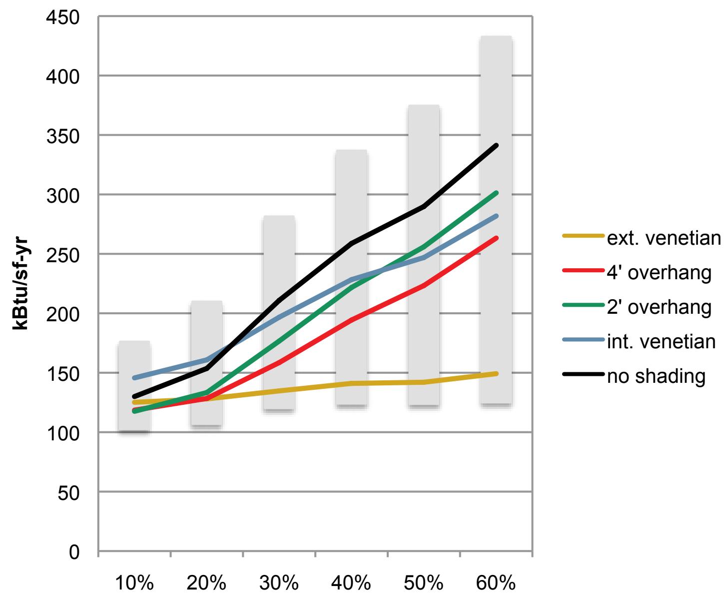


West-Facing School—Phoenix, AZ
Shading Type and Window Area

The energy performance of a perimeter school (classroom) zone in Phoenix has been calculated for many window design variations. The bars in Figures 22, 23 and 24 show the range of possible energy performance for these variations grouped by window area for the west-facing orientation. Each of the three figures represents a different type of glazing with the performance of five shading types superimposed. All cases have light controls.

- For clear double-glazing (Window B), fixed exterior blinds lower energy use significantly especially as window area increases. Four-foot overhangs also provide substantial energy savings with 2-foot overhangs reducing energy use as well. Fixed interior blinds also provide significant savings above 20% window area.
- For low-E double-glazing (Window E), fixed exterior blinds lower energy use significantly especially as window area increases above 20% WWR. Overhangs also provide smaller energy savings above 20% WWR. Fixed vertical interior shading devices perform worse than no shading at all.
- For low-E triple-glazing (Window J), fixed exterior blinds lower energy use above 30% WWR. Overhangs provide smaller energy savings. Fixed vertical interior shading devices perform worse than no shading at all.

Figure 22: West-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window B: Clear Double Glazing



Products Simulated			Center of Glass		
ID	Layers	Description-	U	SHGC	VT
A	1	Clear, high VT, high SHGC	1.03	0.82	0.88
B	2	Clear, high VT, high SHGC	0.47	0.70	0.79
E	2	Low-E tint, mod. VT, mod. SHGC, argon	0.24	0.29	0.52
H	2	Low-E, high VT, low SHGC, argon	0.24	0.27	0.64
J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34

Figure 23: West-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window E: Low-E Tinted Double Glazing

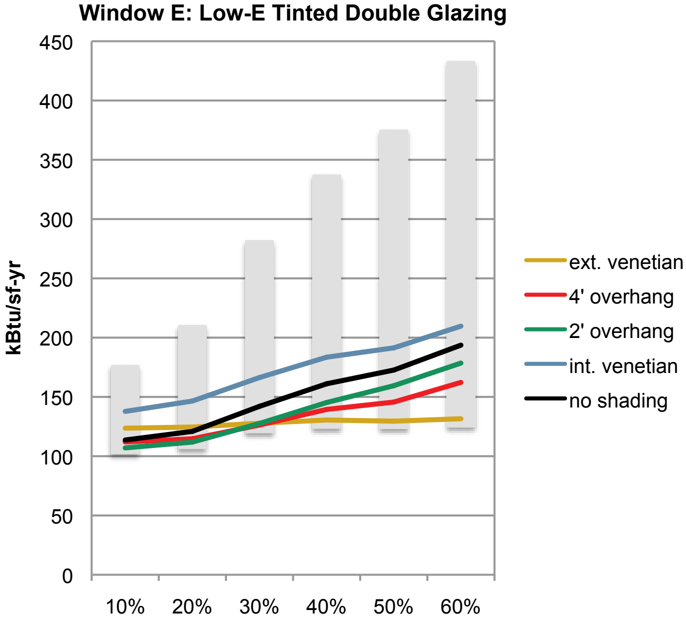
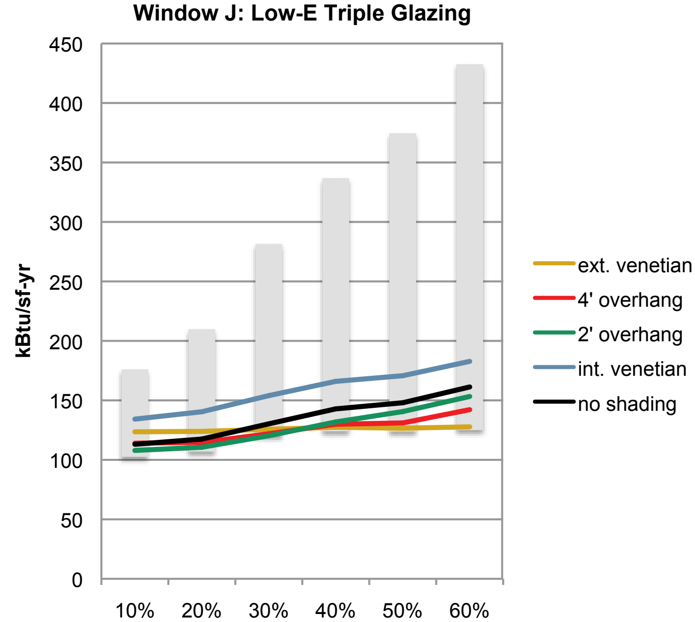
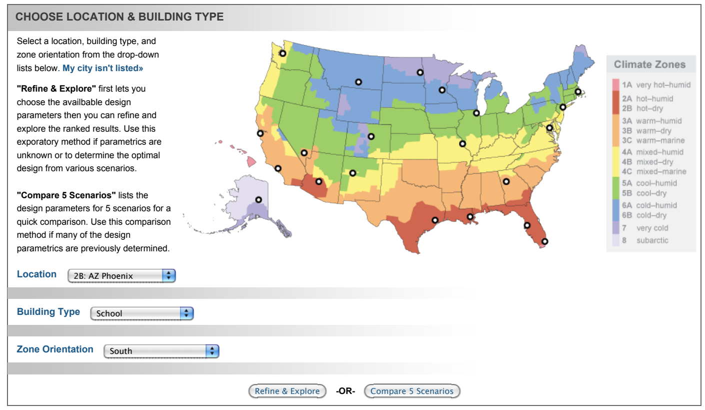


Figure 24: West-Facing School Zones - Phoenix, AZ
Impact of Shading on Energy Use
Window J: Low-E Triple Glazing



Finding the Optimal Window Design for a School in Phoenix, Arizona

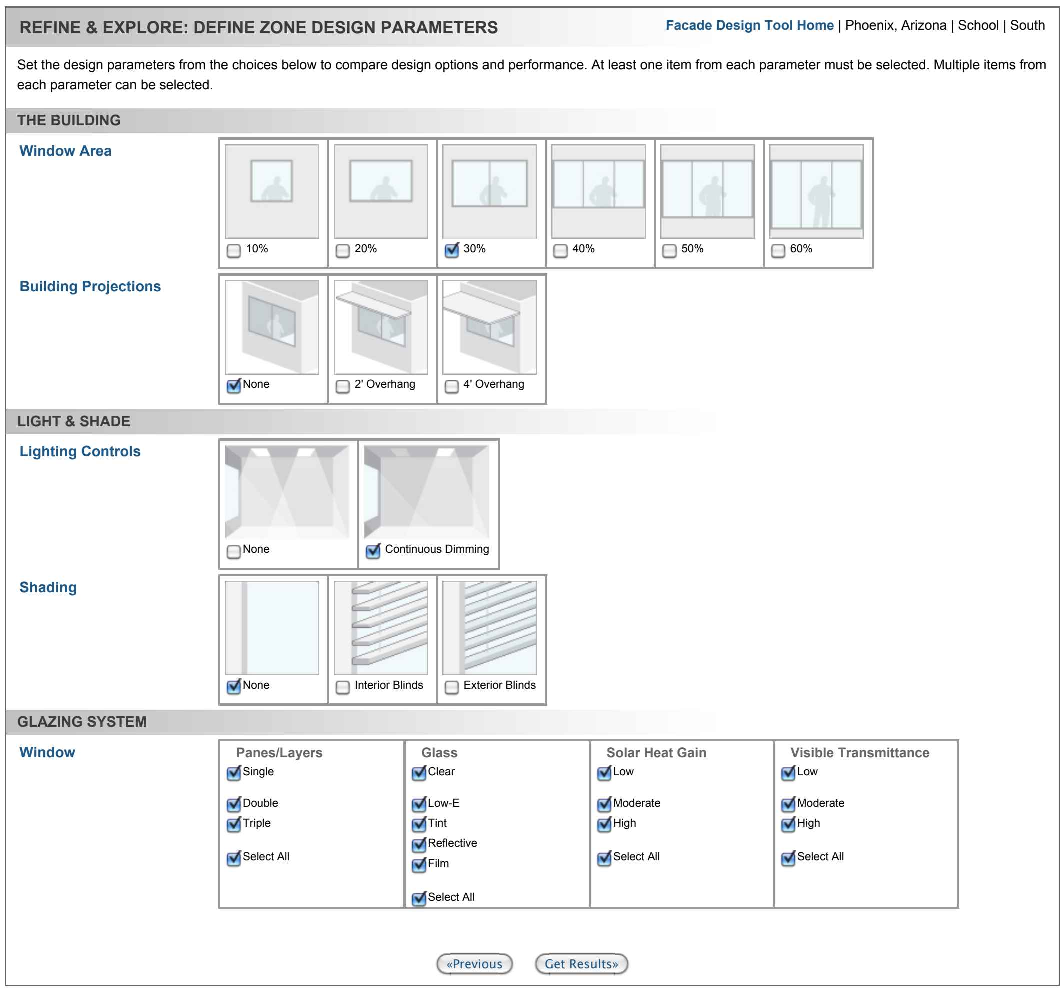
Using the Facade Design Tool, it is possible to find the window design with the lowest energy use for an School Perimeter Zone in Phoenix, Arizona. Finding the optimal design is a process and there is not one clear answer. It depends on the fixed conditions of the design and other assumptions made by the design team. The following steps illustrate how the Facade Design Tool can be used to find the best option for a given set of conditions and then explore other questions.



STEP 1:
Select the location, building type and zone orientation.

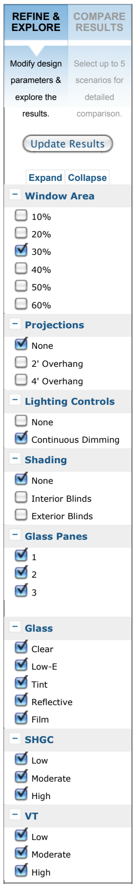
In this case, the location is *Phoenix, Arizona*, the building type is *School*, and the zone orientation is *South*.

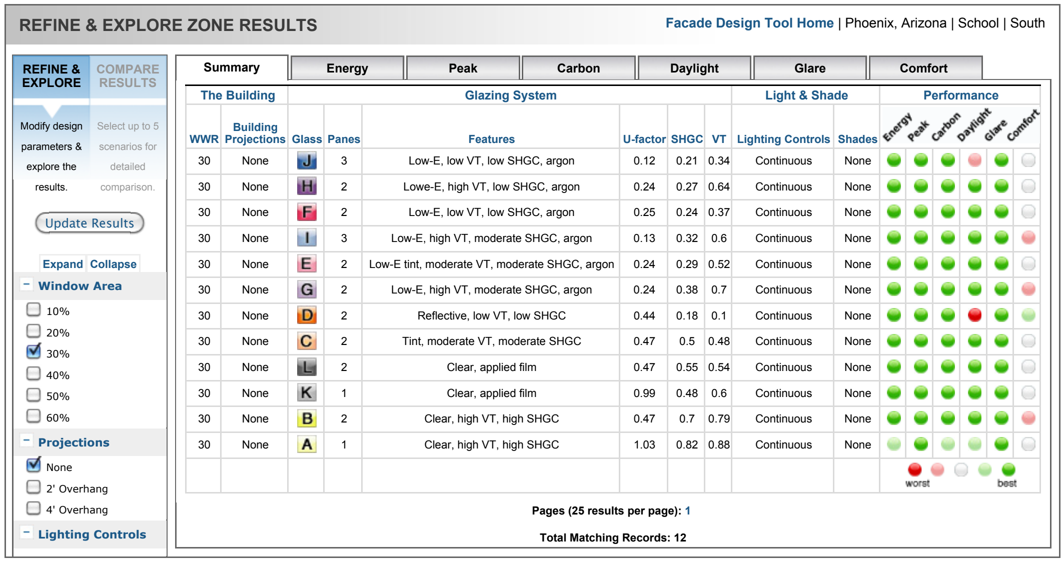
STEP 2:
Select the design variables to be explored.



This is where the designer determines which variables are fixed and which are open to exploration. For example, the window-to-wall ratio (WWR) may be fixed at 30%, there may be a desire for no exterior shading devices, and a decision to use lighting controls in the space has been made. In this case, the main variable to be explored is glazing type. Select *Get Results* to go to the next screen.

STEP 3:
Review results on the *Summary* tab.

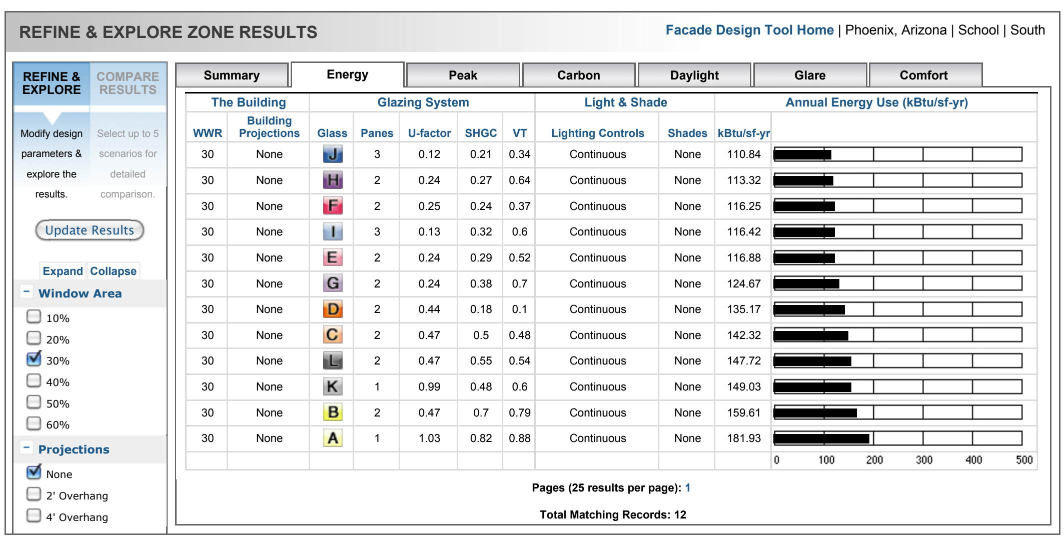




The Building		Glazing System						Light & Shade	
WWR	Building Projections	Glass	Panes	Features	U-factor	SHGC	VT	Lighting Controls	Shades
30	None	J	3	Low-E, low VT, low SHGC, argon	0.12	0.21	0.34	Continuous	None
30	None	H	2	Lowe-E, high VT, low SHGC, argon	0.24	0.27	0.64	Continuous	None
30	None	F	2	Low-E, low VT, low SHGC, argon	0.25	0.24	0.37	Continuous	None
30	None	I	3	Low-E, high VT, moderate SHGC, argon	0.13	0.32	0.6	Continuous	None
30	None	E	2	Low-E tint, moderate VT, moderate SHGC, argon	0.24	0.29	0.52	Continuous	None
30	None	G	2	Low-E, high VT, moderate SHGC, argon	0.24	0.38	0.7	Continuous	None
30	None	D	2	Reflective, low VT, low SHGC	0.44	0.18	0.1	Continuous	None
30	None	C	2	Tint, moderate VT, moderate SHGC	0.47	0.5	0.48	Continuous	None
30	None	L	2	Clear, applied film	0.47	0.55	0.54	Continuous	None
30	None	K	1	Clear, applied film	0.99	0.48	0.6	Continuous	None
30	None	B	2	Clear, high VT, high SHGC	0.47	0.7	0.79	Continuous	None
30	None	A	1	Clear, high VT, high SHGC	1.03	0.82	0.88	Continuous	None

This is a list of all the window design scenarios in the database that meet the conditions specified (30% WWR, no shading, continuous lighting controls). There are twelve options on the list representing different glazing types. The circles on the right side show a ranking of each window design option for six performance indicators (energy, peak demand, carbon, daylight, glare and thermal comfort). A red circle indicates poor performance and should be avoided.

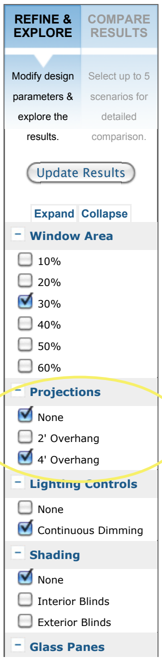
STEP 4:
Select the *Energy* tab to see the energy use results.

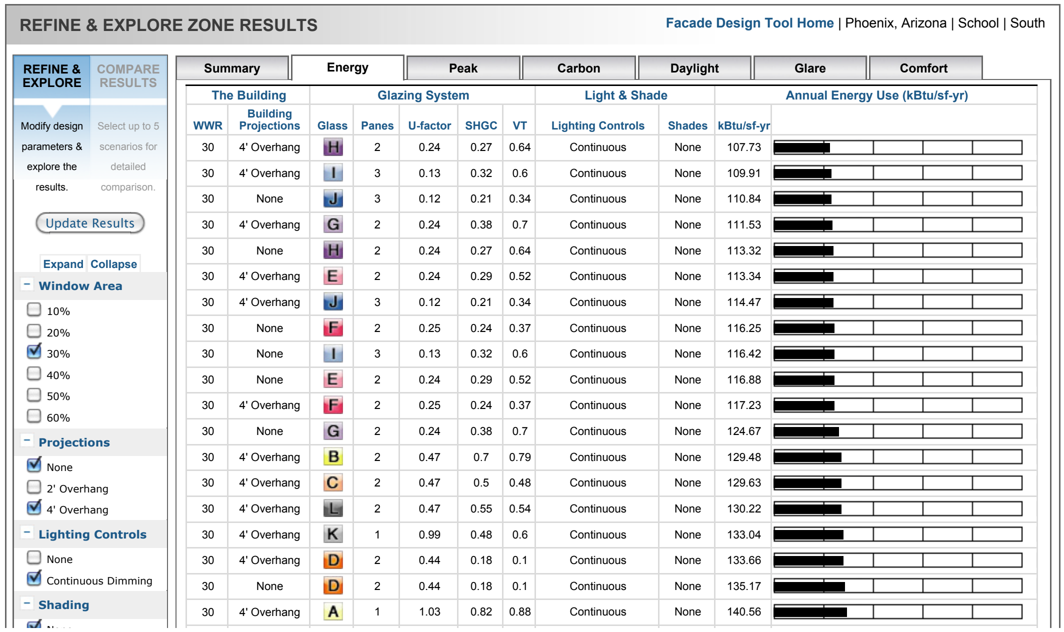


The Building		Glazing System					Light & Shade		Annual Energy Use (kBtu/sf-yr)
WWR	Building Projections	Glass	Panes	U-factor	SHGC	VT	Lighting Controls	Shades	kBtu/sf-yr
30	None	J	3	0.12	0.21	0.34	Continuous	None	110.84
30	None	H	2	0.24	0.27	0.64	Continuous	None	113.32
30	None	F	2	0.25	0.24	0.37	Continuous	None	116.25
30	None	I	3	0.13	0.32	0.6	Continuous	None	116.42
30	None	E	2	0.24	0.29	0.52	Continuous	None	116.88
30	None	G	2	0.24	0.38	0.7	Continuous	None	124.67
30	None	D	2	0.44	0.18	0.1	Continuous	None	135.17
30	None	C	2	0.47	0.5	0.48	Continuous	None	142.32
30	None	L	2	0.47	0.55	0.54	Continuous	None	147.72
30	None	K	1	0.99	0.48	0.6	Continuous	None	149.03
30	None	B	2	0.47	0.7	0.79	Continuous	None	159.61
30	None	A	1	1.03	0.82	0.88	Continuous	None	181.93

In the *Energy* tab, the energy use results are listed in rank order from best to worst for the window design scenarios in this set. Glazing J has the lowest energy use at 110.84 kBtu/sf-yr. Glazing H is within 3% of the lowest energy use and would be an excellent choice as well. At this point, the designer may be finished and can make a decision based on cost and other parameters, however, this analysis only optimizes within a narrow set of assumptions. The designer may wish to explore other variables as well to make sure the lowest energy use is being achieved.

STEP 5:
Explore impact of exterior shading devices.

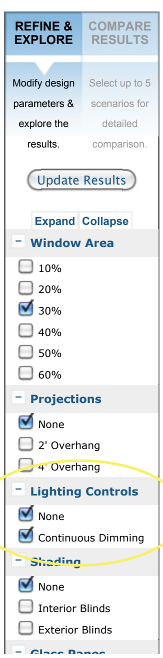


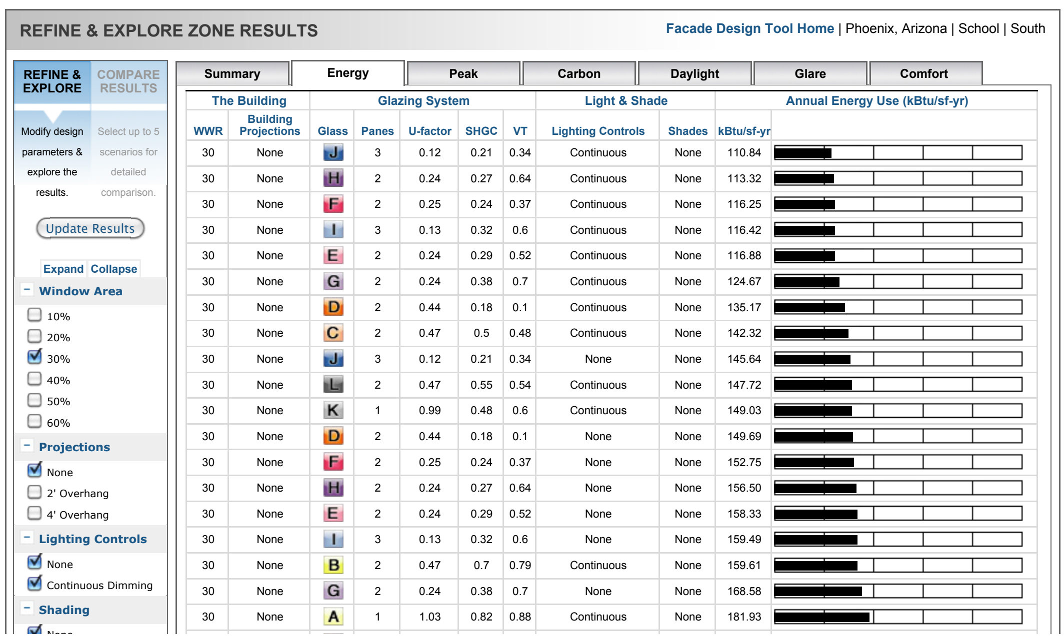


The Building		Glazing System					Light & Shade		Annual Energy Use (kBtu/sf-yr)
WWR	Building Projections	Glass	Panes	U-factor	SHGC	VT	Lighting Controls	Shades	kBtu/sf-yr
30	4' Overhang	H	2	0.24	0.27	0.64	Continuous	None	107.73
30	4' Overhang	I	3	0.13	0.32	0.6	Continuous	None	109.91
30	None	J	3	0.12	0.21	0.34	Continuous	None	110.84
30	4' Overhang	G	2	0.24	0.38	0.7	Continuous	None	111.53
30	None	H	2	0.24	0.27	0.64	Continuous	None	113.32
30	4' Overhang	E	2	0.24	0.29	0.52	Continuous	None	113.34
30	4' Overhang	J	3	0.12	0.21	0.34	Continuous	None	114.47
30	None	F	2	0.25	0.24	0.37	Continuous	None	116.25
30	None	I	3	0.13	0.32	0.6	Continuous	None	116.42
30	None	E	2	0.24	0.29	0.52	Continuous	None	116.88
30	4' Overhang	F	2	0.25	0.24	0.37	Continuous	None	117.23
30	None	G	2	0.24	0.38	0.7	Continuous	None	124.67
30	4' Overhang	B	2	0.47	0.7	0.79	Continuous	None	129.48
30	4' Overhang	C	2	0.47	0.5	0.48	Continuous	None	129.63
30	4' Overhang	L	2	0.47	0.55	0.54	Continuous	None	130.22
30	4' Overhang	K	1	0.99	0.48	0.6	Continuous	None	133.04
30	4' Overhang	D	2	0.44	0.18	0.1	Continuous	None	133.66
30	None	D	2	0.44	0.18	0.1	Continuous	None	135.17
30	4' Overhang	A	1	1.03	0.82	0.88	Continuous	None	140.56

The designer can use the Explore & Refine Dashboard at the left side of the Facade Design Tool to change the parameters of the analysis. Previously, only scenarios with no shading were included in the analysis. In this example, the question is whether exterior shading devices improve energy use. The Projection option *4-foot Overhang* is checked, the results are updated, and a new set of scenarios is listed in rank order that includes all glazings with and without the overhang. Two overhang scenarios outperform the best case without an overhang which is 3% greater than the best case with an overhang. The designer must decide if adding overhangs is worth the investment.

STEP 6:
Explore impact of lighting controls.

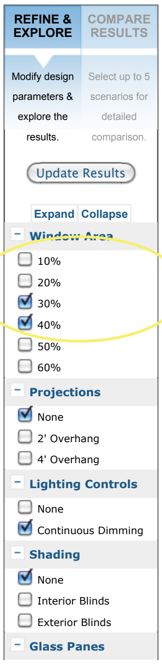


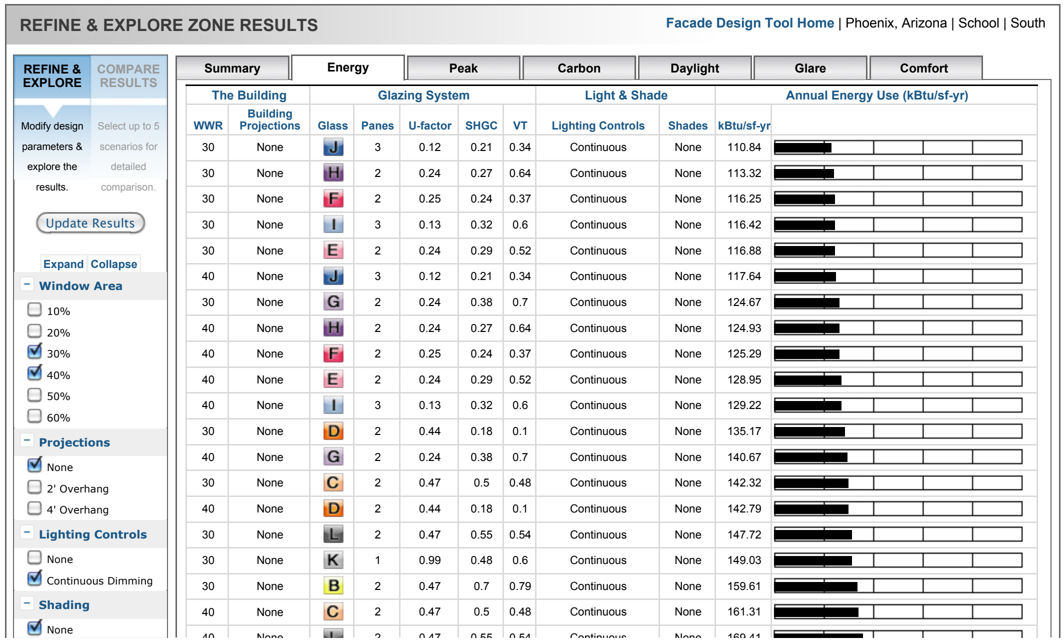


The Building		Glazing System					Light & Shade		Annual Energy Use (kBtu/sf-yr)
WWR	Building Projections	Glass	Panes	U-factor	SHGC	VT	Lighting Controls	Shades	kBtu/sf-yr
30	None	J	3	0.12	0.21	0.34	Continuous	None	110.84
30	None	H	2	0.24	0.27	0.64	Continuous	None	113.32
30	None	F	2	0.25	0.24	0.37	Continuous	None	116.25
30	None	I	3	0.13	0.32	0.6	Continuous	None	116.42
30	None	E	2	0.24	0.29	0.52	Continuous	None	116.88
30	None	G	2	0.24	0.38	0.7	Continuous	None	124.67
30	None	D	2	0.44	0.18	0.1	Continuous	None	135.17
30	None	C	2	0.47	0.5	0.48	Continuous	None	142.32
30	None	J	3	0.12	0.21	0.34	None	None	145.64
30	None	L	2	0.47	0.55	0.54	Continuous	None	147.72
30	None	K	1	0.99	0.48	0.6	Continuous	None	149.03
30	None	D	2	0.44	0.18	0.1	None	None	149.69
30	None	F	2	0.25	0.24	0.37	None	None	152.75
30	None	H	2	0.24	0.27	0.64	None	None	156.50
30	None	E	2	0.24	0.29	0.52	None	None	158.33
30	None	I	3	0.13	0.32	0.6	None	None	159.49
30	None	B	2	0.47	0.7	0.79	Continuous	None	159.61
30	None	G	2	0.24	0.38	0.7	None	None	168.58
30	None	A	1	1.03	0.82	0.88	Continuous	None	181.93

Previously, only scenarios with continuous dimming light controls were included in the analysis. In this example, the question is to determine the impact of these light controls on energy use. *4-foot Overhang* for Projections is unchecked from the previous example. Lighting Controls option *None* is checked, the results are updated, and a new set of scenarios is listed in rank order that includes all glazings with and without the lighting controls. The eight lowest energy use options all include light controls. The best option without light controls uses 145.64 kBtu/sf-yr compared to 110.84 kBtu/sf-yr for the best option using light controls (a 31% increase). It is apparent from the analysis that light controls make a significant difference in energy use.

STEP 7: Explore impact of increasing window area.





The Building		Glazing System					Light & Shade		Annual Energy Use (kBtu/sf-yr)
WWR	Building Projections	Glass	Panes	U-factor	SHGC	VT	Lighting Controls	Shades	kBtu/sf-yr
30	None	J	3	0.12	0.21	0.34	Continuous	None	110.84
30	None	H	2	0.24	0.27	0.64	Continuous	None	113.32
30	None	F	2	0.25	0.24	0.37	Continuous	None	116.25
30	None	I	3	0.13	0.32	0.6	Continuous	None	116.42
30	None	E	2	0.24	0.29	0.52	Continuous	None	116.88
40	None	J	3	0.12	0.21	0.34	Continuous	None	117.64
30	None	G	2	0.24	0.38	0.7	Continuous	None	124.67
40	None	H	2	0.24	0.27	0.64	Continuous	None	124.93
40	None	F	2	0.25	0.24	0.37	Continuous	None	125.29
40	None	E	2	0.24	0.29	0.52	Continuous	None	128.95
40	None	I	3	0.13	0.32	0.6	Continuous	None	129.22
30	None	D	2	0.44	0.18	0.1	Continuous	None	135.17
40	None	G	2	0.24	0.38	0.7	Continuous	None	140.67
30	None	C	2	0.47	0.5	0.48	Continuous	None	142.32
40	None	D	2	0.44	0.18	0.1	Continuous	None	142.79
30	None	L	2	0.47	0.55	0.54	Continuous	None	147.72
30	None	K	1	0.99	0.48	0.6	Continuous	None	149.03
30	None	B	2	0.47	0.7	0.79	Continuous	None	159.61
40	None	C	2	0.47	0.5	0.48	Continuous	None	161.31

Previously, only scenarios with 30% window-to-wall ratios (WWR) were included in the analysis. In this example, the question is what is the impact of increasing the WWR on energy use. *None* for Lighting Controls is unchecked from the previous example. The *40%* Window Area option is checked and a new set of scenarios is listed in rank order that includes all glazings with both 30% and 40% WWR. The five lowest energy use options have 30% WWR. The best option with 40% WWR is Glazing J which uses 117.64 kBtu/sf-yr compared to 110.84 kBtu/sf-yr for the best option with 30% WWR (a 6% increase). The designer must decide if other benefits of larger window area outweigh the additional energy use increase.

SUMMARY

Cases with Lowest Energy Use for South-Facing Schools in Phoenix, Arizona

South	No Shading		2-ft Overhang		4-ft Overhang	
WWR	Best Case	kBtu/sf-yr	Best Case	kBtu/sf-yr	Best Case	kBtu/sf-yr
10%	H	**99.06**	H	95.35	G	108.19
20%	H	100.83	H	**94.57**	H	**105.74**
30%	J	110.84	H	101.89	H	107.73
40%	J	117.64	J	109.23	H	111.90
50%	J	118.90	J	113.38	J	109.36
60%	J	126.72	J	119.92	J	115.20

The Facade Design Tool can be used to answer the question, what is the best combination of window area, shading device and glazing type to save energy? The table above shows the best cases for a south-facing School Perimeter Zone assuming all design options are possibilities. It also shows however, that there are a number of very good choices if options are constrained by cost or other design considerations. For example, the best case uses Glazing H with 20% WWR and a 2-foot overhang. However, with no shading devices, the lowest energy use can be achieved with Glazing H with 10% WWR (about 5% more). The design team must decide the costs and benefits of these options. The table below shows the option with the lowest overall energy use for each orientation in Phoenix.

Cases with Lowest Overall Energy Use for All Orientations—Schools in Phoenix, Arizona

Orientation	WWR	Exterior Shading	Light Controls	Window Case	kBtu/sf-yr
North	30%	2-ft overhang	Cont. dimming	H	97.06
East	10%	2-ft overhang	Cont. dimming	H	100.09
South	20%	2-ft overhang	Cont. dimming	H	94.57
West	10%	2-ft overhang	Cont. dimming	H	102.56