WINDOW SELECTION METHODOLOGIES AND OPTIMIZATION IN HIGH-PERFORMANCE COMMERCIAL BUILDINGS

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Recent research estimates that windows in commercial buildings are responsible for almost 1.5% of the total U.S. energy consumption (Apte and Arasteh, 2006). Therefore, selecting appropriate high-performance windows is important in terms of energy consumption and savings and also in terms of occupant comfort and productivity. Determining the optimum window design for a high-performance commercial building helps decision-makers (architects, designers, building owners, building operators) in the design and selection process of glazing products and attributes in a set of situations and conditions (orientation, window area, shading type, and glazing type). This study focuses on the energy performance (energy and peak demand), carbon emissions, and to a lesser extent, the human factor issues (glare and thermal comfort) of a hypothetical 3-story, 48,000 square foot office building. The design parametrics considered are orientation, daylighting controls, window area, shading type, and glazing type. This study uses an existing simulated data set (8640 records for 6 U.S. cities) that was generated using generic set of commercial glazing products and this data set was analyzed in terms of annual energy performance and carbon emissions to determine the optimum window design in a heating-dominated and cooling-dominated climate.

Keywords: fenestration, windows, window systems, high-performance window, glazing, window optimization, window selection, window design, decision-making methodology, high-performance building, high-performance commercial building, energy, peak demand, carbon emissions

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INTRODUCTION

Using data from the U.S. Energy Information Administration (EIA), Architecture 2030 (an organization established in response to the global-warming crisis) reports that buildings are responsible for 48% of all energy consumption and green house gas emissions (see Figure 1). In terms of electricity, building operation is responsible for 76% of all power plant-generated electricity (see Figure 2). According to U.S. Department of Energy's (DOE) Energy Efficiency and Renewable Energy (EERE), 53% of the primary end use of commercial buildings is attributed to lighting, space heating and space cooling (see Figure 3).

Windows—an important design element in any building—provide light, view, and fresh air to the building's occupants. As such, windows are an important contributor to the building envelope and can be an integral part of energy conservation strategies. Recent research estimates that windows are responsible for 39% of commercial heating energy use and 28% of commercial cooling energy use—34% of all commercial space conditioning energy use. This is equivalent to 1.48 quads of space conditioning energy use-—almost 1.5% of the total U.S. energy consumption (Apte and Arasteh, 2006). These figures are significant.

Integrated design is important in achieving the energy-efficient goals of a building and the comfort and health of its occupants. Window selection and orientation will have an impact on many of these objectives, especially the energy use and environmental qualities. Therefore, the complex and inter-related building performance issues such as daylighting strategies, HVAC design and sizing, and shading options must be considered in the early design stages.

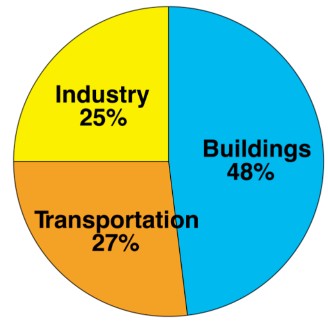


Figure 1. U.S. Energy Consumption. Source: Architecture2030, www.architecture2030.org/current_situation/building_sector.html.

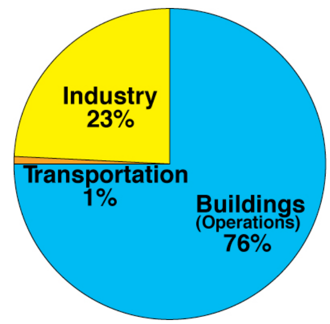


Figure 2. U.S. Electricity Consumption. Source: Architecture2030, www.architecture2030.org/current_situation/building_sector.html.

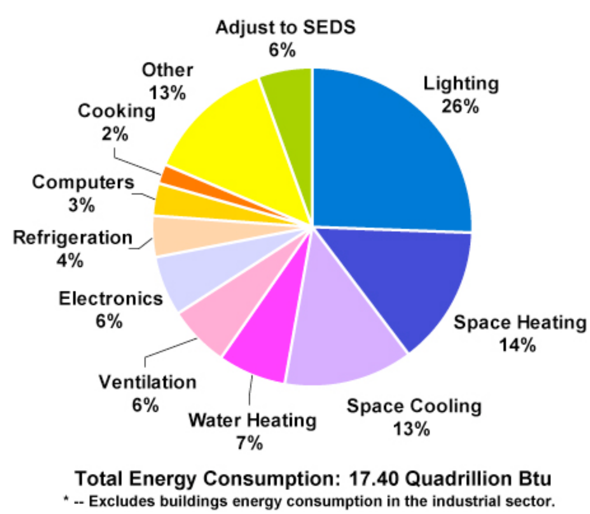


Figure 3. U.S Commercial Buildings Primary Energy End-Use, 2005. Source: Buildings Energy Data Book, U.S. DOE, Energy Efficiency and Renewable Energy.

To aid in the necessary early decision-making efforts required for integrated design, this analysis will help to define what is the optimum window for a high-performance building focusing on the energy use and environmental impacts of various glazing options and strategies with recognition of the human-centered issues of glare and thermal comfort.

ASSUMPTIONS

The decision-making methodology is based on the results of an existing simulated data set for 6 U.S. cities with office as the building type. Orientation, window-to-wall ratio (WWR), daylighting controls, interior shades, exterior shades, and glass type were all taken into consideration. Complete details of all modeling methods and assumptions for the simulated data set (window and frame attributes, shading conditions, lighting conditions, mechanical system information, annual energy use, peak demand, daylight illuminance, glare, and thermal comfort) can be found in Appendix A of the book, *Window Systems for High-performance Buildings* (Carmody et al, 2004). Computer simulations were performed using the U.S. Department of Energy's DOE-2.1E to calculate the energy use and energy cost of a commercial building given information about the building's climate, construction, operation, utility rate schedule and heating, ventilating, and HVAC equipment. ASHRAE 90.1-99 is the standard that was used for the computer simulations.

To illustrate the impact of window performance, a city in a heating-dominated climate (Minneapolis, Minnesota) and a city in a cooling-dominated climate (Phoenix, Arizona) were chosen. Minneapolis is in Zone 1 (ASHRAE 90.1-99 Zone 19) and Phoenix is in Zone 5 (ASHRAE 90.1-99 Zone 5). These 2 cities were selected to demonstrate the difference in performance and strategies between window design selections for a hot climate and those for a cold climate.

The decision-making methodology of this analysis focuses on the environmental impact of windows (energy and peak demand) and to a lesser degree the human-centered issues (glare and thermal comfort). The modeling assumptions for the simulations are based on a perimeter zone model. Therefore, finding the optimum window is for each of the 4 orientations. The focus on the individual perimeter zones can then be generally applied to whole-building and site design. For comparison of simulated data with that of specified baseline data, such as the CBECS database, whole-building performance is needed. An average whole-building performance number was then determined.

The decision-making methodology for this analysis mines the entire data set of the simulations to reveal the optimum window per orientation and then focuses on design strategies such as window area, shading, and daylighting controls. The methodology compares simulated performance to defined performance targets as well as providing carbon emission information. For a complete description of methodologies and assumptions refer to Haglund's Master of Architecture Thesis, *Window Optimization in High-performance Commercial Buildings* (Haglund, 2008) and Appendix A of the book, *Window Systems for High-performance Buildings* (Carmody et al, 2004).

SUMMARY OF METHODOLOGIES

This analysis is about performance of window design options in a hypothetical, 3-story, 48,000 square foot office building. The performance attributes are measured in terms of annual energy use (kBtu/sf) and peak demand (W/sf) with human-centered issues such as a weighted glare index and thermal comfort (predicted percent people dissatisfied) taken into account. Energy use and peak demand are measurable parametrics that play an important role in the determination of the optimum window. The human-centered issues of glare and thermal comfort are important, and to a lesser degree, also aid in the determination of the optimum window.

Performance targets for energy and carbon emissions were used to compare window design options. The methodology for comparing energy performance has multiple paths. First, an annual energy use and peak demand comparison is done using the existing data set. Then performance comparisons are done using code-based requirements and also using an existing building stock database. Baselines from the existing data set, code budget building and existing building stock database were determined from which to specify the top performing window design options and establish the targets. The targets for carbon emissions follow the same methodology—averages were determined and reductions in emissions are compared to that baseline data.

Existing Data Set Performance and Targets

The results in the existing data set are from various combinations of glazing, shading devices, and daylighting controls. This query of existing data focused on locating the best performers per orientation, the effects of daylighting controls, finding the optimum WWR, the optimum shading condition, and the optimum glazing condition. After the top performers were identified, performance relative to annual energy and peak demand were compared to a baseline window which is double-glazed, clear glass window with no daylighting controls and no shading at a 0.30 WWR. This window option was chosen because 44% of commercial window sales in 2005 were of clear glass and 88% were insulating glass units (Ducker, 2006). The 30% and 50% performance targets are based on the performance of this design option (Table 1 and Table 2).

Table 1. Annual energy and peak baseline and target data for Phoenix, Arizona derived from the existing data set.

Phoenix Energy (kBtu/sf)

	Baseline	30%	50%
North	151.88	106.32	75.94
East	194.05	135.84	97.03
South	192.83	134.98	96.42
West	192.98	135.09	96.49

Phoenix Peak (W/sf)

	Baseline	30%	50%
North	5.74	4.02	2.87
East	8.62	6.03	4.31
South	8.46	5.92	4.23
West	8.39	5.87	4.20

Table 2. Annual energy and peak baseline and target data for Minneapolis, Minnesota derived from the existing data set.

MInneapolis Energy (kBtu/sf)

	Baseline	30%	50%
North	140.62	98.43	70.31
East	161.98	113.39	80.99
South	154.29	108.00	77.15
West	161.64	113.15	80.82

Minneapolis Peak (W/sf)

	Baseline	30%	50%
North	4.70	3.29	2.35
East	7.62	5.33	3.81
South	6.99	4.89	3.50
West	6.88	4.82	3.44

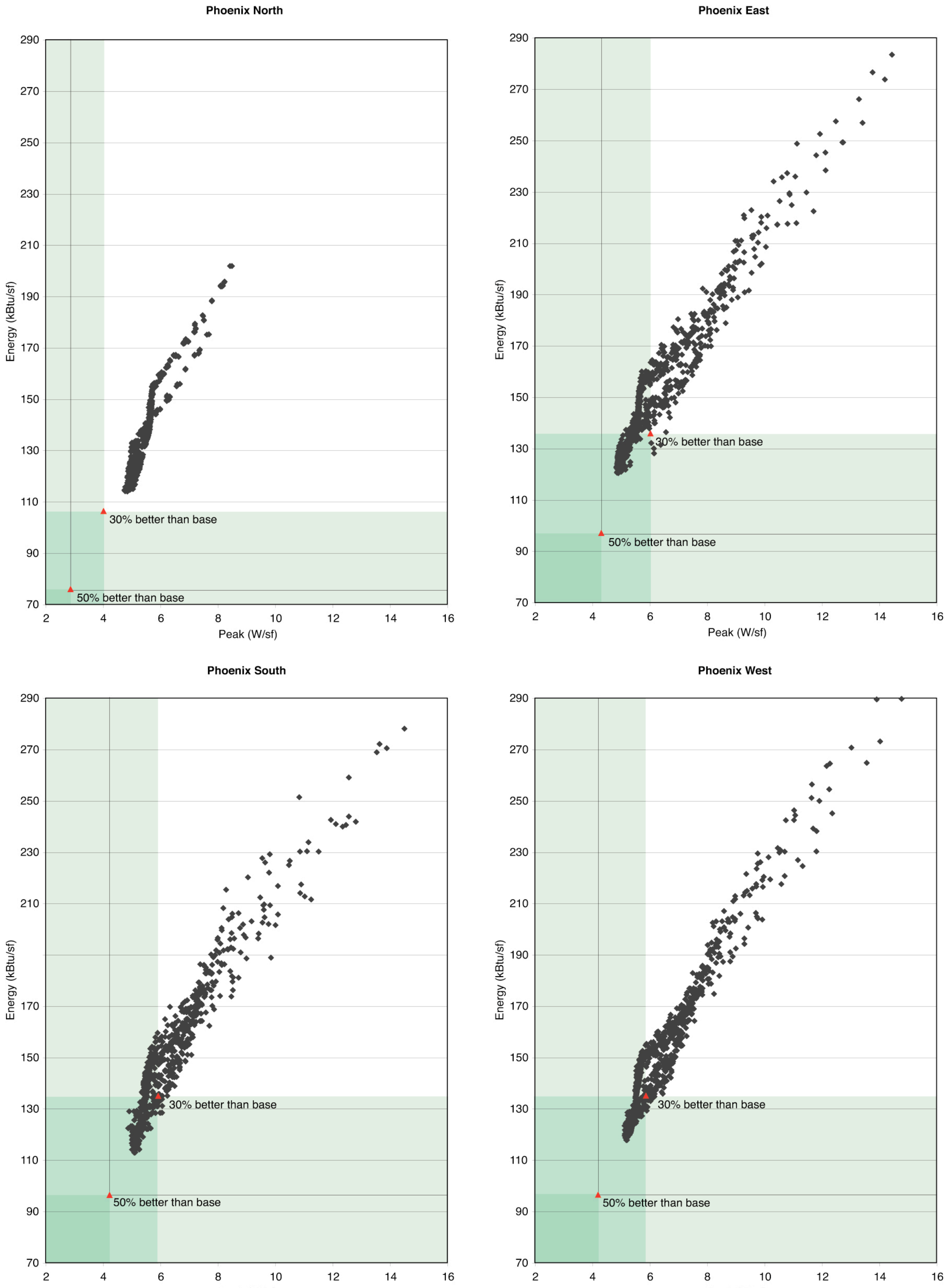


Figure 4. Annual energy and peak demand as compared to the baseline's 30% and 50% performance targets of the simulated data set for the 4 orientations in Phoenix, Arizona.

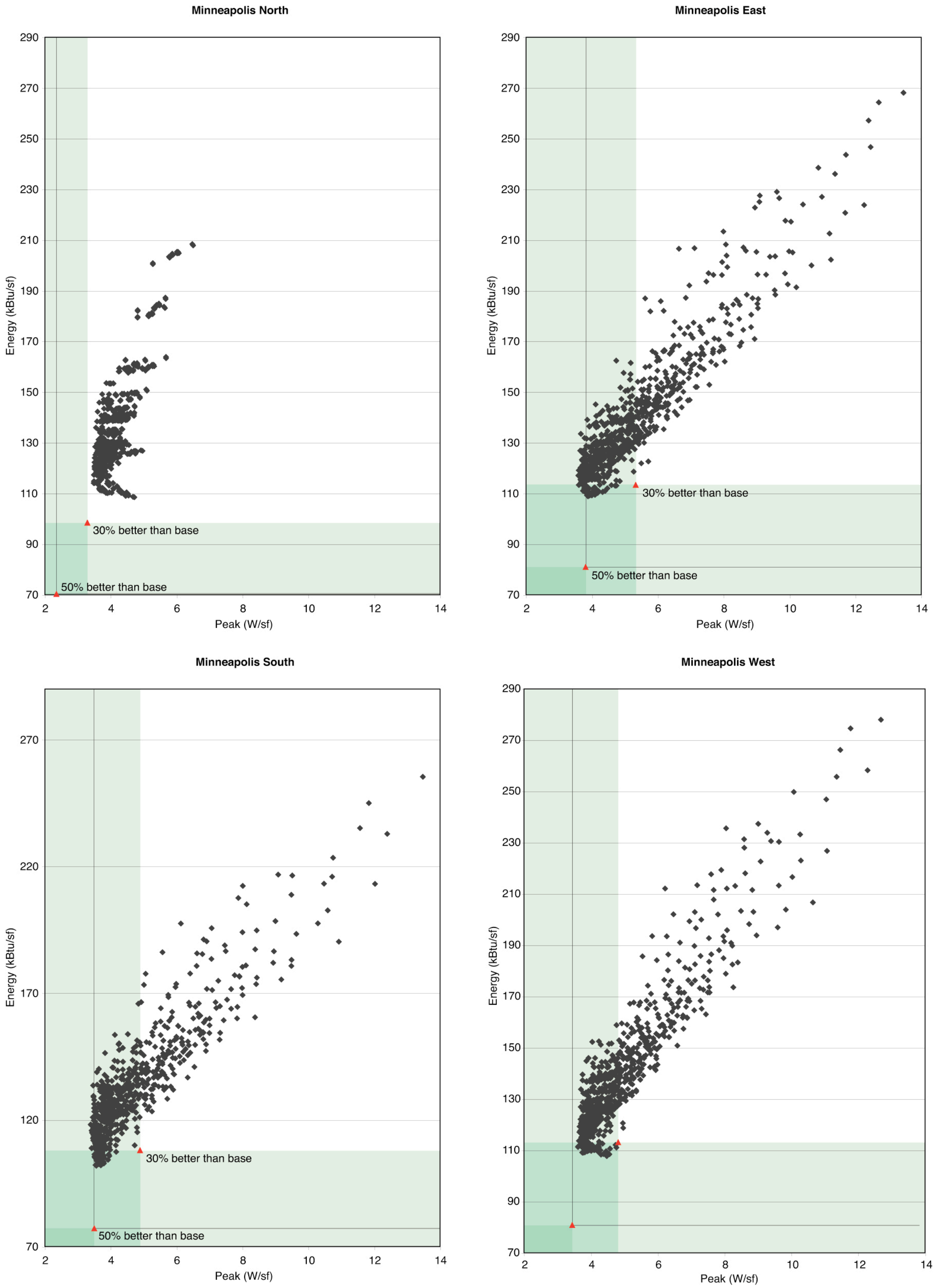


Figure 5. Annual energy and peak demand as compared to the baseline's 30% and 50% performance targets of the simulated data set for the 4 orientations in Minneapolis, Minnesota.

Code Base Performance and Targets

ASHRAE 90.1-99 was the standard that was used for the simulations in this analysis. The Prescriptive Building Envelope Option has limitations on the allowable window area, maximum U-factor, and maximum solar heat gain coefficient (SHGC). For Phoenix the U-factor for a fixed window must be 1.22, with the SHGC being between 0.17–0.25. For Minneapolis the U-factor for a fixed window must be between 0.46–0.57, with the SHGC being between 0.26–0.49. These options allow the vertical fenestration area to be up to 50% of the gross wall area. If a building has greater than 50% glazing area another compliance (performance) path must be used. EnvStd 4.0 is simulation software that implements the Building Envelope Trade-off Option of ASHRAE Standard 90.1-1999 and was used for performance compliance for the options that fall outside the prescriptive path.

A budget building was created to compare performance of window options that fall outside of the prescriptive requirements. The same window market information as for the existing data set was used and the budget building was modeled at 0.30 WWR using clear, double glazing (window B), no interior or exterior shading and no daylighting controls. According to the ASHRAE 90.1-99 prescriptive path, design option 6 should not comply, using the simulation software and entering the specific attributes for that window, compliance is achieved for both Phoenix and Minneapolis. The 30% and 50% performance targets are based on this budget building.

CBECS Database Performance

Commercial Buildings Energy Consumption Survey (CBECS) is a national-level sample survey that quadrennially collects information on the stock of U.S. commercial buildings, the energy-related building characteristics, and the energy consumption and expenditures. For this analysis consumption data was derived and compared to offices as the principal building activity. The CBECS database provides results of whole-building performance. Since the results from the simulated data set are for each of the 4 perimeter zones, an average whole-building performance number was generated. The average annual energy use for the south region (used for Phoenix, Arizona) is 212.09 kBtu/sf and for the midwest region (Minneapolis, Minnesota) it is 228.67 kBtu/sf). The 30% and 50% performance targets are based on these averages (Table 3).

Table 3. Annual energy average, 30% better, 50% better performance targets using the CBECS database. Total Energy = ((kWh x 3.412) x 3.03) + (cf x 1.031). 1 kWh = 3.412 kBtu. Source to site conversion = 3.03. 1 Cubic Foot = 1,031 Btu = 1.031 kBtu.

ELECTRICITY					
CBECS Table	C14A	C15A	C15A	C16A	C16A
	Consumption (kWh/sf)	**Intensity Midwest** (kWh/sf)	**Intensity South South** (kWh/sf)	**Expenditure Midwest** (kWh)	**Expenditure South** (kWh)
CBECS	17.30	17.90	18.80	0.070	0.070
30% better	12.11	12.53	13.16	0.049	0.049
50% better	8.65	8.95	9.40	0.035	0.035

GAS					
CBECS Table	C24A	C25A	C25A	C26A	C26A
	Consumption (cf/sf)	**Intensity Midwest** (cf/sf)	**Intensity South** (cf/sf)	**Expenditure Midwest** (cf)	**Expenditure South** (cf)
CBECS	31.80	42.30	17.20	7970	8710
30% better	22.26	29.61	12.04	5579	6097
50% better	15.90	21.15	8.60	3985	4355

TOTALS	**Average** (kBtu/sf)	**Midwest** (kBtu/sf)	**South** (kBtu/sf)	**Midwest** (kBtu)	**South** (kBtu)
CBECS	211.64	228.67	212.09	8218	8981
30% better	148.15	160.07	148.47	5752	6287
50% better	105.82	114.33	106.05	4109	4490

Figure 6 shows the number of windows from the data set and their associated whole-building annual energy use (kBtu/sf) in Phoenix and Minneapolis. Based on the CBECS averages for each region, the 30% (light green) and 50% (dark green) performance targets are indicated in Figure 16. In Phoenix, there are no window options that perform worse than either the CBECS national (211.64 kBtu/sf) or southern region (212.09 kBtu/sf) average. Also, there are no options that perform 50% better than the southern region average. In Minneapolis, there are 19 window options that perform worse then the national average (211.64 kBtu/sf), 3 that perform worse than the midwest region average (228.67 kBtu/sf), and none that perform 50% better than the midwest region average. For both cities, there is a vast range of window options that perform between the 30% and 50% performance targets.

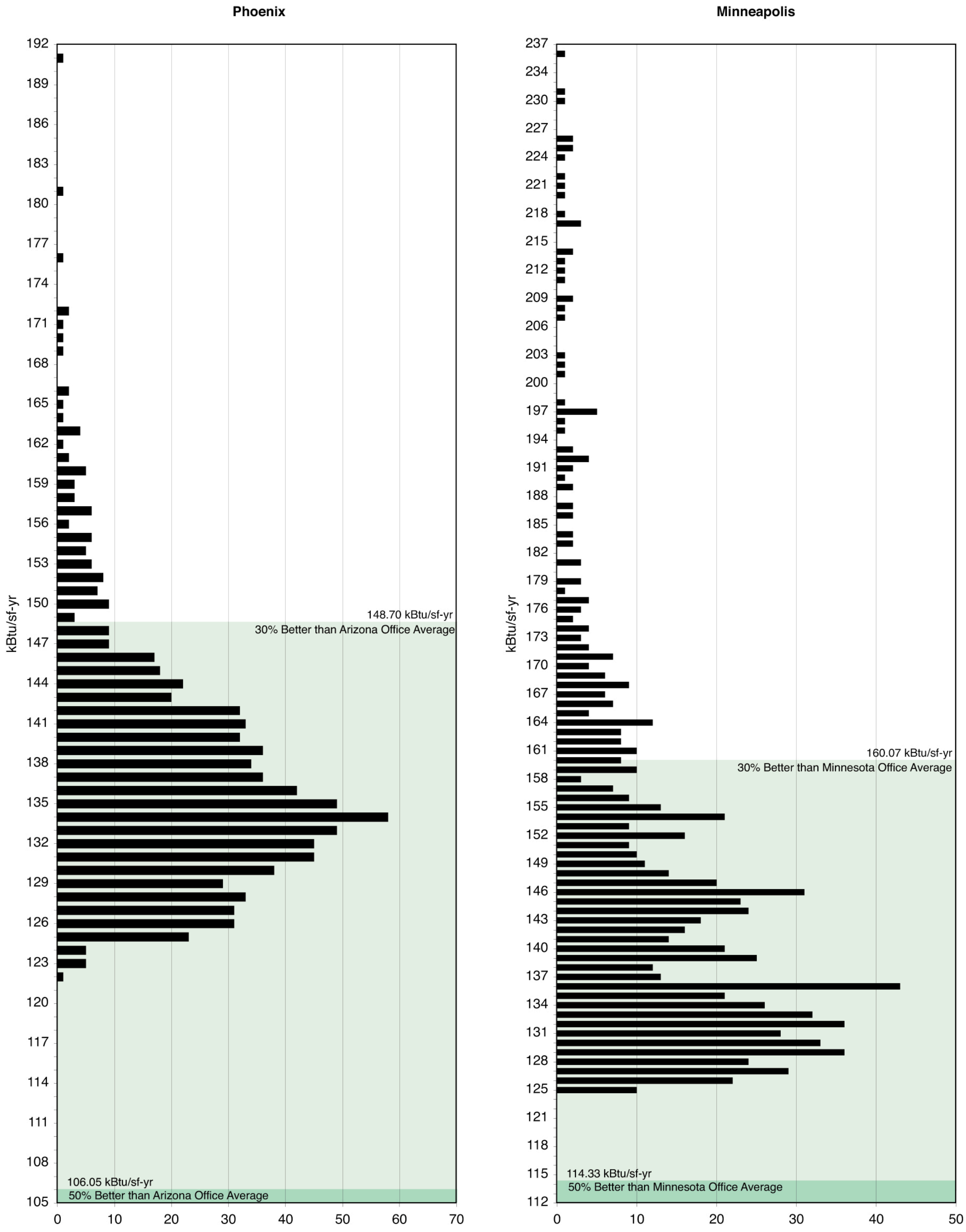


Figure 6. Summary of the number of windows associated with whole-building annual energy use in Phoenix, Arizona and Minneapolis, Minnesota. The shaded areas represent 30% (light green) and 50% (dark green) better annual energy performance than the CBECS average for each region.

Carbon Emissions

Since 76% of energy produced goes to operate buildings, these buildings are a major source of demand for energy and materials that produce by-product greenhouse gases. A major contributor to the GHG emissions is carbon dioxide (CO_2). Power Profiler was used to determine the emission output. For an office in Phoenix, the output is 1.254 lbs/kWh and for Minneapolis it is 1.814 lbs/kWh. Power Profiler was used to find the base emissions for a 48,000 square foot office building in Phoenix (787,311 lbs CO2) and Minneapolis (1,138,902 lbs CO_2). The baseline emissions for the existing data set and the code budget building are 955,330 lbs CO_2 for Phoenix and 1,297,828 lbs CO_2 for Minneapolis. The emissions for the CBECS database are 1,234,635 lbs CO_2 for Phoenix and 1,925,605 lbs CO_2 for Minneapolis. The 30% and 50% emission reduction targets are based on these figures (Table 4).

Table 4. CO_2 emissions baseline data with 30% and 50% targets for Phoenix, Arizona and Minneapolis, Minnesota. Source: eGRID2006 Version 2.1 and EPA's Power Profiler.

	Emissions (lbs)	Output (lbs/kWh)	30% Reduction (lbs)	50% Reduction (lbs)
U.S.	5,363,507,606,000	1.363		
Arizona	66,348,350,000	1.219	46,443,845,000	33,174,175,000
Arizona Office	787,311	1.254	551,118	393,656
Arizona Perimeter	73,810	1.254	51,667	36,905
Minnesota	83,156,146,000	1.588	58,209,302,000	41,578,073,000
Minnesota Office	1,138,902	1.814	797,231	569,451
Minnesota Perimeter	106,772	1.814	74,740	53,386

ANALYSIS OF DATA

The query and analysis of the data set recognizes the best window design options in each climate (per orientation) based on performance metrics (energy and peak). This analysis also recognizes and documents if best performers are outside the acceptable ranges for glare and thermal comfort.

The top 50 performing windows in the database are identified in terms of annual energy (kBtu/sf) and the corresponding peak demand (W/sf). The number of 50 for the top performers was determined because in the simulated data set there is a performance shift between the top 30–70 (dependent on the orientation and climate). Though the focus is on annual energy, it is important to also show peak demand for it may be valuable to reduce peak load.

Glare level and thermal comfort are recognized as best, good, average, poor and worst based on the "bubble diagrams" that were developed for the book, *Window Systems for High-performance Buildings* (Carmody et al., 2004). The bubble diagrams rank each of the attributes: annual energy, peak demand, daylight, glare, view and thermal comfort for each orientation on a scale from 1–10 with number 1 being worst and number 10 being best. There are no thermal comfort results provided for window-to-wall ratio (WWR) 0.15 in the data set.

Top Performers in Phoenix, Arizona

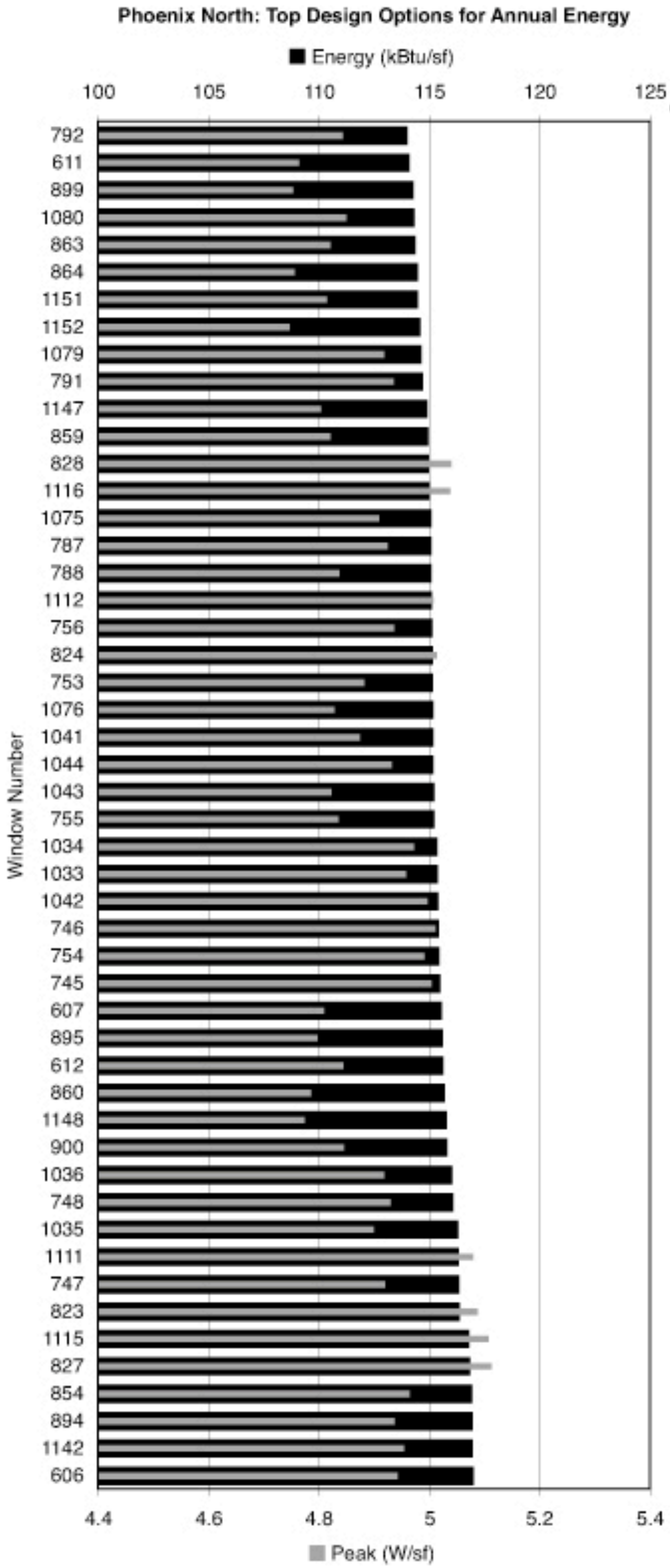
In the results for all orientations in Phoenix, the top performers all had daylighting controls (continuous dimming). Window A (single clear), window B (double clear), window C (double bronze tint), window D (double reflective tint), and window E (double low-E tint) are not represented as top performing design options. All the top performing options are either using window F (double spectrally selective tint), window G (double spectrally selective low-E), window H (triple low-E), or window I (quadruple low-E). These 4 glazing types not only provide a low U-factor, but most importantly for a warm climate, they provide a low solar heat gain coefficient (SHGC). A combination of interior shades and exterior shades are prevalent in the results, mostly using an exterior shading device with or without interior shades.

Figure 7 shows the top 50 performing, north-oriented window options for annual energy. The top performers in the north orientation have the lowest annual energy use compared to the other orientations. The best performing options are almost all of window H or I and mostly made up of 0.45 or 0.60 WWR. The north orientation is the only orientation where windows without exterior shading are part of the best performing set. The top performers for both energy and peak demand have either no exterior shading device or a setback as the exterior shading This illustrates the impact of the window design options allowing much indirect light to enter the space.

Figure 8 shows the top 50 performing, east-oriented window options for annual energy. These results introduce window G into the top performing set—though always with a 0.15 or 0.30 WWR. All the best performers for both energy and peak include an exterior shading device and many also include interior shades. Exterior shading of overhangs and fins (ov2f) dominates the top performers which is expected due to the fins blocking the extreme sun angle. The majority of the options that also have a lower peak demand have a 0.30 WWR, illustrating that a smaller window area can help reduce peak demand.

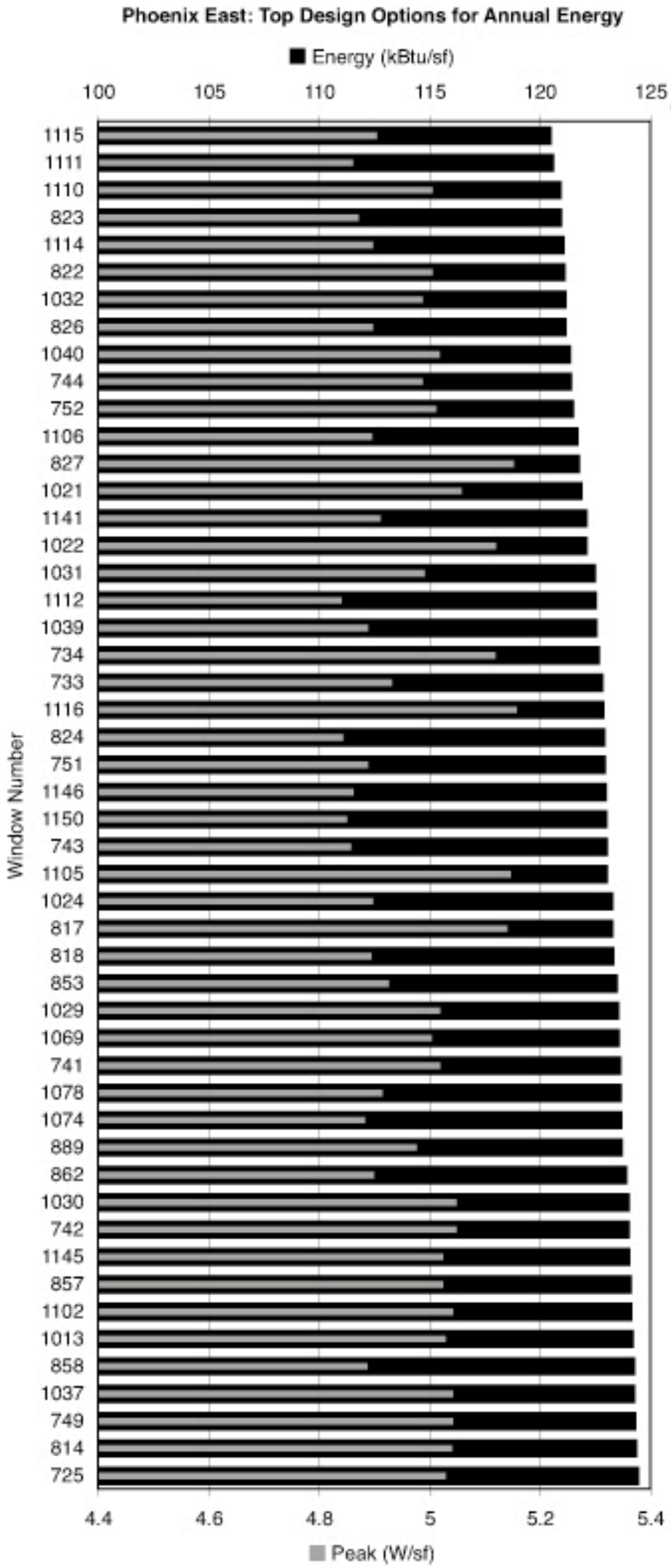
Figure 9 shows the top 50 performing, south-oriented window options for annual energy. Like the east orientation, window G is part of the top performing set with a 0.15 or 0.30 WWR along with window H or I. All the best performers include an exterior shading device and many include interior shades. Exterior shading of overhangs and fins (ov2f) dominates the top performers which is expected due to the fins blocking the extreme sun angle coming from the east and west and the overhang blocking the direct southern sun exposure. The south orientation has fewer options that perform best for both annual energy and peak demand. The south orientation has no window options that were removed from the top performing set due to glare or thermal comfort issues—due to the use of shading devices that help to reduce direct sun resulting in minimal glare and thermal comfort issues.

Figure 10 shows the top 50 performing, west-oriented window options for annual energy and peak demand. Like the east and south orientations, glazing G is part of the top performing set with a 0.15 or 0.30 WWR along with window H or I. All the best performers include an exterior shading device and many include interior shades. Using overhangs and fins (ov2f) dominates the top performers due to the fins blocking the extreme sun angle.



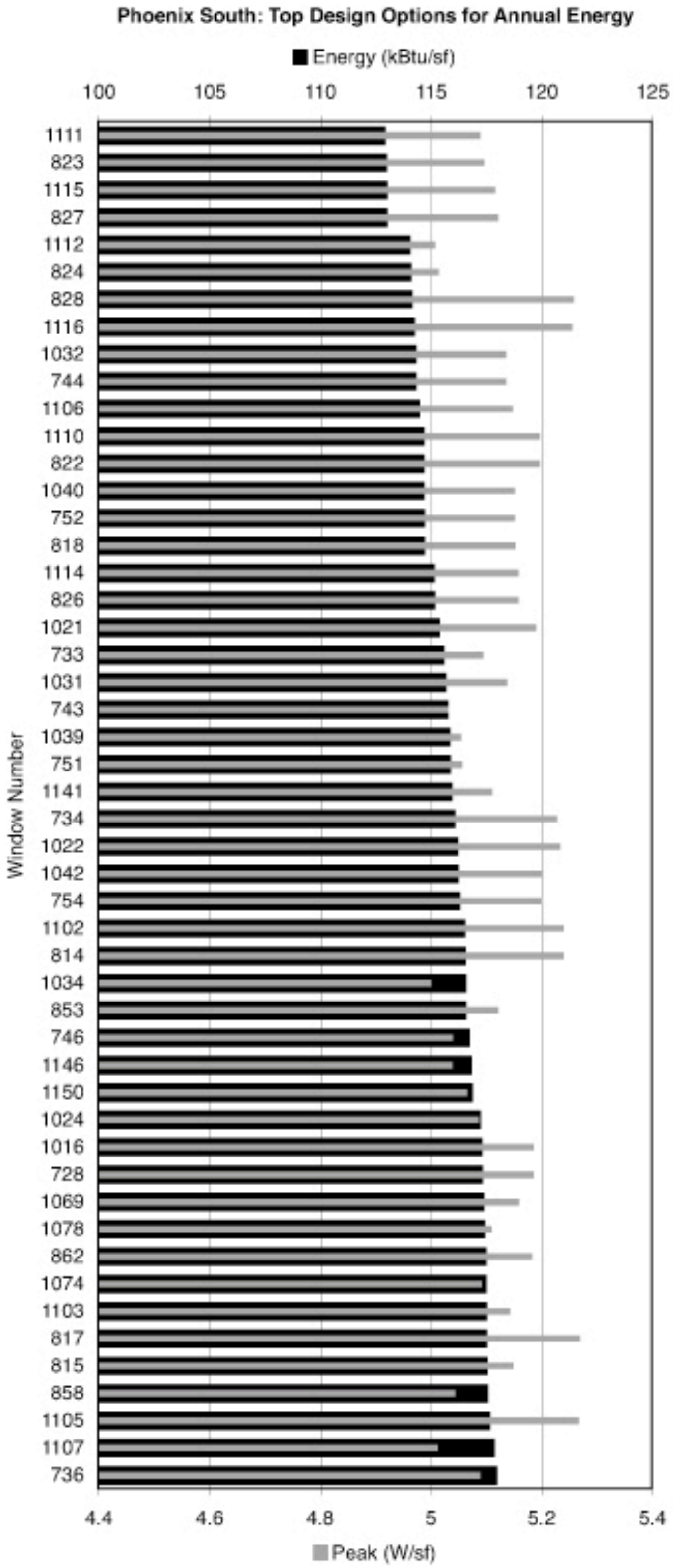
Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
792	cont	no	fins	0.60	I	good	good
611	cont	no	none	0.45	I	best	good
899	cont	yes	none	0.45	I	best	good
1080	cont	yes	fins	0.60	I	good	good
863	cont	no	setback	0.45	I	best	good
864	cont	no	setback	0.6	I	good	good
1151	cont	yes	setback	0.45	I	best	good
1152	cont	yes	setback	0.60	I	good	good
1079	cont	yes	fins	0.45	I	best	good
791	cont	no	fins	0.45	I	best	good
1147	cont	yes	setback	0.45	H	best	good
859	cont	no	setback	0.45	H	best	good
828	cont	no	ov2f	0.60	I	best	good
1116	cont	yes	ov2f	0.60	I	best	good
1075	cont	yes	fins	0.45	H	best	good
787	cont	no	fins	0.45	H	best	good
788	cont	no	fins	0.60	H	good	good
1112	cont	yes	ov2f	0.60	H	best	good
756	cont	no	ov2	0.60	I	good	good
824	cont	no	ov2f	0.60	H	best	good
753	cont	no	ov1	0.45	I	best	good
1076	cont	yes	fins	0.60	H	good	good
1041	cont	yes	ov1	0.45	I	best	good
1044	cont	yes	ov2	0.60	I	good	good
1043	cont	yes	ov1	0.60	I	good	good
755	cont	no	ov1	0.60	I	good	good
1034	cont	yes	ov2	0.45	H	best	good
1033	cont	yes	ov1	0.45	H	best	good
1042	cont	yes	ov2	0.45	I	best	good
746	cont	no	ov2	0.45	H	best	good
754	cont	no	ov2	0.45	I	best	good
745	cont	no	ov1	0.45	H	best	good
607	cont	no	none	0.45	H	good	good
895	cont	yes	none	0.45	H	good	good
612	cont	no	none	0.60	I	good	good
860	cont	no	setback	0.60	H	good	good
1148	cont	yes	setback	0.60	H	good	good
900	cont	yes	none	0.60	I	good	good
1036	cont	yes	ov2	0.60	H	good	good
748	cont	no	ov2	0.60	H	good	good
1035	cont	yes	ov1	0.60	H	good	good
1111	cont	yes	ov2f	0.45	H	best	good
747	cont	no	ov1	0.60	H	good	good
823	cont	no	ov2f	0.45	H	best	good
1115	cont	yes	ov2f	0.45	I	best	good
827	cont	no	ov2f	0.45	I	best	good
854	cont	no	setback	0.30	G	best	good
894	cont	yes	none	0.30	H	best	good
1142	cont	yes	setback	0.30	G	best	good
606	cont	no	none	0.30	H	best	good

Figure 7. Top 50 north-oriented design options in terms of annual energy use in Phoenix, Arizona. Results include all glazing and shading conditions. See Appendix for simulation data set.



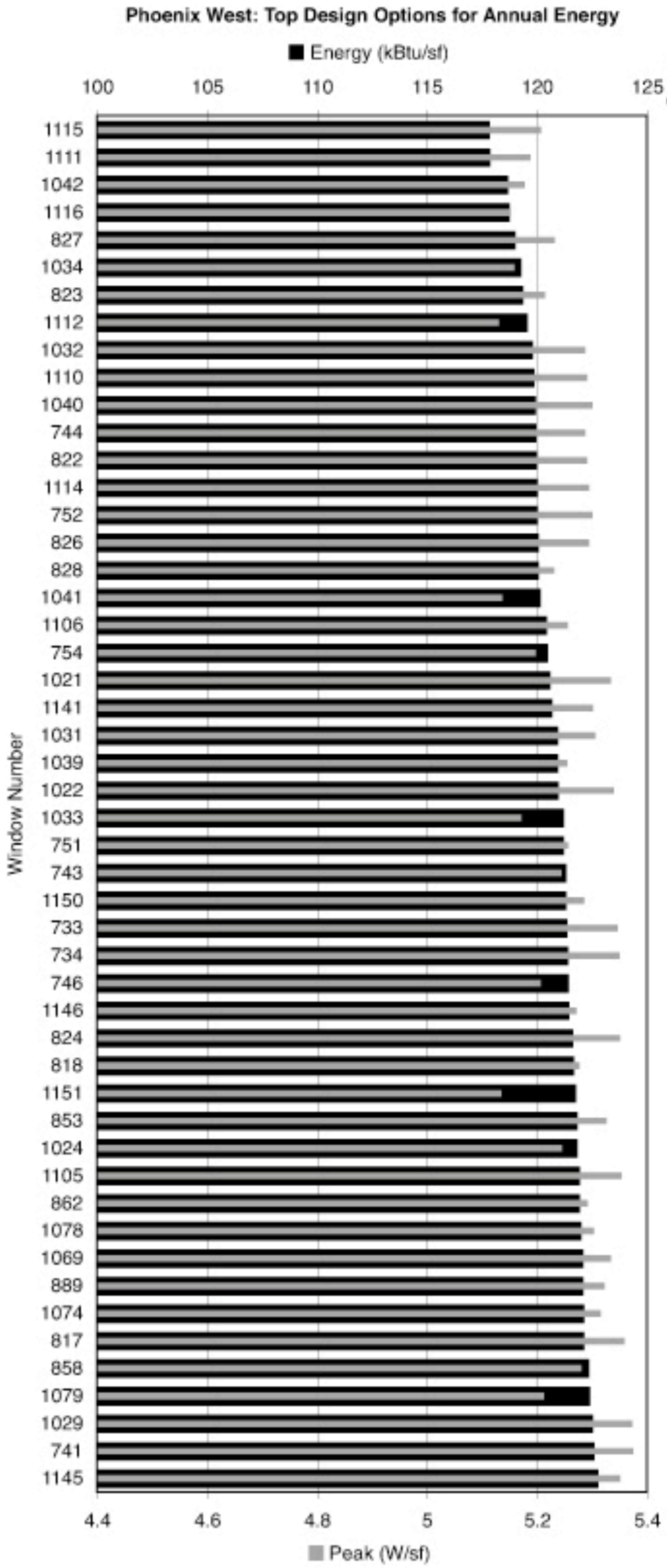
Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
1115	cont	yes	ov2f	0.45	I	best	best
1111	cont	yes	ov2f	0.45	H	best	best
1110	cont	yes	ov2f	0.30	H	best	best
823	cont	no	ov2f	0.45	H	best	best
1114	cont	yes	ov2f	0.30	I	best	best
822	cont	no	ov2f	0.30	H	best	best
1032	cont	yes	ov2	0.30	H	best	best
826	cont	no	ov2f	0.30	I	best	best
1040	cont	yes	ov2	0.30	I	best	best
744	cont	no	ov2	0.30	H	best	best
752	cont	no	ov2	0.30	I	best	best
1106	cont	yes	ov2f	0.30	G	best	best
827	cont	no	ov2f	0.45	I	best	best
1021	cont	yes	ov1	0.15	G	best	-
1141	cont	yes	setback	0.15	G	best	-
1022	cont	yes	ov2	0.15	G	best	-
1031	cont	yes	ov1	0.30	H	best	best
1112	cont	yes	ov2f	0.60	H	best	best
1039	cont	yes	ov1	0.30	I	best	best
734	cont	no	ov2	0.15	G	best	-
733	cont	no	ov1	0.15	G	best	-
1116	cont	yes	ov2f	0.60	I	best	best
824	cont	no	ov2f	0.60	H	best	best
751	cont	no	ov1	0.30	I	best	best
1146	cont	yes	setback	0.30	H	best	best
1150	cont	yes	setback	0.30	I	best	best
743	cont	no	ov1	0.30	H	best	best
1105	cont	yes	ov2f	0.15	G	best	-
1024	cont	yes	ov2	0.30	G	best	best
817	cont	no	ov2f	0.15	G	best	-
818	cont	no	ov2f	0.30	G	best	good
853	cont	no	setback	0.15	G	best	-
1029	cont	yes	ov1	0.15	H	best	-
1069	cont	yes	fins	0.15	G	good	-
741	cont	no	ov1	0.15	H	good	-
1078	cont	yes	fins	0.30	I	best	best
1074	cont	yes	fins	0.30	H	best	best
889	cont	yes	none	0.15	G	best	-
862	cont	no	setback	0.30	I	best	best
1030	cont	yes	ov2	0.15	H	best	-
742	cont	no	ov2	0.15	H	best	-
1145	cont	yes	setback	0.15	H	best	-
857	cont	no	setback	0.15	H	best	-
1102	cont	yes	ov2f	0.30	F	best	good
1013	cont	yes	ov1	0.15	F	best	-
858	cont	no	setback	0.30	H	best	best
1037	cont	yes	ov1	0.15	I	best	-
749	cont	no	ov1	0.15	I	best	-
814	cont	no	ov2f	0.30	F	best	good
725	cont	no	ov1	0.15	F	best	-

Figure 8. Top 50 east-oriented design options in terms of annual energy use in Phoenix, Arizona. Results include all glazing and shading conditions. See Appendix for simulation data set.



Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
1111	cont	yes	ov2f	0.45	H	best	best
823	cont	no	ov2f	0.45	H	best	best
1115	cont	yes	ov2f	0.45	I	best	best
827	cont	no	ov2f	0.45	I	best	best
1112	cont	yes	ov2f	0.60	H	best	best
824	cont	no	ov2f	0.60	H	best	best
828	cont	no	ov2f	0.60	I	best	best
1116	cont	yes	ov2f	0.60	I	best	best
1032	cont	yes	ov2	0.30	H	best	best
744	cont	no	ov2	0.30	H	best	best
1106	cont	yes	ov2f	0.30	G	best	best
1110	cont	yes	ov2f	0.30	H	best	best
822	cont	no	ov2f	0.30	H	best	best
1040	cont	yes	ov2	0.30	I	best	best
752	cont	no	ov2	0.30	I	best	best
818	cont	no	ov2f	0.30	G	best	best
1114	cont	yes	ov2f	0.30	I	best	best
826	cont	no	ov2f	0.30	I	best	best
1021	cont	yes	ov1	0.15	G	best	-
733	cont	no	ov1	0.15	G	best	-
1031	cont	yes	ov1	0.30	H	best	best
743	cont	no	ov1	0.30	H	best	best
1039	cont	yes	ov1	0.30	I	best	best
751	cont	no	ov1	0.30	I	best	best
1141	cont	yes	setback	0.15	G	best	-
734	cont	no	ov2	0.15	G	best	-
1022	cont	yes	ov2	0.15	G	best	-
1042	cont	yes	ov2	0.45	I	best	best
754	cont	no	ov2	0.45	I	best	best
1102	cont	yes	ov2f	0.30	F	best	best
814	cont	no	ov2f	0.30	F	best	best
1034	cont	yes	ov2	0.45	H	best	best
853	cont	no	setback	0.15	G	best	-
746	cont	no	ov2	0.45	H	best	best
1146	cont	yes	setback	0.30	H	best	best
1150	cont	yes	setback	0.30	I	best	best
1024	cont	yes	ov2	0.30	G	best	best
1016	cont	yes	ov2	0.30	F	best	best
728	cont	no	ov2	0.30	F	best	best
1069	cont	yes	fins	0.15	G	best	-
1078	cont	yes	fins	0.30	I	best	best
862	cont	no	setback	0.30	I	best	best
1074	cont	yes	fins	0.30	H	best	best
1103	cont	yes	ov2f	0.45	F	best	best
817	cont	no	ov2f	0.15	G	best	-
815	cont	no	ov2f	0.45	F	best	good
858	cont	no	setback	0.30	H	best	best
1105	cont	yes	ov2f	0.15	G	best	-
1107	cont	yes	ov2f	0.45	G	best	best
736	cont	no	ov2	0.30	G	best	best

Figure 9. Top 50 south-oriented design options in terms of annual energy use in Phoenix, Arizona. Results include all glazing and shading conditions. See Appendix for simulation data set.



Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
1115	cont	yes	ov2f	0.45	I	average	good
1111	cont	yes	ov2f	0.45	H	average	good
1042	cont	yes	ov2	0.45	I	average	best
1116	cont	yes	ov2f	0.60	I	average	good
827	cont	no	ov2f	0.45	I	average	good
1034	cont	yes	ov2	0.45	H	average	best
823	cont	no	ov2f	0.45	H	average	good
1112	cont	yes	ov2f	0.60	H	average	good
1032	cont	yes	ov2	0.30	H	good	good
1110	cont	yes	ov2f	0.30	H	good	good
1040	cont	yes	ov2	0.30	I	good	best
744	cont	no	ov2	0.30	H	good	good
822	cont	no	ov2f	0.30	H	good	good
1114	cont	yes	ov2f	0.30	I	good	good
752	cont	no	ov2	0.30	I	good	best
826	cont	no	ov2f	0.30	I	good	good
828	cont	no	ov2f	0.60	I	average	good
1041	cont	yes	ov1	0.45	I	average	best
1106	cont	yes	ov2f	0.30	G	average	good
754	cont	no	ov2	0.45	I	average	best
1021	cont	yes	ov1	0.15	G	best	-
1141	cont	yes	setback	0.15	G	best	-
1031	cont	yes	ov1	0.30	H	good	best
1039	cont	yes	ov1	0.30	I	good	best
1022	cont	yes	ov2	0.15	G	best	-
1033	cont	yes	ov1	0.45	H	average	best
751	cont	no	ov1	0.30	I	good	best
743	cont	no	ov1	0.30	H	good	best
1150	cont	yes	setback	0.30	I	good	best
733	cont	no	ov1	0.15	G	good	-
734	cont	no	ov2	0.15	G	best	-
746	cont	yes	ov2	0.45	H	average	best
1146	cont	yes	setback	0.30	H	good	best
824	cont	no	ov2f	0.60	H	average	good
818	cont	no	ov2f	0.30	G	average	good
1151	cont	yes	setback	0.45	I	average	best
853	cont	no	setback	0.15	G	best	-
1024	cont	yes	ov2	0.30	G	average	good
1105	cont	yes	ov2f	0.15	G	good	-
862	cont	no	setback	0.30	I	good	best
1078	cont	yes	fins	0.30	I	good	best
1069	cont	yes	fins	0.15	G	best	-
889	cont	yes	none	0.15	G	best	-
1074	cont	yes	fins	0.30	H	good	good
817	cont	no	ov2f	0.15	G	best	-
858	cont	no	setback	0.30	H	good	best
1079	cont	yes	fins	0.45	I	poor	best
1029	cont	yes	ov1	0.15	H	best	-
741	cont	no	ov1	0.15	H	best	-
1145	cont	yes	setback	0.15	H	best	-

Figure 10. Top 50 west-oriented design options in terms of annual energy use in Phoenix, Arizona. Results include all glazing and shading conditions. See Appendix for simulation data set.

Top Performers in Minneapolis, Minnesota

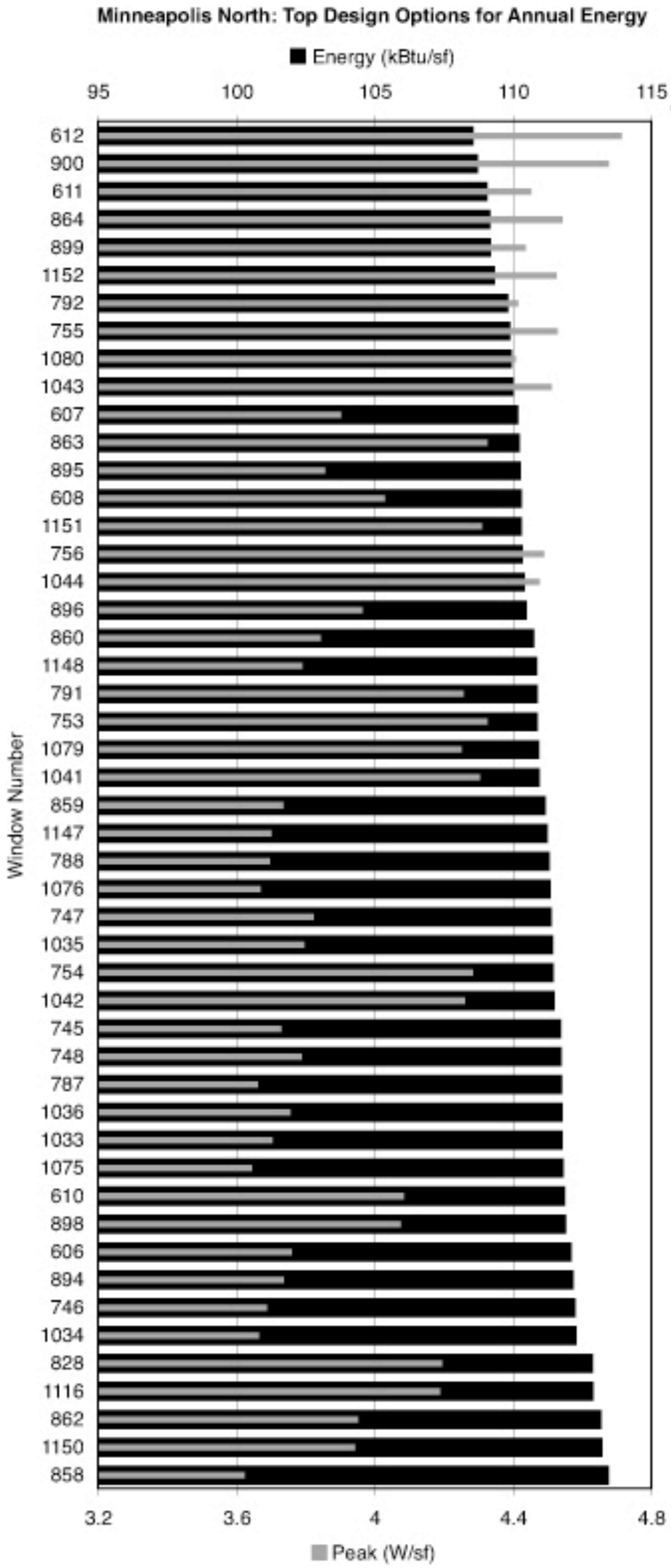
In the results for all orientations in Minneapolis, the top performers all had daylighting controls (continuous dimming). Window A (single clear), window B (double clear), window C (double bronze tint), window D (double reflective tint), window E (double low-E tint), and window F (double spectrally selective tint) are not represented as top performing design options. All the top performing options are either using window G (double spectrally selective low-E), window H (triple low-E), or window I (quadruple low-E). These 3 glazing types provide a low U-factor which is necessary for reducing heat loss in a cold climate. A combination of no shading, interior shades, and exterior shades are prevalent in the results.

Figure 11 shows the top 50 performing, north-oriented window options for annual energy. The best performing options are all of window H or I in combination with 0.45 or 0.60 WWR. Window I is the very top performer in this set—illustrating the impact of a very low U-factor on reducing annual energy. A combination of windows with and without shading devices makes up the top performing set for annual energy. Peak demand is not as critical of an energy-performance attribute in a heating climate as it is in a cooling climate. The top 6 performers have have either no exterior shading device or a setback. This illustrates the impact of the window design options allowing much indirect light to enter the space.

Figure 12 shows the top 50 performing, east-oriented window options for annual energy. Windows H or I are the best performers and with most of the options having 0.30 WWR. Double clear (window G) is introduced as a top performer but only with a 0.15 WWR. A combination of interior and exterior shading devices makes up the top performing set. Unlike Phoenix, exterior shading of overhangs and fins (ov2f) does not dominate the east-oriented top performers, though the options with overhangs and fins (ov2f) with a 0.15 or 0.30 WWR have the lowest peak demand.

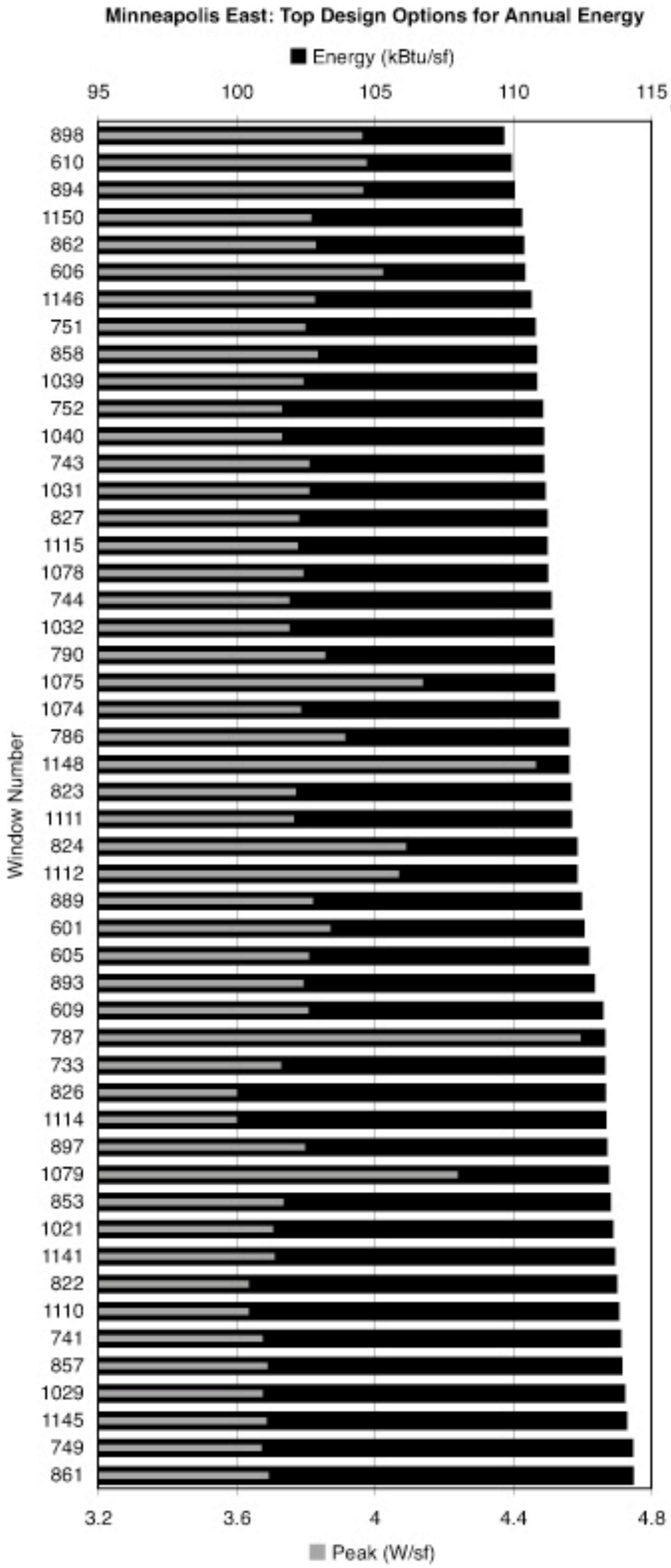
Figure 13 shows the top 50 performing, south-oriented window options for annual energy. The top performers in the south orientation have the lowest annual energy use compared to the other orientations. Like the east orientation, window H or I are the best performers and with 0.30, 0.45, or 0.60 WWR—though the very top performers have a 0.45 WWR. A combination of interior and exterior shading devices make up the top performing set. Design option 601 is the only top option using window G. Exterior shading of overhangs (ov1 and ov2) dominate the top performers due to the overhang blocking the southern sun. The options with overhangs or overhangs with fins (ov2f) have the lowest peak demand.

Figure 14 shows the top 50 performing, west-oriented window options for annual energy. The best performing windows are all of window H or I with a 0.30, 0.45 or 0.60 WWR. A combination of interior and exterior shading devices make up the top performing set with overhangs (ov1 and ov2) being the very top performers. The options with deep overhangs (ov2) and overhangs with fins (ov2f) have the lowest peak demand due to the overhangs and fins blocking the extreme sun angle.



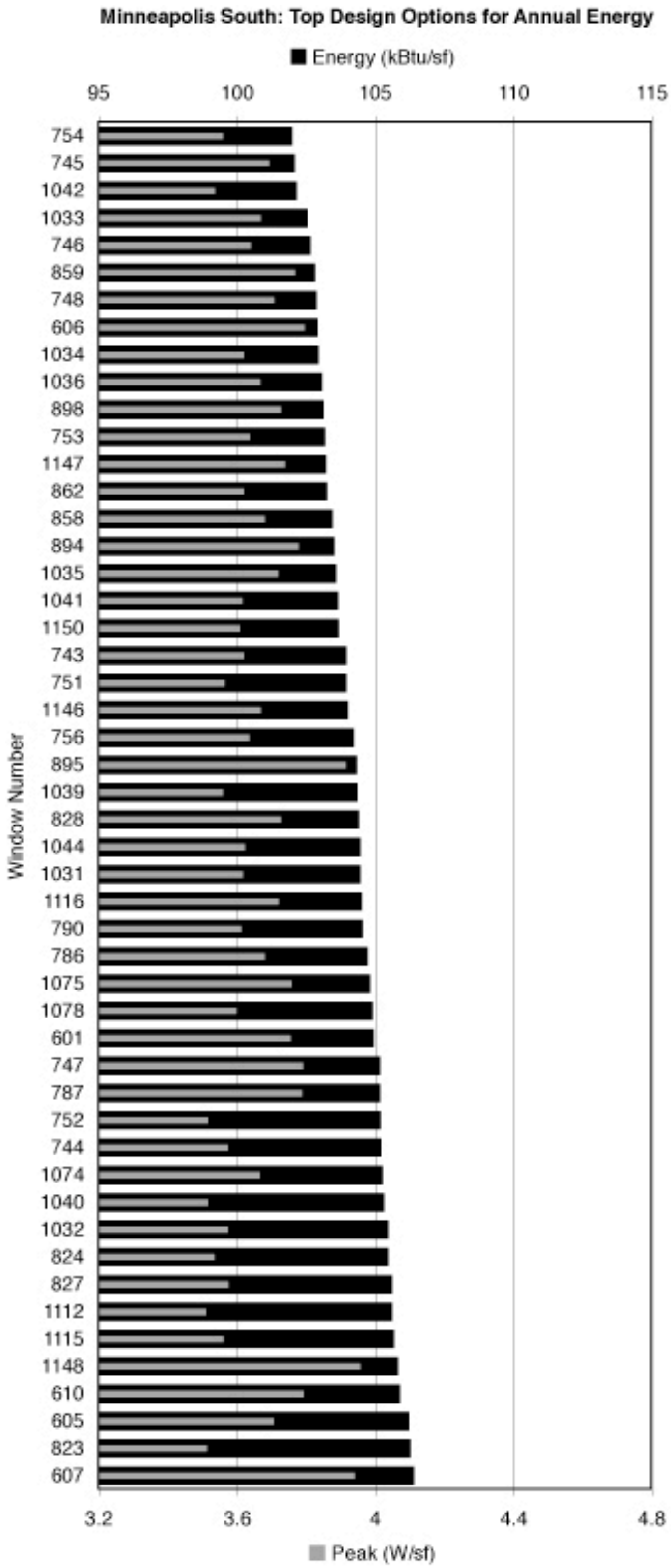
Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
612	cont	no	none	0.60	I	good	average
900	cont	yes	none	0.60	I	good	average
611	cont	no	none	0.45	I	good	average
864	cont	no	setback	0.60	I	good	average
899	cont	yes	none	0.45	I	good	average
1152	cont	yes	setback	0.60	I	good	average
792	cont	no	fins	0.60	I	good	average
755	cont	no	ov1	0.60	I	good	average
1080	cont	yes	fins	0.60	I	good	average
1043	cont	yes	ov1	0.60	I	good	average
607	cont	no	none	0.45	H	good	average
863	cont	no	setback	0.45	I	best	average
895	cont	yes	none	0.45	H	good	average
608	cont	no	none	0.60	H	good	average
1151	cont	yes	setback	0.45	I	best	average
756	cont	no	ov2	0.60	I	good	average
1044	cont	yes	ov2	0.60	I	good	average
896	cont	yes	none	0.60	H	good	average
860	cont	no	setback	0.60	H	good	average
1148	cont	yes	setback	0.60	H	good	average
791	cont	no	fins	0.45	I	best	average
753	cont	no	ov1	0.45	I	best	average
1079	cont	yes	fins	0.45	I	best	average
1041	cont	yes	ov1	0.45	I	best	average
859	cont	no	setback	0.45	H	best	average
1147	cont	yes	setback	0.45	H	best	average
788	cont	no	fins	0.60	H	good	average
1076	cont	yes	fins	0.60	H	good	average
747	cont	no	ov1	0.60	H	good	average
1035	cont	yes	ov1	0.60	H	good	average
754	cont	no	ov2	0.45	I	best	average
1042	cont	yes	ov2	0.45	I	best	average
745	cont	no	ov1	0.45	H	best	average
748	cont	no	ov2	0.60	H	good	average
787	cont	no	fins	0.45	H	best	average
1036	cont	yes	ov2	0.60	H	good	average
1033	cont	yes	ov1	0.45	H	best	average
1075	cont	yes	fins	0.45	H	best	average
610	cont	no	none	0.30	I	best	average
898	cont	yes	none	0.30	I	best	average
606	cont	no	none	0.30	H	best	average
894	cont	yes	none	0.30	H	best	average
746	cont	no	ov2	0.45	H	best	average
1034	cont	yes	ov2	0.45	H	best	average
828	cont	no	ov2f	0.60	I	best	average
1116	cont	yes	ov2f	0.60	I	best	average
862	cont	no	setback	0.30	I	best	average
1150	cont	yes	setback	0.30	I	best	average
858	cont	no	setback	0.30	H	best	average

Figure 11. Top 50 north-oriented design options in terms of annual energy use in Minneapolis, Minnesota. Results include all glazing and shading conditions. See Appendix for simulation data set.



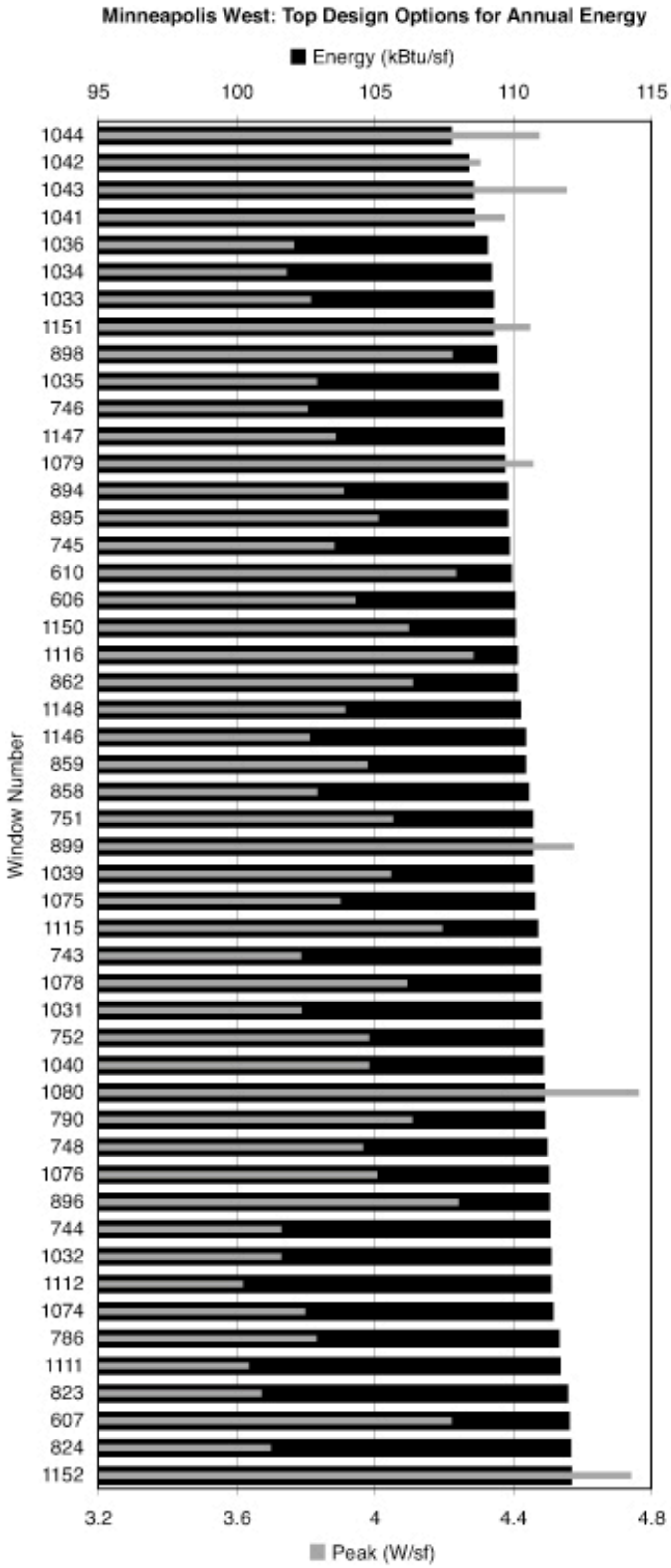
Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
898	cont	yes	none	0.30	I	best	good
610	cont	no	none	0.30	I	best	good
894	cont	yes	none	0.30	H	best	average
1150	cont	yes	setback	0.30	I	best	average
862	cont	no	setback	0.30	I	best	average
606	cont	no	none	0.30	H	best	good
1146	cont	yes	setback	0.30	H	best	average
751	cont	no	ov1	0.30	I	best	average
858	cont	no	setback	0.30	H	best	average
1039	cont	yes	ov1	0.30	I	best	average
752	cont	no	ov2	0.30	I	best	average
1040	cont	yes	ov2	0.30	I	best	average
743	cont	no	ov1	0.30	H	best	average
1031	cont	yes	ov1	0.30	H	best	average
827	cont	no	ov2f	0.45	I	best	average
1115	cont	yes	ov2f	0.45	I	best	average
1078	cont	yes	fins	0.30	I	best	average
744	cont	no	ov2	0.30	H	best	average
1032	cont	yes	ov2	0.30	H	best	average
790	cont	no	fins	0.30	I	best	average
1075	cont	yes	fins	0.45	H	best	average
1074	cont	yes	fins	0.30	H	best	average
786	cont	no	fins	0.30	H	best	average
1148	cont	yes	setback	0.60	H	average	average
823	cont	no	ov2f	0.45	H	best	average
1111	cont	yes	ov2f	0.45	H	best	average
824	cont	no	ov2f	0.60	H	best	average
1112	cont	yes	ov2f	0.60	H	best	average
889	cont	yes	none	0.15	G	best	-
601	cont	no	none	0.15	G	best	-
605	cont	no	none	0.15	H	best	-
893	cont	yes	none	0.15	H	best	-
609	cont	no	none	0.15	I	best	-
787	cont	no	fins	0.45	H	best	average
733	cont	no	ov1	0.15	G	best	-
826	cont	no	ov2f	0.30	I	best	average
1114	cont	yes	ov2f	0.30	I	best	average
897	cont	yes	none	0.15	I	best	-
1079	cont	yes	fins	0.45	I	best	average
853	cont	no	setback	0.15	G	best	-
1021	cont	yes	ov1	0.15	G	best	-
1141	cont	yes	setback	0.15	G	best	-
822	cont	no	ov2f	0.30	H	best	average
1110	cont	yes	ov2f	0.30	H	best	average
741	cont	no	ov1	0.15	H	best	-
857	cont	no	setback	0.15	H	best	-
1029	cont	yes	ov1	0.15	H	best	-
1145	cont	yes	setback	0.15	H	best	-
749	cont	no	ov1	0.15	I	best	-
861	cont	no	setback	0.15	I	best	-

Figure 12. Top 50 east-oriented design options in terms of annual energy use in Minneapolis, Minnesota. Results include all glazing and shading conditions. See Appendix for simulation data set.



Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
754	cont	no	ov2	0.45	I	best	good
745	cont	no	ov1	0.45	H	good	good
1042	cont	yes	ov2	0.45	I	best	good
1033	cont	yes	ov1	0.45	H	good	good
746	cont	no	ov2	0.45	H	best	good
859	cont	no	setback	0.45	H	best	good
748	cont	no	ov2	0.60	H	good	good
606	cont	no	none	0.30	H	best	good
1034	cont	yes	ov2	0.45	H	best	good
1036	cont	yes	ov2	0.60	H	good	good
898	cont	yes	none	0.30	I	best	good
753	cont	no	ov1	0.45	I	best	good
1147	cont	yes	setback	0.45	H	good	good
862	cont	no	setback	0.30	I	best	good
858	cont	no	setback	0.30	H	best	good
894	cont	yes	none	0.30	H	best	good
1035	cont	yes	ov1	0.60	H	good	good
1041	cont	yes	ov1	0.45	I	good	good
1150	cont	yes	setback	0.30	I	best	good
743	cont	no	ov1	0.30	H	best	good
751	cont	no	ov1	0.30	I	best	good
1146	cont	yes	setback	0.30	H	best	good
756	cont	no	ov2	0.60	I	good	good
895	cont	yes	none	0.45	H	good	good
1039	cont	yes	ov1	0.30	I	best	good
828	cont	no	ov2f	0.60	I	best	average
1044	cont	yes	ov2	0.60	I	good	good
1031	cont	yes	ov1	0.30	H	best	good
1116	cont	yes	ov2f	0.60	I	best	average
790	cont	no	fins	0.30	I	best	good
786	cont	no	fins	0.30	H	best	average
1075	cont	yes	fins	0.45	H	good	good
1078	cont	yes	fins	0.30	I	best	good
601	cont	no	none	0.15	G	best	-
747	cont	no	ov1	0.60	H	good	good
787	cont	no	fins	0.45	H	good	good
752	cont	no	ov2	0.30	I	best	good
744	cont	no	ov2	0.30	H	best	good
1074	cont	yes	fins	0.30	H	best	good
1040	cont	yes	ov2	0.30	I	best	average
1032	cont	yes	ov2	0.30	H	best	good
824	cont	no	ov2f	0.60	H	best	average
827	cont	no	ov2f	0.45	I	best	average
1112	cont	yes	ov2f	0.60	H	best	average
1115	cont	yes	ov2f	0.45	I	best	average
1148	cont	yes	setback	0.60	H	good	good
610	cont	no	none	0.30	I	best	good
605	cont	no	none	0.15	H	best	-
823	cont	no	ov2f	0.45	H	best	average
607	cont	no	none	0.45	H	good	good

Figure 13. Top 50 south-oriented design options in terms of annual energy use in Minneapolis, Minnesota. Results include all glazing and shading conditions. See Appendix for simulation data set.



Window Number	Daylight Controls	Interior Shades	Exterior Shades	WWR	Glass	Glare Level	Thermal Comfort
1044	cont	yes	ov2	0.60	I	average	average
1042	cont	yes	ov2	0.45	I	average	average
1043	cont	yes	ov1	0.60	I	average	average
1041	cont	yes	ov1	0.45	I	average	average
1036	cont	yes	ov2	0.60	H	average	average
1034	cont	yes	ov2	0.45	H	average	average
1033	cont	yes	ov1	0.45	H	average	average
1151	cont	yes	setback	0.45	I	average	average
898	cont	yes	none	0.30	I	best	average
1035	cont	yes	ov1	0.60	H	average	average
746	cont	no	ov2	0.45	H	average	average
1147	cont	yes	setback	0.45	H	average	average
1079	cont	yes	fins	0.45	I	average	average
894	cont	yes	none	0.30	H	best	average
895	cont	yes	none	0.45	H	average	average
745	cont	no	ov1	0.45	H	average	average
610	cont	no	none	0.30	I	good	average
606	cont	no	none	0.30	H	good	average
1150	cont	yes	setback	0.30	I	best	average
1116	cont	yes	ov2f	0.60	I	average	average
862	cont	no	setback	0.30	I	best	average
1148	cont	yes	setback	0.60	H	average	average
1146	cont	yes	setback	0.30	H	best	average
859	cont	no	setback	0.45	H	average	average
858	cont	no	setback	0.30	H	good	average
751	cont	no	ov1	0.30	I	good	average
899	cont	yes	none	0.45	I	average	average
1039	cont	yes	ov1	0.30	I	best	average
1075	cont	yes	fins	0.45	H	average	average
1115	cont	yes	ov2f	0.45	I	average	average
743	cont	no	ov1	0.30	H	good	average
1078	cont	yes	fins	0.30	I	best	average
1031	cont	yes	ov1	0.30	H	best	average
752	cont	no	ov2	0.30	I	best	average
1040	cont	yes	ov2	0.30	I	best	average
1080	cont	yes	fins	0.60	I	average	average
790	cont	no	fins	0.30	I	good	average
748	cont	no	ov2	0.60	H	average	average
1076	cont	yes	fins	0.60	H	average	average
896	cont	yes	none	0.60	H	average	average
744	cont	no	ov2	0.30	H	good	average
1032	cont	yes	ov2	0.30	H	good	average
1112	cont	yes	ov2f	0.60	H	average	average
1074	cont	yes	fins	0.30	H	best	average
786	cont	no	fins	0.30	H	good	average
1111	cont	yes	ov2f	0.45	H	average	average
823	cont	no	ov2f	0.45	H	average	average
607	cont	no	none	0.45	H	average	average
824	cont	no	ov2f	0.60	H	average	average
1152	cont	yes	setback	0.60	I	average	average

Figure 14. Top 50 west-oriented design options in terms of annual energy use in Minneapolis, Minnesota. Results include all glazing and shading conditions. See Appendix for simulation data set.

What are the Effects of Daylighting Controls?

In all of the simulations, the results using daylighting controls outperformed the results of not using daylight controls. In each unshaded glazing and WWR condition, the use of daylighting controls aided in the reduction of annual energy and peak demand. In both Phoenix and Minneapolis there is a performance benefit, and in many cases an extreme benefit, to using daylighting controls. Therefore, the analysis for finding the optimum window will only include the cases that use daylighting controls of continuous dimming. See *Window Systems for High-performance Buildings* (Carmody et al., 2004) for all daylighting assumptions and refer to Haglund's Master of Architecture Thesis, *Window Optimization in High-performance Commercial Buildings* (Haglund, 2008) for the methodology of eliminating the option of no daylighting controls from the rest of the study.

What is the Optimum WWR?

Window-to-wall ratio (WWR) is an important variable in a window design in terms of energy performance. The size of the window area will affect the amount of heat gain, heat loss, view, glare, and availability of natural light. Finding the optimum WWR is based on the top 50 performers—all which employ daylighting controls, a combination of glass types, and a combination of interior shades and exterior shading devices. Refer to Haglund's Master of Architecture Thesis, *Window Optimization in High-performance Commercial Buildings* (Haglund, 2008) for the charts summarizing the window-to-wall ratios of the top performing design options for all 4 orientations in Phoenix and Minneapolis.

Figure 15 shows the total number of windows per WWR from the top 50 performers in Phoenix. For the north orientation, the majority of the design options are either 0.45 or 0.60 WWR. For the east orientation, the majority of the design options are either 0.15 or 0.30 WWR. For the south and west orientations, the majority of the design options have a 0.30 WWR.

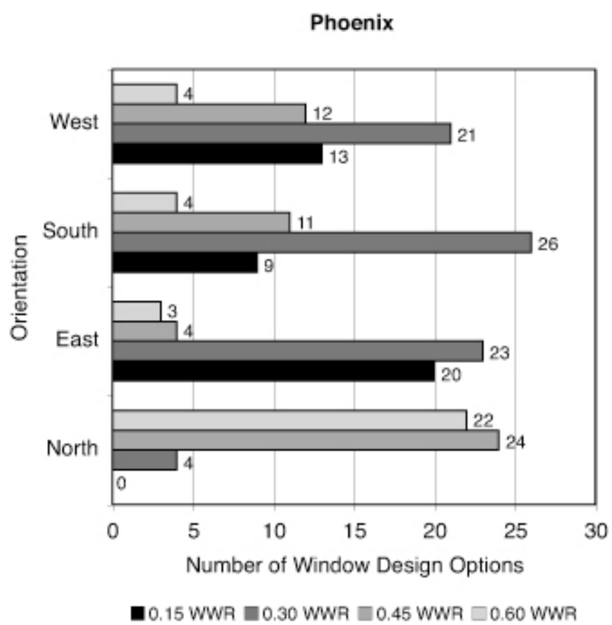


Figure 15. Of the top performing set, the number of windows per WWR for each orientation in Phoenix, Arizona.

There is no definitive optimum window-to-wall ratio for any orientation in Phoenix because shading devices and glazing type impact what WWR performs the best. A moderate or large WWR in combination with triple (window H) or quad (window I) glazing using no exterior shading or a shallow shading device makes up the very top performers for the north orientation—showing the benefit of window area on daylighting strategies as well as showing that heat loss and/or gain is not increased with a larger window area when using high-performing glass. A moderate WWR in combination with triple (window H) or quad (window I) glazing with deep overhangs (ov2) or overhangs with fins (ov2f) make up the very top performers for the east orientation. For double glazing (window F or G), a small WWR is used with the larger WWR requiring more extreme shading. A moderate to large WWR in combination with triple (window H) or quad (window I) glazing using overhangs with fins (ov2f) as the exterior shading device make up the very top performers for the south orientation. A moderate to large WWR in combination with triple (window H) or quad (window I) glazing using deep overhangs (ov2) or overhangs with fins (ov2f) as the shading device make up the very top performers for the west orientation.

Figure 16 shows the total number of windows per WWR from the top 50 performers in Minneapolis. For the top 50 performers in the north orientation, the majority of the design options are of 0.45 or 0.60 WWR. For the east orientation, the most of the design options have either 0.15 or 0.30 WWR, with the majority of the design options having a 0.30 WWR. For the south and west orientations, most of the design options have 0.30, 0.45 or 0.60 WWR, with the majority of the design options having a 0.30 WWR.

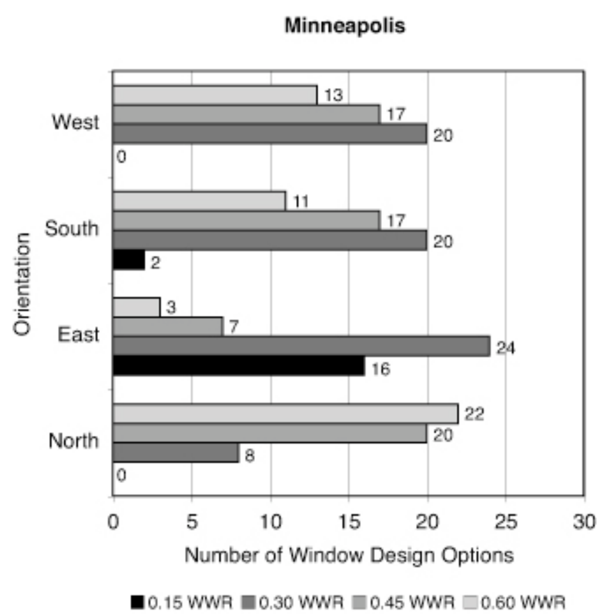


Figure 16. Of the top performing set, the number of windows per WWR for each orientation in Minneapolis, Minnesota.

There is no definitive optimum window-to-wall ratio for any orientation in Minneapolis because shading devices and glazing type impact what WWR performs the best. A moderate to large

WWR in combination with triple (window H) or quad (window I) glazing with either no shading or a shallow shading device make up the very top performers for the north orientation—showing the benefit of WWR on daylighting strategies as well that showing that heat loss and/or gain is not increased with the increase of window area when using high-performing glass. A moderate WWR in combination with triple (window H) or quad (window I) glazing with either no shading or a shallow shading device make up the very top performers for the east orientation. A moderate WWR in combination with triple (window H) or quad (window I) glazing with either no shading or a shallow shading device make up the very top performers for the south orientation. A moderate WWR in combination with triple (window H) or quad (window I) glazing with either overhangs or setback make up the very top performers for the west orientation.

What is the Optimum Shading Condition?

Historically, shading strategies are influenced by orientation. Horizontal shading devices, such as overhangs, were considered most effective on the south orientation due to the path of the sun. Vertical devices, such as fins, were considered most effective on the east and west due to the extreme angle of the sun. High-performance glass can influence these typical strategies. Finding the optimum shading condition is based on the top 50 performers—all which employ daylighting controls, a combination of glass types, and a combination of WWR. Refer to Haglund's Master of Architecture Thesis, *Window Optimization in High-performance Commercial Buildings* (Haglund, 2008) for the charts summarizing the shading conditions of the top performing design options for all 4 orientations in Phoenix and Minneapolis.

Figure 17 shows the total number of windows per exterior shading device from the top 50 performers in Phoenix. For the north orientation with or without interior shades, a setback has just a single result more than the other 5 strategies. For the east orientation when not using interior shades, the majority of the design options use shallow overhangs (ov1). When using interior shades, the majority of the design options use overhangs with fins (ov2f). For the south orientation with or without interior shades, the majority of the design options use overhangs with fins (ov2f). For the west orientation with no interior shades, the majority of the design options use overhangs with fins (ov2f). When adding interior shades, the majority of the design options have setback or deep overhangs (ov2).

There is no definitive optimum shading device for any orientation in Phoenix because WWR and glazing type impact what shading device performs best. No exterior shading device or shallow devices (ov1, fins or setback) used with a moderate to large WWR with quad glazing (window I) make up the very top performers for the north orientation. Overhangs with fins (ov2f) or deep overhangs (ov2) used with moderate WWR with triple (window H) or quad (window I) glazing make up the very top performers in the east orientation—showing the benefit of shading devices to block the extreme sun angles allowing for a large window area when using high-performing glass. Overhangs with fins (ov2f) or deep overhangs (ov2) used with moderate to large WWR with triple (window H) or quad (window I) glazing make up the very top performers in the south orientation —showing the benefit of shading devices to block the extreme angles of the sun which allows for a large window area when using high-performing glass. Overhangs with fins (ov2f) or deep overhangs (ov2) used with moderate to large WWR with triple (window H) or quad (window I) glazing make up the very top performers in the west orientation—showing the benefit of shading devices to block the extreme angles of the sun allowing for large window area when using high-performing glass.

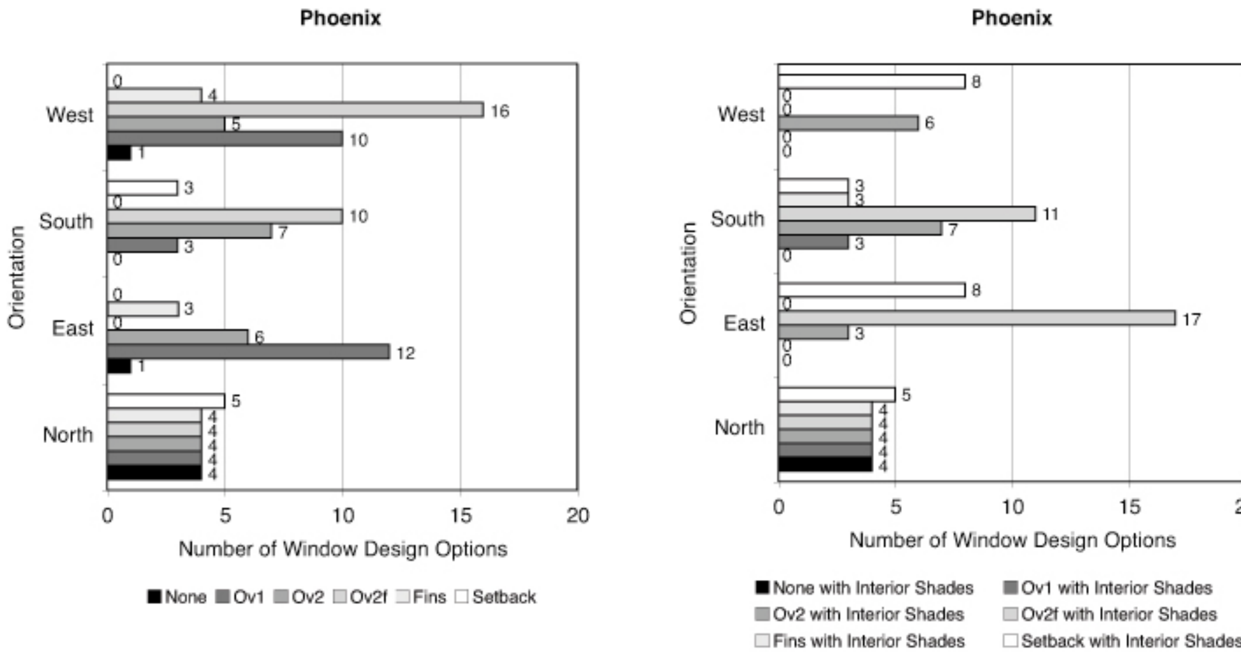


Figure 17. Of the top performing set, the number of window (without and with interior shades) per exterior shading device for each orientation in Phoenix, Arizona.

Figure 18 shows the total number of windows per shading device from the top 50 performers in Minneapolis. For the north orientation with or without interior shades, no exterior shading and setback have the majority of design options. For the east orientation without interior shades no exterior shades, shallow overhangs (ov1), overhangs with fins (ov2f), and setback equally make up the majority of design options. When using interior shades, the majority of the design options equally use no exterior shades, overhangs with fins (ov2f), or setback. For the south orientation with or without interior shades, the majority of the design options use deep overhangs (ov2). For the west orientation with no interior shades, the majority of the design options use also use deep overhangs (ov2). When adding interior shades, the majority of the design options changes to equally include shallow overhangs (ov1), deep overhangs (ov2), fins, and setback.

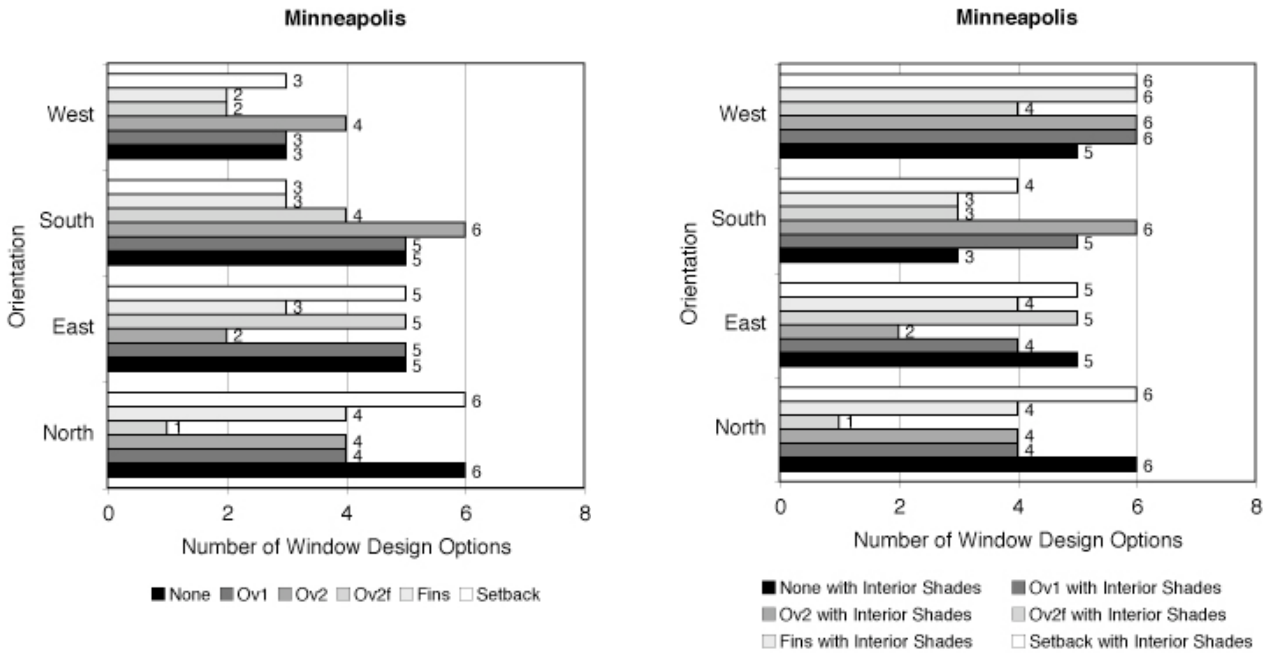


Figure 18. Of the top performing set, the number of windows (without and with interior shades) per shading device for each orientation in Minneapolis, Minnesota.

There is no definitive optimum shading device for any orientation in Minneapolis because WWR and glazing type impact what shading device performs best. No exterior shading device or shallow devices (ov1, fins or setback) used with a moderate to large WWR with quad glazing (window I) make up the very top performers for the north orientation. No exterior shading device or shallow devices (ov1, fins or setback) used with a 0.30 WWR with triple (window H) or quad (window I) glazing make up the very top performers for the east orientation. Overhangs (ov1 and ov2) and setback used with a moderate or large WWR with triple (window H) or quad (window I) glazing make up the very top performers for the south orientation. Overhangs (ov1 and ov2) and setback used with a moderate or large WWR with triple (window H) or quad (window I) glazing make up the very top performers for the west orientation.

What is the Optimum Glazing Condition?

An important energy-related item with a window assembly is its ability to control heat loss. A window's ability to resist this heat transfer is referred to as it's insulating value, or U-factor. The U-factor of a window is especially important in a heating dominated climate. Another important energy-related item in a window assembly is its ability to control solar heat gain from diffused or direct solar radiation. Controlling solar heat gain is important in commercial buildings, especially in a cooling dominated climate. A solar heat gain coefficient (SHGC), is used to measure the amount of heat the window transmits. U-factor and SHCG are important in choosing glazing, yet shading devices and window area can influence what type of glazing is the best. Finding the optimum glazing type is based on the top 50 performers—all which employ daylighting controls, a combination of window-to-wall ratios, and a combination of interior and exterior shading devices Refer to Haglund's Master of Architecture Thesis, *Window Optimization in High-performance Commercial Buildings* (Haglund, 2008) for the charts summarizing the glazing type of the top performing design options for all 4 orientations in Phoenix and Minneapolis.

Figure 19 shows the total number of windows per glazing type from the top 50 performers in Phoenix. For the north orientation, triple (window H) and quad (window I) glazing have equally the most results. For the east orientation, the majority of the design options include triple glazing (window H), though double clear (window G) and quad (window I) glazing also make up many of the results. For the south orientation, double clear (window G), triple (window H) and quad (window I) glazing all make up the majority of the results. In the west orientation, triple (window H) and quad (window I) glazing make up the majority of the results with double clear (window G) having just as many results in the west as it did in the east.

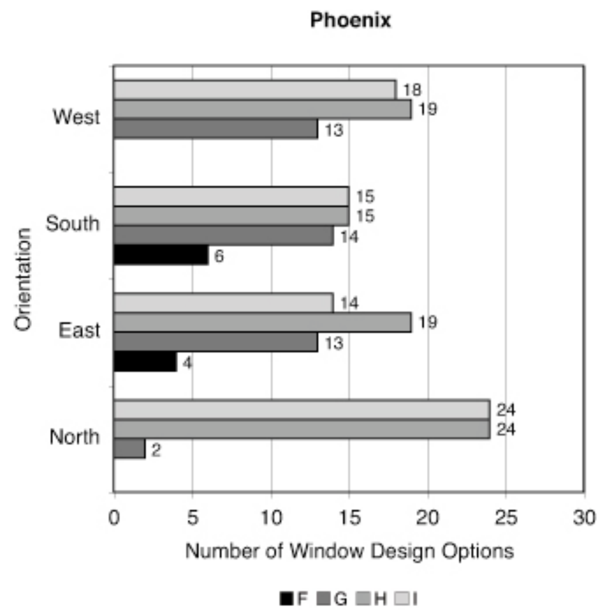


Figure 19. Of the top performing set, the number of windows per glass type for each orientation in Phoenix, Arizona.

There is no definitive optimum glazing type for any orientation in Phoenix because WWR and shading devices impact what glazing performs best. Quad glazing (window I) used with a moderate or large WWR and either no exterior shading device or a shallow device (fins or setback) make up the very top performers for the north orientation. Triple (window H) or quad (window I) glazing used with a moderate WWR with a deep shading device (ov2 or ov2f) make up the very top performers in the east orientation. Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a deep shading device (ov2 or ov2f) make up the very top performers in the south orientation. Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a deep shading device (ov2 or ov2f) make up the very top performers in the west orientation.

Figure 20 shows the total number of windows per glazing type from the top 50 performers in Minneapolis. For the top 50 performers in the north orientation, triple glazing (window H) and quad glazing (window I) are the only glazing with quad glazing having the majority. For the east orientation, double clear (window G) is introduced, yet the majority of the design options are triple glazing (window H). For the south orientation, triple glazing (window H) has the most results, though quad glazing (window I) also has many results. In the west orientation, triple (window H) and quad (window I) glazing again make up the only results, with triple having the majority.

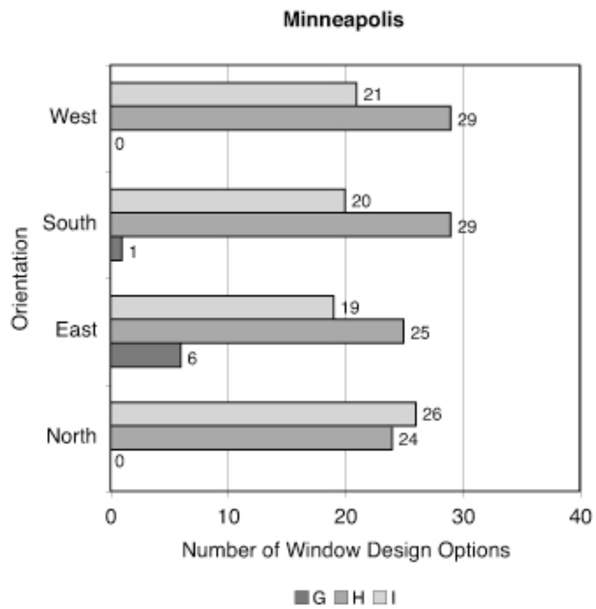


Figure 20. Of the top performing set, the number of windows per glass type for each orientation in Minneapolis, Minnesota.

There is no definitive optimum glazing type for any orientation in Minneapolis because WWR and shading devices impact what glazing performs best. Quad glazing (window I) used with a moderate or large WWR and either no exterior shading device or a shallow device (ov1, fins, or setback) make up the very top performers for the north orientation. Triple (window H) or quad glazing (window I) used with a moderate WWR and either no exterior shading device or a shallow device (ov1, fins or setback) make up the very top performers for the east orientation. Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a shading device (ov1, ov2, or setback) make up the very top performers for the south orientation. Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a shading device (ov1, ov2, or setback) make up the very top performers for the west orientation.

Fixed Parametrics & Optimum Design Condtions

Fixed parametrics are determined using the analysis above of finding the optimum window-to-wall ratio, shading device, and glazing type of the top 50 performers. The rationale for fixing these parametrics is to determine the optimum window design based on certain design conditions or criteria. This aids in answering certain design conditions such as:

- What is the best glazing to use with overhangs?
- What is the best shading device to use with 45% glazing area?
- What is the best window area to use with double clear low-E glass?

Table 5 illustrates the parameters that are fixed for each orientation in Phoenix and Minneapolis. Items with an "x" are fixed because they are part of the top 50 performers set. Items with an "•" are added for they are important for comparative reasons. Refer to Haglund's Master of Architecture Thesis, *Window Optimization in High-performance Commercial Buildings* (Haglund, 2008) for the methodology of determining the fixed parametrics of this study and for determing the optimum design condition for each orientation.

Table 5. Fixed parametrics for Phoenix, Arizona and Minneapolis, Minnesota. The "x" indicates parametric defined by the top 50 performers and the "•" indicates an optional fixed parametric.

Phoenix

	WWR				Exterior Shading						Glazing								
	0.15	0.30	0.45	0.60	none	ov1	ov2	ov2f	fins	setbck	A	B	C	D	E	F	G	H	I
North	•	x	x	x	x	x	x	x	x	x						•	x	x	x
East	x	x	x	x	x	x	x	x	x	x						x	x	x	x
South	x	x	x	x	•	x	x	x	x	x						x	x	x	x
West	x	x	x	x	x	x	•	x	x	x						•	x	x	x

Minneapolis

	WWR				Exterior Shading						Glazing								
	0.15	0.30	0.45	0.60	none	ov1	ov2	ov2f	fins	setbck	A	B	C	D	E	F	G	H	I
North	•	x	x	x	x	x	x	x	x	x						•	•	x	x
East	x	x	x	x	x	x	x	x	x	x						•	x	x	x
South	x	x	x	x	x	x	x	x	x	x						•	x	x	x
West	•	x	x	x	x	x	x	x	x	x						•	•	x	x

After establishing the fixed parametrics the optimum window was determined for specific design conditions in both Minneapolis and Phoenix. See Figure 21 for a graphic sample of the results of the findings. These optimum determinations were for:

- Optimum window area with fixed shading device and glass type
- Optimum shading device with fixed window-to-wall ratio and glass type
- Optimum glazing with fixed window-to-wall ratio and shading device

Minneapolis East Glass H

Window	Interior Shades	Exterior Shades	WWR	Energy (kBtu/sf)	Peak (W/sf)	Glare Level	Thermal Comfort
605	no	none	0.15	112.74	3.81	best	-
893	yes	none	0.15	112.92	3.79	best	-
741	no	ov1	0.15	113.89	3.67	best	-
857	no	setback	0.15	113.92	3.69	best	-
1029	yes	ov1	0.15	114.02	3.67	best	-
1145	yes	setback	0.15	114.09	3.68	best	-
785	no	fins	0.15	114.42	3.70	best	-

Minneapolis East Glass I

Window	Interior Shades	Exterior Shades	WWR	Energy (kBtu/sf)	Peak (W/sf)	Glare Level	Thermal Comfort
609	no	none	0.15	113.23	3.81	best	-
897	yes	none	0.15	113.38	3.80	best	-
749	no	ov1	0.15	114.31	3.67	best	-
861	no	setback	0.15	114.34	3.69	best	-
1037	yes	ov1	0.15	114.40	3.67	best	-
1149	yes	setback	0.15	114.46	3.69	best	-
789	no	fins	0.15	114.79	3.70	best	-
					3.69	best	-
					3.65	best	-
					3.65	best	-
					3.59	best	-
					3.59	best	-
					3.96	best	good
					3.97	best	good
					3.81	best	average
					3.83	best	average
					3.80	best	average
					3.79	best	average
					3.73	best	average
					3.73	best	average
					3.79	best	average
					3.86	best	average
					3.60	best	average
					3.60	best	average
					3.88	poor	average
					3.92	poor	average
					3.85	poor	average
					3.95	poor	average
					3.78	best	average
					3.78	best	average
					4.05	poor	average
					4.24	best	average
					4.36	poor	average
					4.21	poor	average
					4.51	best	average
					4.71	poor	average
					3.99	poor	average
					4.09	poor	average
					4.25	poor	average
					4.44	poor	average
					4.07	best	average
					4.07	best	average
					4.57	poor	average
					5.21	good	average
					5.13	poor	average
					4.96	poor	average
					5.26	good	average
					5.58	poor	average

Minneapolis East Glass H

Window	Interior Shades	Exterior Shades	WWR	Energy (kBtu/sf)	Peak (W/sf)	Glare Level	Thermal Comfort
1075	yes	fins	0.45	111.49	4.14	best	average
1074	yes	fins	0.30	111.65	3.78	best	average
786	no	fins	0.30	112.00	3.91	best	average
787	no	fins	0.45	113.32	4.59	best	average
785	no	fins	0.15	114.42	3.70	best	-
1073	yes	fins	0.15	114.62	3.69	best	-

Minneapolis East Glass I

Window	Interior Shades	Exterior Shades	WWR	Energy (kBtu/sf)	Peak (W/sf)	Glare Level	Thermal Comfort
1078	yes	fins	0.30	111.24	3.79	best	average
790	no	fins	0.30	111.48	3.86	best	average
1079	yes	fins	0.45	113.44	4.24	best	average
789	no	fins	0.15	114.79	3.70	best	-
1077	yes	fins	0.15	114.96	3.69	best	-
791	no	fins	0.45	117.41	4.51	best	average
					5.21	good	average
					5.26	good	average
					3.96	best	good
					3.97	best	good
					3.81	best	-
					3.80	best	-
					4.21	poor	average
					4.71	poor	average
					4.96	poor	average
					5.58	poor	average
					3.92	poor	average
					4.09	poor	average
					3.80	best	average
					3.79	best	average
					4.05	poor	average
					3.67	best	-
					3.67	best	-
					4.57	poor	average
					3.88	poor	average
					3.85	poor	average
					3.99	poor	average
					3.73	best	average
					3.73	best	average
					3.65	best	-
					3.65	best	-
					4.25	poor	average
					3.78	best	average
					3.78	best	average
					3.60	best	average
					3.60	best	average
					3.59	best	-
					3.59	best	-
					4.07	best	average
					4.07	best	average
					3.95	poor	average
					3.81	best	average
					3.83	best	average
					3.69	best	-
					4.36	poor	average
					3.69	best	-
					4.44	poor	average
					5.13	poor	average

Minneapolis East 60 WWR

Window	Interior Shades	Exterior Shades	Glass	Energy (kBtu/sf)	Peak (W/sf)	Glare Level	Thermal Comfort
1076	yes	fins	H	115.13	4.74	good	average
788	no	fins	H	121.90	5.49	good	average
1080	yes	fins	I	123.16	5.21	good	average
792	no	fins	I	130.00	5.26	good	average
1072	yes	fins	G	132.61	5.31	average	average
1068	yes	fins	F	134.76	5.44	good	average
1064	yes	fins	E	143.03	5.94	good	average
780	no	fins	F	149.78	6.40	good	average
784	no	fins	G	152.00	7.18	average	average
1060	yes	fins	D	154.94	5.15	best	average
772	no	fins	D	154.94	5.16	best	average
1056	yes	fins	C	155.59	6.25	good	average
1052	yes	fins	B	162.83	7.29	average	average
776	no	fins	E	167.64	7.97	good	average
768	no	fins	C	184.44	8.49	good	average
764	no	fins	B	200.03	10.66	average	poor
1048	yes	fins	A	203.89	8.09	average	poor
760	no	fins	A	243.67	11.71	average	poor
896	yes	none	H	114.87	4.84	poor	good
608	no	none	H	122.63	5.71	poor	average
900	yes	none	I	126.38	4.96	poor	average
612	no	none	I	132.16	5.58	poor	average
892	yes	none	G	134.01	5.49	poor	average
888	yes	none	F	136.19	5.77	poor	average
884	yes	none	E	144.00	6.15	average	average
880	yes	none	D	145.75	5.04	poor	average
600	no	none	F	150.16	6.77	poor	average
604	no	none	G	152.92	7.57	poor	average
592	no	none	D	154.06	5.39	poor	average
876	yes	none	C	157.33	6.54	average	average
872	yes	none	B	166.00	7.68	average	average
596	no	none	E	168.17	8.49	poor	average
588	no	none	C	184.88	9.02	poor	average
584	no	none	B	202.24	11.26	poor	poor
868	yes	none	A	207.06	8.60	poor	average
580	no	none	A	246.71	12.46	poor	poor
1043	yes	ov1	I	109.48	4.09	poor	average
1035	yes	ov1	H	111.03	4.20	poor	average
747	no	ov1	H	113.10	4.70	poor	average
755	no	ov1	I	121.20	4.57	poor	average
1019	yes	ov1	F	125.19	4.48	poor	average
1027	yes	ov1	G	126.12	4.71	average	average
1011	yes	ov1	E	133.58	5.08	average	average
731	no	ov1	F	133.72	5.49	poor	average
739	no	ov1	G	136.30	5.96	poor	average
1003	yes	ov1	D	142.58	4.53	poor	average
715	no	ov1	D	143.15	4.51	poor	average
995	yes	ov1	C	146.21	5.41	average	average
723	no	ov1	E	147.40	6.67	poor	average
987	yes	ov1	B	152.35	6.29	average	average
707	no	ov1	C	161.10	7.11	poor	average
699	no	ov1	B	175.62	8.83	poor	average
979	yes	ov1	A	192.14	6.96	average	average
691	no	ov1	A	217.59	9.87	poor	poor

Minneapolis East 60 WWR

Window	Interior Shades	Exterior Shades	Glass	Energy (kBtu/sf)	Peak (W/sf)	Glare Level	Thermal Comfort
1044	yes	ov2	I	109.26	3.99	poor	average
748	no	ov2	H	110.61	4.32	poor	average
1036	yes	ov2	H	110.70	4.07	poor	average
756	no	ov2	I	116.37	4.25	poor	average
1028	yes	ov2	G	123.33	4.31	average	average
1020	yes	ov2	F	124.17	4.28	poor	average
732	no	ov2	F	128.36	4.97	poor	average
1012	yes	ov2	E	129.44	4.58	average	average
740	no	ov2	G	131.13	5.40	poor	average
996	yes	ov2	C	140.64	4.75	average	average
724	no	ov2	E	141.03	6.03	poor	average
716	no	ov2	D	141.44	4.23	poor	average
1004	yes	ov2	D	142.70	4.33	poor	average
988	yes	ov2	B	146.76	5.64	average	average
708	no	ov2	C	153.81	6.32	poor	average
700	no	ov2	B	166.01	7.87	poor	average
980	yes	ov2	A	185.88	6.09	average	average
692	no	ov2	A	205.76	8.67	poor	poor
824	no	ov2f	H	112.30	4.09	best	average
1112	yes	ov2f	H	112.30	4.07	best	average
828	no	ov2f	I	117.28	4.07	best	average
1116	yes	ov2f	I	117.31	4.07	best	average
1108	yes	ov2f	G	124.77	4.32	good	average
1104	yes	ov2f	F	127.32	4.55	best	average
816	no	ov2f	F	129.21	4.60	best	average
820	no	ov2f	G	131.66	4.94	good	average
1100	yes	ov2f	E	132.06	4.71	best	average
812	no	ov2f	E	142.19	5.49	best	average
1092	yes	ov2f	C	144.12	4.95	best	average
1096	yes	ov2f	D	145.13	4.11	best	poor
808	no	ov2f	D	145.14	4.11	best	poor
1088	yes	ov2f	B	145.93	5.16	good	average
804	no	ov2f	C	155.43	5.78	best	poor
800	no	ov2f	B	167.02	7.34	good	poor
1084	yes	ov2f	A	187.01	5.62	good	poor
796	no	ov2f	A	208.29	8.06	good	poor
1148	yes	setback	H	112.01	4.46	average	average
1152	yes	setback	I	117.16	4.44	poor	average
860	no	setback	H	118.60	5.27	poor	average
864	no	setback	I	126.37	5.13	poor	average
1140	yes	setback	F	130.83	5.15	average	average
1144	yes	setback	G	132.17	5.29	average	average
1136	yes	setback	E	142.17	5.82	average	average
1132	yes	setback	D	143.72	4.76	poor	average
852	no	setback	F	144.39	6.22	poor	average
856	no	setback	G	146.69	6.91	poor	average
844	no	setback	D	150.44	5.02	poor	average
1128	yes	setback	C	152.25	5.98	average	average
848	no	setback	E	160.74	7.77	poor	average
1124	yes	setback	B	161.01	7.09	average	average
840	no	setback	C	176.66	8.21	poor	average
836	no	setback	B	191.36	10.21	poor	average
1120	yes	setback	A	201.33	7.95	average	average
832	no	setback	A	236.10	11.38	poor	poor

Figure 21. Samples of the optimum conditions after establishing the fixed parametrics.

COMPARE PERFORMANCE OF FINDINGS: ENERGY

The following tables summarize the top window design options (per orientation) in terms of optimum performance, whether the design options meet the 30% and 50% performance targets determined from the existing data set, from the CBECS database, and of the ASHRAE 90.1-99 budget building and if the options follow the prescriptive or performance path for code compliance.

Phoenix, Arizona: Performance Summary for North Orientation

Table 6 shows the annual performance summary for the north orientation in Phoenix. The very top performers in the set were optimum in WWR, shading, and glass type, all using either 0.45 or 0.60 WWR with quad glazing (window I). Though exterior shading devices are part of the very top performers, when looking at the entire top performing set, WWR and glass type make more of an impact on energy performance which would be expected on the north orientation due to the lack of direct solar gain.

As compared to the existing data set, the top performing design options performed 18.53–24.94% better than the baseline (151.88 kBtu/sf). No design options meet the 30% or 50% performance targets.

As compared to the CBECS database, the top performing design options performed 13.20–42.03% better than the regional CBECS average (212.09 kBtu/sf). Only 2 design options (option 1145 and option 1149) did not meet the 30% performance target. No design options meet the 50% performance target.

As compared to ASHRAE 90.1-99, the top performing design options performed 18.53–24.94% better than the budget building (151.88 kBtu/sf). No design options met the 30% or 50% performance targets. When determining a performance compliance for a design option with a specific orientation with 0.15, 0.30, or 0.45 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, a single other orientation also had to be assigned triple (window H) or quad (window I) glazing to achieve compliance. When determining performance compliance for a design option with double tint (window F) or double clear (window G) glazing with 0.60 WWR, 2 other orientations also had to be assigned double tint (window F) or double clear (window G) glazing to achieve compliance.

Phoenix, Arizona: Performance Summary for East Orientation

Table 7 shows the annual performance summary for the east orientation in Phoenix. The very top performers in the set were optimum in WWR, shading, and glass type, all using either 0.30 or 0.45 WWR with triple (window H) or quad (window I) glazing with either deep overhangs (ov2) or overhangs with fins (ov2f). When shallow shading devices are used, high-performing glass becomes important. Exterior shading devices make more of an impact on energy performance which would be expected on the east orientation due to the exposure to the extreme angle of the sun.

As compared to the existing data set, the top performing design options performed 23.46–37.91% better than the baseline (194.05 kBtu/sf). Only 3 design options (option 1140, option 891, and option 888) did not meet the 30% performance target. No design options meet the 50% performance target.

As compared to the CBECS database, the top performing design options performed 20.79–42.03% better than the regional CBECS average (212.09 kBtu/sf). Only 2 design options (option 1143 and option 1140) did not meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 23.46–37.91% better than the budget building (194.05 kBtu/sf). Only 3 design options (option 1140, option 891, and option 888) did not meet the 30% performance target. No design options meet the 50% performance target. When determining a performance compliance for a design option with a specific orientation with 0.15, 0.30, or 0.45 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, a single other orientation also had to be assigned triple (window H) or quad (window I) glazing to achieve compliance. When determining performance compliance for a design option with double tint (window F) or double clear (window G) glazing with 0.60 WWR, 2 other orientations also had to be assigned double tint (window F) or double clear (window G) glazing to achieve compliance.

Phoenix, Arizona: Performance Summary for South Orientation
Table 8 shows the annual performance summary for the south orientation in Phoenix. The very top performers in the set were optimum in WWR, shading, and glass type, all using either 0.45 or 0.60 WWR with triple (window H) or quad (window I) glazing and with overhangs with fins (ov2f). Glass type and exterior shading devices make more of an impact on energy performance when using a moderate or large WWR which would be expected on the south orientation due to the exposure to the sun.

As compared to the existing data set, the top performing design options performed 28.10–41.43% better than the baseline (192.83 kBtu/sf). A single design option (option 896) did not meet the 30% performance target. No design options meet the 50% performance target.

As compared to the CBECS database, the top performing design options performed 38.73–42.03% better than the regional CBECS average (212.09 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 28.10–41.43% better than the budget building (192.83 kBtu/sf). A single design option (option 896) did not meet the 30% performance target. No design options meet the 50% performance target. When determining a performance compliance for a design option with a specific orientation with 0.15, 0.30, or 0.45 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, a single other orientation also had to be assigned triple (window H) or quad (window I) glazing to achieve compliance. When determining performance compliance for a design option with double tint (window F) or double clear (window G) glazing with 0.60 WWR, 2 other orientations also had to be assigned double tint (window F) or double clear (window G) glazing to achieve compliance.

Phoenix, Arizona: Performance Summary for West Orientation

Table 9 shows the annual performance summary for the west orientation in Phoenix. The very top performers in the set were optimum in WWR, shading, and glass type, all using either deep overhangs (ov2) or overhangs with fins (ov2f) with triple (window H) or quad (window I) glazing. The combination of exterior shading device with high-performance glass with shading devices make more of an impact on energy performance which would be expected on the west orientation due to the exposure to the extreme angle of the sun.

As compared to the existing data set, the top performing design options performed 30.51–38.95% better than the baseline (192.98 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the CBECS database, the top performing design options performed 38.7–42.03% better than the regional CBECS average (212.09 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 30.51–38.95% better than the budget building (192.98 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target. When determining a performance compliance for a design option with a specific orientation with 0.15, 0.30, or 0.45 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, a single other orientation also had to be assigned triple (window H) or quad (window I) glazing to achieve compliance. When determining performance compliance for a design option with double tint (window F) or double clear (window G) glazing with 0.60 WWR, 2 other orientations also had to be assigned double tint (window F) or double clear (window G) glazing to achieve compliance.

Phoenix North Annual Performance Summary

							Optimum				Existing Data Set (baseline 151.88 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 151.88 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
792	no	fins	0.60	I	113.99	4.84	x	x	x	x	24.94%			131.88	37.82%	x		24.94%				x				x	
611	no	none	0.45	I	114.08	4.76	x	x	x	x	24.89%			134.67	36.50%	x		24.89%			x		x				
899	yes	none	0.45	I	114.25	4.75	x	x	x	x	24.77%			129.86	38.77%	x		24.77%			x		x				
1080	yes	fins	0.60	I	114.30	4.85	x	x	x	x	24.75%			127.48	39.89%	x		24.75%				x				x	
863	no	setback	0.45	I	114.33	4.82	x	x	x	x	24.72%			128.35	39.48%	x		24.72%			x		x				
864	no	setback	0.60	I	114.46	4.75	x	x	x	x	24.64%			130.47	38.48%	x		24.64%				x				x	
1151	yes	setback	0.45	I	114.46	4.81	x	x	x	x	24.64%			125.63	40.77%	x		24.64%			x		x				
1152	yes	setback	0.60	I	114.57	4.75	x	x	x	x	24.57%			127.08	40.08%	x		24.57%				x				x	
1079	yes	fins	0.45	I	114.61	4.92	x		x	x	24.54%			128.20	39.55%	x		24.54%			x		x				
791	no	fins	0.45	I	114.68	4.93	x		x	x	24.49%			129.00	39.18%	x		24.49%			x		x				
1147	yes	setback	0.45	H	114.89	4.80	x	x		x	24.36%			125.07	41.03%	x		24.36%			x		x				
859	no	setback	0.45	H	114.93	4.82	x	x		x	24.33%			126.32	40.44%	x		24.33%			x		x				
828	no	ov2f	0.60	I	114.96	5.04	x		x	x	24.31%			124.26	41.41%	x		24.31%				x				x	
1116	yes	ov2f	0.60	I	115.01	5.04	x		x	x	24.28%			123.28	41.87%	x		24.28%				x				x	
1075	yes	fins	0.45	H	115.06	4.91	x	x		x	24.25%			125.62	40.77%	x		24.25%			x		x				
787	no	fins	0.45	H	115.07	4.92	x	x		x	24.24%			127.03	40.11%	x		24.24%			x		x				
788	no	fins	0.60	H	115.07	4.84	x	x		x	24.24%			130.10	38.66%	x		24.24%				x				x	
1112	yes	ov2f	0.60	H	115.09	5.01	x	x	x	x	24.22%			123.73	41.66%	x		24.22%				x				x	
756	no	ov2	0.60	I	115.10	4.94	x		x	x	24.21%			124.05	41.51%	x		24.21%				x				x	
824	no	ov2f	0.60	H	115.14	5.01	x	x	x	x	24.19%			125.47	40.84%	x		24.19%				x				x	
753	no	ov1	0.45	I	115.14	4.88	x		x	x	24.19%			127.66	39.81%	x		24.19%			x			x			
1076	yes	fins	0.60	H	115.15	4.83	x	x		x	24.18%			124.10	41.49%	x		24.18%				x				x	
1041	yes	ov1	0.45	I	115.16	4.87	x		x	x	24.17%			124.40	41.35%	x		24.17%			x			x			
1044	yes	ov2	0.60	I	115.16	4.93	x		x	x	24.17%			125.47	40.84%	x		24.17%				x				x	
1043	yes	ov1	0.60	I	115.20	4.82	x		x	x	24.15%			123.79	41.63%	x		24.15%				x				x	
755	no	ov1	0.60	I	115.20	4.83	x		x	x	24.15%			124.33	41.38%	x		24.15%				x				x	
1034	yes	ov2	0.45	H	115.32	4.97	x		x	x	24.07%			123.39	41.82%	x		24.07%			x				x		
1033	yes	ov1	0.45	H	115.36	4.96	x		x	x	24.04%			124.13	41.47%	x		24.04%			x			x			
1042	yes	ov2	0.45	I	115.37	5.00	x		x	x	24.04%			123.70	41.67%	x		24.04%			x				x		
746	no	ov2	0.45	H	115.40	5.01	x		x	x	24.02%			125.16	40.99%	x		24.02%			x				x		
754	no	ov2	0.45	I	115.41	4.99	x		x	x	24.01%			128.47	39.43%	x		24.01%			x				x		
745	no	ov1	0.45	H	115.48	5.00	x		x	x	23.97%			126.61	40.30%	x		23.97%			x			x			
607	no	none	0.45	H	115.54	4.81	x			x	23.93%			133.92	36.86%	x		23.93%			x		x				
895	yes	none	0.45	H	115.57	4.80	x			x	23.91%			129.53	38.93%	x		23.91%			x		x				
612	no	none	0.60	I	115.60	4.84			x	x	23.88%			123.30	41.86%	x		23.88%				x				x	
900	yes	none	0.60	I	115.80	4.84			x	x	23.75%			123.54	41.75%	x		23.75%				x				x	
1111	yes	ov2f	0.45	H	116.29	5.08			x	x	23.43%			122.96	42.03%	x		23.43%			x				x		
823	no	ov2f	0.45	H	116.36	5.09			x	x	23.39%			123.29	41.87%	x		23.39%			x				x		
854	no	setback	0.30	G	116.92	4.96	x	x	x	x	23.02%			127.95	39.67%	x		23.02%			x		x				
894	yes	none	0.30	H	116.93	4.94		x	x	x	23.01%			125.09	41.02%	x		23.01%			x						
1142	yes	setback	0.30	G	116.93	4.95	x	x	x	x	23.01%			126.37	40.42%	x		23.01%			x		x				
606	no	none	0.30	H	116.99	4.94		x	x	x	22.97%			125.82	40.68%	x		22.97%			x						
1146	yes	setback	0.30	H	117.22	4.97		x			22.82%			124.28	41.40%	x		22.82%			x						
1070	yes	fins	0.30	G	117.25	4.98	x	x	x		22.80%			126.72	40.25%	x		22.80%			x		x				
782	no	fins	0.30	G	117.25	4.99	x	x	x		22.80%			128.85	39.25%	x		22.80%			x		x				
858	no	setback	0.30	H	117.25	4.98		x			22.80%			124.59	41.25%	x		22.80%			x						
898	yes	none	0.30	I	117.50	4.96		x			22.63%			124.79	41.16%	x		22.63%			x						
610	no	none	0.30	I	117.52	4.96		x			22.62%			125.36	40.89%	x		22.62%			x						
1024	yes	ov2	0.30	G	117.78	5.06	x		x		22.45%			125.18	40.98%	x		22.45%			x		x				
736	no	ov2	0.30	G	117.81	5.06	x		x		22.43%			125.63	40.77%	x		22.43%			x		x				
1150	yes	setback	0.30	I	117.91	5.01		x			22.37%			124.08	41.49%	x		22.37%			x						
1023	yes	ov1	0.30	G	117.91	5.04	x		x		22.36%			125.84	40.67%	x		22.36%			x		x				
735	no	ov1	0.30	G	117.92	5.05	x		x		22.36%			126.75	40.24%	x		22.36%			x		x				

Table 6. Annual performance summary for the north orientation in Phoenix, Arizona. *Table continues on next page.*

Phoenix North Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 151.88 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 151.88 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
862	no	setback	0.30	I	117.93	5.01		x			22.35%			124.31	41.39%	x		22.35%			x						
602	no	none	0.30	G	118.11	4.87	x				22.23%			130.49	38.47%	x		22.23%			x		x				
890	yes	none	0.30	G	118.17	4.86	x				22.19%			127.93	39.68%	x		22.19%			x		x				
1106	yes	ov2f	0.30	G	118.44	5.14	x		x		22.01%			124.91	41.11%	x		22.01%			x		x				
818	no	ov2f	0.30	G	118.49	5.15	x		x		21.98%			125.23	40.95%	x		21.98%			x		x				
1107	yes	ov2f	0.45	G	118.55	5.01	x	x			21.95%			126.41	40.40%	x		21.95%			x		x				
819	no	ov2f	0.45	G	118.57	5.03	x	x			21.93%			127.69	39.79%	x		21.93%			x		x				
889	yes	none	0.15	G	119.13	5.03		x	x		21.56%			124.92	41.10%	x		21.56%			x		x				
601	no	none	0.15	G	119.20	5.04		x	x		21.52%			125.74	40.72%	x		21.52%			x		x				
1138	yes	setback	0.30	F	119.23	5.10	x	x			21.50%			126.74	40.24%	x		21.50%			x		x				
850	no	setback	0.30	F	119.24	5.10	x	x			21.49%			127.24	40.01%	x		21.49%			x		x				
598	no	none	0.30	F	119.34	4.98	x	x			21.42%			129.13	39.11%	x		21.42%			x		x				
886	yes	none	0.30	F	119.35	4.98	x	x			21.42%			128.04	39.63%	x		21.42%			x		x				
779	no	fins	0.45	G	119.54	4.95	x	x			21.29%			133.02	37.28%	x		21.29%			x		x				
1067	yes	fins	0.45	G	119.60	4.94	x		x		21.25%			130.70	38.38%	x		21.25%			x		x				
1141	yes	setback	0.15	G	119.76	5.07			x		21.15%			124.47	41.31%	x		21.15%			x		x				
853	no	setback	0.15	G	119.80	5.08			x		21.12%			124.79	41.16%	x		21.12%			x		x				
851	no	setback	0.45	F	119.82	4.86	x	x			21.11%			131.65	37.93%	x		21.11%			x		x				
1139	yes	setback	0.45	F	119.90	4.85	x	x			21.05%			129.42	38.98%	x		21.05%			x		x				
1103	yes	ov2f	0.45	F	120.19	5.13	x				20.87%			126.58	40.32%	x		20.87%			x		x				
815	no	ov2f	0.45	F	120.22	5.14	x				20.84%			127.16	40.05%	x		20.84%			x		x				
733	no	ov1	0.15	G	120.27	5.04			x		20.82%			124.52	41.29%	x		20.82%			x		x				
1021	yes	ov1	0.15	G	120.29	5.17			x		20.80%			124.36	41.36%	x		20.80%			x		x				
1018	yes	ov2	0.45	F	120.33	5.04	x				20.77%			127.47	39.90%	x		20.77%			x		x				
730	no	ov2	0.45	F	120.35	5.04	x				20.76%			128.12	39.59%	x		20.76%			x		x				
729	no	ov1	0.45	F	120.47	5.02	x				20.68%			129.76	38.82%	x		20.68%			x		x				
1017	yes	ov1	0.45	F	120.48	5.01	x				20.67%			128.29	39.51%	x		20.67%			x		x				
1015	yes	ov1	0.30	F	120.53	5.16	x				20.64%			126.27	40.47%	x		20.64%			x		x				
727	no	ov1	0.30	F	120.54	5.16	x				20.63%			126.46	40.37%	x		20.63%			x		x				
1016	yes	ov2	0.30	F	120.68	5.17	x				20.54%			125.69	40.74%	x		20.54%			x		x				
728	no	ov2	0.30	F	120.69	5.17	x				20.53%			125.75	40.71%	x		20.53%			x		x				
1069	yes	fins	0.15	G	120.86	5.14			x		20.43%			125.04	41.04%	x		20.43%			x		x				
781	no	fins	0.15	G	120.92	5.15			x		20.38%			125.55	40.81%	x		20.38%			x		x				
820	no	ov2f	0.60	G	120.96	4.96		x			20.36%			131.40	38.04%	x		20.36%				x				x	
1108	yes	ov2f	0.60	G	121.06	4.96		x			20.29%			129.06	39.15%	x		20.29%				x				x	
816	no	ov2f	0.60	F	121.29	5.07		x			20.14%			129.96	38.73%	x		20.14%				x				x	
1104	yes	ov2f	0.60	F	121.30	5.07		x			20.14%			129.03	39.16%	x		20.14%				x				x	
1022	yes	ov2	0.15	G	121.59	5.21			x		19.94%			124.59	41.26%	x		19.94%			x		x				
734	no	ov2	0.15	G	121.61	5.22			x		19.93%			124.66	41.22%	x		19.93%			x		x				
893	yes	none	0.15	H	122.79	5.09		x			19.16%			134.90	36.39%	x		19.16%			x						
885	yes	none	0.15	F	122.80	5.10		x			19.15%			132.52	37.52%	x		19.15%			x		x				
605	no	none	0.15	H	122.82	5.10		x			19.14%			123.39	41.82%	x		19.14%			x						
597	no	none	0.15	F	122.82	5.11		x			19.14%			125.47	40.84%	x		19.14%			x		x				
1105	yes	ov2f	0.15	G	123.04	5.27			x		18.99%			135.26	36.23%	x		18.99%			x		x				
817	no	ov2f	0.15	G	123.06	5.27			x		18.97%			132.15	37.69%	x		18.97%			x		x				
1145	yes	setback	0.15	H	123.09	5.16		x			18.95%			184.10	13.20%	x		18.95%			x						
857	no	setback	0.15	H	123.10	5.16		x			18.95%			125.28	40.93%	x		18.95%			x						
897	yes	none	0.15	I	123.51	5.13		x			18.68%			127.75	39.77%	x		18.68%			x						
609	no	none	0.15	I	123.53	5.13		x			18.67%			128.47	39.43%	x		18.67%			x						
1149	yes	setback	0.15	I	123.73	5.18		x			18.53%			173.81	18.05%	x		18.53%			x						
861	no	setback	0.15	I	123.74	5.18		x			18.53%			130.88	38.29%	x		18.53%			x						

Table 6 continued.

Phoenix East Annual Performance Summary

							Optimum				Existing Data Set (baseline 194.05 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 194.05 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
1115	yes	ov2f	0.45	I	120.48	4.90	x	x	x	x	37.91%	x		122.96	42.03%	x		37.91%	x		x				x		
1111	yes	ov2f	0.45	H	120.61	4.86	x	x	x	x	37.84%	x		123.30	41.86%	x		37.84%	x		x				x		
1110	yes	ov2f	0.30	H	120.94	5.00	x	x	x	x	37.67%	x		124.00	41.53%	x		37.67%	x		x						
823	no	ov2f	0.45	H	120.97	4.87	x	x	x	x	37.66%	x		123.54	41.75%	x		37.66%	x		x				x		
1114	yes	ov2f	0.30	I	121.08	4.90	x	x		x	37.61%	x		123.83	41.61%	x		37.61%	x		x						
822	no	ov2f	0.30	H	121.12	5.00	x	x		x	37.58%	x		124.04	41.52%	x		37.58%	x		x						
1032	yes	ov2	0.30	H	121.16	4.99	x	x	x	x	37.56%	x		123.70	41.68%	x		37.56%	x		x						
826	no	ov2f	0.30	I	121.17	4.90	x	x		x	37.56%	x		123.85	41.61%	x		37.56%	x		x						
1040	yes	ov2	0.30	I	121.37	5.02	x	x	x	x	37.46%	x		123.59	41.73%	x		37.46%	x		x						
744	no	ov2	0.30	H	121.41	4.99	x	x	x	x	37.43%	x		123.75	41.65%	x		37.43%	x		x						
752	no	ov2	0.30	I	121.50	5.01	x	x	x	x	37.39%	x		123.61	41.72%	x		37.39%	x		x						
1106	yes	ov2f	0.30	G	121.71	4.89	x	x		x	37.28%	x		124.91	41.11%	x		37.28%	x		x				x		
827	no	ov2f	0.45	I	121.77	5.15	x	x		x	37.25%	x		123.29	41.87%	x		37.25%	x		x				x		
1021	yes	ov1	0.15	G	121.89	5.06	x	x	x	x	37.19%	x		124.36	41.36%	x		37.19%	x		x			x			
1141	yes	setback	0.15	G	122.11	4.91	x	x	x	x	37.07%	x		124.10	41.49%	x		37.07%	x			x				x	
1022	yes	ov2	0.15	G	122.12	5.12	x	x	x	x	37.07%	x		124.59	41.26%	x		37.07%	x		x				x		
1031	yes	ov1	0.30	H	122.50	4.99	x		x	x	36.87%	x		124.09	41.49%	x		36.87%	x		x						
1112	yes	ov2f	0.60	H	122.53	4.84		x	x	x	36.86%	x		123.73	41.66%	x		36.86%	x			x				x	
1039	yes	ov1	0.30	I	122.56	4.89	x		x	x	36.84%	x		123.92	41.57%	x		36.84%	x		x						
734	no	ov2	0.15	G	122.67	5.12	x		x	x	36.78%	x		124.66	41.22%	x		36.78%	x		x				x		
733	no	ov1	0.15	G	122.84	4.93	x		x	x	36.70%	x		124.52	41.29%	x		36.70%	x		x			x			
1116	yes	ov2f	0.60	I	122.88	5.16		x	x	x	36.68%	x		123.28	41.87%	x		36.68%	x			x				x	
824	no	ov2f	0.60	H	122.94	4.84		x	x	x	36.65%	x		124.05	41.51%	x		36.65%	x			x				x	
751	no	ov1	0.30	I	122.95	4.89			x	x	36.64%	x		123.99	41.54%	x		36.64%	x		x						
1146	yes	setback	0.30	H	122.98	4.86	x		x	x	36.62%	x		124.28	41.40%	x		36.62%	x		x						
1150	yes	setback	0.30	I	123.01	4.85	x		x	x	36.61%	x		124.08	41.49%	x		36.61%	x		x						
1105	yes	ov2f	0.15	G	123.04	5.15			x	x	36.60%	x		125.15	40.99%	x		36.60%	x		x				x		
817	no	ov2f	0.15	G	123.30	5.14			x	x	36.46%	x		125.20	40.97%	x		36.46%	x		x				x		
853	no	setback	0.15	G	123.48	4.93			x	x	36.37%	x		124.79	41.16%	x		36.37%	x			x				x	
1029	yes	ov1	0.15	H	123.54	5.02		x		x	36.33%	x		124.87	41.12%	x		36.33%	x		x			x			
1069	yes	fins	0.15	G	123.58	5.00	x		x	x	36.31%	x		125.04	41.04%	x		36.31%	x			x				x	
741	no	ov1	0.15	H	123.63	5.02		x		x	36.29%	x		124.88	41.12%	x		36.29%	x		x						
1078	yes	fins	0.30	I	123.67	4.91	x		x	x	36.27%	x		124.40	41.35%	x		36.27%	x		x						
1074	yes	fins	0.30	H	123.68	4.88	x		x	x	36.26%	x		124.64	41.23%	x		36.26%	x		x						
889	yes	none	0.15	G	123.71	4.98	x		x	x	36.25%	x		124.92	41.10%	x		36.25%	x			x				x	
862	no	setback	0.30	I	123.92	4.90	x			x	36.14%	x		124.31	41.39%	x		36.14%	x		x						
1102	yes	ov2f	0.30	F	124.14	5.04	x	x		x	36.03%	x		125.91	40.63%	x		36.03%	x		x				x		
1013	yes	ov1	0.15	F	124.21	5.03	x	x		x	35.99%	x		125.33	40.91%	x		35.99%	x		x			x			
1037	yes	ov1	0.15	I	124.29	5.04		x		x	35.95%	x		125.03	41.05%	x		35.95%	x		x						
749	no	ov1	0.15	I	124.31	5.04		x		x	35.94%	x		125.04	41.05%	x		35.94%	x		x						
814	no	ov2f	0.30	F	124.37	5.04	x	x		x	35.91%	x		125.95	40.61%	x		35.91%	x		x				x		
725	no	ov1	0.15	F	124.46	5.03	x	x		x	35.86%	x		125.38	40.89%	x		35.86%	x		x			x			
1014	yes	ov2	0.15	F	124.55	5.06	x	x			35.81%	x		125.58	40.79%	x		35.81%	x		x				x		
726	no	ov2	0.15	F	124.62	5.06	x	x			35.78%	x		125.59	40.78%	x		35.78%	x		x				x		
1137	yes	setback	0.15	F	124.69	5.03	x	x			35.74%	x		125.54	40.81%	x		35.74%	x			x				x	
893	yes	none	0.15	H	124.77	5.03	x				35.70%	x		125.24	40.95%	x		35.70%	x		x						
750	no	ov2	0.15	I	124.78	5.07		x			35.70%	x		125.28	40.93%	x		35.70%	x		x						
1038	yes	ov2	0.15	I	124.79	5.07		x			35.69%	x		125.28	40.93%	x		35.69%	x		x						
1016	yes	ov2	0.30	F	124.79	4.99	x				35.69%	x		125.69	40.74%	x		35.69%	x		x				x		
790	no	fins	0.30	I	124.85	4.96	x				35.66%	x		124.80	41.16%	x		35.66%	x		x						
849	no	setback	0.15	F	125.00	5.03	x				35.58%	x		125.60	40.78%	x		35.58%	x			x				x	
898	yes	none	0.30	I	125.01	4.93	x		x		35.58%	x		124.79	41.16%	x		35.58%	x		x						
894	yes	none	0.30	H	125.03	4.89			x		35.57%	x		125.09	41.02%	x		35.57%	x		x						

Table 7. Annual performance summary for the east orientation in Phoenix, Arizona. Table continues on next page.

Phoenix East Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 194.05 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 194.05 kBtu/sf)									
																					Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
728	no	ov2	0.30	F	125.12	4.99	x				35.52%	x		125.75	40.71%	x		35.52%	x		x				x		
897	yes	none	0.15	I	125.47	5.06	x				35.34%	x		125.41	40.87%	x		35.34%	x		x						
781	no	fins	0.15	G	125.54	5.04	x				35.31%	x		125.55	40.81%	x		35.31%	x			x				x	
885	yes	none	0.15	F	125.81	5.04	x				35.16%	x		125.82	40.68%	x		35.16%	x			x				x	
609	no	none	0.15	I	125.82	5.06	x				35.16%	x		125.49	40.83%	x		35.16%	x		x						
1107	yes	ov2f	0.45	G	125.87	4.90		x			35.14%	x		126.41	40.40%	x		35.14%	x			x				x	
1065	yes	fins	0.15	F	125.89	5.05	x				35.12%	x		125.98	40.60%	x		35.12%	x			x				x	
777	no	fins	0.15	F	126.44	5.07	x				34.84%	x		126.13	40.53%	x		34.84%	x			x				x	
1103	yes	ov2f	0.45	F	126.52	4.92		x			34.80%	x		126.58	40.32%	x		34.80%	x		x				x		
601	no	none	0.15	F	126.61	5.03	x				34.76%	x		125.74	40.72%	x		34.76%	x			x				x	
815	no	ov2f	0.45	F	126.89	4.92		x			34.61%	x		127.16	40.05%	x		34.61%	x		x				x		
597	no	none	0.15	F	126.97	5.09	x				34.57%	x		126.12	40.54%	x		34.57%	x			x				x	
1075	yes	fins	0.45	H	127.41	4.89			x		34.34%	x		125.62	40.77%	x		34.34%	x			x				x	
1026	yes	ov2	0.45	G	130.01	4.93			x		33.00%	x		127.98	39.66%	x		33.00%	x			x				x	
1025	yes	ov1	0.45	G	131.08	4.94			x		32.45%	x		136.55	35.62%	x		32.45%	x			x				x	
1020	yes	ov2	0.60	F	131.65	5.02		x	x		32.16%	x		135.19	36.26%	x		32.16%	x			x				x	
1108	yes	ov2f	0.60	G	131.70	5.13		x			32.13%	x		145.18	31.55%	x		32.13%	x			x				x	
1080	yes	fins	0.60	I	133.77	5.67			x		31.06%	x		138.73	34.59%	x		31.06%	x			x				x	
1019	yes	ov1	0.60	F	135.33	5.23			x		30.26%	x		135.34	36.19%	x		30.26%	x			x				x	
1143	yes	setback	0.45	G	135.52	5.28			x		30.16%	x		167.99	20.79%			30.16%	x			x				x	
1140	yes	setback	0.60	F	141.39	5.89			x		27.14%			166.99	21.26%			27.14%				x				x	
891	yes	none	0.45	G	141.98	5.91			x		26.83%			130.70	38.38%	x		26.83%				x				x	
888	yes	none	0.60	F	148.53	6.59			x		23.46%			131.37	38.06%	x		23.46%				x				x	

Table 7 continued.

Phoenix South Annual Performance Summary

							Optimum				Existing Data Set (baseline 192.83 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 192.83 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
1111	yes	ov2f	0.45	H	112.94	5.09	x	x	x	x	41.43%	x		123.30	41.86%	x		41.43%	x		x				x		
823	no	ov2f	0.45	H	113.01	5.10	x	x	x	x	41.40%	x		123.54	41.75%	x		41.40%	x		x				x		
1115	yes	ov2f	0.45	I	113.02	5.12	x	x	x	x	41.39%	x		122.96	42.03%	x		41.39%	x		x				x		
827	no	ov2f	0.45	I	113.03	5.12	x	x	x	x	41.38%	x		123.29	41.87%	x		41.38%	x		x				x		
1112	yes	ov2f	0.60	H	114.06	5.01		x	x	x	40.85%	x		123.73	41.66%	x		40.85%	x			x				x	
824	no	ov2f	0.60	H	114.10	5.01		x	x	x	40.83%	x		124.05	41.51%	x		40.83%	x			x				x	
828	no	ov2f	0.60	I	114.15	5.26		x	x	x	40.81%	x		124.26	41.41%	x		40.81%	x			x				x	
1116	yes	ov2f	0.60	I	114.26	5.26		x	x	x	40.75%	x		123.28	41.87%	x		40.75%	x			x				x	
1032	yes	ov2	0.30	H	114.31	5.14	x	x	x	x	40.72%	x		123.70	41.68%	x		40.72%	x		x						
744	no	ov2	0.30	H	114.33	5.14	x	x	x	x	40.71%	x		123.75	41.65%	x		40.71%	x		x						
1106	yes	ov2f	0.30	G	114.48	5.15	x	x	x	x	40.63%	x		124.91	41.11%	x		40.63%	x		x				x		
1110	yes	ov2f	0.30	H	114.68	5.20			x	x	40.53%	x		124.00	41.53%	x		40.53%	x		x						
822	no	ov2f	0.30	H	114.69	5.20			x	x	40.52%	x		124.04	41.52%	x		40.52%	x		x						
1040	yes	ov2	0.30	I	114.70	5.15	x	x	x	x	40.52%	x		123.59	41.73%	x		40.52%	x		x						
752	no	ov2	0.30	I	114.71	5.15	x	x	x	x	40.51%	x		123.61	41.72%	x		40.51%	x		x						
818	no	ov2f	0.30	G	114.72	5.15	x	x	x	x	40.51%	x		125.23	40.95%	x		40.51%	x		x				x		
1114	yes	ov2f	0.30	I	115.17	5.16		x		x	40.27%	x		123.83	41.61%	x		40.27%	x		x						
826	no	ov2f	0.30	I	115.17	5.16		x		x	40.27%	x		123.85	41.61%	x		40.27%	x		x						
1021	yes	ov1	0.15	G	115.39	5.19	x	x	x	x	40.16%	x		124.36	41.36%	x		40.16%	x		x			x			
733	no	ov1	0.15	G	115.59	5.09	x	x	x	x	40.06%	x		124.52	41.29%	x		40.06%	x		x			x			
1031	yes	ov1	0.30	H	115.67	5.14	x		x	x	40.02%	x		124.09	41.49%	x		40.02%	x		x						
743	no	ov1	0.30	H	115.78	5.03	x		x	x	39.96%	x		124.18	41.45%	x		39.96%	x		x						
1039	yes	ov1	0.30	I	115.85	5.05	x		x	x	39.92%	x		123.92	41.57%	x		39.92%	x		x						
751	no	ov1	0.30	I	115.89	5.06	x		x	x	39.90%	x		123.99	41.54%	x		39.90%	x		x						
1141	yes	setback	0.15	G	115.96	5.11	x		x	x	39.86%	x		124.47	41.31%	x		39.86%	x			x				x	
734	no	ov2	0.15	G	116.09	5.23	x		x	x	39.80%	x		124.66	41.22%	x		39.80%	x		x				x		
1022	yes	ov2	0.15	G	116.21	5.23	x		x	x	39.73%	x		124.59	41.26%	x		39.73%	x		x				x		
1042	yes	ov2	0.45	I	116.25	5.20			x	x	39.71%	x		123.39	41.82%	x		39.71%	x		x				x		
754	no	ov2	0.45	I	116.30	5.20			x	x	39.69%	x		123.70	41.67%	x		39.69%	x		x				x		
1102	yes	ov2f	0.30	F	116.54	5.24	x	x		x	39.56%	x		125.91	40.63%	x		39.56%	x		x				x		
814	no	ov2f	0.30	F	116.55	5.24	x	x		x	39.56%	x		125.95	40.61%	x		39.56%	x		x				x		
1034	yes	ov2	0.45	H	116.59	5.00			x	x	39.54%	x		123.79	41.63%	x		39.54%	x		x				x		
853	no	setback	0.15	G	116.59	5.12	x		x	x	39.54%	x		124.79	41.16%	x		39.54%	x			x				x	
746	no	ov2	0.45	H	116.73	5.04			x	x	39.47%	x		124.13	41.47%	x		39.47%	x		x				x		
1146	yes	setback	0.30	H	116.82	5.04	x		x	x	39.42%	x		124.28	41.40%	x		39.42%	x		x						
1150	yes	setback	0.30	I	116.88	5.06	x		x	x	39.38%	x		124.08	41.49%	x		39.38%	x		x						
1016	yes	ov2	0.30	F	117.31	5.18	x			x	39.16%	x		125.69	40.74%	x		39.16%	x		x				x		
728	no	ov2	0.30	F	117.33	5.18	x			x	39.15%	x		125.75	40.71%	x		39.15%	x		x				x		
1069	yes	fins	0.15	G	117.40	5.16	x		x	x	39.12%	x		125.04	41.04%	x		39.12%	x			x				x	
1078	yes	fins	0.30	I	117.43	5.11	x		x	x	39.10%	x		124.40	41.35%	x		39.10%	x		x						
862	no	setback	0.30	I	117.50	5.18	x			x	39.06%	x		124.31	41.39%	x		39.06%	x		x						
1074	yes	fins	0.30	H	117.51	5.09	x		x	x	39.06%	x		124.64	41.23%	x		39.06%	x		x						
1103	yes	ov2f	0.45	F	117.53	5.14		x		x	39.05%	x		126.58	40.32%	x		39.05%	x			x				x	
817	no	ov2f	0.15	G	117.53	5.27			x	x	39.05%	x		125.20	40.97%	x		39.05%	x		x				x		
815	no	ov2f	0.45	F	117.54	5.15		x		x	39.04%	x		127.16	40.05%	x		39.04%	x			x				x	
858	no	setback	0.30	H	117.59	5.04	x			x	39.02%	x		124.59	41.25%	x		39.02%	x		x						
1105	yes	ov2f	0.15	G	117.66	5.27			x	x	38.98%	x		125.15	40.99%	x		38.98%	x		x				x		
1107	yes	ov2f	0.45	G	117.87	5.01		x		x	38.87%	x		126.41	40.40%	x		38.87%	x		x				x		
725	no	ov1	0.15	F	118.14	5.17	x	x			38.73%	x		125.38	40.89%	x		38.73%	x		x			x			
741	no	ov1	0.15	H	118.15	5.15		x			38.73%	x		124.88	41.12%	x		38.73%	x		x						
1013	yes	ov1	0.15	F	118.17	5.17	x	x			38.72%	x		125.33	40.91%	x		38.72%	x		x			x			
1029	yes	ov1	0.15	H	118.24	5.15		x			38.68%	x		124.87	41.12%	x		38.68%	x		x						
819	no	ov2f	0.45	G	118.34	5.03		x			38.63%	x		127.69	39.79%	x		38.63%	x		x				x		

Table 8. Annual performance summary for the east orientation in Phoenix, Arizona. Table continues on next page.

Phoenix South Annual Performance Summary-Continued

											Existing Data Set (baseline 192.83 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 192.83 kBtu/sf)									
							Optimum														Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
889	yes	none	0.15	G	118.36	5.08	x		x		38.62%	x		124.92	41.10%	x		38.62%	x			x				x	
781	no	fins	0.15	G	118.55	5.17	x				38.52%	x		125.55	40.81%	x		38.52%	x			x				x	
786	no	fins	0.30	H	118.60	5.10	x				38.49%	x		125.10	41.02%	x		38.49%	x		x						
1137	yes	setback	0.15	F	118.86	5.19	x				38.36%	x		125.54	40.81%	x		38.36%	x			x				x	
849	no	setback	0.15	F	118.89	5.19	x				38.35%	x		125.60	40.78%	x		38.35%	x			x				x	
790	no	fins	0.30	I	119.04	5.39	x				38.27%	x		124.80	41.16%	x		38.27%	x		x						
749	no	ov1	0.15	I	119.09	5.17		x			38.24%	x		125.04	41.05%	x		38.24%	x		x						
1037	yes	ov1	0.15	I	119.09	5.17		x			38.24%	x		125.03	41.05%	x		38.24%	x		x						
1033	yes	ov1	0.45	H	119.51	5.00			x		38.02%	x		124.33	41.38%	x		38.02%	x		x			x			
893	yes	none	0.15	H	119.77	5.16	x				37.89%	x		125.24	40.95%	x		37.89%	x		x						
605	no	none	0.15	H	119.91	5.17	x				37.82%	x		125.38	40.88%	x		37.82%	x		x						
1065	yes	fins	0.15	F	119.96	5.22	x				37.79%	x		125.98	40.60%	x		37.79%	x			x				x	
745	no	ov1	0.45	H	120.21	5.12			x		37.66%	x		125.16	40.99%	x		37.66%	x		x			x			
777	no	fins	0.15	F	120.24	5.22	x				37.64%	x		126.13	40.53%	x		37.64%	x			x				x	
885	yes	none	0.15	F	120.33	5.17	x				37.60%	x		125.82	40.68%	x		37.60%	x			x				x	
898	yes	none	0.30	I	120.52	5.18	x		x		37.50%	x		124.79	41.16%	x		37.50%	x		x						
609	no	none	0.15	I	120.72	5.19	x				37.40%	x		125.49	40.83%	x		37.40%	x		x						
897	yes	none	0.15	I	120.74	5.18	x				37.38%	x		125.41	40.87%	x		37.38%	x		x						
601	no	none	0.15	G	120.91	5.10	x				37.30%	x		125.74	40.72%	x		37.30%	x			x				x	
894	yes	none	0.30	H	121.05	5.01			x		37.22%	x		125.09	41.02%	x		37.22%	x		x						
597	no	none	0.15	F	121.11	5.18	x				37.19%	x		126.12	40.54%	x		37.19%	x			x				x	
816	no	ov2f	0.60	F	121.32	5.28		x			37.09%	x		129.96	38.73%	x		37.09%	x			x				x	
1104	yes	ov2f	0.60	F	121.35	5.28		x			37.07%	x		129.03	39.16%	x		37.07%	x			x				x	
1108	yes	ov2f	0.60	G	122.35	4.98		x			36.55%	x		129.06	39.15%	x		36.55%	x			x				x	
756	no	ov2	0.60	I	122.41	5.66			x		36.52%	x		125.83	40.67%	x		36.52%	x			x				x	
1147	yes	setback	0.45	H	122.44	4.88			x		36.50%	x		125.07	41.03%	x		36.50%	x			x				x	
1044	yes	ov2	0.60	I	122.53	5.64			x		36.46%	x		124.40	41.35%	x		36.46%	x			x				x	
1036	yes	ov2	0.60	H	122.56	5.15			x		36.44%	x		125.11	41.01%	x		36.44%	x			x				x	
748	no	ov2	0.60	H	122.66	5.17			x		36.39%	x		125.99	40.60%	x		36.39%	x			x				x	
1075	yes	fins	0.45	H	123.23	4.97			x		36.09%	x		125.62	40.77%	x		36.09%	x			x				x	
1035	yes	ov1	0.60	H	126.38	5.40			x		34.46%	x		125.83	40.67%	x		34.46%	x			x				x	
895	yes	none	0.45	H	129.25	5.18			x		32.97%	x		126.61	40.30%	x		32.97%	x			x				x	
1076	yes	fins	0.60	H	130.08	5.53			x		32.54%	x		127.66	39.81%	x		32.54%	x			x				x	
1148	yes	setback	0.60	H	130.56	5.63		x	x		32.29%	x		127.00	40.12%	x		32.29%	x			x				x	
896	yes	none	0.60	H	138.65	5.92			x		28.10%			129.16	39.10%	x		28.10%				x				x	

Table 8 continued.

Phoenix West Annual Performance Summary

							Optimum				Existing Data Set (baseline 192.98 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 192.98 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
1115	yes	ov2f	0.45	I	117.81	5.21	x	x	x	x	38.95%	x		122.96	42.03%	x		38.95%	x		x				x		
1111	yes	ov2f	0.45	H	117.83	5.19	x	x	x	x	38.94%	x		123.30	41.86%	x		38.94%	x		x				x		
1042	yes	ov2	0.45	I	118.65	5.18	x		x	x	38.52%	x		123.39	41.82%	x		38.52%	x		x				x		
1116	yes	ov2f	0.60	I	118.73	5.15		x	x	x	38.48%	x		123.28	41.87%	x		38.48%	x			x				x	
1034	yes	ov2	0.45	H	119.25	5.16	x			x	38.21%	x		123.79	41.63%	x		38.21%	x		x				x		
1112	yes	ov2f	0.60	H	119.53	5.13		x		x	38.06%	x		123.73	41.66%	x		38.06%	x			x				x	
1032	yes	ov2	0.30	H	119.77	5.29	x	x	x	x	37.94%	x		123.70	41.68%	x		37.94%	x		x						
1110	yes	ov2f	0.30	H	119.84	5.29		x	x	x	37.90%	x		124.00	41.53%	x		37.90%	x		x						
1040	yes	ov2	0.30	I	119.90	5.30	x	x	x	x	37.87%	x		123.59	41.73%	x		37.87%	x		x						
744	no	ov2	0.30	H	119.92	5.29	x	x	x	x	37.86%	x		123.75	41.65%	x		37.86%	x		x						
822	no	ov2f	0.30	H	119.94	5.29		x	x	x	37.85%	x		124.04	41.52%	x		37.85%	x		x						
1114	yes	ov2f	0.30	I	119.97	5.29		x	x	x	37.83%	x		123.83	41.61%	x		37.83%	x		x						
752	no	ov2	0.30	I	119.98	5.30	x		x	x	37.83%	x		123.61	41.72%	x		37.83%	x		x						
826	no	ov2f	0.30	I	120.03	5.29		x	x	x	37.80%	x		123.85	41.61%	x		37.80%	x		x						
1041	yes	ov1	0.45	I	120.13	5.14	x		x	x	37.75%	x		124.10	41.49%	x		37.75%	x		x			x			
1106	yes	ov2f	0.30	G	120.43	5.25	x	x		x	37.60%	x		124.91	41.11%	x		37.60%	x		x				x		
1021	yes	ov1	0.15	G	120.56	5.33	x	x	x	x	37.53%	x		124.36	41.36%	x		37.53%	x		x			x			
1141	yes	setback	0.15	G	120.66	5.30	x	x	x	x	37.48%	x		124.47	41.31%	x		37.48%	x			x				x	
1031	yes	ov1	0.30	H	120.92	5.30	x		x	x	37.34%	x		124.09	41.49%	x		37.34%	x		x						
1039	yes	ov1	0.30	I	120.93	5.25	x		x	x	37.34%	x		123.92	41.57%	x		37.34%	x		x						
1022	yes	ov2	0.15	G	120.94	5.34	x	x	x	x	37.33%	x		124.59	41.26%	x		37.33%	x		x				x		
1033	yes	ov1	0.45	H	121.18	5.17	x			x	37.21%	x		124.33	41.38%	x		37.21%	x		x			x			
743	no	ov1	0.30	H	121.29	5.24	x			x	37.15%	x		124.18	41.45%	x		37.15%	x		x						
1150	yes	setback	0.30	I	121.31	5.28	x		x	x	37.14%	x		124.08	41.49%	x		37.14%	x		x						
733	no	ov1	0.15	G	121.34	5.35	x			x	37.12%	x		124.52	41.29%	x		37.12%	x		x			x			
734	no	ov2	0.15	G	121.38	5.35	x			x	37.10%	x		124.66	41.22%	x		37.10%	x		x				x		
1146	yes	setback	0.30	H	121.42	5.27	x		x	x	37.08%	x		124.28	41.40%	x		37.08%	x		x						
1151	yes	setback	0.45	I	121.74	5.13	x		x	x	36.92%	x		125.63	40.77%	x		36.92%	x			x				x	
1024	yes	ov2	0.30	G	121.82	5.24	x			x	36.88%	x		125.18	40.98%	x		36.88%	x		x				x		
1105	yes	ov2f	0.15	G	121.91	5.35			x	x	36.83%	x		125.15	40.99%	x		36.83%	x		x				x		
1078	yes	fins	0.30	I	121.96	5.30	x		x	x	36.80%	x		124.40	41.35%	x		36.80%	x		x						
1069	yes	fins	0.15	G	122.06	5.33	x		x	x	36.75%	x		125.04	41.04%	x		36.75%	x			x				x	
889	yes	none	0.15	G	122.07	5.32	x		x	x	36.74%	x		124.92	41.10%	x		36.74%	x			x				x	
1074	yes	fins	0.30	H	122.11	5.31	x		x	x	36.73%	x		124.64	41.23%	x		36.73%	x		x						
1079	yes	fins	0.45	I	122.37	5.21	x		x	x	36.59%	x		128.20	39.55%	x		36.59%	x			x				x	
1029	yes	ov1	0.15	H	122.51	5.37		x		x	36.51%	x		124.87	41.12%	x		36.51%	x		x						
741	no	ov1	0.15	H	122.56	5.37		x		x	36.49%	x		124.88	41.12%	x		36.49%	x		x						
1145	yes	setback	0.15	H	122.75	5.35		x		x	36.39%	x		125.07	41.03%	x		36.39%	x		x						
857	no	setback	0.15	H	122.86	5.35		x			36.34%	x		125.08	41.02%	x		36.34%	x		x						
1102	yes	ov2f	0.30	F	122.95	5.33	x	x			36.29%	x		125.91	40.63%	x		36.29%	x		x				x		
814	no	ov2f	0.30	F	123.08	5.33	x	x			36.22%	x		125.95	40.61%	x		36.22%	x		x				x		
1013	yes	ov1	0.15	F	123.09	5.38	x	x			36.22%	x		125.33	40.91%	x		36.22%	x		x			x			
1107	yes	ov2f	0.45	G	123.11	5.17		x			36.21%	x		126.41	40.40%	x		36.21%	x			x				x	
898	yes	none	0.30	I	123.14	5.27	x		x		36.19%	x		124.79	41.16%	x		36.19%	x		x						
1037	yes	ov1	0.15	I	123.15	5.38		x			36.19%	x		125.03	41.05%	x		36.19%	x		x						
749	no	ov1	0.15	I	123.18	5.38		x			36.17%	x		125.04	41.05%	x		36.17%	x		x						
1044	yes	ov2	0.60	I	123.23	5.30			x		36.14%	x		124.40	41.35%	x		36.14%	x			x				x	
1103	yes	ov2f	0.45	F	123.24	5.25		x			36.14%	x		126.58	40.32%	x		36.14%	x		x				x		
725	no	ov1	0.15	F	123.25	5.39	x	x			36.13%	x		125.38	40.89%	x		36.13%	x		x			x			
1137	yes	setback	0.15	F	123.33	5.40	x	x			36.09%	x		125.54	40.81%	x		36.09%	x			x				x	
893	yes	none	0.15	H	123.33	5.36	x				36.09%	x		125.24	40.95%	x		36.09%	x		x						
1016	yes	ov2	0.30	F	123.39	5.32	x	x			36.06%	x		125.69	40.74%	x		36.06%	x		x				x		
894	yes	none	0.30	H	123.41	5.32	x		x		36.05%	x		125.09	41.02%	x		36.05%	x		x						

Table 9. Annual performance summary for the west orientation in Phoenix, Arizona. Table continues on next page.

Phoenix West Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 192.98 kBtu/sf)			CBECS (average 212.09 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 192.98 kBtu/sf)									
																					Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
1149	yes	setback	0.15	I	123.44	5.36		x			36.03%	x		125.23	40.95%	x		36.03%	x		x						
861	no	setback	0.15	I	123.49	5.36		x			36.01%	x		125.24	40.95%	x		36.01%	x		x						
1014	yes	ov2	0.15	F	123.59	5.38	x				35.95%	x		125.58	40.79%	x		35.95%	x		x				x		
849	no	setback	0.15	F	123.60	5.40	x				35.95%	x		125.60	40.78%	x		35.95%	x			x				x	
728	no	ov2	0.30	F	123.61	5.32	x	x			35.94%	x		125.75	40.71%	x		35.94%	x		x				x		
726	no	ov2	0.15	F	123.64	5.38	x				35.93%	x		125.59	40.78%	x		35.93%	x		x				x		
781	no	fins	0.15	G	123.66	5.36	x		x		35.92%	x		125.55	40.81%	x		35.92%	x			x				x	
605	no	none	0.15	H	123.82	5.38	x				35.84%	x		125.38	40.88%	x		35.84%	x		x						
897	yes	none	0.15	I	123.91	5.38	x				35.79%	x		125.41	40.87%	x		35.79%	x		x						
885	yes	none	0.15	F	124.32	5.40	x				35.58%	x		125.82	40.68%	x		35.58%	x			x				x	
1065	yes	fins	0.15	F	124.40	5.39	x				35.54%	x		125.98	40.60%	x		35.54%	x			x				x	
1043	yes	ov1	0.60	I	124.50	5.51			x		35.49%	x		125.47	40.84%	x		35.49%	x			x				x	
601	no	none	0.15	G	124.59	5.35	x				35.44%	x		125.74	40.72%	x		35.44%	x			x				x	
777	no	fins	0.15	F	124.88	5.42	x				35.29%	x		126.13	40.53%	x		35.29%	x			x				x	
1035	yes	ov1	0.60	H	125.00	5.21			x		35.23%	x		125.83	40.67%	x		35.23%	x			x				x	
597	no	none	0.15	F	125.26	5.39	x				35.09%	x		126.12	40.54%	x		35.09%	x			x				x	
1080	yes	fins	0.60	I	126.20	5.27			x		34.60%	x		127.48	39.89%	x		34.60%	x			x				x	
899	yes	none	0.45	I	127.25	5.73			x		34.06%	x		129.86	38.77%	x		34.06%	x			x				x	
895	yes	none	0.45	H	127.30	5.25			x		34.03%	x		126.61	40.30%	x		34.03%	x			x				x	
1152	yes	setback	0.60	I	128.32	5.69			x		33.51%	x		127.08	40.08%	x		33.51%	x			x				x	
1148	yes	setback	0.60	H	128.59	5.23			x		33.37%	x		127.00	40.12%	x		33.37%	x			x				x	
1104	yes	ov2f	0.60	F	129.39	5.63		x			32.95%	x		129.03	39.16%	x		32.95%	x			x				x	
1108	yes	ov2f	0.60	G	131.00	5.59		x			32.12%	x		129.06	39.15%	x		32.12%	x			x				x	
896	yes	none	0.60	H	134.11	5.55			x		30.51%	x		129.16	39.10%	x		30.51%	x			x				x	

Table 9 continued.

Minneapolis, Minnesota: Performance Summary for North Orientation
Table 10 shows the annual performance summary for the north orientation in Minneapolis. Only the top 2 performers in the set were optimum in WWR, shading, and glass type, all using 0.60 WWR with quad glazing (window I). Though exterior shading devices are part of the very top performers, when looking at the entire top performing set, WWR and glass type make more of an impact on energy performance which would be expected on the north orientation due to the lack of direct solar gain.

As compared to the existing data set, the top performing design options performed 11.76–22.81% better than the baseline (140.62 kBtu/sf). No design options meet the 30% or 50% performance targets.

As compared to the CBECS database, the top performing design options performed 34.47–47.57% better than the regional CBECS average (228.67 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 11.76–22.81% better than the budget building (140.62 kBtu/sf). No design options meet the 30% or 50% performance targets. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with double clear (window G) glazing with 0.60 WWR, all 4 orientations also had to be assigned double clear (window G) glazing to achieve compliance. Design options with double tint (window E) and double tint (window F) fail compliance following the performance path.

Minneapolis, Minnesota: Performance Summary for East Orientation
Table 11 shows the annual performance summary for the east orientation in Minneapolis. Only the top 3 performers in the set were optimum in WWR, shading, and glass type, all using 0.30 WWR with quad glazing (window I). Though exterior shading devices are part of the very top performers, when looking at the entire top performing set, WWR and glass type make more of an impact on energy performance.

As compared to the existing data set, the top performing design options performed 10.15–32.30% better than the baseline (161.98 kBtu/sf). Less than half the design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the CBECS database, the top performing design options performed 35.23–47.57% better than the regional CBECS average (228.67 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 10.15–32.30% better than the budget building (161.98 kBtu/sf). Less than half the design options meet the 30% performance target. No design options meet the 50% performance target. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with double clear (window G) glazing with 0.60 WWR, all 4 orientations also had to be assigned double clear (window G) glazing to achieve compliance. Design options with double tint (window E) and double tint (window F) fail compliance following the performance path.

Minneapolis, Minnesota: Performance Summary for South Orientation
Table 12 shows the annual performance summary for the south orientation in Minneapolis. The very top performers in the set were optimum in WWR, shading, and glass type, all using 0.45 WWR with triple (window H) or quad (window I) glazing. Though exterior shading devices are part of the very top performers, when looking at the entire top performing set, WWR and glass type make more of an impact on energy performance.

As compared to the existing data set, the top performing design options performed 23.92–33.90% better than the baseline (154.29 kBtu/sf). More than half the design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the CBECS database, the top performing design options performed 35.23–47.57% better than the regional CBECS average (228.67 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 23.92–33.90% better than the budget building (154.29 kBtu/sf). More than half the design options meet the 30% performance target. No design options meet the 50% performance target. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with double clear (window G) glazing with 0.60 WWR, all 4 orientations also had to be assigned double clear (window G) glazing to achieve compliance. Design options with double tint (window E) and double tint (window F) fail compliance following the performance path.

Minneapolis, Minnesota: Performance Summary for West Orientation
Table 13 shows the annual performance summary for the west orientation in Minneapolis. Only the top 2 performers in the set were optimum in WWR, shading, and glass type, using 0.45 or 0.60 WWR with quad glazing (window I). The combination of high-performing glass with exterior shading devices make more of an impact on energy performance which would be expected on the west orientation due to the exposure to the extreme sun angle.

As compared to the existing data set, the top performing design options performed 22.86–33.32% better than the baseline (161.64 kBtu/sf). Less than half the design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the CBECS database, the top performing design options performed 39.84–47.57% better than the regional CBECS average (228.67 kBtu/sf). All design options meet the 30% performance target. No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 22.86–33.32% better than the budget building (161.64 kBtu/sf). Less than half the design options meet the 30% performance target. No design options meet the 50% performance target. When determining performance compliance for a design options with triple (window H) or quad (window I) glazing with 0.60 WWR, compliance was achieved when double clear (window B) was left in all 3 other orientations. When determining performance compliance for a design options with double clear (window G) glazing with 0.60 WWR, all 4 orientations also had to be assigned double clear (window G) glazing to achieve compliance. Design options with double tint (window E) and double tint (window F) fail compliance following the performance path.

Minneapolis North Annual Performance Summary

							Optimum				Existing Data Set (baseline 140.62 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 140.62 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
612	no	none	0.60	I	108.54	4.71	x	x	x	x	22.81%			136.74	40.20%	x		22.81%				x					
900	yes	none	0.60	I	108.70	4.67	x	x	x	x	22.70%			129.89	43.20%	x		22.70%				x					
611	no	none	0.45	I	109.05	4.45		x	x	x	22.45%			127.58	44.21%	x		22.45%			x						
864	no	setback	0.60	I	109.16	4.54	x		x	x	22.37%			133.12	41.78%	x		22.37%				x				x	
899	yes	none	0.45	I	109.17	4.44		x	x	x	22.36%			123.33	46.07%	x		22.36%			x						
1152	yes	setback	0.60	I	109.31	4.52	x		x	x	22.26%			125.01	45.33%	x		22.26%				x				x	
792	no	fins	0.60	I	109.81	4.41	x		x	x	21.91%			135.89	40.57%	x		21.91%				x				x	
755	no	ov1	0.60	I	109.88	4.53	x		x	x	21.86%			128.52	43.80%	x		21.86%				x				x	
1080	yes	fins	0.60	I	109.92	4.40	x		x	x	21.83%			127.31	44.33%	x		21.83%				x				x	
1043	yes	ov1	0.60	I	110.01	4.51	x		x	x	21.77%			122.15	46.58%	x		21.77%				x				x	
607	no	none	0.45	H	110.16	3.90	x	x		x	21.66%			121.93	46.68%	x		21.66%			x						
863	no	setback	0.45	I	110.23	4.32			x	x	21.61%			124.72	45.46%	x		21.61%			x						
895	yes	none	0.45	H	110.25	3.85	x	x		x	21.60%			120.97	47.10%	x		21.60%			x						
608	no	none	0.60	H	110.29	4.03	x	x		x	21.57%			126.94	44.49%	x		21.57%				x				x	
1151	yes	setback	0.45	I	110.30	4.31			x	x	21.56%			121.82	46.73%	x		21.56%			x						
756	no	ov2	0.60	I	110.33	4.49	x		x	x	21.54%			125.27	45.22%	x		21.54%				x				x	
1044	yes	ov2	0.60	I	110.40	4.48	x		x	x	21.49%			120.58	47.27%	x		21.49%				x				x	
896	yes	none	0.60	H	110.46	3.96	x	x		x	21.45%			122.78	46.31%	x		21.45%				x				x	
860	no	setback	0.60	H	110.75	3.84	x			x	21.25%			125.47	45.13%	x		21.25%				x				x	
1148	yes	setback	0.60	H	110.84	3.79	x			x	21.18%			122.12	46.60%	x		21.18%				x				x	
791	no	fins	0.45	I	110.85	4.25			x	x	21.17%			127.15	44.39%	x		21.17%			x						
753	no	ov1	0.45	I	110.88	4.32			x	x	21.15%			122.24	46.54%	x		21.15%			x						
1079	yes	fins	0.45	I	110.92	4.25			x	x	21.12%			122.80	46.30%	x		21.12%			x						
1041	yes	ov1	0.45	I	110.93	4.30			x	x	21.11%			120.46	47.32%	x		21.11%			x						
788	no	fins	0.60	H	111.28	3.69	x			x	20.86%			127.42	44.28%	x		20.86%				x				x	
1076	yes	fins	0.60	H	111.33	3.67	x			x	20.83%			123.46	46.01%	x		20.83%				x				x	
747	no	ov1	0.60	H	111.37	3.82	x			x	20.80%			122.80	46.30%	x		20.80%				x				x	
1035	yes	ov1	0.60	H	111.42	3.79	x			x	20.76%			121.66	46.80%	x		20.76%				x				x	
754	no	ov2	0.45	I	111.45	4.28			x	x	20.74%			121.03	47.07%	x		20.74%			x						
1042	yes	ov2	0.45	I	111.47	4.26			x	x	20.73%			120.35	47.37%	x		20.73%			x						
745	no	ov1	0.45	H	111.70	3.73	x			x	20.57%			121.14	47.02%	x		20.57%			x						
748	no	ov2	0.60	H	111.73	3.79	x			x	20.55%			121.81	46.73%	x		20.55%				x				x	
787	no	fins	0.45	H	111.75	3.66	x			x	20.53%			122.77	46.31%	x		20.53%			x						
1036	yes	ov2	0.60	H	111.76	3.75	x			x	20.53%			121.80	46.74%	x		20.53%				x				x	
1033	yes	ov1	0.45	H	111.76	3.70	x			x	20.52%			121.40	46.91%	x		20.52%			x						
1075	yes	fins	0.45	H	111.80	3.64	x			x	20.50%			122.28	46.53%	x		20.50%			x						
610	no	none	0.30	I	111.84	4.08		x	x	x	20.46%			120.48	47.31%	x		20.46%			x						
898	yes	none	0.30	I	111.90	4.07		x	x	x	20.43%			119.89	47.57%	x		20.43%			x						
606	no	none	0.30	H	112.08	3.76		x	x	x	20.30%			120.55	47.28%	x		20.30%			x						
894	yes	none	0.30	H	112.15	3.74		x	x	x	20.25%			120.79	47.17%	x		20.25%			x						
828	no	ov2f	0.60	I	112.86	4.19	x		x	x	19.74%			126.34	44.75%	x		19.74%				x				x	
1116	yes	ov2f	0.60	I	112.88	4.19	x		x	x	19.73%			123.74	45.89%	x		19.73%				x				x	
862	no	setback	0.30	I	113.17	3.95			x	x	19.52%			120.62	47.25%	x		19.52%			x						
1150	yes	setback	0.30	I	113.20	3.94			x	x	19.50%			120.76	47.19%	x		19.50%			x						
858	no	setback	0.30	H	113.43	3.62			x	x	19.33%			121.55	46.84%	x		19.33%			x						
1146	yes	setback	0.30	H	113.45	3.62			x		19.32%			121.74	46.76%	x		19.32%			x						
790	no	fins	0.30	I	113.92	3.91			x		18.99%			121.30	46.95%	x		18.99%			x						
1078	yes	fins	0.30	I	113.97	3.89			x		18.95%			121.42	46.90%	x		18.95%			x						
824	no	ov2f	0.60	H	114.06	3.50	x				18.89%			124.23	45.67%	x		18.89%				x				x	
1112	yes	ov2f	0.60	H	114.06	3.48	x				18.89%			124.24	45.67%	x		18.89%				x				x	
1115	yes	ov2f	0.45	I	114.11	4.07			x		18.86%			122.48	46.44%	x		18.86%			x						
827	no	ov2f	0.45	I	114.12	4.07			x		18.85%			122.87	46.27%	x		18.85%			x						
786	no	fins	0.30	H	114.24	3.60			x		18.76%			122.28	46.53%	x		18.76%			x						

Table 10. Annual performance summary for the north orientation in Minneapolis, Minnesota. Table continues on next 2 pages.

Minneapolis North Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 140.62 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 140.62 kBtu/sf)									
																					Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
1074	yes	fins	0.30	H	114.27	3.59			x		18.74%			122.43	46.46%	x		18.74%			x						
751	no	ov1	0.30	I	114.32	3.95			x		18.71%			120.73	47.20%	x		18.71%			x						
1039	yes	ov1	0.30	I	114.34	3.95			x		18.69%			120.88	47.14%	x		18.69%			x						
743	no	ov1	0.30	H	114.53	3.64			x		18.56%			121.60	46.82%	x		18.56%			x						
1031	yes	ov1	0.30	H	114.56	3.64			x		18.54%			121.81	46.73%	x		18.54%			x						
752	no	ov2	0.30	I	114.84	3.90			x		18.33%			121.25	46.98%	x		18.33%			x						
1040	yes	ov2	0.30	I	114.85	3.90			x		18.33%			121.30	46.95%	x		18.33%			x						
744	no	ov2	0.30	H	115.11	3.61			x		18.14%			122.16	46.58%	x		18.14%			x						
1032	yes	ov2	0.30	H	115.12	3.61			x		18.13%			122.27	46.53%	x		18.13%			x						
601	no	none	0.15	G	115.49	3.71	x	x	x		17.87%			122.69	46.35%	x		17.87%			x						
889	yes	none	0.15	G	115.57	3.69	x	x	x		17.82%			123.29	46.08%	x		17.82%			x						
602	no	none	0.30	G	116.45	3.88		x			17.19%			128.39	43.85%	x		17.19%			x						
605	no	none	0.15	H	116.54	3.66		x			17.12%			121.03	47.07%	x		17.12%			x						
893	yes	none	0.15	H	116.57	3.65		x			17.10%			121.32	46.95%	x		17.10%			x						
890	yes	none	0.30	G	116.60	3.85		x			17.08%			127.68	44.16%	x		17.08%			x						
826	no	ov2f	0.30	I	116.81	3.75			x		16.93%			123.08	46.17%	x		16.93%			x						
1114	yes	ov2f	0.30	I	116.81	3.75			x		16.93%			123.11	46.16%	x		16.93%			x						
609	no	none	0.15	I	116.84	3.79		x			16.91%			120.99	47.09%	x		16.91%			x						
897	yes	none	0.15	I	116.86	3.78		x			16.89%			121.21	47.00%	x		16.89%			x						
853	no	setback	0.15	G	117.21	3.59	x		x		16.65%			124.18	45.69%	x		16.65%			x						
1141	yes	setback	0.15	G	117.25	3.57	x		x		16.62%			124.60	45.51%	x		16.62%			x						
733	no	ov1	0.15	G	117.28	3.61	x		x		16.60%			123.89	45.82%	x		16.60%			x						
1021	yes	ov1	0.15	G	117.32	3.60	x		x		16.57%			124.38	45.61%	x		16.57%			x						
822	no	ov2f	0.30	H	117.33	3.49			x		16.56%			124.16	45.70%	x		16.56%			x						
1110	yes	ov2f	0.30	H	117.34	3.49			x		16.55%			124.22	45.68%	x		16.55%			x						
857	no	setback	0.15	H	117.57	3.56			x		16.39%			122.21	46.55%	x		16.39%			x						
1145	yes	setback	0.15	H	117.59	3.56			x		16.38%			122.36	46.49%	x		16.38%			x						
741	no	ov1	0.15	H	117.64	3.57			x		16.34%			122.10	46.60%	x		16.34%			x						
1029	yes	ov1	0.15	H	117.65	3.57			x		16.34%			122.24	46.54%	x		16.34%			x						
781	no	fins	0.15	G	117.75	3.61	x		x		16.26%			124.37	45.61%	x		16.26%			x						
1069	yes	fins	0.15	G	117.79	3.58	x		x		16.24%			124.79	45.43%	x		16.24%			x						
785	no	fins	0.15	H	117.93	3.58			x		16.14%			122.35	46.50%	x		16.14%			x						
1073	yes	fins	0.15	H	117.93	3.57			x		16.14%			122.52	46.42%	x		16.14%			x						
742	no	ov2	0.15	H	118.52	3.56			x		15.72%			122.76	46.32%	x		15.72%			x						
1030	yes	ov2	0.15	H	118.52	3.56			x		15.71%			122.82	46.29%	x		15.71%			x						
750	no	ov2	0.15	I	118.62	3.66			x		15.65%			122.58	46.39%	x		15.65%			x						
1038	yes	ov2	0.15	I	118.62	3.66			x		15.64%			122.61	46.38%	x		15.64%			x						
734	no	ov2	0.15	G	118.65	3.60	x		x		15.62%			124.72	45.46%	x		15.62%			x						
1022	yes	ov2	0.15	G	118.67	3.59	x		x		15.61%			125.09	45.30%	x		15.61%			x						
597	no	none	0.15	F	118.71	3.69	x	x			15.58%			124.01	45.77%	x		15.58%			x						
885	yes	none	0.15	F	118.74	3.68	x	x			15.56%			124.30	45.64%	x		15.56%			x						
598	no	none	0.30	F	118.77	3.84		x			15.54%			128.47	43.82%	x		15.54%			x						
886	yes	none	0.30	F	118.84	3.83		x			15.49%			128.52	43.79%	x		15.49%			x						
825	no	ov2f	0.15	I	119.54	3.58			x		14.99%			123.58	45.96%	x		14.99%			x						
1113	yes	ov2f	0.15	I	119.54	3.58			x		14.99%			123.59	45.95%	x		14.99%			x						
821	no	ov2f	0.15	H	119.63	3.51			x		14.93%			123.87	45.83%	x		14.93%			x						
1109	yes	ov2f	0.15	H	119.63	3.51			x		14.92%			123.90	45.82%	x		14.92%			x						
603	no	none	0.45	G	119.76	4.01		x			14.83%			138.93	39.24%	x		14.83%			x						
849	no	setback	0.15	F	119.95	3.58	x				14.70%			125.37	45.17%	x		14.70%			x						
1137	yes	setback	0.15	F	119.97	3.58	x				14.69%			125.53	45.11%	x		14.69%			x						
725	no	ov1	0.15	F	120.02	3.61	x				14.65%			125.19	45.25%	x		14.65%			x						
1013	yes	ov1	0.15	F	120.04	3.61	x				14.64%			125.35	45.18%	x		14.64%			x						
891	yes	none	0.45	G	120.05	4.00		x			14.63%			132.80	41.93%	x		14.63%			x						

Table 10 continued.

Minneapolis North Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 140.62 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 140.62 kBtu/sf)									
																					Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
777	no	fins	0.15	F	120.32	3.59	x				14.44%			125.51	45.11%	x		14.44%			x						
1065	yes	fins	0.15	F	120.33	3.58	x				14.43%			125.70	45.03%	x		14.43%			x						
1105	yes	ov2f	0.15	G	120.44	3.50	x				14.35%			126.48	44.69%	x		14.35%			x						
817	no	ov2f	0.15	G	120.44	3.51	x				14.35%			126.27	44.78%	x		14.35%			x						
726	no	ov2	0.15	F	121.03	3.59	x				13.93%			125.93	44.93%	x		13.93%			x						
1014	yes	ov2	0.15	F	121.04	3.59	x				13.92%			126.01	44.89%	x		13.92%			x						
887	yes	none	0.45	F	121.21	3.96		x			13.80%			133.93	41.43%	x		13.80%			x						
813	no	ov2f	0.15	F	122.25	3.50	x				13.06%			127.20	44.37%	x		13.06%			x						
1101	yes	ov2f	0.15	F	122.26	3.51	x				13.06%			127.24	44.36%	x		13.06%			x						
604	no	none	0.60	G	124.09	4.14		x			11.76%			149.84	34.47%	x		11.76%				x				x	

Table 10 continued.

Minneapolis East Annual Performance Summary

							Optimum				Existing Data Set (baseline 161.98 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 161.98 kBtu/sf)									
																					Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
898	yes	none	0.30	I	109.66	3.96	x	x	x	x	32.30%	x		119.89	47.57%	x		32.30%	x		x						
610	no	none	0.30	I	109.94	3.97	x	x	x	x	32.13%	x		120.48	47.31%	x		32.13%	x		x						
894	yes	none	0.30	H	110.04	3.96	x	x	x	x	32.07%	x		120.79	47.17%	x		32.07%	x		x						
1150	yes	setback	0.30	I	110.30	3.81	x		x	x	31.90%	x		120.76	47.19%	x		31.90%	x		x						
862	no	setback	0.30	I	110.38	3.83	x		x	x	31.85%	x		120.62	47.25%	x		31.85%	x		x						
606	no	none	0.30	H	110.42	4.02	x	x	x	x	31.83%	x		120.55	47.28%	x		31.83%	x		x						
1146	yes	setback	0.30	H	110.65	3.82	x		x	x	31.69%	x		121.74	46.76%	x		31.69%	x		x						
751	no	ov1	0.30	I	110.79	3.80	x		x	x	31.60%	x		120.73	47.20%	x		31.60%	x		x						
858	no	setback	0.30	H	110.84	3.83	x		x	x	31.57%	x		121.55	46.84%	x		31.57%	x		x						
1039	yes	ov1	0.30	I	110.84	3.79	x		x	x	31.57%	x		120.88	47.14%	x		31.57%	x		x						
752	no	ov2	0.30	I	111.05	3.73	x		x	x	31.44%	x		121.25	46.98%	x		31.44%	x		x						
1040	yes	ov2	0.30	I	111.11	3.73	x		x	x	31.41%	x		121.30	46.95%	x		31.41%	x		x						
743	no	ov1	0.30	H	111.11	3.81	x		x	x	31.41%	x		121.60	46.82%	x		31.41%	x		x						
1031	yes	ov1	0.30	H	111.15	3.81	x		x	x	31.38%	x		121.81	46.73%	x		31.38%	x		x						
827	no	ov2f	0.45	I	111.21	3.78		x	x	x	31.34%	x		122.87	46.27%	x		31.34%	x		x						
1115	yes	ov2f	0.45	I	111.23	3.78	x	x	x	x	31.33%	x		122.48	46.44%	x		31.33%	x		x						
1078	yes	fins	0.30	I	111.24	3.79	x		x	x	31.33%	x		121.42	46.90%	x		31.33%	x		x						
744	no	ov2	0.30	H	111.35	3.75	x		x	x	31.25%	x		122.16	46.58%	x		31.25%	x		x						
1032	yes	ov2	0.30	H	111.43	3.75	x		x	x	31.21%	x		122.27	46.53%	x		31.21%	x		x						
790	no	fins	0.30	I	111.48	3.86	x		x	x	31.18%	x		121.30	46.95%	x		31.18%	x		x						
1075	yes	fins	0.45	H	111.49	4.14	x	x	x	x	31.17%	x		122.28	46.53%	x		31.17%	x		x						
1074	yes	fins	0.30	H	111.65	3.78	x		x	x	31.07%	x		122.43	46.46%	x		31.07%	x		x						
786	no	fins	0.30	H	112.00	3.91			x	x	30.85%	x		122.28	46.53%	x		30.85%	x		x						
1148	yes	setback	0.60	H	112.01	4.46		x	x	x	30.85%	x		122.12	46.60%	x		30.85%	x			x					
823	no	ov2f	0.45	H	112.09	3.77	x			x	30.80%	x		123.95	45.79%	x		30.80%	x		x						
1111	yes	ov2f	0.45	H	112.11	3.76	x			x	30.79%	x		123.99	45.78%	x		30.79%	x		x						
824	no	ov2f	0.60	H	112.30	4.09	x		x	x	30.67%	x		124.23	45.67%	x		30.67%	x			x				x	
1112	yes	ov2f	0.60	H	112.30	4.07	x		x	x	30.67%	x		124.24	45.67%	x		30.67%	x			x				x	
889	yes	none	0.15	G	112.47	3.82	x	x	x	x	30.56%	x		123.29	46.08%	x		30.56%	x		x						
601	no	none	0.15	G	112.55	3.87	x	x	x	x	30.51%	x		122.69	46.35%	x		30.51%	x		x						
605	no	none	0.15	H	112.74	3.81		x	x	x	30.40%	x		121.03	47.07%	x		30.40%	x		x						
893	yes	none	0.15	H	112.92	3.79		x	x	x	30.29%	x		121.32	46.95%	x		30.29%	x		x						
609	no	none	0.15	I	113.23	3.81		x		x	30.09%	x		120.99	47.09%	x		30.09%	x		x						
787	no	fins	0.45	H	113.32	4.59			x	x	30.04%	x		122.77	46.31%	x		30.04%	x		x						
733	no	ov1	0.15	G	113.32	3.73	x		x	x	30.04%	x		123.89	45.82%	x		30.04%	x		x						
826	no	ov2f	0.30	I	113.33	3.60			x	x	30.03%	x		123.08	46.17%	x		30.03%	x		x						
1114	yes	ov2f	0.30	I	113.35	3.60			x	x	30.02%	x		123.11	46.16%	x		30.02%	x		x						
897	yes	none	0.15	I	113.38	3.80		x		x	30.01%	x		121.21	47.00%	x		30.01%	x		x						
853	no	setback	0.15	G	113.51	3.73	x		x	x	29.92%			124.18	45.69%	x		29.92%			x						
1021	yes	ov1	0.15	G	113.59	3.70	x		x	x	29.87%			124.38	45.61%	x		29.87%			x						
1141	yes	setback	0.15	G	113.66	3.71	x		x	x	29.83%			124.60	45.51%	x		29.83%			x						
822	no	ov2f	0.30	H	113.75	3.63			x	x	29.77%			124.16	45.70%	x		29.77%			x						
1110	yes	ov2f	0.30	H	113.80	3.63			x	x	29.74%			124.22	45.68%	x		29.74%			x						
741	no	ov1	0.15	H	113.89	3.67			x	x	29.69%			122.10	46.60%	x		29.69%			x						
857	no	setback	0.15	H	113.92	3.69			x	x	29.67%			122.21	46.55%	x		29.67%			x						
1029	yes	ov1	0.15	H	114.02	3.67			x	x	29.61%			122.24	46.54%	x		29.61%			x						
1145	yes	setback	0.15	H	114.09	3.68			x	x	29.57%			122.36	46.49%	x		29.57%			x						
1069	yes	fins	0.15	G	114.34	3.71	x		x		29.41%			124.79	45.43%	x		29.41%			x						
781	no	fins	0.15	G	114.38	3.75	x		x		29.39%			124.37	45.61%	x		29.39%			x						
785	no	fins	0.15	H	114.42	3.70			x		29.36%			122.35	46.50%	x		29.36%			x						
1073	yes	fins	0.15	H	114.62	3.69			x		29.24%			122.52	46.42%	x		29.24%			x						
734	no	ov2	0.15	G	114.68	3.69	x		x		29.20%			124.72	45.46%	x		29.20%			x						
597	no	none	0.15	F	114.83	3.82	x	x			29.11%			124.01	45.77%	x		29.11%			x						

Table 11. Annual performance summary for the east orientation in Minneapolis, Minnesota. Table continues on next page.

Minneapolis East Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 161.98 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 161.98 kBtu/sf)			Prescriptive					Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
885	yes	none	0.15	F	114.86	3.80	x	x			29.09%			124.30	45.64%	x		29.09%			x						
1022	yes	ov2	0.15	G	115.03	3.67	x		x		28.98%			125.09	45.30%	x		28.98%			x						
1076	yes	fins	0.60	H	115.13	4.74			x		28.92%			123.46	46.01%	x		28.92%				x				x	
742	no	ov2	0.15	H	115.18	3.67			x		28.90%			122.76	46.32%	x		28.90%			x						
1030	yes	ov2	0.15	H	115.25	3.67			x		28.85%			122.82	46.29%	x		28.85%			x						
736	no	ov2	0.30	G	115.42	3.89	x	x			28.75%			128.44	43.83%	x		28.75%			x						
1023	yes	ov1	0.30	G	115.47	3.91		x			28.71%			128.49	43.81%	x		28.71%			x						
1024	yes	ov2	0.30	G	115.52	3.85	x	x			28.68%			129.01	43.58%	x		28.68%			x						
1142	yes	setback	0.30	G	115.61	3.90		x			28.63%			128.70	43.72%	x		28.63%			x						
890	yes	none	0.30	G	115.63	4.08		x			28.62%			127.68	44.16%	x		28.62%			x						
735	no	ov1	0.30	G	115.71	4.11		x			28.56%			127.87	44.08%	x		28.56%			x						
725	no	ov1	0.15	F	115.91	3.70	x				28.44%			125.19	45.25%	x		28.44%			x						
849	no	setback	0.15	F	115.99	3.71	x				28.39%			125.37	45.17%	x		28.39%			x						
1013	yes	ov1	0.15	F	116.01	3.70	x				28.38%			125.35	45.18%	x		28.38%			x						
1137	yes	setback	0.15	F	116.11	3.70	x				28.32%			125.53	45.11%	x		28.32%			x						
777	no	fins	0.15	F	116.60	3.72	x				28.02%			125.51	45.11%	x		28.02%			x						
1065	yes	fins	0.15	F	116.68	3.70	x				27.97%			125.70	45.03%	x		27.97%			x						
817	no	ov2f	0.15	G	116.84	3.60	x		x		27.87%			126.27	44.78%	x		27.87%			x						
821	no	ov2f	0.15	H	116.90	3.61			x		27.83%			123.87	45.83%	x		27.83%			x						
1109	yes	ov2f	0.15	H	116.94	3.61			x		27.81%			123.90	45.82%	x		27.81%			x						
886	yes	none	0.30	F	116.98	4.10		x			27.78%			128.52	43.79%	x		27.78%			x						
825	no	ov2f	0.15	I	117.07	3.59			x		27.73%			123.58	45.96%	x		27.73%			x						
1105	yes	ov2f	0.15	G	117.12	3.59	x				27.70%			126.48	44.69%	x		27.70%			x						
726	no	ov2	0.15	F	117.27	3.66	x				27.61%			125.93	44.93%	x		27.61%			x						
828	no	ov2f	0.60	I	117.28	4.07		x			27.60%			126.34	44.75%	x		27.60%				x				x	
1116	yes	ov2f	0.60	I	117.31	4.07		x			27.58%			123.74	45.89%	x		27.58%				x				x	
1138	yes	setback	0.30	F	117.32	4.03		x			27.57%			129.58	43.33%	x		27.57%			x						
1014	yes	ov2	0.15	F	117.35	3.66	x				27.55%			126.01	44.89%	x		27.55%			x						
813	no	ov2f	0.15	F	119.11	3.60	x				26.47%			127.20	44.37%	x		26.47%			x						
1101	yes	ov2f	0.15	F	119.16	3.60	x				26.44%			127.24	44.36%	x		26.44%			x						
1107	yes	ov2f	0.45	G	120.57	3.91		x			25.56%			134.91	41.00%	x		25.56%			x						
815	no	ov2f	0.45	F	122.24	4.02		x			24.54%			135.86	40.59%	x		24.54%			x						
1103	yes	ov2f	0.45	F	122.28	4.02		x			24.51%			135.93	40.56%	x		24.51%			x						
1028	yes	ov2	0.60	G	123.33	4.31		x	x		23.86%			135.97	40.54%	x		23.86%				x				x	
1027	yes	ov1	0.60	G	126.12	4.71			x		22.14%			136.47	40.32%	x		22.14%				x				x	
1104	yes	ov2f	0.60	F	127.32	4.55		x			21.40%			140.13	38.72%	x		21.40%				x					x
986	yes	ov2	0.45	B	131.27	4.74			x		18.96%			141.76	38.01%	x		18.96%			x						
985	yes	ov1	0.45	B	135.58	5.24			x		16.30%			143.59	37.21%	x		16.30%			x						
1123	yes	setback	0.45	B	141.13	5.76			x		12.87%			146.46	35.95%	x		12.87%			x						
884	yes	none	0.60	E	144.00	6.15			x		11.10%			146.45	35.96%	x		11.10%				x					x
871	yes	none	0.45	B	145.54	6.29			x		10.15%			148.10	35.23%	x		10.15%			x						

Table 11 continued.

Minneapolis South Annual Performance Summary

							Optimum				Existing Data Set (baseline 154.29 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 154.29 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
754	no	ov2	0.45	I	101.98	3.56	x	x	x	x	33.90%	x		121.03	47.07%	x		33.90%	x		x						
745	no	ov1	0.45	H	102.07	3.69	x	x	x	x	33.84%	x		121.14	47.02%	x		33.84%	x		x						
1042	yes	ov2	0.45	I	102.14	3.54	x	x	x	x	33.80%	x		120.35	47.37%	x		33.80%	x		x						
1033	yes	ov1	0.45	H	102.54	3.67	x	x	x	x	33.54%	x		121.40	46.91%	x		33.54%	x		x						
746	no	ov2	0.45	H	102.64	3.64	x	x		x	33.48%	x		121.53	46.86%	x		33.48%	x		x						
859	no	setback	0.45	H	102.81	3.77	x		x	x	33.36%	x		121.32	46.95%	x		33.36%	x		x						
748	no	ov2	0.60	H	102.86	3.71	x	x	x	x	33.33%	x		121.81	46.73%	x		33.33%	x			x				x	
606	no	none	0.30	H	102.90	3.79	x		x	x	33.31%	x		120.55	47.28%	x		33.31%	x		x						
1034	yes	ov2	0.45	H	102.94	3.62	x			x	33.28%	x		121.76	46.75%	x		33.28%	x		x						
1036	yes	ov2	0.60	H	103.05	3.67	x		x	x	33.21%	x		121.80	46.74%	x		33.21%	x			x				x	
898	yes	none	0.30	I	103.11	3.73	x	x	x	x	33.17%	x		119.89	47.57%	x		33.17%	x		x						
753	no	ov1	0.45	I	103.18	3.64	x			x	33.13%	x		122.24	46.54%	x		33.13%	x		x						
1147	yes	setback	0.45	H	103.20	3.74	x		x	x	33.11%	x		121.53	46.85%	x		33.11%	x		x						
862	no	setback	0.30	I	103.25	3.62	x	x	x	x	33.08%	x		120.62	47.25%	x		33.08%	x		x						
858	no	setback	0.30	H	103.44	3.68		x	x	x	32.96%	x		121.55	46.84%	x		32.96%	x		x						
894	yes	none	0.30	H	103.51	3.78	x		x	x	32.91%	x		120.79	47.17%	x		32.91%	x		x						
1035	yes	ov1	0.60	H	103.59	3.72			x	x	32.86%	x		121.66	46.80%	x		32.86%	x			x				x	
1041	yes	ov1	0.45	I	103.64	3.61	x			x	32.83%	x		120.46	47.32%	x		32.83%	x		x						
1150	yes	setback	0.30	I	103.67	3.61	x		x	x	32.81%	x		120.76	47.19%	x		32.81%	x		x						
743	no	ov1	0.30	H	103.93	3.62			x	x	32.64%	x		121.60	46.82%	x		32.64%	x		x						
751	no	ov1	0.30	I	103.93	3.56			x	x	32.64%	x		120.73	47.20%	x		32.64%	x		x						
1146	yes	setback	0.30	H	103.99	3.67			x	x	32.60%	x		121.74	46.76%	x		32.60%	x		x						
756	no	ov2	0.60	I	104.21	3.63		x		x	32.46%	x		125.27	45.22%	x		32.46%	x			x				x	
895	yes	none	0.45	H	104.33	3.91			x	x	32.38%	x		120.97	47.10%	x		32.38%	x		x						
1039	yes	ov1	0.30	I	104.33	3.56			x	x	32.38%	x		120.88	47.14%	x		32.38%	x		x						
828	no	ov2f	0.60	I	104.40	3.73	x	x	x	x	32.34%	x		126.34	44.75%	x		32.34%	x			x				x	
1044	yes	ov2	0.60	I	104.43	3.62		x		x	32.31%	x		120.58	47.27%	x		32.31%	x			x				x	
1031	yes	ov1	0.30	H	104.45	3.62			x	x	32.30%	x		121.81	46.73%	x		32.30%	x		x						
1116	yes	ov2f	0.60	I	104.50	3.72	x	x	x	x	32.27%	x		123.74	45.89%	x		32.27%	x			x				x	
790	no	fins	0.30	I	104.54	3.61	x		x	x	32.24%	x		121.30	46.95%	x		32.24%	x		x						
786	no	fins	0.30	H	104.72	3.68	x		x	x	32.13%	x		122.28	46.53%	x		32.13%	x		x						
1075	yes	fins	0.45	H	104.81	3.76	x		x	x	32.07%	x		122.28	46.53%	x		32.07%	x		x						
1078	yes	fins	0.30	I	104.90	3.60	x		x	x	32.01%	x		121.42	46.90%	x		32.01%	x		x						
601	no	none	0.15	G	104.92	3.75	x	x	x	x	32.00%	x		122.69	46.35%	x		32.00%	x		x						
787	no	fins	0.45	H	105.17	3.79			x	x	31.83%	x		122.77	46.31%	x		31.83%	x		x						
752	no	ov2	0.30	I	105.19	3.52			x	x	31.82%	x		121.25	46.98%	x		31.82%	x		x						
744	no	ov2	0.30	H	105.20	3.57			x	x	31.82%	x		122.16	46.58%	x		31.82%	x		x						
1040	yes	ov2	0.30	I	105.32	3.52			x	x	31.74%	x		121.30	46.95%	x		31.74%	x		x						
1032	yes	ov2	0.30	H	105.45	3.57			x	x	31.65%	x		122.27	46.53%	x		31.65%	x		x						
824	no	ov2f	0.60	H	105.45	3.53	x			x	31.65%	x		124.23	45.67%	x		31.65%	x			x				x	
827	no	ov2f	0.45	I	105.59	3.57			x	x	31.56%	x		122.87	46.27%	x		31.56%	x		x						
1112	yes	ov2f	0.60	H	105.60	3.51	x			x	31.56%	x		124.24	45.67%	x		31.56%	x			x				x	
1115	yes	ov2f	0.45	I	105.68	3.56			x	x	31.50%	x		122.48	46.44%	x		31.50%	x		x						
1148	yes	setback	0.60	H	105.80	3.95			x	x	31.43%	x		122.12	46.60%	x		31.43%	x			x				x	
610	no	none	0.30	I	105.87	3.79	x			x	31.38%	x		120.48	47.31%	x		31.38%	x		x						
605	no	none	0.15	H	106.21	3.71		x		x	31.16%	x		121.03	47.07%	x		31.16%	x		x						
693	no	ov1	0.15	B	106.43	3.71			x		31.02%	x		125.17	45.26%	x		31.02%	x		x						
889	yes	none	0.15	G	106.44	3.72	x	x			31.01%	x		123.29	46.08%	x		31.01%	x		x						
733	no	ov1	0.15	G	106.82	3.59	x		x		30.77%	x		123.89	45.82%	x		30.77%	x		x						
853	no	setback	0.15	G	106.88	3.62	x		x		30.73%	x		124.18	45.69%	x		30.73%	x		x						
735	no	ov1	0.30	G	107.00	3.64	x	x			30.65%	x		127.87	44.08%	x		30.65%	x		x						
609	no	none	0.15	I	107.01	3.67		x			30.65%	x		120.99	47.09%	x		30.65%	x		x						
893	yes	none	0.15	H	107.14	3.70		x			30.56%	x		121.32	46.95%	x		30.56%	x		x						

Table 12. Annual performance summary for the south orientation in Minneapolis, Minnesota. Table continues on next page.

Minneapolis South Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 154.29 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 154.29 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
781	no	fins	0.15	G	107.42	3.66	x		x		30.38%	x		124.37	45.61%	x		30.38%	x		x						
1076	yes	fins	0.60	H	107.42	4.16			x		30.38%	x		123.46	46.01%	x		30.38%	x			x				x	
854	no	setback	0.30	G	107.51	3.71		x			30.32%	x		128.20	43.94%	x		30.32%	x		x						
597	no	none	0.15	F	107.51	3.69	x	x			30.32%	x		124.01	45.77%	x		30.32%	x		x						
897	yes	none	0.15	I	107.79	3.66		x			30.14%	x		121.21	47.00%	x		30.14%	x		x						
736	no	ov2	0.30	G	108.04	3.58	x				29.98%			128.44	43.83%	x		29.98%			x						
885	yes	none	0.15	F	108.38	3.68	x	x			29.76%			124.30	45.64%	x		29.76%			x						
694	no	ov2	0.15	B	108.64	3.66			x		29.59%			126.09	44.86%	x		29.59%			x						
1069	yes	fins	0.15	G	108.68	3.63	x				29.56%			124.79	45.43%	x		29.56%			x						
826	no	ov2f	0.30	I	108.79	3.42			x		29.49%			123.08	46.17%	x		29.49%			x						
1114	yes	ov2f	0.30	I	108.86	3.42			x		29.44%			123.11	46.16%	x		29.44%			x						
822	no	ov2f	0.30	H	109.03	3.49			x		29.34%			124.16	45.70%	x		29.34%			x						
1110	yes	ov2f	0.30	H	109.15	3.49			x		29.25%			124.22	45.68%	x		29.25%			x						
850	no	setback	0.30	F	109.17	3.63		x			29.25%			129.36	43.43%	x		29.25%			x						
727	no	ov1	0.30	F	109.28	3.57		x			29.18%			129.26	43.47%	x		29.18%			x						
886	yes	none	0.30	F	109.75	3.83		x			28.87%			128.52	43.79%	x		28.87%			x						
896	yes	none	0.60	H	109.99	4.73			x		28.71%			122.78	46.31%	x		28.71%				x				x	
738	no	ov2	0.45	G	110.45	3.65		x			28.41%			132.54	42.04%	x		28.41%			x						
1025	yes	ov1	0.45	G	110.70	3.66		x			28.25%			131.92	42.31%	x		28.25%			x						
1017	yes	ov1	0.45	F	111.29	3.57		x			27.87%			132.80	41.93%	x		27.87%			x						
730	no	ov2	0.45	F	111.37	3.55		x			27.82%			132.91	41.87%	x		27.82%			x						
729	no	ov1	0.45	F	111.56	3.61		x			27.69%			133.25	41.73%	x		27.69%			x						
1018	yes	ov2	0.45	F	111.85	3.53		x			27.50%			133.26	41.73%	x		27.50%			x						
818	no	ov2f	0.30	G	111.90	3.47	x				27.48%			130.98	42.72%	x		27.48%			x						
817	no	ov2f	0.15	G	112.42	3.50			x		27.14%			126.27	44.78%	x		27.14%			x						
797	no	ov2f	0.15	B	112.60	3.57			x		27.02%			128.30	43.89%	x		27.02%			x						
1027	yes	ov1	0.60	G	115.59	3.97		x			25.08%			136.47	40.32%	x		25.08%				x				x	
1028	yes	ov2	0.60	G	115.76	3.79		x			24.98%			135.97	40.54%	x		24.98%				x				x	
732	no	ov2	0.60	F	116.83	3.66		x			24.28%			138.93	39.24%	x		24.28%				x					x
1020	yes	ov2	0.60	F	117.39	3.67		x			23.92%			137.69	39.79%	x		23.92%				x					x

Table 12 continued.

Minneapolis West Annual Performance Summary

							Optimum				Existing Data Set (baseline 161.64 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 161.64 kBtu/sf)									
																		Prescriptive								Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
1044	yes	ov2	0.60	I	107.78	4.47	x	x	x	x	33.32%	x		120.58	47.27%	x		33.32%	x			x				x	
1042	yes	ov2	0.45	I	108.38	4.30	x	x	x	x	32.95%	x		120.35	47.37%	x		32.95%	x		x						
1043	yes	ov1	0.60	I	108.55	4.55	x		x	x	32.84%	x		122.15	46.58%	x		32.84%	x			x				x	
1041	yes	ov1	0.45	I	108.59	4.37	x	x	x	x	32.82%	x		120.46	47.32%	x		32.82%	x		x						
1036	yes	ov2	0.60	H	109.08	3.76		x		x	32.52%	x		121.80	46.74%	x		32.52%	x			x				x	
1034	yes	ov2	0.45	H	109.20	3.74		x		x	32.45%	x		121.76	46.75%	x		32.45%	x		x						
1033	yes	ov1	0.45	H	109.27	3.81		x		x	32.40%	x		121.40	46.91%	x		32.40%	x		x						
1151	yes	setback	0.45	I	109.29	4.45	x		x	x	32.39%	x		121.82	46.73%	x		32.39%	x		x						
898	yes	none	0.30	I	109.40	4.22	x	x	x	x	32.32%	x		119.89	47.57%	x		32.32%	x		x						
1035	yes	ov1	0.60	H	109.47	3.83		x		x	32.28%	x		121.66	46.80%	x		32.28%	x			x				x	
746	no	ov2	0.45	H	109.61	3.80		x		x	32.19%	x		121.53	46.86%	x		32.19%	x		x						
1147	yes	setback	0.45	H	109.68	3.89		x	x	x	32.15%	x		121.53	46.85%	x		32.15%	x		x						
1079	yes	fins	0.45	I	109.70	4.46	x		x	x	32.13%	x		122.80	46.30%	x		32.13%	x		x						
894	yes	none	0.30	H	109.80	3.91		x	x	x	32.07%	x		120.79	47.17%	x		32.07%	x		x						
895	yes	none	0.45	H	109.81	4.01			x	x	32.07%	x		120.97	47.10%	x		32.07%	x		x						
610	no	none	0.30	I	109.93	4.23	x	x	x	x	31.99%	x		120.48	47.31%	x		31.99%	x		x						
606	no	none	0.30	H	110.05	3.94		x	x	x	31.92%	x		120.55	47.28%	x		31.92%	x		x						
1150	yes	setback	0.30	I	110.08	4.10			x	x	31.90%	x		120.76	47.19%	x		31.90%	x		x						
1116	yes	ov2f	0.60	I	110.13	4.28	x		x	x	31.87%	x		123.74	45.89%	x		31.87%	x			x				x	
862	no	setback	0.30	I	110.15	4.11			x	x	31.85%	x		120.62	47.25%	x		31.85%	x		x						
1148	yes	setback	0.60	H	110.25	3.91		x	x	x	31.79%	x		122.12	46.60%	x		31.79%	x			x				x	
1146	yes	setback	0.30	H	110.45	3.81		x	x	x	31.67%	x		121.74	46.76%	x		31.67%	x		x						
858	no	setback	0.30	H	110.55	3.83		x	x	x	31.61%	x		121.55	46.84%	x		31.61%	x		x						
751	no	ov1	0.30	I	110.69	4.05			x	x	31.52%	x		120.73	47.20%	x		31.52%	x		x						
1039	yes	ov1	0.30	I	110.71	4.05			x	x	31.51%	x		120.88	47.14%	x		31.51%	x		x						
1115	yes	ov2f	0.45	I	110.89	4.19	x		x	x	31.40%	x		122.48	46.44%	x		31.40%	x		x						
743	no	ov1	0.30	H	110.98	3.79			x	x	31.34%	x		121.60	46.82%	x		31.34%	x		x						
1078	yes	fins	0.30	I	110.99	4.09			x	x	31.34%	x		121.42	46.90%	x		31.34%	x		x						
1031	yes	ov1	0.30	H	111.01	3.79			x	x	31.32%	x		121.81	46.73%	x		31.32%	x		x						
752	no	ov2	0.30	I	111.07	3.98			x	x	31.28%	x		121.25	46.98%	x		31.28%	x		x						
1040	yes	ov2	0.30	I	111.08	3.98			x	x	31.28%	x		121.30	46.95%	x		31.28%	x		x						
1080	yes	fins	0.60	I	111.11	4.76			x	x	31.26%	x		127.31	44.33%	x		31.26%	x			x				x	
790	no	fins	0.30	I	111.14	4.11			x	x	31.24%	x		121.30	46.95%	x		31.24%	x		x						
1076	yes	fins	0.60	H	111.31	4.01			x	x	31.14%	x		123.46	46.01%	x		31.14%	x			x				x	
896	yes	none	0.60	H	111.32	4.24			x	x	31.13%	x		122.78	46.31%	x		31.13%	x			x				x	
744	no	ov2	0.30	H	111.33	3.73			x	x	31.12%	x		122.16	46.58%	x		31.12%	x		x						
1032	yes	ov2	0.30	H	111.36	3.73			x	x	31.10%	x		122.27	46.53%	x		31.10%	x		x						
1074	yes	fins	0.30	H	111.43	3.80			x	x	31.06%	x		122.43	46.46%	x		31.06%	x		x						
601	no	none	0.15	G	112.29	3.93	x	x	x		30.53%	x		122.69	46.35%	x		30.53%	x		x						
889	yes	none	0.15	G	112.35	3.85	x		x		30.49%	x		123.29	46.08%	x		30.49%	x		x						
605	no	none	0.15	H	112.58	3.88		x	x		30.35%	x		121.03	47.07%	x		30.35%	x		x						
893	yes	none	0.15	H	112.76	3.86		x	x		30.24%	x		121.32	46.95%	x		30.24%	x		x						
609	no	none	0.15	I	113.03	3.94		x			30.07%	x		120.99	47.09%	x		30.07%	x		x						
897	yes	none	0.15	I	113.14	3.93		x			30.01%	x		121.21	47.00%	x		30.01%	x		x						
826	no	ov2f	0.30	I	113.29	3.91			x		29.91%			123.08	46.17%	x		29.91%			x						
1114	yes	ov2f	0.30	I	113.30	3.91			x		29.91%			123.11	46.16%	x		29.91%			x						
733	no	ov1	0.15	G	113.35	3.78	x		x		29.88%			123.89	45.82%	x		29.88%			x						
853	no	setback	0.15	G	113.48	3.81	x		x		29.79%			124.18	45.69%	x		29.79%			x						
1141	yes	setback	0.15	G	113.62	3.75	x		x		29.71%			124.60	45.51%	x		29.71%			x						
1021	yes	ov1	0.15	G	113.63	3.74	x		x		29.70%			124.38	45.61%	x		29.70%			x						
822	no	ov2f	0.30	H	113.75	3.64			x		29.63%			124.16	45.70%	x		29.63%			x						
1110	yes	ov2f	0.30	H	113.75	3.64			x		29.63%			124.22	45.68%	x		29.63%			x						
741	no	ov1	0.15	H	113.90	3.74			x		29.54%			122.10	46.60%	x		29.54%			x						

Table 13. Annual performance summary for the west orientation in Minneapolis, Minnesota. Table continues on next page.

Minneapolis West Annual Performance Summary-Continued

							Optimum				Existing Data Set (baseline 161.64 kBtu/sf)			CBECS (average 228.67 kBtu/sf)				ASHRAE 90.1-99 Compliance (budget bldg 161.64 kBtu/sf)									
																			Prescriptive							Performance	
Window	Interior Shades	Exterior Shades	WWR	Glass	Energy (kBtu/sf)	Peak (W/sf)	WWR	Shading	Glass	Top 50	% Diff	30% better	50% better	Energy (kBtu/sf)	% Diff	30% better	50% better	% Diff	30% better	50% better	Yes	No	SHGC North	Trade-off ov1	Trade-off ov2	Yes	No
857	no	setback	0.15	H	113.90	3.78			x		29.54%			122.21	46.55%	x		29.54%			x						
1145	yes	setback	0.15	H	113.97	3.77			x		29.49%			122.36	46.49%	x		29.49%			x						
1029	yes	ov1	0.15	H	113.98	3.74			x		29.49%			122.24	46.54%	x		29.49%			x						
781	no	fins	0.15	G	114.19	3.84	x		x		29.35%			124.37	45.61%	x		29.35%			x						
1069	yes	fins	0.15	G	114.25	3.77	x		x		29.32%			124.79	45.43%	x		29.32%			x						
785	no	fins	0.15	H	114.33	3.81			x		29.27%			122.35	46.50%	x		29.27%			x						
1073	yes	fins	0.15	H	114.43	3.79			x		29.21%			122.52	46.42%	x		29.21%			x						
597	no	none	0.15	F	114.72	3.88	x	x			29.03%			124.01	45.77%	x		29.03%			x						
734	no	ov2	0.15	G	114.75	3.74	x		x		29.01%			124.72	45.46%	x		29.01%			x						
885	yes	none	0.15	F	114.79	3.86	x	x			28.98%			124.30	45.64%	x		28.98%			x						
1022	yes	ov2	0.15	G	115.04	3.71	x		x		28.83%			125.09	45.30%	x		28.83%			x						
742	no	ov2	0.15	H	115.24	3.72			x		28.71%			122.76	46.32%	x		28.71%			x						
1030	yes	ov2	0.15	H	115.26	3.72			x		28.69%			122.82	46.29%	x		28.69%			x						
890	yes	none	0.30	G	115.34	3.98		x			28.65%			127.68	44.16%	x		28.65%			x						
1142	yes	setback	0.30	G	115.52	3.86		x			28.54%			128.70	43.72%	x		28.54%			x						
1023	yes	ov1	0.30	G	115.55	3.83		x			28.51%			128.49	43.81%	x		28.51%			x						
736	no	ov2	0.30	G	115.61	3.84		x			28.48%			128.44	43.83%	x		28.48%			x						
725	no	ov1	0.15	F	116.01	3.75	x				28.23%			125.19	45.25%	x		28.23%			x						
849	no	setback	0.15	F	116.03	3.78	x				28.21%			125.37	45.17%	x		28.21%			x						
1013	yes	ov1	0.15	F	116.06	3.75	x				28.20%			125.35	45.18%	x		28.20%			x						
1137	yes	setback	0.15	F	116.09	3.77	x				28.18%			125.53	45.11%	x		28.18%			x						
777	no	fins	0.15	F	116.54	3.80	x				27.90%			125.51	45.11%	x		27.90%			x						
1065	yes	fins	0.15	F	116.59	3.78	x				27.87%			125.70	45.03%	x		27.87%			x						
817	no	ov2f	0.15	G	116.93	3.68	x		x		27.66%			126.27	44.78%	x		27.66%			x						
821	no	ov2f	0.15	H	116.95	3.67			x		27.65%			123.87	45.83%	x		27.65%			x						
1109	yes	ov2f	0.15	H	116.97	3.67			x		27.64%			123.90	45.82%	x		27.64%			x						
886	yes	none	0.30	F	116.97	3.99		x			27.63%			128.52	43.79%	x		27.63%			x						
825	no	ov2f	0.15	I	117.09	3.74			x		27.56%			123.58	45.96%	x		27.56%			x						
1105	yes	ov2f	0.15	G	117.10	3.66	x				27.55%			126.48	44.69%	x		27.55%			x						
598	no	none	0.30	F	117.29	4.05		x			27.44%			128.47	43.82%	x		27.44%			x						
726	no	ov2	0.15	F	117.39	3.72	x				27.38%			125.93	44.93%	x		27.38%			x						
1014	yes	ov2	0.15	F	117.43	3.72	x				27.35%			126.01	44.89%	x		27.35%			x						
1138	yes	setback	0.30	F	117.44	3.88		x			27.35%			129.58	43.33%	x		27.35%			x						
850	no	setback	0.30	F	117.59	3.91		x			27.25%			129.36	43.43%	x		27.25%			x						
728	no	ov2	0.30	F	117.87	3.79	x				27.08%			129.87	43.20%	x		27.08%			x						
1016	yes	ov2	0.30	F	117.90	3.79	x				27.06%			130.02	43.14%	x		27.06%			x						
1026	yes	ov2	0.45	G	118.36	3.84		x			26.77%			132.31	42.14%	x		26.77%			x						
1025	yes	ov1	0.45	G	118.93	3.99		x			26.42%			131.92	42.31%	x		26.42%			x						
813	no	ov2f	0.15	F	119.26	3.66	x				26.22%			127.20	44.37%	x		26.22%			x						
1101	yes	ov2f	0.15	F	119.28	3.66	x				26.20%			127.24	44.36%	x		26.20%			x						
1018	yes	ov2	0.45	F	119.57	3.80		x			26.02%			133.26	41.73%	x		26.02%			x						
1017	yes	ov1	0.45	F	119.81	3.86		x			25.88%			132.80	41.93%	x		25.88%			x						
1028	yes	ov2	0.60	G	122.52	4.13		x			24.20%			135.97	40.54%	x		24.20%				x				x	
1019	yes	ov1	0.60	F	124.65	4.15		x			22.88%			137.57	39.84%	x		22.88%				x					x
1020	yes	ov2	0.60	F	124.68	3.94		x			22.86%			137.69	39.79%	x		22.86%				x					x

Table 13 continued.

COMPARE PERFORMANCE OF FINDINGS: CARBON

The following tables summarize the top window design options (per orientation) in terms of carbon emission, whether the design options meet the 30% and 50% performance targets determined from the existing data set, from the CBECS database, and of the ASHRAE 90.1-99 budget building and if the options follow the prescriptive or performance path for code compliance.

Carbon Comparison in Phoenix, Arizona

For all orientations in Phoenix, the carbon emissions reduction based on the EPA Power Profiler typically ranged between 4–9% compared to a regional office building and 5–11% for an average state building. The emissions reduction were about equal to slightly above the national average. The carbon emission reduction of the existing data set and code base typically ranged between 20–25% of the average of each. The carbon emission reduction as compared to the CBECS database typically ranged between 39–42% of the average.

Phoenix, Arizona: Carbon Summary for North Orientation

Table 14 shows the annual carbon emission comparison for the north orientation in Phoenix. As compared to the average emissions of a 48,000 square foot office building (787,331 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed -12.18–25.08% better than the baseline (955,330 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 13.20–42.03% better than the regional CBECS average (1,234,635 lbs CO_2). All but 2 design options meet the 30% performance target (option 1145 and option 1149). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed -12.18–25.08% better than the budget building (955,330 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Phoenix, Arizona: Carbon Summary for East Orientation

Table 15 shows the annual carbon emission comparison for the east orientation in Phoenix. As compared to the average emissions of a 48,000 square foot office building (787,331 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed -2.36–25.08% better than the baseline (955,330 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 20.79–42.03% better than the regional CBECS average (1,234,635 lbs CO_2). All but 2 design options meet the 30% performance target (option 1143 and option 1140). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed -2.36–25.08% better than the budget building (955,330 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Phoenix, Arizona: Carbon Summary for South Orientation
Table 16 shows the annual carbon emission comparison for the south orientation in Phoenix. As compared to the average emissions of a 48,000 square foot office building (787,331 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed 20.81–25.08% better than the baseline (955,330 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 38.73–42.03% better than the regional CBECS average (1,234,635 lbs CO_2). All design options meet the 30% performance target). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 20.81–25.08% better than the budget building (955,330 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Phoenix, Arizona: Carbon Summary for West Orientation
Table 17 shows the annual carbon emission comparison for the west orientation in Phoenix. As compared to the average emissions of a 48,000 square foot office building (787,331 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed 20.87–25.08% better than the baseline (955,330 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 38.77–42.03% better than the regional CBECS average (1,234,635 lbs CO_2). All design options meet the 30% performance target). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 20.87–25.08% better than the budget building (955,330 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Phoenix North Annual Carbon Emission Comparison

	Whole Bldg		EPA Power Profiler (average 787,311 lbs CO_2)								Data Set (955,330 lbs CO_2)			CBECS (1,234,635 lbs CO_2)			Code Base (955,330 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	551,118 lbs	393,656 lbs	% Diff	668,731 lbs	497,665 lbs	% Diff	864,245 lbs	617,318 lbs	% Diff	908,480 lbs	648,914 lbs
792	131.88	612204	767704	746277	834434	2.49%	5.21%	-5.99%			19.64%			37.82%	x		19.64%		
611	134.67	625181	783977	762095	852121	0.42%	3.20%	-8.23%			17.94%			36.50%	x		17.94%		
899	129.86	602830	755949	734850	821657	3.98%	6.66%	-4.36%			20.87%			38.77%	x		20.87%		
1080	127.48	591776	742087	721375	806591	5.74%	8.37%	-2.45%			22.32%			39.89%	x		22.32%		
863	128.35	595829	747170	726316	812115	5.10%	7.75%	-3.15%			21.79%			39.48%	x		21.79%		
864	130.47	605679	759521	738323	825540	3.53%	6.22%	-4.86%			20.50%			38.48%	x		20.50%		
1151	125.63	583172	731298	710887	794864	7.11%	9.71%	-0.96%			23.45%			40.77%	x		23.45%		
1152	127.08	589948	739794	719146	804099	6.04%	8.66%	-2.13%			22.56%			40.08%	x		22.56%		
1079	128.20	595138	746304	725474	811174	5.21%	7.85%	-3.03%			21.88%			39.55%	x		21.88%		
791	129.00	598825	750926	729967	816198	4.62%	7.28%	-3.67%			21.40%			39.18%	x		21.40%		
1147	125.07	580597	728069	707748	791354	7.52%	10.11%	-0.51%			23.79%			41.03%	x		23.79%		
859	126.32	586380	735320	714797	799236	6.60%	9.21%	-1.51%			23.03%			40.44%	x		23.03%		
828	124.26	576844	723362	703173	786238	8.12%	10.69%	0.14%			24.28%			41.41%	x		24.28%		
1116	123.28	572276	717635	697605	780013	8.85%	11.39%	0.93%			24.88%			41.87%	x		24.88%		
1075	125.62	583130	731245	710836	794806	7.12%	9.71%	-0.95%			23.46%			40.77%	x		23.46%		
787	127.03	589675	739452	718814	803727	6.08%	8.70%	-2.09%			22.60%			40.11%	x		22.60%		
788	130.10	603939	757339	736201	823168	3.81%	6.49%	-4.55%			20.72%			38.66%	x		20.72%		
1112	123.73	574364	720253	700150	782859	8.52%	11.07%	0.57%			24.61%			41.66%	x		24.61%		
824	124.05	575875	722147	701992	784918	8.28%	10.84%	0.30%			24.41%			41.51%	x		24.41%		
753	125.47	582459	730403	710017	793891	7.23%	9.82%	-0.84%			23.54%			40.84%	x		23.54%		
1076	127.66	592636	743166	722424	807763	5.61%	8.24%	-2.60%			22.21%			39.81%	x		22.21%		
1041	124.10	576070	722391	702229	785183	8.25%	10.81%	0.27%			24.38%			41.49%	x		24.38%		
1044	124.40	577470	724147	703936	787092	8.02%	10.59%	0.03%			24.20%			41.35%	x		24.20%		
1043	125.47	582456	730400	710014	793887	7.23%	9.82%	-0.84%			23.54%			40.84%	x		23.54%		
1034	123.79	574648	720608	700495	783245	8.47%	11.03%	0.52%			24.57%			41.63%	x		24.57%		
1033	124.33	577139	723733	703533	786641	8.08%	10.64%	0.09%			24.24%			41.38%	x		24.24%		
1042	123.39	572785	718272	698224	780705	8.77%	11.32%	0.84%			24.81%			41.82%	x		24.81%		
746	124.13	576235	722599	702431	785409	8.22%	10.78%	0.24%			24.36%			41.47%	x		24.36%		
754	123.70	574251	720111	700012	782704	8.54%	11.09%	0.59%			24.62%			41.67%	x		24.62%		
745	125.16	580997	728570	708235	791899	7.46%	10.04%	-0.58%			23.74%			40.99%	x		23.74%		
607	128.47	596359	747834	726961	812837	5.01%	7.67%	-3.24%			21.72%			39.43%	x		21.72%		
895	126.61	587741	737027	716456	801091	6.39%	9.00%	-1.75%			22.85%			40.30%	x		22.85%		
612	133.92	621689	779598	757839	847362	0.98%	3.74%	-7.63%			18.39%			36.86%	x		18.39%		
900	129.53	601304	754035	732989	819577	4.23%	6.90%	-4.10%			21.07%			38.93%	x		21.07%		
1111	123.30	572382	717767	697734	780157	8.83%	11.38%	0.91%			24.87%			41.86%	x		24.87%		
823	123.54	573481	719145	699073	781654	8.66%	11.21%	0.72%			24.72%			41.75%	x		24.72%		
1115	122.96	570785	715764	695787	777980	9.09%	11.62%	1.19%			25.08%			42.03%	x		25.08%		
827	123.29	572333	717705	697674	780089	8.84%	11.39%	0.92%			24.87%			41.87%	x		24.87%		
854	127.95	593955	744819	724031	809560	5.40%	8.04%	-2.83%			22.04%			39.67%	x		22.04%		
894	125.09	580674	728166	707842	791459	7.51%	10.09%	-0.53%			23.78%			41.02%	x		23.78%		
1142	126.37	586614	735614	715082	799554	6.57%	9.17%	-1.56%			23.00%			40.42%	x		23.00%		
606	125.82	584071	732425	711983	796089	6.97%	9.57%	-1.11%			23.33%			40.68%	x		23.33%		
1146	124.28	576915	723452	703260	786335	8.11%	10.68%	0.12%			24.27%			41.40%	x		24.27%		
1070	126.72	588256	737673	717084	801793	6.30%	8.92%	-1.84%			22.78%			40.25%	x		22.78%		
782	128.85	598142	750070	729135	815268	4.73%	7.39%	-3.55%			21.49%			39.25%	x		21.49%		
858	124.59	578385	725295	705052	788339	7.88%	10.45%	-0.13%			24.08%			41.25%	x		24.08%		
898	124.79	579317	726464	706188	789609	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		
610	125.36	581953	729769	709401	793202	7.31%	9.90%	-0.75%			23.61%			40.89%	x		23.61%		
1024	125.18	581115	728718	708379	792059	7.44%	10.03%	-0.60%			23.72%			40.98%	x		23.72%		
736	125.63	583197	731329	710917	794898	7.11%	9.70%	-0.96%			23.45%			40.77%	x		23.45%		
1150	124.08	576017	722325	702165	785111	8.25%	10.81%	0.28%			24.39%			41.49%	x		24.39%		
1023	125.84	584147	732521	712076	796193	6.96%	9.56%	-1.13%			23.32%			40.67%	x		23.32%		

Table 14. Annual carbon emission comparison for the north orientation in Phoenix, Arizona. Table continues on next page.

Phoenix North Annual Carbon Emission Comparison-Continued

Window	Whole Bldg kBtu/sf	kWh	EPA Power Profiler (average 787,311 lbs CO_2) Averages (lbs CO_2) Office	State	National	% Diff from Average Office	State	National	30% Target 551,118 lbs	50% Target 393,656 lbs	Data Set (955,330 lbs CO_2) % Diff	30% Target 668,731 lbs	50% Target 497,665 lbs	CBECS (1,234,635 lbs CO_2) % Diff	30% Target 864,245 lbs	50% Target 617,318 lbs	Code Base (955,330 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs
735	126.75	588410	737866	717272	802003	6.28%	8.90%	-1.87%			22.76%			40.24%	x		22.76%		
862	124.31	577066	723640	703443	786541	8.09%	10.65%	0.10%			24.25%			41.39%	x		24.25%		
602	130.49	605778	759645	738443	825675	3.51%	6.21%	-4.87%			20.48%			38.47%	x		20.48%		
890	127.93	593876	744721	723935	809453	5.41%	8.05%	-2.81%			22.05%			39.68%	x		22.05%		
1106	124.91	579851	727133	706838	790337	7.64%	10.22%	-0.38%			23.89%			41.11%	x		23.89%		
818	125.23	581362	729027	708680	792396	7.40%	9.99%	-0.65%			23.69%			40.95%	x		23.69%		
1107	126.41	586814	735865	715326	799828	6.53%	9.14%	-1.59%			22.97%			40.40%	x		22.97%		
819	127.69	592768	743332	722585	807943	5.59%	8.22%	-2.62%			22.19%			39.79%	x		22.19%		
889	124.92	579902	727197	706901	790406	7.64%	10.21%	-0.39%			23.88%			41.10%	x		23.88%		
601	125.74	583689	731946	711516	795568	7.03%	9.63%	-1.05%			23.38%			40.72%	x		23.38%		
1138	126.74	588367	737812	717219	801944	6.29%	8.90%	-1.86%			22.77%			40.24%	x		22.77%		
850	127.24	590679	740712	720038	805096	5.92%	8.54%	-2.26%			22.47%			40.01%	x		22.47%		
598	129.13	599461	751724	730743	817066	4.52%	7.18%	-3.78%			21.31%			39.11%	x		21.31%		
886	128.04	594376	745348	724545	810135	5.33%	7.97%	-2.90%			21.98%			39.63%	x		21.98%		
779	133.02	617519	774369	752755	841678	1.64%	4.39%	-6.91%			18.94%			37.28%	x		18.94%		
1067	130.70	606733	760843	739607	826977	3.36%	6.06%	-5.04%			20.36%			38.38%	x		20.36%		
1141	124.47	577826	724594	704370	787577	7.97%	10.53%	-0.03%			24.15%			41.31%	x		24.15%		
853	124.79	579314	726460	706184	789606	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		
851	131.65	611146	766377	744986	832991	2.66%	5.38%	-5.80%			19.78%			37.93%	x		19.78%		
1139	129.42	600797	753400	732372	818887	4.31%	6.98%	-4.01%			21.14%			38.98%	x		21.14%		
1103	126.58	587593	736841	716275	800889	6.41%	9.02%	-1.72%			22.87%			40.32%	x		22.87%		
815	127.16	590279	740210	719550	804551	5.98%	8.61%	-2.19%			22.52%			40.05%	x		22.52%		
733	124.52	578042	724864	704633	787871	7.93%	10.50%	-0.07%			24.12%			41.29%	x		24.12%		
1021	124.36	577295	723928	703723	786854	8.05%	10.62%	0.06%			24.22%			41.36%	x		24.22%		
1018	127.47	591720	742017	721307	806514	5.75%	8.38%	-2.44%			22.33%			39.90%	x		22.33%		
730	128.12	594751	745817	725001	810645	5.27%	7.91%	-2.96%			21.93%			39.59%	x		21.93%		
729	129.76	602351	755348	734266	821004	4.06%	6.74%	-4.28%			20.93%			38.82%	x		20.93%		
1017	128.29	595529	746794	725950	811706	5.15%	7.79%	-3.10%			21.83%			39.51%	x		21.83%		
1015	126.27	586154	735037	714521	798927	6.64%	9.25%	-1.48%			23.06%			40.47%	x		23.06%		
727	126.46	587046	736156	715610	800144	6.50%	9.11%	-1.63%			22.94%			40.37%	x		22.94%		
1016	125.69	583459	731658	711237	795255	7.07%	9.66%	-1.01%			23.41%			40.74%	x		23.41%		
728	125.75	583758	732032	711600	795661	7.02%	9.62%	-1.06%			23.37%			40.71%	x		23.37%		
1069	125.04	580475	727916	707599	791188	7.54%	10.12%	-0.49%			23.80%			41.04%	x		23.80%		
781	125.55	582802	730833	710435	794359	7.17%	9.76%	-0.90%			23.50%			40.81%	x		23.50%		
820	131.40	609986	764922	743573	831411	2.84%	5.56%	-5.60%			19.93%			38.04%	x		19.93%		
1108	129.06	599095	751265	730297	816566	4.58%	7.24%	-3.72%			21.36%			39.15%	x		21.36%		
816	129.96	603282	756516	735401	822274	3.91%	6.59%	-4.44%			20.81%			38.73%	x		20.81%		
1104	129.03	598975	751114	730150	816403	4.60%	7.26%	-3.70%			21.38%			39.16%	x		21.38%		
1022	124.59	578375	725282	705039	788325	7.88%	10.45%	-0.13%			24.08%			41.26%	x		24.08%		
734	124.66	578713	725706	705451	788786	7.82%	10.40%	-0.19%			24.04%			41.22%	x		24.04%		
893	134.90	626228	785290	763372	853549	0.26%	3.04%	-8.41%			17.80%			36.39%	x		17.80%		
885	132.52	615180	771436	749904	838490	2.02%	4.75%	-6.50%			19.25%			37.52%	x		19.25%		
605	123.39	572797	718287	698239	780722	8.77%	11.31%	0.84%			24.81%			41.82%	x		24.81%		
597	125.47	582453	730396	710010	793883	7.23%	9.82%	-0.83%			23.55%			40.84%	x		23.55%		
1105	135.26	627899	787386	765409	855827	-0.01%	2.78%	-8.70%			17.58%			36.23%	x		17.58%		
817	132.15	613462	769282	747811	836149	2.29%	5.02%	-6.20%			19.47%			37.69%	x		19.47%		
1145	184.10	854623	1071697	1041785	1164851	-36.12%	-32.32%	-47.95%			-12.18%			13.20%			-12.18%		
857	125.28	581571	729290	708935	792681	7.37%	9.95%	-0.68%			23.66%			40.93%	x		23.66%		
897	127.75	593037	743668	722912	808309	5.54%	8.18%	-2.67%			22.16%			39.77%	x		22.16%		
609	128.47	596379	747859	726986	812865	5.01%	7.66%	-3.25%			21.72%			39.43%	x		21.72%		
1149	173.81	806855	1011796	983556	1099743	-28.51%	-24.93%	-39.68%			-5.91%			18.05%			-5.91%		
861	130.88	607567	761889	740624	828113	3.23%	5.93%	-5.18%			20.25%			38.29%	x		20.25%		

Table 14 continued.

Window	Whole Bldg kBtu/sf	kWh	EPA Power Profiler (average 787,311 lbs CO_2) Averages (lbs CO_2) Office	State	National	% Diff from Average Office	State	National	30% Target 551,118 lbs	50% Target 393,656 lbs	Data Set (955,330 lbs CO_2) % Diff	30% Target 668,731 lbs	50% Target 497,665 lbs	CBECS (1,234,635 lbs CO_2) % Diff	30% Target 864,245 lbs	50% Target 617,318 lbs	Code Base (955,330 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs
1115	122.96	570785	715764	695787	777980	9.09%	11.62%	1.19%			25.08%			42.03%	x		25.08%		
1111	123.30	572382	717767	697734	780157	8.83%	11.38%	0.91%			24.87%			41.86%	x		24.87%		
1110	124.00	575647	721862	701714	784607	8.31%	10.87%	0.34%			24.44%			41.53%	x		24.44%		
823	123.54	573481	719145	699073	781654	8.66%	11.21%	0.72%			24.72%			41.75%	x		24.72%		
1114	123.83	574843	720853	700733	783511	8.44%	11.00%	0.48%			24.54%			41.61%	x		24.54%		
822	124.04	575806	722061	701908	784824	8.29%	10.85%	0.32%			24.42%			41.52%	x		24.42%		
1032	123.70	574229	720083	699985	782674	8.54%	11.09%	0.59%			24.62%			41.68%	x		24.62%		
826	123.85	574927	720959	700836	783626	8.43%	10.98%	0.47%			24.53%			41.61%	x		24.53%		
1040	123.59	573716	719440	699360	781975	8.62%	11.17%	0.68%			24.69%			41.73%	x		24.69%		
744	123.75	574451	720362	700256	782977	8.50%	11.06%	0.55%			24.60%			41.65%	x		24.60%		
752	123.61	573837	719591	699507	782139	8.60%	11.15%	0.66%			24.68%			41.72%	x		24.68%		
1106	124.91	579851	727133	706838	790337	7.64%	10.22%	-0.38%			23.89%			41.11%	x		23.89%		
827	123.29	572333	717705	697674	780089	8.84%	11.39%	0.92%			24.87%			41.87%	x		24.87%		
1021	124.36	577295	723928	703723	786854	8.05%	10.62%	0.06%			24.22%			41.36%	x		24.22%		
1141	124.10	576070	722391	702229	785183	8.25%	10.81%	0.27%			24.38%			41.49%	x		24.38%		
1022	124.59	578375	725282	705039	788325	7.88%	10.45%	-0.13%			24.08%			41.26%	x		24.08%		
1031	124.09	576062	722381	702219	785172	8.25%	10.81%	0.27%			24.38%			41.49%	x		24.38%		
1112	123.73	574364	720253	700150	782859	8.52%	11.07%	0.57%			24.61%			41.66%	x		24.61%		
1039	123.92	575234	721344	701211	784044	8.38%	10.94%	0.41%			24.49%			41.57%	x		24.49%		
734	124.66	578713	725706	705451	788786	7.82%	10.40%	-0.19%			24.04%			41.22%	x		24.04%		
733	124.52	578042	724864	704633	787871	7.93%	10.50%	-0.07%			24.12%			41.29%	x		24.12%		
1116	123.28	572276	717635	697605	780013	8.85%	11.39%	0.93%			24.88%			41.87%	x		24.88%		
824	124.05	575875	722147	701992	784918	8.28%	10.84%	0.30%			24.41%			41.51%	x		24.41%		
751	123.99	575601	721804	701658	784545	8.32%	10.88%	0.35%			24.44%			41.54%	x		24.44%		
1146	124.28	576915	723452	703260	786335	8.11%	10.68%	0.12%			24.27%			41.40%	x		24.27%		
1150	124.08	576017	722325	702165	785111	8.25%	10.81%	0.28%			24.39%			41.49%	x		24.39%		
1105	125.15	580958	728521	708188	791846	7.47%	10.05%	-0.58%			23.74%			40.99%	x		23.74%		
817	125.20	581180	728800	708459	792149	7.43%	10.02%	-0.61%			23.71%			40.97%	x		23.71%		
853	124.79	579314	726460	706184	789606	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		
1029	124.87	579669	726905	706616	790089	7.67%	10.25%	-0.35%			23.91%			41.12%	x		23.91%		
1069	125.04	580475	727916	707599	791188	7.54%	10.12%	-0.49%			23.80%			41.04%	x		23.80%		
741	124.88	579707	726953	706663	790141	7.67%	10.24%	-0.36%			23.91%			41.12%	x		23.91%		
1078	124.40	577491	724173	703961	787120	8.02%	10.59%	0.02%			24.20%			41.35%	x		24.20%		
1074	124.64	578615	725583	705331	788652	7.84%	10.41%	-0.17%			24.05%			41.23%	x		24.05%		
889	124.92	579902	727197	706901	790406	7.64%	10.21%	-0.39%			23.88%			41.10%	x		23.88%		
862	124.31	577066	723640	703443	786541	8.09%	10.65%	0.10%			24.25%			41.39%	x		24.25%		
1102	125.91	584487	732946	712489	796655	6.91%	9.50%	-1.19%			23.28%			40.63%	x		23.28%		
1013	125.33	581823	729607	709243	793025	7.33%	9.92%	-0.73%			23.63%			40.91%	x		23.63%		
1037	125.03	580392	727812	707498	791075	7.56%	10.14%	-0.48%			23.82%			41.05%	x		23.82%		
749	125.04	580440	727872	707557	791140	7.55%	10.13%	-0.49%			23.81%			41.05%	x		23.81%		
814	125.95	584682	733192	712728	796922	6.87%	9.47%	-1.22%			23.25%			40.61%	x		23.25%		
725	125.38	582019	729852	709482	793292	7.30%	9.89%	-0.76%			23.60%			40.89%	x		23.60%		
1014	125.58	582952	731022	710618	794563	7.15%	9.74%	-0.92%			23.48%			40.79%	x		23.48%		
726	125.59	583024	731113	710707	794662	7.14%	9.73%	-0.93%			23.47%			40.78%	x		23.47%		
1137	125.54	582759	730780	710383	794301	7.18%	9.77%	-0.89%			23.50%			40.81%	x		23.50%		
893	125.24	581366	729033	708685	792401	7.40%	9.99%	-0.65%			23.69%			40.95%	x		23.69%		
750	125.28	581560	729277	708922	792667	7.37%	9.96%	-0.68%			23.66%			40.93%	x		23.66%		
1038	125.28	581556	729271	708916	792660	7.37%	9.96%	-0.68%			23.66%			40.93%	x		23.66%		
1016	125.69	583459	731658	711237	795255	7.07%	9.66%	-1.01%			23.41%			40.74%	x		23.41%		
790	124.80	579341	726493	706216	789641	7.72%	10.30%	-0.30%			23.95%			41.16%	x		23.95%		
849	125.60	583079	731181	710774	794737	7.13%	9.72%	-0.94%			23.46%			40.78%	x		23.46%		
898	124.79	579317	726464	706188	789609	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		

Table 15. Annual carbon emission comparison for the east orientation in Phoenix, Arizona. Table continues on next page.

Phoenix East Annual Carbon Emission Comparison-Continued

	Whole Bldg		EPA Power Profiler (average 787,311 lbs CO_2)								Data Set (955,330 lbs CO_2)			CBECS (1,234,635 lbs CO_2)			Code Base (955,330 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	551,118 lbs	393,656 lbs	% Diff	668,731 lbs	497,665 lbs	% Diff	864,245 lbs	617,318 lbs	% Diff	908,480 lbs	648,914 lbs
894	125.09	580674	728166	707842	791459	7.51%	10.09%	-0.53%			23.78%			41.02%	x		23.78%		
728	125.75	583758	732032	711600	795661	7.02%	9.62%	-1.06%			23.37%			40.71%	x		23.37%		
897	125.41	582189	730065	709688	793524	7.27%	9.86%	-0.79%			23.58%			40.87%	x		23.58%		
781	125.55	582802	730833	710435	794359	7.17%	9.76%	-0.90%			23.50%			40.81%	x		23.50%		
885	125.82	584079	732435	711993	796100	6.97%	9.57%	-1.12%			23.33%			40.68%	x		23.33%		
609	125.49	582556	730525	710136	794024	7.21%	9.80%	-0.85%			23.53%			40.83%	x		23.53%		
1107	126.41	586814	735865	715326	799828	6.53%	9.14%	-1.59%			22.97%			40.40%	x		22.97%		
1065	125.98	584842	733392	712922	797140	6.85%	9.45%	-1.25%			23.23%			40.60%	x		23.23%		
777	126.13	585531	734256	713762	798079	6.74%	9.34%	-1.37%			23.14%			40.53%	x		23.14%		
1103	126.58	587593	736841	716275	800889	6.41%	9.02%	-1.72%			22.87%			40.32%	x		22.87%		
601	125.74	583689	731946	711516	795568	7.03%	9.63%	-1.05%			23.38%			40.72%	x		23.38%		
815	127.16	590279	740210	719550	804551	5.98%	8.61%	-2.19%			22.52%			40.05%	x		22.52%		
597	126.12	585463	734171	713680	797986	6.75%	9.35%	-1.36%			23.15%			40.54%	x		23.15%		
1075	125.62	583130	731245	710836	794806	7.12%	9.71%	-0.95%			23.46%			40.77%	x		23.46%		
1026	127.98	594113	745018	724224	809776	5.37%	8.01%	-2.85%			22.01%			39.66%	x		22.01%		
1025	136.55	633871	794874	772688	863966	-0.96%	1.86%	-9.74%			16.80%			35.62%	x		16.80%		
1020	135.19	627565	786966	765001	855371	0.04%	2.83%	-8.64%			17.62%			36.26%	x		17.62%		
1108	145.18	673971	845159	821570	918622	-7.35%	-4.35%	-16.68%			11.53%			31.55%	x		11.53%		
1080	138.73	644002	807578	785038	877774	-2.57%	0.29%	-11.49%			15.47%			34.59%	x		15.47%		
1019	135.34	628251	787827	765838	856306	-0.07%	2.73%	-8.76%			17.53%			36.19%	x		17.53%		
1143	167.99	779836	977914	950620	1062916	-24.21%	-20.74%	-35.01%			-2.36%			20.79%			-2.36%		
1140	166.99	775193	972092	944960	1056588	-23.47%	-20.02%	-34.20%			-1.75%			21.26%			-1.75%		
891	130.70	606733	760843	739607	826977	3.36%	6.06%	-5.04%			20.36%			38.38%	x		20.36%		
888	131.37	609853	764756	743411	831230	2.86%	5.58%	-5.58%			19.95%			38.06%	x		19.95%		

Table 15 continued.

Phoenix South Annual Carbon Emission Comparison

Window	Whole Bldg kBtu/sf	kWh	EPA Power Profiler (average 787,311 lbs CO_2) Averages (lbs CO_2) Office	State	National	% Diff from Average Office	State	National	30% Target 551,118 lbs	50% Target 393,656 lbs	Data Set (955,330 lbs CO_2) % Diff	30% Target 668,731 lbs	50% Target 497,665 lbs	CBECS (1,234,635 lbs CO_2) % Diff	30% Target 864,245 lbs	50% Target 617,318 lbs	Code Base (955,330 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs
1111	123.30	572382	717767	697734	780157	8.83%	11.38%	0.91%			24.87%			41.86%	x		24.87%		
823	123.54	573481	719145	699073	781654	8.66%	11.21%	0.72%			24.72%			41.75%	x		24.72%		
1115	122.96	570785	715764	695787	777980	9.09%	11.62%	1.19%			25.08%			42.03%	x		25.08%		
827	123.29	572333	717705	697674	780089	8.84%	11.39%	0.92%			24.87%			41.87%	x		24.87%		
1112	123.73	574364	720253	700150	782859	8.52%	11.07%	0.57%			24.61%			41.66%	x		24.61%		
824	124.05	575875	722147	701992	784918	8.28%	10.84%	0.30%			24.41%			41.51%	x		24.41%		
828	124.26	576844	723362	703173	786238	8.12%	10.69%	0.14%			24.28%			41.41%	x		24.28%		
1116	123.28	572276	717635	697605	780013	8.85%	11.39%	0.93%			24.88%			41.87%	x		24.88%		
1032	123.70	574229	720083	699985	782674	8.54%	11.09%	0.59%			24.62%			41.68%	x		24.62%		
744	123.75	574451	720362	700256	782977	8.50%	11.06%	0.55%			24.60%			41.65%	x		24.60%		
1106	124.91	579851	727133	706838	790337	7.64%	10.22%	-0.38%			23.89%			41.11%	x		23.89%		
1110	124.00	575647	721862	701714	784607	8.31%	10.87%	0.34%			24.44%			41.53%	x		24.44%		
822	124.04	575806	722061	701908	784824	8.29%	10.85%	0.32%			24.42%			41.52%	x		24.42%		
1040	123.59	573716	719440	699360	781975	8.62%	11.17%	0.68%			24.69%			41.73%	x		24.69%		
752	123.61	573837	719591	699507	782139	8.60%	11.15%	0.66%			24.68%			41.72%	x		24.68%		
818	125.23	581362	729027	708680	792396	7.40%	9.99%	-0.65%			23.69%			40.95%	x		23.69%		
1114	123.83	574843	720853	700733	783511	8.44%	11.00%	0.48%			24.54%			41.61%	x		24.54%		
826	123.85	574927	720959	700836	783626	8.43%	10.98%	0.47%			24.53%			41.61%	x		24.53%		
1021	124.36	577295	723928	703723	786854	8.05%	10.62%	0.06%			24.22%			41.36%	x		24.22%		
733	124.52	578042	724864	704633	787871	7.93%	10.50%	-0.07%			24.12%			41.29%	x		24.12%		
1031	124.09	576062	722381	702219	785172	8.25%	10.81%	0.27%			24.38%			41.49%	x		24.38%		
743	124.18	576485	722912	702735	785749	8.18%	10.74%	0.20%			24.33%			41.45%	x		24.33%		
1039	123.92	575234	721344	701211	784044	8.38%	10.94%	0.41%			24.49%			41.57%	x		24.49%		
751	123.99	575601	721804	701658	784545	8.32%	10.88%	0.35%			24.44%			41.54%	x		24.44%		
1141	124.47	577826	724594	704370	787577	7.97%	10.53%	-0.03%			24.15%			41.31%	x		24.15%		
734	124.66	578713	725706	705451	788786	7.82%	10.40%	-0.19%			24.04%			41.22%	x		24.04%		
1022	124.59	578375	725282	705039	788325	7.88%	10.45%	-0.13%			24.08%			41.26%	x		24.08%		
1042	123.39	572785	718272	698224	780705	8.77%	11.32%	0.84%			24.81%			41.82%	x		24.81%		
754	123.70	574251	720111	700012	782704	8.54%	11.09%	0.59%			24.62%			41.67%	x		24.62%		
1102	125.91	584487	732946	712489	796655	6.91%	9.50%	-1.19%			23.28%			40.63%	x		23.28%		
814	125.95	584682	733192	712728	796922	6.87%	9.47%	-1.22%			23.25%			40.61%	x		23.25%		
1034	123.79	574648	720608	700495	783245	8.47%	11.03%	0.52%			24.57%			41.63%	x		24.57%		
853	124.79	579314	726460	706184	789606	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		
746	124.13	576235	722599	702431	785409	8.22%	10.78%	0.24%			24.36%			41.47%	x		24.36%		
1146	124.28	576915	723452	703260	786335	8.11%	10.68%	0.12%			24.27%			41.40%	x		24.27%		
1150	124.08	576017	722325	702165	785111	8.25%	10.81%	0.28%			24.39%			41.49%	x		24.39%		
1016	125.69	583459	731658	711237	795255	7.07%	9.66%	-1.01%			23.41%			40.74%	x		23.41%		
728	125.75	583758	732032	711600	795661	7.02%	9.62%	-1.06%			23.37%			40.71%	x		23.37%		
1069	125.04	580475	727916	707599	791188	7.54%	10.12%	-0.49%			23.80%			41.04%	x		23.80%		
1078	124.40	577491	724173	703961	787120	8.02%	10.59%	0.02%			24.20%			41.35%	x		24.20%		
862	124.31	577066	723640	703443	786541	8.09%	10.65%	0.10%			24.25%			41.39%	x		24.25%		
1074	124.64	578615	725583	705331	788652	7.84%	10.41%	-0.17%			24.05%			41.23%	x		24.05%		
1103	126.58	587593	736841	716275	800889	6.41%	9.02%	-1.72%			22.87%			40.32%	x		22.87%		
817	125.20	581180	728800	708459	792149	7.43%	10.02%	-0.61%			23.71%			40.97%	x		23.71%		
815	127.16	590279	740210	719550	804551	5.98%	8.61%	-2.19%			22.52%			40.05%	x		22.52%		
858	124.59	578385	725295	705052	788339	7.88%	10.45%	-0.13%			24.08%			41.25%	x		24.08%		
1105	125.15	580958	728521	708188	791846	7.47%	10.05%	-0.58%			23.74%			40.99%	x		23.74%		
1107	126.41	586814	735865	715326	799828	6.53%	9.14%	-1.59%			22.97%			40.40%	x		22.97%		
725	125.38	582019	729852	709482	793292	7.30%	9.89%	-0.76%			23.60%			40.89%	x		23.60%		
741	124.88	579707	726953	706663	790141	7.67%	10.24%	-0.36%			23.91%			41.12%	x		23.91%		
1013	125.33	581823	729607	709243	793025	7.33%	9.92%	-0.73%			23.63%			40.91%	x		23.63%		
1029	124.87	579669	726905	706616	790089	7.67%	10.25%	-0.35%			23.91%			41.12%	x		23.91%		

Table 16. Annual carbon emission comparison for the south orientation in Phoenix, Arizona. Table continues on next page.

Phoenix South Annual Carbon Emission Comparison-Continued

	Whole Bldg		**EPA Power Profiler** (average 787,311 lbs CO_2)								**Data Set** (955,330 lbs CO_2)			**CBECS** (1,234,635 lbs CO_2)			**Code Base** (955,330 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	551,118 lbs	393,656 lbs	% Diff	668,731 lbs	497,665 lbs	% Diff	864,245 lbs	617,318 lbs	% Diff	908,480 lbs	648,914 lbs
819	127.69	592768	743332	722585	807943	5.59%	8.22%	-2.62%			22.19%			39.79%	x		22.19%		
889	124.92	579902	727197	706901	790406	7.64%	10.21%	-0.39%			23.88%			41.10%	x		23.88%		
781	125.55	582802	730833	710435	794359	7.17%	9.76%	-0.90%			23.50%			40.81%	x		23.50%		
786	125.10	580740	728248	707922	791548	7.50%	10.08%	-0.54%			23.77%			41.02%	x		23.77%		
1137	125.54	582759	730780	710383	794301	7.18%	9.77%	-0.89%			23.50%			40.81%	x		23.50%		
849	125.60	583079	731181	710774	794737	7.13%	9.72%	-0.94%			23.46%			40.78%	x		23.46%		
790	124.80	579341	726493	706216	789641	7.72%	10.30%	-0.30%			23.95%			41.16%	x		23.95%		
749	125.04	580440	727872	707557	791140	7.55%	10.13%	-0.49%			23.81%			41.05%	x		23.81%		
1037	125.03	580392	727812	707498	791075	7.56%	10.14%	-0.48%			23.82%			41.05%	x		23.82%		
1033	124.33	577139	723733	703533	786641	8.08%	10.64%	0.09%			24.24%			41.38%	x		24.24%		
893	125.24	581366	729033	708685	792401	7.40%	9.99%	-0.65%			23.69%			40.95%	x		23.69%		
605	125.38	582022	729855	709484	793295	7.30%	9.89%	-0.76%			23.60%			40.88%	x		23.60%		
1065	125.98	584842	733392	712922	797140	6.85%	9.45%	-1.25%			23.23%			40.60%	x		23.23%		
745	125.16	580997	728570	708235	791899	7.46%	10.04%	-0.58%			23.74%			40.99%	x		23.74%		
777	126.13	585531	734256	713762	798079	6.74%	9.34%	-1.37%			23.14%			40.53%	x		23.14%		
885	125.82	584079	732435	711993	796100	6.97%	9.57%	-1.12%			23.33%			40.68%	x		23.33%		
898	124.79	579317	726464	706188	789609	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		
609	125.49	582556	730525	710136	794024	7.21%	9.80%	-0.85%			23.53%			40.83%	x		23.53%		
897	125.41	582189	730065	709688	793524	7.27%	9.86%	-0.79%			23.58%			40.87%	x		23.58%		
601	125.74	583689	731946	711516	795568	7.03%	9.63%	-1.05%			23.38%			40.72%	x		23.38%		
894	125.09	580674	728166	707842	791459	7.51%	10.09%	-0.53%			23.78%			41.02%	x		23.78%		
597	126.12	585463	734171	713680	797986	6.75%	9.35%	-1.36%			23.15%			40.54%	x		23.15%		
816	129.96	603282	756516	735401	822274	3.91%	6.59%	-4.44%			20.81%			38.73%	x		20.81%		
1104	129.03	598975	751114	730150	816403	4.60%	7.26%	-3.70%			21.38%			39.16%	x		21.38%		
1108	129.06	599095	751265	730297	816566	4.58%	7.24%	-3.72%			21.36%			39.15%	x		21.36%		
756	125.83	584133	732503	712058	796173	6.96%	9.56%	-1.13%			23.32%			40.67%	x		23.32%		
1147	125.07	580597	728069	707748	791354	7.52%	10.11%	-0.51%			23.79%			41.03%	x		23.79%		
1044	124.40	577470	724147	703936	787092	8.02%	10.59%	0.03%			24.20%			41.35%	x		24.20%		
1036	125.11	580801	728324	707996	791631	7.49%	10.07%	-0.55%			23.76%			41.01%	x		23.76%		
748	125.99	584874	733433	712962	797184	6.84%	9.44%	-1.25%			23.23%			40.60%	x		23.23%		
1075	125.62	583130	731245	710836	794806	7.12%	9.71%	-0.95%			23.46%			40.77%	x		23.46%		
1035	125.83	584139	732511	712066	796182	6.96%	9.56%	-1.13%			23.32%			40.67%	x		23.32%		
895	126.61	587745	737032	716461	801096	6.39%	9.00%	-1.75%			22.85%			40.30%	x		22.85%		
1076	127.66	592619	743144	722403	807740	5.61%	8.24%	-2.59%			22.21%			39.81%	x		22.21%		
1148	127.00	589555	739302	718668	803564	6.10%	8.72%	-2.06%			22.61%			40.12%	x		22.61%		
896	129.16	599582	751876	730891	817231	4.50%	7.17%	-3.80%			21.30%			39.10%	x		21.30%		

Table 16 continued.

Phoenix West Annual Carbon Emission Comparison

	Whole Bldg		EPA Power Profiler (average 787,311 lbs CO_2)								Data Set (955,330 lbs CO_2)			CBECS (1,234,635 lbs CO_2)			Code Base (955,330 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	551,118 lbs	393,656 lbs	% Diff	668,731 lbs	497,665 lbs	% Diff	864,245 lbs	617,318 lbs	% Diff	908,480 lbs	648,914 lbs
1115	122.96	570785	715764	695787	777980	9.09%	11.62%	1.19%			25.08%			42.03%	x		25.08%		
1111	123.30	572382	717767	697734	780157	8.83%	11.38%	0.91%			24.87%			41.86%	x		24.87%		
1042	123.39	572785	718272	698224	780705	8.77%	11.32%	0.84%			24.81%			41.82%	x		24.81%		
1116	123.28	572276	717635	697605	780013	8.85%	11.39%	0.93%			24.88%			41.87%	x		24.88%		
1034	123.79	574648	720608	700495	783245	8.47%	11.03%	0.52%			24.57%			41.63%	x		24.57%		
1112	123.73	574364	720253	700150	782859	8.52%	11.07%	0.57%			24.61%			41.66%	x		24.61%		
1032	123.70	574229	720083	699985	782674	8.54%	11.09%	0.59%			24.62%			41.68%	x		24.62%		
1110	124.00	575647	721862	701714	784607	8.31%	10.87%	0.34%			24.44%			41.53%	x		24.44%		
1040	123.59	573716	719440	699360	781975	8.62%	11.17%	0.68%			24.69%			41.73%	x		24.69%		
744	123.75	574451	720362	700256	782977	8.50%	11.06%	0.55%			24.60%			41.65%	x		24.60%		
822	124.04	575806	722061	701908	784824	8.29%	10.85%	0.32%			24.42%			41.52%	x		24.42%		
1114	123.83	574843	720853	700733	783511	8.44%	11.00%	0.48%			24.54%			41.61%	x		24.54%		
752	123.61	573837	719591	699507	782139	8.60%	11.15%	0.66%			24.68%			41.72%	x		24.68%		
826	123.85	574927	720959	700836	783626	8.43%	10.98%	0.47%			24.53%			41.61%	x		24.53%		
1041	124.10	576070	722391	702229	785183	8.25%	10.81%	0.27%			24.38%			41.49%	x		24.38%		
1106	124.91	579851	727133	706838	790337	7.64%	10.22%	-0.38%			23.89%			41.11%	x		23.89%		
1021	124.36	577295	723928	703723	786854	8.05%	10.62%	0.06%			24.22%			41.36%	x		24.22%		
1141	124.47	577826	724594	704370	787577	7.97%	10.53%	-0.03%			24.15%			41.31%	x		24.15%		
1031	124.09	576062	722381	702219	785172	8.25%	10.81%	0.27%			24.38%			41.49%	x		24.38%		
1039	123.92	575234	721344	701211	784044	8.38%	10.94%	0.41%			24.49%			41.57%	x		24.49%		
1022	124.59	578375	725282	705039	788325	7.88%	10.45%	-0.13%			24.08%			41.26%	x		24.08%		
1033	124.33	577139	723733	703533	786641	8.08%	10.64%	0.09%			24.24%			41.38%	x		24.24%		
743	124.18	576485	722912	702735	785749	8.18%	10.74%	0.20%			24.33%			41.45%	x		24.33%		
1150	124.08	576017	722325	702165	785111	8.25%	10.81%	0.28%			24.39%			41.49%	x		24.39%		
733	124.52	578042	724864	704633	787871	7.93%	10.50%	-0.07%			24.12%			41.29%	x		24.12%		
734	124.66	578713	725706	705451	788786	7.82%	10.40%	-0.19%			24.04%			41.22%	x		24.04%		
1146	124.28	576915	723452	703260	786335	8.11%	10.68%	0.12%			24.27%			41.40%	x		24.27%		
1151	125.63	583172	731298	710887	794864	7.11%	9.71%	-0.96%			23.45%			40.77%	x		23.45%		
1024	125.18	581115	728718	708379	792059	7.44%	10.03%	-0.60%			23.72%			40.98%	x		23.72%		
1105	125.15	580958	728521	708188	791846	7.47%	10.05%	-0.58%			23.74%			40.99%	x		23.74%		
1078	124.40	577491	724173	703961	787120	8.02%	10.59%	0.02%			24.20%			41.35%	x		24.20%		
1069	125.04	580475	727916	707599	791188	7.54%	10.12%	-0.49%			23.80%			41.04%	x		23.80%		
889	124.92	579902	727197	706901	790406	7.64%	10.21%	-0.39%			23.88%			41.10%	x		23.88%		
1074	124.64	578615	725583	705331	788652	7.84%	10.41%	-0.17%			24.05%			41.23%	x		24.05%		
1079	128.20	595138	746304	725474	811174	5.21%	7.85%	-3.03%			21.88%			39.55%	x		21.88%		
1029	124.87	579669	726905	706616	790089	7.67%	10.25%	-0.35%			23.91%			41.12%	x		23.91%		
741	124.88	579707	726953	706663	790141	7.67%	10.24%	-0.36%			23.91%			41.12%	x		23.91%		
1145	125.07	580579	728047	707726	791330	7.53%	10.11%	-0.51%			23.79%			41.03%	x		23.79%		
857	125.08	580643	728126	707803	791416	7.52%	10.10%	-0.52%			23.78%			41.03%	x		23.78%		
1102	125.91	584487	732946	712489	796655	6.91%	9.50%	-1.19%			23.28%			40.63%	x		23.28%		
814	125.95	584682	733192	712728	796922	6.87%	9.47%	-1.22%			23.25%			40.61%	x		23.25%		
1013	125.33	581823	729607	709243	793025	7.33%	9.92%	-0.73%			23.63%			40.91%	x		23.63%		
1107	126.41	586814	735865	715326	799828	6.53%	9.14%	-1.59%			22.97%			40.40%	x		22.97%		
898	124.79	579317	726464	706188	789609	7.73%	10.30%	-0.29%			23.96%			41.16%	x		23.96%		
1037	125.03	580392	727812	707498	791075	7.56%	10.14%	-0.48%			23.82%			41.05%	x		23.82%		
749	125.04	580440	727872	707557	791140	7.55%	10.13%	-0.49%			23.81%			41.05%	x		23.81%		
1044	124.40	577470	724147	703936	787092	8.02%	10.59%	0.03%			24.20%			41.35%	x		24.20%		
1103	126.58	587593	736841	716275	800889	6.41%	9.02%	-1.72%			22.87%			40.32%	x		22.87%		
725	125.38	582019	729852	709482	793292	7.30%	9.89%	-0.76%			23.60%			40.89%	x		23.60%		
1137	125.54	582759	730780	710383	794301	7.18%	9.77%	-0.89%			23.50%			40.81%	x		23.50%		
893	125.24	581366	729033	708685	792401	7.40%	9.99%	-0.65%			23.69%			40.95%	x		23.69%		
1016	125.69	583459	731658	711237	795255	7.07%	9.66%	-1.01%			23.41%			40.74%	x		23.41%		

Table 17. Annual carbon emission comparison for the west orientation in Phoenix, Arizona. Table continues on next page.

Phoenix West Annual Carbon Emission Comparison-Continued

	Whole Bldg		EPA Power Profiler (average 787,311 lbs CO_2)								Data Set (955,330 lbs CO_2)			CBECS (1,234,635 lbs CO_2)			Code Base (955,330 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	551,118 lbs	393,656 lbs	% Diff	668,731 lbs	497,665 lbs	% Diff	864,245 lbs	617,318 lbs	% Diff	908,480 lbs	648,914 lbs
894	125.09	580674	728166	707842	791459	7.51%	10.09%	-0.53%			23.78%			41.02%	x		23.78%		
1149	125.23	581347	729009	708662	792376	7.41%	9.99%	-0.64%			23.69%			40.95%	x		23.69%		
861	125.24	581375	729044	708696	792414	7.40%	9.99%	-0.65%			23.69%			40.95%	x		23.69%		
1014	125.58	582952	731022	710618	794563	7.15%	9.74%	-0.92%			23.48%			40.79%	x		23.48%		
849	125.60	583079	731181	710774	794737	7.13%	9.72%	-0.94%			23.46%			40.78%	x		23.46%		
728	125.75	583758	732032	711600	795661	7.02%	9.62%	-1.06%			23.37%			40.71%	x		23.37%		
726	125.59	583024	731113	710707	794662	7.14%	9.73%	-0.93%			23.47%			40.78%	x		23.47%		
781	125.55	582802	730833	710435	794359	7.17%	9.76%	-0.90%			23.50%			40.81%	x		23.50%		
605	125.38	582022	729855	709484	793295	7.30%	9.89%	-0.76%			23.60%			40.88%	x		23.60%		
897	125.41	582189	730065	709688	793524	7.27%	9.86%	-0.79%			23.58%			40.87%	x		23.58%		
885	125.82	584079	732435	711993	796100	6.97%	9.57%	-1.12%			23.33%			40.68%	x		23.33%		
1065	125.98	584842	733392	712922	797140	6.85%	9.45%	-1.25%			23.23%			40.60%	x		23.23%		
1043	125.47	582456	730400	710014	793887	7.23%	9.82%	-0.84%			23.54%			40.84%	x		23.54%		
601	125.74	583689	731946	711516	795568	7.03%	9.63%	-1.05%			23.38%			40.72%	x		23.38%		
777	126.13	585531	734256	713762	798079	6.74%	9.34%	-1.37%			23.14%			40.53%	x		23.14%		
1035	125.83	584139	732511	712066	796182	6.96%	9.56%	-1.13%			23.32%			40.67%	x		23.32%		
597	126.12	585463	734171	713680	797986	6.75%	9.35%	-1.36%			23.15%			40.54%	x		23.15%		
1080	127.48	591776	742087	721375	806591	5.74%	8.37%	-2.45%			22.32%			39.89%	x		22.32%		
899	129.86	602830	755949	734850	821657	3.98%	6.66%	-4.36%			20.87%			38.77%	x		20.87%		
895	126.61	587741	737027	716456	801091	6.39%	9.00%	-1.75%			22.85%			40.30%	x		22.85%		
1152	127.08	589948	739794	719146	804099	6.04%	8.66%	-2.13%			22.56%			40.08%	x		22.56%		
1148	127.00	589550	739295	718661	803556	6.10%	8.72%	-2.06%			22.61%			40.12%	x		22.61%		
1104	129.03	598975	751114	730150	816403	4.60%	7.26%	-3.70%			21.38%			39.16%	x		21.38%		
1108	129.06	599095	751265	730297	816566	4.58%	7.24%	-3.72%			21.36%			39.15%	x		21.36%		
896	129.16	599563	751852	730867	817204	4.50%	7.17%	-3.80%			21.30%			39.10%	x		21.30%		

Table 17 oontinued.

Carbon Comparison in Minneapolis, Minnesota

For all orientations in Minneapolis, the carbon emissions reduction based on the EPA Power Profiler typically ranged between 5–11% compared to a regional office building, 13–22% for an average state building, and 25–33% of the national average. The carbon emission reduction of the existing data set and code base typically ranged between 12–22% of the average of each. The carbon emission reduction as compared to the CBECS database typically ranged between 40–48% of the average.

Minneapolis, Minnesota: Carbon Summary for North Orientation

Table 18 shows the annual carbon emission comparison for the north orientation in Minneapolis. As compared to the average emissions of a 48,000 square foot office building (1,138,902 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed 2.78–22.21% better than the baseline (1,297,828 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 34.47–47.57% better than the regional CBECS average (1,925,605 lbs CO_2). All design options meet the 30% performance target). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 2.78–22.21% better than the budget building (1,297,828 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Minneapolis, Minnesota: Carbon Summary for East Orientation

Table 19 shows the annual carbon emission comparison for the east orientation in Minneapolis. As compared to the average emissions of a 48,000 square foot office building (1,138,902 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed 3.91–22.21% better than the baseline (1,297,828 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 35.23–47.57% better than the regional CBECS average (1,925,605 lbs CO_2). All design options meet the 30% performance target). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 3.91–22.21% better than the budget building (1,297,828 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Minneapolis, Minnesota: Carbon Summary for South Orientation
Table 20 shows the annual carbon emission comparison for the south orientation in Minneapolis. As compared to the average emissions of a 48,000 square foot office building (1,138,902 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed 9.86–22.21% better than the baseline (1,297,828 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 39.24–47.57% better than the regional CBECS average (1,925,605 lbs CO_2). All design options meet the 30% performance target). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 9.86–22.21% better than the budget building (1,297,828 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Minneapolis, Minnesota: Carbon Summary for West Orientation
Table 21 shows the annual carbon emission comparison for the west orientation in Minneapolis. As compared to the average emissions of a 48,000 square foot office building (1,138,902 lbs CO_2) determined from the EPA's Power Profiler, none of the window design options meet the 30% and 50% reduction targets.

As compared to the existing data set, the top performing design options performed 10.66–22.21% better than the baseline (1,297,828 lbs CO_2). None of the window design options meet the 30% and 50% reduction targets.

As compared to the CBECS database, the top performing design options performed 39.79–47.57% better than the regional CBECS average (1,925,605 lbs CO_2). All design options meet the 30% performance target). No design options meet the 50% performance target.

As compared to the ASHRAE 90.1-99, the top performing design options performed 10.66–22.21% better than the budget building (1,297,828 lb_s CO2). None of the window design options meet the 30% and 50% reduction targets.

Minneapolis North Annual Carbon Emission Comparison

	Whole Bldg		EPA Power Profiler (average 1,138,902 lbs CO_2)								Data Set (1,297,828 lbs CO_2)			CBECS (1,925,605 lbs CO_2)			Code Base (1,297,828 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	797,231 lbs	569,451 lbs	% Diff	908,480 lbs	648,914 lbs	% Diff	1,347,924 lbs	962,803 lbs	% Diff	908,480 lbs	648,914 lbs
612	136.74	634777	1151486	1008026	865201	-1.10%	11.49%	24.03%			11.28%			40.20%	x		11.28%		
900	129.89	602975	1093796	957524	821854	3.96%	15.93%	27.84%			15.72%			43.20%	x		15.72%		
611	127.58	592251	1074343	940494	807238	5.67%	17.42%	29.12%			17.22%			44.21%	x		17.22%		
864	133.12	617967	1120993	981332	842290	1.57%	13.84%	26.04%			13.63%			41.78%	x		13.63%		
899	123.33	572519	1038550	909160	780344	8.81%	20.17%	31.48%			19.98%			46.07%	x		19.98%		
1152	125.01	580307	1052676	921527	790958	7.57%	19.09%	30.55%			18.89%			45.33%	x		18.89%		
792	135.89	630820	1144307	1001742	859808	-0.47%	12.04%	24.51%			11.83%			40.57%	x		11.83%		
755	128.52	596610	1082250	947417	813179	4.97%	16.81%	28.60%			16.61%			43.80%	x		16.61%		
1080	127.31	591002	1072077	938511	805535	5.87%	17.60%	29.27%			17.39%			44.33%	x		17.39%		
1043	122.15	567059	1028645	900490	772901	9.68%	20.93%	32.14%			20.74%			46.58%	x		20.74%		
607	121.93	566012	1026745	898826	771474	9.85%	21.08%	32.26%			20.89%			46.68%	x		20.89%		
863	124.72	578956	1050227	919382	789117	7.79%	19.27%	30.71%			19.08%			45.46%	x		19.08%		
895	120.97	561556	1018663	891751	765401	10.56%	21.70%	32.79%			21.51%			47.10%	x		21.51%		
608	126.94	589288	1068968	935789	803199	6.14%	17.83%	29.48%			17.63%			44.49%	x		17.63%		
1151	121.82	565511	1025838	898032	770792	9.93%	21.15%	32.32%			20.96%			46.73%	x		20.96%		
756	125.27	581520	1054877	923454	792612	7.38%	18.92%	30.41%			18.72%			45.22%	x		18.72%		
1044	120.58	559769	1015420	888912	762964	10.84%	21.95%	33.01%			21.76%			47.27%	x		21.76%		
896	122.78	569958	1033903	905093	776852	9.22%	20.53%	31.79%			20.34%			46.31%	x		20.34%		
860	125.47	582467	1056594	924957	793902	7.23%	18.79%	30.29%			18.59%			45.13%	x		18.59%		
1148	122.12	566882	1028323	900208	772659	9.71%	20.96%	32.16%			20.77%			46.60%	x		20.77%		
791	127.15	590261	1070734	937335	804526	5.99%	17.70%	29.36%			17.50%			44.39%	x		17.50%		
753	122.24	567451	1029356	901113	773436	9.62%	20.88%	32.09%			20.69%			46.54%	x		20.69%		
1079	122.80	570040	1034053	905224	776965	9.21%	20.52%	31.78%			20.32%			46.30%	x		20.32%		
1041	120.46	559198	1014385	888007	762187	10.93%	22.03%	33.08%			21.84%			47.32%	x		21.84%		
788	127.42	591499	1072980	939301	806214	5.79%	17.53%	29.21%			17.32%			44.28%	x		17.32%		
1076	123.46	573134	1039664	910136	781181	8.71%	20.09%	31.41%			19.89%			46.01%	x		19.89%		
747	122.80	570048	1034067	905236	776976	9.20%	20.52%	31.78%			20.32%			46.30%	x		20.32%		
1035	121.66	564771	1024494	896856	769783	10.05%	21.25%	32.41%			21.06%			46.80%	x		21.06%		
754	121.03	561838	1019175	892199	765786	10.51%	21.66%	32.76%			21.47%			47.07%	x		21.47%		
1042	120.35	558674	1013435	887174	761473	11.02%	22.10%	33.14%			21.91%			47.37%	x		21.91%		
745	121.14	562354	1020110	893018	766489	10.43%	21.59%	32.70%			21.40%			47.02%	x		21.40%		
748	121.81	565470	1025763	897967	770736	9.93%	21.16%	32.33%			20.96%			46.73%	x		20.96%		
787	122.77	569896	1033791	904995	776768	9.23%	20.54%	31.80%			20.34%			46.31%	x		20.34%		
1036	121.80	565419	1025670	897885	770666	9.94%	21.16%	32.33%			20.97%			46.74%	x		20.97%		
1033	121.40	563569	1022314	894948	768145	10.24%	21.42%	32.55%			21.23%			46.91%	x		21.23%		
1075	122.28	567637	1029693	901407	773689	9.59%	20.85%	32.07%			20.66%			46.53%	x		20.66%		
610	120.48	559293	1014557	888157	762316	10.92%	22.02%	33.07%			21.83%			47.31%	x		21.83%		
898	119.89	556534	1009553	883776	758556	11.36%	22.40%	33.40%			22.21%			47.57%	x		22.21%		
606	120.55	559615	1015141	888668	762755	10.87%	21.97%	33.03%			21.78%			47.28%	x		21.78%		
894	120.79	560750	1017201	890471	764303	10.69%	21.81%	32.89%			21.62%			47.17%	x		21.62%		
828	126.34	586481	1063876	931332	799373	6.59%	18.23%	29.81%			18.03%			44.75%	x		18.03%		
1116	123.74	574442	1042037	912213	782964	8.51%	19.90%	31.25%			19.71%			45.89%	x		19.71%		
862	120.62	559925	1015704	889161	763178	10.82%	21.93%	32.99%			21.74%			47.25%	x		21.74%		
1150	120.76	560605	1016938	890241	764105	10.71%	21.83%	32.91%			21.64%			47.19%	x		21.64%		
858	121.55	564269	1023584	896059	769099	10.13%	21.32%	32.47%			21.13%			46.84%	x		21.13%		
1146	121.74	565124	1025135	897417	770264	9.99%	21.20%	32.37%			21.01%			46.76%	x		21.01%		
790	121.30	563110	1021481	894218	767518	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
1078	121.42	563659	1022477	895090	768267	10.22%	21.41%	32.54%			21.22%			46.90%	x		21.22%		
824	124.23	576684	1046105	915774	786020	8.15%	19.59%	30.98%			19.40%			45.67%	x		19.40%		
1112	124.24	576744	1046214	915870	786102	8.14%	19.58%	30.98%			19.39%			45.67%	x		19.39%		
1115	122.48	568555	1031359	902865	774941	9.44%	20.72%	31.96%			20.53%			46.44%	x		20.53%		
827	122.87	570401	1034707	905796	777456	9.15%	20.47%	31.74%			20.27%			46.27%	x		20.27%		
786	122.28	567628	1029678	901394	773677	9.59%	20.85%	32.07%			20.66%			46.53%	x		20.66%		
1074	122.43	568340	1030969	902524	774647	9.48%	20.75%	31.98%			20.56%			46.46%	x		20.56%		

Table 18. Annual carbon emission comparison for the north orientation in Minneapolis, Minnesota. Table continues on next page.

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Minneapolis North Annual Carbon Emission Comparison-Continued

	Whole Bldg		EPA Power Profiler (average 1,138,902 lbs CO_2)								Data Set (1,297,828 lbs CO_2)			CBECS (1,925,605 lbs CO_2)			Code Base (1,297,828 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	797,231 lbs	569,451 lbs	% Diff	908,480 lbs	648,914 lbs	% Diff	1,347,924 lbs	962,803 lbs	% Diff	908,480 lbs	648,914 lbs
751	120.73	560438	1016635	889976	763877	10.74%	21.86%	32.93%			21.67%			47.20%	x		21.67%		
1039	120.88	561150	1017925	891105	764847	10.62%	21.76%	32.84%			21.57%			47.14%	x		21.57%		
743	121.60	564505	1024012	896434	769420	10.09%	21.29%	32.44%			21.10%			46.82%	x		21.10%		
1031	121.81	565457	1025739	897946	770718	9.94%	21.16%	32.33%			20.96%			46.73%	x		20.96%		
752	121.25	562840	1020991	893789	767150	10.35%	21.52%	32.64%			21.33%			46.98%	x		21.33%		
1040	121.30	563107	1021476	894214	767515	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
744	122.16	567065	1028656	900499	772909	9.68%	20.93%	32.14%			20.74%			46.58%	x		20.74%		
1032	122.27	567582	1029594	901321	773615	9.60%	20.86%	32.07%			20.67%			46.53%	x		20.67%		
601	122.69	569539	1033143	904427	776281	9.29%	20.59%	31.84%			20.39%			46.35%	x		20.39%		
889	123.29	572352	1038246	908894	780115	8.84%	20.20%	31.50%			20.00%			46.08%	x		20.00%		
602	128.39	596025	1081189	946487	812382	5.07%	16.89%	28.67%			16.69%			43.85%	x		16.69%		
605	121.03	561821	1019142	892171	765761	10.52%	21.66%	32.76%			21.47%			47.07%	x		21.47%		
893	121.32	563165	1021582	894306	767594	10.30%	21.48%	32.60%			21.29%			46.95%	x		21.29%		
890	127.68	592713	1075181	941228	807868	5.59%	17.36%	29.07%			17.16%			44.16%	x		17.16%		
826	123.08	571378	1036479	907348	778788	8.99%	20.33%	31.62%			20.14%			46.17%	x		20.14%		
1114	123.11	571514	1036726	907564	778973	8.97%	20.31%	31.60%			20.12%			46.16%	x		20.12%		
609	120.99	561654	1018840	891906	765534	10.54%	21.69%	32.78%			21.50%			47.09%	x		21.50%		
897	121.21	562661	1020666	893505	766906	10.38%	21.55%	32.66%			21.36%			47.00%	x		21.36%		
853	124.18	576466	1045709	915428	785723	8.18%	19.62%	31.01%			19.43%			45.69%	x		19.43%		
1141	124.60	578420	1049254	918531	788386	7.87%	19.35%	30.78%			19.15%			45.51%	x		19.15%		
733	123.89	575126	1043278	913300	783896	8.40%	19.81%	31.17%			19.61%			45.82%	x		19.61%		
1021	124.38	577382	1047372	916883	786972	8.04%	19.49%	30.90%			19.30%			45.61%	x		19.30%		
822	124.16	576394	1045578	915313	785624	8.19%	19.63%	31.02%			19.44%			45.70%	x		19.44%		
1110	124.22	576659	1046060	915735	785986	8.15%	19.59%	30.99%			19.40%			45.68%	x		19.40%		
857	122.21	567338	1029152	900933	773282	9.64%	20.89%	32.10%			20.70%			46.55%	x		20.70%		
1145	122.36	568003	1030358	901989	774188	9.53%	20.80%	32.02%			20.61%			46.49%	x		20.61%		
741	122.10	566820	1028212	900110	772576	9.72%	20.97%	32.16%			20.77%			46.60%	x		20.77%		
1029	122.24	567461	1029374	901127	773449	9.62%	20.88%	32.09%			20.68%			46.54%	x		20.68%		
781	124.37	577345	1047303	916824	786921	8.04%	19.50%	30.91%			19.30%			45.61%	x		19.30%		
1069	124.79	579275	1050805	919889	789552	7.74%	19.23%	30.67%			19.03%			45.43%	x		19.03%		
785	122.35	567948	1030257	901901	774113	9.54%	20.81%	32.03%			20.62%			46.50%	x		20.62%		
1073	122.52	568778	1031763	903219	775244	9.41%	20.69%	31.93%			20.50%			46.42%	x		20.50%		
742	122.76	569873	1033749	904958	776736	9.23%	20.54%	31.80%			20.35%			46.32%	x		20.35%		
1030	122.82	570165	1034279	905421	777134	9.19%	20.50%	31.76%			20.31%			46.29%	x		20.31%		
750	122.58	569043	1032244	903640	775605	9.37%	20.66%	31.90%			20.46%			46.39%	x		20.46%		
1038	122.61	569184	1032501	903865	775798	9.34%	20.64%	31.88%			20.44%			46.38%	x		20.44%		
734	124.72	578955	1050224	919380	789115	7.79%	19.27%	30.71%			19.08%			45.46%	x		19.08%		
1022	125.09	580696	1053382	922145	791489	7.51%	19.03%	30.50%			18.83%			45.30%	x		18.83%		
597	124.01	575657	1044241	914143	784620	8.31%	19.73%	31.11%			19.54%			45.77%	x		19.54%		
885	124.30	577031	1046735	916326	786494	8.09%	19.54%	30.94%			19.35%			45.64%	x		19.35%		
598	128.47	596383	1081839	947057	812870	5.01%	16.84%	28.63%			16.64%			43.82%	x		16.64%		
886	128.52	596631	1082289	947450	813208	4.97%	16.81%	28.60%			16.61%			43.79%	x		16.61%		
825	123.58	573657	1040614	910967	781895	8.63%	20.01%	31.35%			19.82%			45.96%	x		19.82%		
1113	123.59	573719	1040726	911065	781978	8.62%	20.00%	31.34%			19.81%			45.95%	x		19.81%		
821	123.87	575007	1043063	913111	783735	8.42%	19.83%	31.19%			19.63%			45.83%	x		19.63%		
1109	123.90	575164	1043347	913360	783948	8.39%	19.80%	31.17%			19.61%			45.82%	x		19.61%		
603	138.93	644933	1169909	1024154	879044	-2.72%	10.08%	22.82%			9.86%			39.24%	x		9.86%		
849	125.37	581983	1055717	924189	793243	7.30%	18.85%	30.35%			18.66%			45.17%	x		18.66%		
1137	125.53	582717	1057049	925355	794244	7.19%	18.75%	30.26%			18.55%			45.11%	x		18.55%		
725	125.19	581175	1054251	922905	792141	7.43%	18.97%	30.45%			18.77%			45.25%	x		18.77%		
1013	125.35	581885	1055540	924034	793110	7.32%	18.87%	30.36%			18.67%			45.18%	x		18.67%		
891	132.80	616475	1118286	978963	840256	1.81%	14.04%	26.22%			13.83%			41.93%	x		13.83%		
777	125.51	582654	1056935	925255	794158	7.20%	18.76%	30.27%			18.56%			45.11%	x		18.56%		
1065	125.70	583527	1058517	926640	795347	7.06%	18.64%	30.17%			18.44%			45.03%	x		18.44%		
1105	126.48	587158	1065104	932406	800296	6.48%	18.13%	29.73%			17.93%			44.69%	x		17.93%		
817	126.27	586180	1063330	930854	798963	6.64%	18.27%	29.85%			18.07%			44.78%	x		18.07%		
726	125.93	584572	1060414	928301	796772	6.89%	18.49%	30.04%			18.29%			44.93%	x		18.29%		
1014	126.01	584965	1061127	928925	797308	6.83%	18.44%	29.99%			18.24%			44.89%	x		18.24%		
887	133.93	621739	1127834	987321	847430	0.97%	13.31%	25.59%			13.10%			41.43%	x		13.10%		
813	127.20	590486	1071142	937692	804833	5.95%	17.67%	29.33%			17.47%			44.37%	x		17.47%		
1101	127.24	590685	1071502	938007	805103	5.92%	17.64%	29.31%			17.44%			44.36%	x		17.44%		
604	149.84	695565	1261755	1104557	948055	-10.79%	3.02%	16.76%			2.78%			34.47%	x		2.78%		

Table 18 continued.

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Minneapolis East Annual Carbon Emission Comparison

Window	Whole Bldg kBtu/sf	kWh	EPA Power Profiler (average 1,138,902 lbs CO_2) Averages (lbs CO_2) Office	State	National	% Diff from Average Office	State	National	30% Target 797,231 lbs	50% Target 569,451 lbs	Data Set (1,297,828 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs	CBECS (1,925,605 lbs CO_2) % Diff	30% Target 1,347,924 lbs	50% Target 962,803 lbs	Code Base (1,297,828 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs
898	119.89	556534	1009553	883776	758556	11.36%	22.40%	33.40%			22.21%			47.57%	x		22.21%		
610	120.48	559293	1014557	888157	762316	10.92%	22.02%	33.07%			21.83%			47.31%	x		21.83%		
894	120.79	560750	1017201	890471	764303	10.69%	21.81%	32.89%			21.62%			47.17%	x		21.62%		
1150	120.76	560605	1016938	890241	764105	10.71%	21.83%	32.91%			21.64%			47.19%	x		21.64%		
862	120.62	559925	1015704	889161	763178	10.82%	21.93%	32.99%			21.74%			47.25%	x		21.74%		
606	120.55	559615	1015141	888668	762755	10.87%	21.97%	33.03%			21.78%			47.28%	x		21.78%		
1146	121.74	565124	1025135	897417	770264	9.99%	21.20%	32.37%			21.01%			46.76%	x		21.01%		
751	120.73	560438	1016635	889976	763877	10.74%	21.86%	32.93%			21.67%			47.20%	x		21.67%		
858	121.55	564269	1023584	896059	769099	10.13%	21.32%	32.47%			21.13%			46.84%	x		21.13%		
1039	120.88	561150	1017925	891105	764847	10.62%	21.76%	32.84%			21.57%			47.14%	x		21.57%		
752	121.25	562840	1020991	893789	767150	10.35%	21.52%	32.64%			21.33%			46.98%	x		21.33%		
1040	121.30	563107	1021476	894214	767515	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
743	121.60	564505	1024012	896434	769420	10.09%	21.29%	32.44%			21.10%			46.82%	x		21.10%		
1031	121.81	565457	1025739	897946	770718	9.94%	21.16%	32.33%			20.96%			46.73%	x		20.96%		
827	122.87	570401	1034707	905796	777456	9.15%	20.47%	31.74%			20.27%			46.27%	x		20.27%		
1115	122.48	568555	1031359	902865	774941	9.44%	20.72%	31.96%			20.53%			46.44%	x		20.53%		
1078	121.42	563659	1022477	895090	768267	10.22%	21.41%	32.54%			21.22%			46.90%	x		21.22%		
744	122.16	567065	1028656	900499	772909	9.68%	20.93%	32.14%			20.74%			46.58%	x		20.74%		
1032	122.27	567582	1029594	901321	773615	9.60%	20.86%	32.07%			20.67%			46.53%	x		20.67%		
790	121.30	563110	1021481	894218	767518	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
1075	122.28	567637	1029693	901407	773689	9.59%	20.85%	32.07%			20.66%			46.53%	x		20.66%		
1074	122.43	568340	1030969	902524	774647	9.48%	20.75%	31.98%			20.56%			46.46%	x		20.56%		
786	122.28	567628	1029678	901394	773677	9.59%	20.85%	32.07%			20.66%			46.53%	x		20.66%		
1148	122.12	566882	1028323	900208	772659	9.71%	20.96%	32.16%			20.77%			46.60%	x		20.77%		
823	123.95	575418	1043808	913764	784295	8.35%	19.77%	31.14%			19.57%			45.79%	x		19.57%		
1111	123.99	575598	1044135	914050	784540	8.32%	19.74%	31.11%			19.55%			45.78%	x		19.55%		
824	124.23	576684	1046105	915774	786020	8.15%	19.59%	30.98%			19.40%			45.67%	x		19.40%		
1112	124.24	576744	1046214	915870	786102	8.14%	19.58%	30.98%			19.39%			45.67%	x		19.39%		
889	123.29	572352	1038246	908894	780115	8.84%	20.20%	31.50%			20.00%			46.08%	x		20.00%		
601	122.69	569539	1033143	904427	776281	9.29%	20.59%	31.84%			20.39%			46.35%	x		20.39%		
605	121.03	561821	1019142	892171	765761	10.52%	21.66%	32.76%			21.47%			47.07%	x		21.47%		
893	121.32	563165	1021582	894306	767594	10.30%	21.48%	32.60%			21.29%			46.95%	x		21.29%		
609	120.99	561654	1018840	891906	765534	10.54%	21.69%	32.78%			21.50%			47.09%	x		21.50%		
787	122.77	569896	1033791	904995	776768	9.23%	20.54%	31.80%			20.34%			46.31%	x		20.34%		
733	123.89	575126	1043278	913300	783896	8.40%	19.81%	31.17%			19.61%			45.82%	x		19.61%		
826	123.08	571378	1036479	907348	778788	8.99%	20.33%	31.62%			20.14%			46.17%	x		20.14%		
1114	123.11	571514	1036726	907564	778973	8.97%	20.31%	31.60%			20.12%			46.16%	x		20.12%		
897	121.21	562661	1020666	893505	766906	10.38%	21.55%	32.66%			21.36%			47.00%	x		21.36%		
853	124.18	576466	1045709	915428	785723	8.18%	19.62%	31.01%			19.43%			45.69%	x		19.43%		
1021	124.38	577382	1047372	916883	786972	8.04%	19.49%	30.90%			19.30%			45.61%	x		19.30%		
1141	124.60	578420	1049254	918531	788386	7.87%	19.35%	30.78%			19.15%			45.51%	x		19.15%		
822	124.16	576394	1045578	915313	785624	8.19%	19.63%	31.02%			19.44%			45.70%	x		19.44%		
1110	124.22	576659	1046060	915735	785986	8.15%	19.59%	30.99%			19.40%			45.68%	x		19.40%		
741	122.10	566820	1028212	900110	772576	9.72%	20.97%	32.16%			20.77%			46.60%	x		20.77%		
857	122.21	567338	1029152	900933	773282	9.64%	20.89%	32.10%			20.70%			46.55%	x		20.70%		
1029	122.24	567461	1029374	901127	773449	9.62%	20.88%	32.09%			20.68%			46.54%	x		20.68%		
1145	122.36	568003	1030358	901989	774188	9.53%	20.80%	32.02%			20.61%			46.49%	x		20.61%		
1069	124.79	579275	1050805	919889	789552	7.74%	19.23%	30.67%			19.03%			45.43%	x		19.03%		
781	124.37	577345	1047303	916824	786921	8.04%	19.50%	30.91%			19.30%			45.61%	x		19.30%		
785	122.35	567948	1030257	901901	774113	9.54%	20.81%	32.03%			20.62%			46.50%	x		20.62%		
1073	122.52	568778	1031763	903219	775244	9.41%	20.69%	31.93%			20.50%			46.42%	x		20.50%		
734	124.72	578955	1050224	919380	789115	7.79%	19.27%	30.71%			19.08%			45.46%	x		19.08%		

Table 19. Annual carbon emission comparison for the east orientation in Minneapolis, Minnesota. Table continues on next page.

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Minneapolis East Annual Carbon Emission Comparison-Continued

Window	Whole Bldg kBtu/sf	kWh	EPA Power Profiler (average 1,138,902 lbs CO_2) Averages (lbs CO_2) Office	State	National	% Diff from Average Office	State	National	30% Target 797,231 lbs	50% Target 569,451 lbs	Data Set (1,297,828 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs	CBECS (1,925,605 lbs CO_2) % Diff	30% Target 1,347,924 lbs	50% Target 962,803 lbs	Code Base (1,297,828 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs
597	124.01	575657	1044241	914143	784620	8.31%	19.73%	31.11%			19.54%			45.77%	x		19.54%		
885	124.30	577031	1046735	916326	786494	8.09%	19.54%	30.94%			19.35%			45.64%	x		19.35%		
1022	125.09	580696	1053382	922145	791489	7.51%	19.03%	30.50%			18.83%			45.30%	x		18.83%		
1076	123.46	573134	1039664	910136	781181	8.71%	20.09%	31.41%			19.89%			46.01%	x		19.89%		
742	122.76	569873	1033749	904958	776736	9.23%	20.54%	31.80%			20.35%			46.32%	x		20.35%		
1030	122.82	570165	1034279	905421	777134	9.19%	20.50%	31.76%			20.31%			46.29%	x		20.31%		
736	128.44	596261	1081618	946863	812704	5.03%	16.86%	28.64%			16.66%			43.83%	x		16.66%		
1023	128.49	596482	1082018	947213	813004	4.99%	16.83%	28.62%			16.63%			43.81%	x		16.63%		
1024	129.01	598887	1086382	951033	816284	4.61%	16.50%	28.33%			16.29%			43.58%	x		16.29%		
1142	128.70	597446	1083767	948744	814319	4.84%	16.70%	28.50%			16.49%			43.72%	x		16.49%		
890	127.68	592713	1075181	941228	807868	5.59%	17.36%	29.07%			17.16%			44.16%	x		17.16%		
735	127.87	593614	1076816	942659	809096	5.45%	17.23%	28.96%			17.03%			44.08%	x		17.03%		
725	125.19	581175	1054251	922905	792141	7.43%	18.97%	30.45%			18.77%			45.25%	x		18.77%		
849	125.37	581983	1055717	924189	793243	7.30%	18.85%	30.35%			18.66%			45.17%	x		18.66%		
1013	125.35	581885	1055540	924034	793110	7.32%	18.87%	30.36%			18.67%			45.18%	x		18.67%		
1137	125.53	582717	1057049	925355	794244	7.19%	18.75%	30.26%			18.55%			45.11%	x		18.55%		
777	125.51	582654	1056935	925255	794158	7.20%	18.76%	30.27%			18.56%			45.11%	x		18.56%		
1065	125.70	583527	1058517	926640	795347	7.06%	18.64%	30.17%			18.44%			45.03%	x		18.44%		
817	126.27	586180	1063330	930854	798963	6.64%	18.27%	29.85%			18.07%			44.78%	x		18.07%		
821	123.87	575007	1043063	913111	783735	8.42%	19.83%	31.19%			19.63%			45.83%	x		19.63%		
1109	123.90	575164	1043347	913360	783948	8.39%	19.80%	31.17%			19.61%			45.82%	x		19.61%		
886	128.52	596631	1082289	947450	813208	4.97%	16.81%	28.60%			16.61%			43.79%	x		16.61%		
825	123.58	573657	1040614	910967	781895	8.63%	20.01%	31.35%			19.82%			45.96%	x		19.82%		
1105	126.48	587158	1065104	932406	800296	6.48%	18.13%	29.73%			17.93%			44.69%	x		17.93%		
726	125.93	584572	1060414	928301	796772	6.89%	18.49%	30.04%			18.29%			44.93%	x		18.29%		
828	126.34	586481	1063876	931332	799373	6.59%	18.23%	29.81%			18.03%			44.75%	x		18.03%		
1116	123.74	574442	1042037	912213	782964	8.51%	19.90%	31.25%			19.71%			45.89%	x		19.71%		
1138	129.58	601536	1091187	955240	819894	4.19%	16.13%	28.01%			15.92%			43.33%	x		15.92%		
1014	126.01	584965	1061127	928925	797308	6.83%	18.44%	29.99%			18.24%			44.89%	x		18.24%		
813	127.20	590486	1071142	937692	804833	5.95%	17.67%	29.33%			17.47%			44.37%	x		17.47%		
1101	127.24	590685	1071502	938007	805103	5.92%	17.64%	29.31%			17.44%			44.36%	x		17.44%		
1107	134.91	626297	1136103	994560	853643	0.25%	12.67%	25.05%			12.46%			41.00%	x		12.46%		
815	135.86	630701	1144091	1001553	859645	-0.46%	12.06%	24.52%			11.85%			40.59%	x		11.85%		
1103	135.93	631008	1144649	1002041	860064	-0.50%	12.02%	24.48%			11.80%			40.56%	x		11.80%		
1028	135.97	631185	1144970	1002322	860305	-0.53%	11.99%	24.46%			11.78%			40.54%	x		11.78%		
1027	136.47	633525	1149215	1006038	863495	-0.91%	11.67%	24.18%			11.45%			40.32%	x		11.45%		
1104	140.13	650519	1180041	1033024	886657	-3.61%	9.30%	22.15%			9.08%			38.72%	x		9.08%		
986	141.76	658091	1193777	1045049	896978	-4.82%	8.24%	21.24%			8.02%			38.01%	x		8.02%		
985	143.59	666569	1209156	1058511	908533	-6.17%	7.06%	20.23%			6.83%			37.21%	x		6.83%		
1123	146.46	679892	1233324	1079668	926692	-8.29%	5.20%	18.63%			4.97%			35.95%	x		4.97%		
884	146.45	679845	1233239	1079594	926629	-8.28%	5.21%	18.64%			4.98%			35.96%	x		4.98%		
871	148.10	687505	1247134	1091758	937069	-9.50%	4.14%	17.72%			3.91%			35.23%	x		3.91%		

Table 19 continued.

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Minneapolis South Annual Carbon Emission Comparison

	Whole Bldg		EPA Power Profiler (average 1,138,902 lbs CO_2)								Data Set (1,297,828 lbs CO_2)			CBECS (1,925,605 lbs CO_2)			Code Base (1,297,828 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	797,231 lbs	569,451 lbs	% Diff	908,480 lbs	648,914 lbs	% Diff	1,347,924 lbs	962,803 lbs	% Diff	908,480 lbs	648,914 lbs
754	121.03	561838	1019175	892199	765786	10.51%	21.66%	32.76%			21.47%			47.07%	x		21.47%		
745	121.14	562354	1020110	893018	766489	10.43%	21.59%	32.70%			21.40%			47.02%	x		21.40%		
1042	120.35	558674	1013435	887174	761473	11.02%	22.10%	33.14%			21.91%			47.37%	x		21.91%		
1033	121.40	563569	1022314	894948	768145	10.24%	21.42%	32.55%			21.23%			46.91%	x		21.23%		
746	121.53	564141	1023351	895855	768924	10.15%	21.34%	32.49%			21.15%			46.86%	x		21.15%		
859	121.32	563180	1021608	894329	767614	10.30%	21.47%	32.60%			21.28%			46.95%	x		21.28%		
748	121.81	565470	1025763	897967	770736	9.93%	21.16%	32.33%			20.96%			46.73%	x		20.96%		
606	120.55	559615	1015141	888668	762755	10.87%	21.97%	33.03%			21.78%			47.28%	x		21.78%		
1034	121.76	565253	1025369	897622	770440	9.97%	21.19%	32.35%			20.99%			46.75%	x		20.99%		
1036	121.80	565419	1025670	897885	770666	9.94%	21.16%	32.33%			20.97%			46.74%	x		20.97%		
898	119.89	556534	1009553	883776	758556	11.36%	22.40%	33.40%			22.21%			47.57%	x		22.21%		
753	122.24	567451	1029356	901113	773436	9.62%	20.88%	32.09%			20.69%			46.54%	x		20.69%		
1147	121.53	564156	1023379	895879	768944	10.14%	21.34%	32.48%			21.15%			46.85%	x		21.15%		
862	120.62	559925	1015704	889161	763178	10.82%	21.93%	32.99%			21.74%			47.25%	x		21.74%		
858	121.55	564269	1023584	896059	769099	10.13%	21.32%	32.47%			21.13%			46.84%	x		21.13%		
894	120.79	560750	1017201	890471	764303	10.69%	21.81%	32.89%			21.62%			47.17%	x		21.62%		
1035	121.66	564771	1024494	896856	769783	10.05%	21.25%	32.41%			21.06%			46.80%	x		21.06%		
1041	120.46	559198	1014385	888007	762187	10.93%	22.03%	33.08%			21.84%			47.32%	x		21.84%		
1150	120.76	560605	1016938	890241	764105	10.71%	21.83%	32.91%			21.64%			47.19%	x		21.64%		
743	121.60	564505	1024012	896434	769420	10.09%	21.29%	32.44%			21.10%			46.82%	x		21.10%		
751	120.73	560438	1016635	889976	763877	10.74%	21.86%	32.93%			21.67%			47.20%	x		21.67%		
1146	121.74	565124	1025135	897417	770264	9.99%	21.20%	32.37%			21.01%			46.76%	x		21.01%		
756	125.27	581520	1054877	923454	792612	7.38%	18.92%	30.41%			18.72%			45.22%	x		18.72%		
895	120.97	561556	1018663	891751	765401	10.56%	21.70%	32.79%			21.51%			47.10%	x		21.51%		
1039	120.88	561150	1017925	891105	764847	10.62%	21.76%	32.84%			21.57%			47.14%	x		21.57%		
828	126.34	586481	1063876	931332	799373	6.59%	18.23%	29.81%			18.03%			44.75%	x		18.03%		
1044	120.58	559769	1015420	888912	762964	10.84%	21.95%	33.01%			21.76%			47.27%	x		21.76%		
1031	121.81	565457	1025739	897946	770718	9.94%	21.16%	32.33%			20.96%			46.73%	x		20.96%		
1116	123.74	574442	1042037	912213	782964	8.51%	19.90%	31.25%			19.71%			45.89%	x		19.71%		
790	121.30	563110	1021481	894218	767518	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
786	122.28	567628	1029678	901394	773677	9.59%	20.85%	32.07%			20.66%			46.53%	x		20.66%		
1075	122.28	567637	1029693	901407	773689	9.59%	20.85%	32.07%			20.66%			46.53%	x		20.66%		
1078	121.42	563659	1022477	895090	768267	10.22%	21.41%	32.54%			21.22%			46.90%	x		21.22%		
601	122.69	569539	1033143	904427	776281	9.29%	20.59%	31.84%			20.39%			46.35%	x		20.39%		
787	122.77	569896	1033791	904995	776768	9.23%	20.54%	31.80%			20.34%			46.31%	x		20.34%		
752	121.25	562840	1020991	893789	767150	10.35%	21.52%	32.64%			21.33%			46.98%	x		21.33%		
744	122.16	567065	1028656	900499	772909	9.68%	20.93%	32.14%			20.74%			46.58%	x		20.74%		
1040	121.30	563107	1021476	894214	767515	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
1032	122.27	567582	1029594	901321	773615	9.60%	20.86%	32.07%			20.67%			46.53%	x		20.67%		
824	124.23	576684	1046105	915774	786020	8.15%	19.59%	30.98%			19.40%			45.67%	x		19.40%		
827	122.87	570401	1034707	905796	777456	9.15%	20.47%	31.74%			20.27%			46.27%	x		20.27%		
1112	124.24	576744	1046214	915870	786102	8.14%	19.58%	30.98%			19.39%			45.67%	x		19.39%		
1115	122.48	568555	1031359	902865	774941	9.44%	20.72%	31.96%			20.53%			46.44%	x		20.53%		
1148	122.12	566882	1028323	900208	772659	9.71%	20.96%	32.16%			20.77%			46.60%	x		20.77%		
610	120.48	559293	1014557	888157	762316	10.92%	22.02%	33.07%			21.83%			47.31%	x		21.83%		
605	121.03	561821	1019142	892171	765761	10.52%	21.66%	32.76%			21.47%			47.07%	x		21.47%		
693	125.17	581068	1054058	922736	791996	7.45%	18.98%	30.46%			18.78%			45.26%	x		18.78%		
889	123.29	572352	1038246	908894	780115	8.84%	20.20%	31.50%			20.00%			46.08%	x		20.00%		
733	123.89	575126	1043278	913300	783896	8.40%	19.81%	31.17%			19.61%			45.82%	x		19.61%		
853	124.18	576466	1045709	915428	785723	8.18%	19.62%	31.01%			19.43%			45.69%	x		19.43%		
735	127.87	593614	1076816	942659	809096	5.45%	17.23%	28.96%			17.03%			44.08%	x		17.03%		
609	120.99	561654	1018840	891906	765534	10.54%	21.69%	32.78%			21.50%			47.09%	x		21.50%		

Table 20. Annual carbon emission comparison for the south orientation in Minneapolis, Minnesota. *Table continues on next page.*

Minneapolis South Annual Carbon Emission Comparison-Continued

	Whole Bldg		EPA Power Profiler (average 1,138,902 lbs CO_2)								Data Set (1,297,828 lbs CO_2)			CBECS (1,925,605 lbs CO_2)			Code Base (1,297,828 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	797,231 lbs	569,451 lbs	% Diff	908,480 lbs	648,914 lbs	% Diff	1,347,924 lbs	962,803 lbs	% Diff	908,480 lbs	648,914 lbs
893	121.32	563165	1021582	894306	767594	10.30%	21.48%	32.60%			21.29%			46.95%	x		21.29%		
781	124.37	577345	1047303	916824	786921	8.04%	19.50%	30.91%			19.30%			45.61%	x		19.30%		
1076	123.46	573134	1039664	910136	781181	8.71%	20.09%	31.41%			19.89%			46.01%	x		19.89%		
854	128.20	595135	1079575	945074	811169	5.21%	17.02%	28.78%			16.82%			43.94%	x		16.82%		
597	124.01	575657	1044241	914143	784620	8.31%	19.73%	31.11%			19.54%			45.77%	x		19.54%		
897	121.21	562661	1020666	893505	766906	10.38%	21.55%	32.66%			21.36%			47.00%	x		21.36%		
736	128.44	596261	1081618	946863	812704	5.03%	16.86%	28.64%			16.66%			43.83%	x		16.66%		
885	124.30	577031	1046735	916326	786494	8.09%	19.54%	30.94%			19.35%			45.64%	x		19.35%		
694	126.09	585316	1061763	929482	797786	6.77%	18.39%	29.95%			18.19%			44.86%	x		18.19%		
1069	124.79	579275	1050805	919889	789552	7.74%	19.23%	30.67%			19.03%			45.43%	x		19.03%		
826	123.08	571378	1036479	907348	778788	8.99%	20.33%	31.62%			20.14%			46.17%	x		20.14%		
1114	123.11	571514	1036726	907564	778973	8.97%	20.31%	31.60%			20.12%			46.16%	x		20.12%		
822	124.16	576394	1045578	915313	785624	8.19%	19.63%	31.02%			19.44%			45.70%	x		19.44%		
1110	124.22	576659	1046060	915735	785986	8.15%	19.59%	30.99%			19.40%			45.68%	x		19.40%		
850	129.36	600526	1089353	953635	818516	4.35%	16.27%	28.13%			16.06%			43.43%	x		16.06%		
727	129.26	600054	1088498	952886	817874	4.43%	16.33%	28.19%			16.13%			43.47%	x		16.13%		
886	128.52	596631	1082289	947450	813208	4.97%	16.81%	28.60%			16.61%			43.79%	x		16.61%		
896	122.78	569958	1033903	905093	776852	9.22%	20.53%	31.79%			20.34%			46.31%	x		20.34%		
738	132.54	615272	1116103	977051	838615	2.00%	14.21%	26.37%			14.00%			42.04%	x		14.00%		
1025	131.92	612414	1110919	972513	834720	2.46%	14.61%	26.71%			14.40%			42.31%	x		14.40%		
1017	132.80	616468	1118273	978951	840246	1.81%	14.04%	26.22%			13.84%			41.93%	x		13.84%		
730	132.91	617013	1119262	979817	840989	1.72%	13.97%	26.16%			13.76%			41.87%	x		13.76%		
729	133.25	618588	1122118	982317	843135	1.47%	13.75%	25.97%			13.54%			41.73%	x		13.54%		
1018	133.26	618596	1122134	982331	843147	1.47%	13.75%	25.97%			13.54%			41.73%	x		13.54%		
818	130.98	608010	1102931	965520	828718	3.16%	15.22%	27.24%			15.02%			42.72%	x		15.02%		
817	126.27	586180	1063330	930854	798963	6.64%	18.27%	29.85%			18.07%			44.78%	x		18.07%		
797	128.30	595592	1080404	945800	811792	5.14%	16.96%	28.72%			16.75%			43.89%	x		16.75%		
1027	136.47	633525	1149215	1006038	863495	-0.91%	11.67%	24.18%			11.45%			40.32%	x		11.45%		
1028	135.97	631185	1144970	1002322	860305	-0.53%	11.99%	24.46%			11.78%			40.54%	x		11.78%		
732	138.93	644936	1169914	1024159	879048	-2.72%	10.07%	22.82%			9.86%			39.24%	x		9.86%		
1020	137.69	639169	1159453	1015001	871188	-1.80%	10.88%	23.51%			10.66%			39.79%	x		10.66%		

Table 20 continued.

Minneapolis West Annual Carbon Emission Comparison

	Whole Bldg		EPA Power Profiler (average 1,138,902 lbs CO_2)								Data Set (1,297,828 lbs CO_2)			CBECS (1,925,605 lbs CO_2)			Code Base (1,297,828 lbs CO_2)		
			Averages (lbs CO_2)			% Diff from Average			30% Target	50% Target		30% Target	50% Target		30% Target	50% Target		30% Target	50% Target
Window	kBtu/sf	kWh	Office	State	National	Office	State	National	797,231 lbs	569,451 lbs	% Diff	908,480 lbs	648,914 lbs	% Diff	1,347,924 lbs	962,803 lbs	% Diff	908,480 lbs	648,914 lbs
1044	120.58	559769	1015420	888912	762964	10.84%	21.95%	33.01%			21.76%			47.27%	x		21.76%		
1042	120.35	558674	1013435	887174	761473	11.02%	22.10%	33.14%			21.91%			47.37%	x		21.91%		
1043	122.15	567059	1028645	900490	772901	9.68%	20.93%	32.14%			20.74%			46.58%	x		20.74%		
1041	120.46	559198	1014385	888007	762187	10.93%	22.03%	33.08%			21.84%			47.32%	x		21.84%		
1036	121.80	565419	1025670	897885	770666	9.94%	21.16%	32.33%			20.97%			46.74%	x		20.97%		
1034	121.76	565253	1025369	897622	770440	9.97%	21.19%	32.35%			20.99%			46.75%	x		20.99%		
1033	121.40	563569	1022314	894948	768145	10.24%	21.42%	32.55%			21.23%			46.91%	x		21.23%		
1151	121.82	565511	1025838	898032	770792	9.93%	21.15%	32.32%			20.96%			46.73%	x		20.96%		
898	119.89	556534	1009553	883776	758556	11.36%	22.40%	33.40%			22.21%			47.57%	x		22.21%		
1035	121.66	564771	1024494	896856	769783	10.05%	21.25%	32.41%			21.06%			46.80%	x		21.06%		
746	121.53	564141	1023351	895855	768924	10.15%	21.34%	32.49%			21.15%			46.86%	x		21.15%		
1147	121.53	564156	1023379	895879	768944	10.14%	21.34%	32.48%			21.15%			46.85%	x		21.15%		
1079	122.80	570040	1034053	905224	776965	9.21%	20.52%	31.78%			20.32%			46.30%	x		20.32%		
894	120.79	560750	1017201	890471	764303	10.69%	21.81%	32.89%			21.62%			47.17%	x		21.62%		
895	120.97	561556	1018663	891751	765401	10.56%	21.70%	32.79%			21.51%			47.10%	x		21.51%		
610	120.48	559293	1014557	888157	762316	10.92%	22.02%	33.07%			21.83%			47.31%	x		21.83%		
606	120.55	559615	1015141	888668	762755	10.87%	21.97%	33.03%			21.78%			47.28%	x		21.78%		
1150	120.76	560605	1016938	890241	764105	10.71%	21.83%	32.91%			21.64%			47.19%	x		21.64%		
1116	123.74	574442	1042037	912213	782964	8.51%	19.90%	31.25%			19.71%			45.89%	x		19.71%		
862	120.62	559925	1015704	889161	763178	10.82%	21.93%	32.99%			21.74%			47.25%	x		21.74%		
1148	122.12	566882	1028323	900208	772659	9.71%	20.96%	32.16%			20.77%			46.60%	x		20.77%		
1146	121.74	565124	1025135	897417	770264	9.99%	21.20%	32.37%			21.01%			46.76%	x		21.01%		
858	121.55	564269	1023584	896059	769099	10.13%	21.32%	32.47%			21.13%			46.84%	x		21.13%		
751	120.73	560438	1016635	889976	763877	10.74%	21.86%	32.93%			21.67%			47.20%	x		21.67%		
1039	120.88	561150	1017925	891105	764847	10.62%	21.76%	32.84%			21.57%			47.14%	x		21.57%		
1115	122.48	568555	1031359	902865	774941	9.44%	20.72%	31.96%			20.53%			46.44%	x		20.53%		
743	121.60	564505	1024012	896434	769420	10.09%	21.29%	32.44%			21.10%			46.82%	x		21.10%		
1078	121.42	563659	1022477	895090	768267	10.22%	21.41%	32.54%			21.22%			46.90%	x		21.22%		
1031	121.81	565457	1025739	897946	770718	9.94%	21.16%	32.33%			20.96%			46.73%	x		20.96%		
752	121.25	562840	1020991	893789	767150	10.35%	21.52%	32.64%			21.33%			46.98%	x		21.33%		
1040	121.30	563107	1021476	894214	767515	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
1080	127.31	591002	1072077	938511	805535	5.87%	17.60%	29.27%			17.39%			44.33%	x		17.39%		
790	121.30	563110	1021481	894218	767518	10.31%	21.48%	32.61%			21.29%			46.95%	x		21.29%		
1076	123.46	573134	1039664	910136	781181	8.71%	20.09%	31.41%			19.89%			46.01%	x		19.89%		
896	122.78	569958	1033903	905093	776852	9.22%	20.53%	31.79%			20.34%			46.31%	x		20.34%		
744	122.16	567065	1028656	900499	772909	9.68%	20.93%	32.14%			20.74%			46.58%	x		20.74%		
1032	122.27	567582	1029594	901321	773615	9.60%	20.86%	32.07%			20.67%			46.53%	x		20.67%		
1074	122.43	568340	1030969	902524	774647	9.48%	20.75%	31.98%			20.56%			46.46%	x		20.56%		
601	122.69	569539	1033143	904427	776281	9.29%	20.59%	31.84%			20.39%			46.35%	x		20.39%		
889	123.29	572352	1038246	908894	780115	8.84%	20.20%	31.50%			20.00%			46.08%	x		20.00%		
605	121.03	561821	1019142	892171	765761	10.52%	21.66%	32.76%			21.47%			47.07%	x		21.47%		
893	121.32	563165	1021582	894306	767594	10.30%	21.48%	32.60%			21.29%			46.95%	x		21.29%		
609	120.99	561654	1018840	891906	765534	10.54%	21.69%	32.78%			21.50%			47.09%	x		21.50%		
897	121.21	562661	1020666	893505	766906	10.38%	21.55%	32.66%			21.36%			47.00%	x		21.36%		
826	123.08	571378	1036479	907348	778788	8.99%	20.33%	31.62%			20.14%			46.17%	x		20.14%		
1114	123.11	571514	1036726	907564	778973	8.97%	20.31%	31.60%			20.12%			46.16%	x		20.12%		
733	123.89	575126	1043278	913300	783896	8.40%	19.81%	31.17%			19.61%			45.82%	x		19.61%		
853	124.18	576466	1045709	915428	785723	8.18%	19.62%	31.01%			19.43%			45.69%	x		19.43%		
1141	124.60	578420	1049254	918531	788386	7.87%	19.35%	30.78%			19.15%			45.51%	x		19.15%		
1021	124.38	577382	1047372	916883	786972	8.04%	19.49%	30.90%			19.30%			45.61%	x		19.30%		
822	124.16	576394	1045578	915313	785624	8.19%	19.63%	31.02%			19.44%			45.70%	x		19.44%		
1110	124.22	576659	1046060	915735	785986	8.15%	19.59%	30.99%			19.40%			45.68%	x		19.40%		

Table 21. Annual carbon emission comparison for the west orientation in Minneapolis, Minnesota. *Table continues on next page.*

Minneapolis West Annual Carbon Emission Comparison-Continued

Window	Whole Bldg kBtu/sf	kWh	EPA Power Profiler (average 1,138,902 lbs CO_2) Averages (lbs CO_2) Office	State	National	% Diff from Average Office	State	National	30% Target 797,231 lbs	50% Target 569,451 lbs	Data Set (1,297,828 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs	CBECS (1,925,605 lbs CO_2) % Diff	30% Target 1,347,924 lbs	50% Target 962,803 lbs	Code Base (1,297,828 lbs CO_2) % Diff	30% Target 908,480 lbs	50% Target 648,914 lbs
741	122.10	566820	1028212	900110	772576	9.72%	20.97%	32.16%			20.77%			46.60%	x		20.77%		
857	122.21	567338	1029152	900933	773282	9.64%	20.89%	32.10%			20.70%			46.55%	x		20.70%		
1145	122.36	568003	1030358	901989	774188	9.53%	20.80%	32.02%			20.61%			46.49%	x		20.61%		
1029	122.24	567461	1029374	901127	773449	9.62%	20.88%	32.09%			20.68%			46.54%	x		20.68%		
781	124.37	577345	1047303	916824	786921	8.04%	19.50%	30.91%			19.30%			45.61%	x		19.30%		
1069	124.79	579275	1050805	919889	789552	7.74%	19.23%	30.67%			19.03%			45.43%	x		19.03%		
785	122.35	567948	1030257	901901	774113	9.54%	20.81%	32.03%			20.62%			46.50%	x		20.62%		
1073	122.52	568778	1031763	903219	775244	9.41%	20.69%	31.93%			20.50%			46.42%	x		20.50%		
597	124.01	575657	1044241	914143	784620	8.31%	19.73%	31.11%			19.54%			45.77%	x		19.54%		
734	124.72	578955	1050224	919380	789115	7.79%	19.27%	30.71%			19.08%			45.46%	x		19.08%		
885	124.30	577031	1046735	916326	786494	8.09%	19.54%	30.94%			19.35%			45.64%	x		19.35%		
1022	125.09	580696	1053382	922145	791489	7.51%	19.03%	30.50%			18.83%			45.30%	x		18.83%		
742	122.76	569873	1033749	904958	776736	9.23%	20.54%	31.80%			20.35%			46.32%	x		20.35%		
1030	122.82	570165	1034279	905421	777134	9.19%	20.50%	31.76%			20.31%			46.29%	x		20.31%		
890	127.68	592713	1075181	941228	807868	5.59%	17.36%	29.07%			17.16%			44.16%	x		17.16%		
1142	128.70	597446	1083767	948744	814319	4.84%	16.70%	28.50%			16.49%			43.72%	x		16.49%		
1023	128.49	596482	1082018	947213	813004	4.99%	16.83%	28.62%			16.63%			43.81%	x		16.63%		
736	128.44	596261	1081618	946863	812704	5.03%	16.86%	28.64%			16.66%			43.83%	x		16.66%		
725	125.19	581175	1054251	922905	792141	7.43%	18.97%	30.45%			18.77%			45.25%	x		18.77%		
849	125.37	581983	1055717	924189	793243	7.30%	18.85%	30.35%			18.66%			45.17%	x		18.66%		
1013	125.35	581885	1055540	924034	793110	7.32%	18.87%	30.36%			18.67%			45.18%	x		18.67%		
1137	125.53	582717	1057049	925355	794244	7.19%	18.75%	30.26%			18.55%			45.11%	x		18.55%		
777	125.51	582654	1056935	925255	794158	7.20%	18.76%	30.27%			18.56%			45.11%	x		18.56%		
1065	125.70	583527	1058517	926640	795347	7.06%	18.64%	30.17%			18.44%			45.03%	x		18.44%		
817	126.27	586180	1063330	930854	798963	6.64%	18.27%	29.85%			18.07%			44.78%	x		18.07%		
821	123.87	575007	1043063	913111	783735	8.42%	19.83%	31.19%			19.63%			45.83%	x		19.63%		
1109	123.90	575164	1043347	913360	783948	8.39%	19.80%	31.17%			19.61%			45.82%	x		19.61%		
886	128.52	596631	1082289	947450	813208	4.97%	16.81%	28.60%			16.61%			43.79%	x		16.61%		
825	123.58	573657	1040614	910967	781895	8.63%	20.01%	31.35%			19.82%			45.96%	x		19.82%		
1105	126.48	587158	1065104	932406	800296	6.48%	18.13%	29.73%			17.93%			44.69%	x		17.93%		
598	128.47	596383	1081839	947057	812870	5.01%	16.84%	28.63%			16.64%			43.82%	x		16.64%		
726	125.93	584572	1060414	928301	796772	6.89%	18.49%	30.04%			18.29%			44.93%	x		18.29%		
1014	126.01	584965	1061127	928925	797308	6.83%	18.44%	29.99%			18.24%			44.89%	x		18.24%		
1138	129.58	601536	1091187	955240	819894	4.19%	16.13%	28.01%			15.92%			43.33%	x		15.92%		
850	129.36	600526	1089353	953635	818516	4.35%	16.27%	28.13%			16.06%			43.43%	x		16.06%		
728	129.87	602893	1093648	957394	821743	3.97%	15.94%	27.85%			15.73%			43.20%	x		15.73%		
1016	130.02	603585	1094903	958493	822686	3.86%	15.84%	27.76%			15.64%			43.14%	x		15.64%		
1026	132.31	614217	1114190	975377	837178	2.17%	14.36%	26.49%			14.15%			42.14%	x		14.15%		
1025	131.92	612414	1110919	972513	834720	2.46%	14.61%	26.71%			14.40%			42.31%	x		14.40%		
813	127.20	590486	1071142	937692	804833	5.95%	17.67%	29.33%			17.47%			44.37%	x		17.47%		
1101	127.24	590685	1071502	938007	805103	5.92%	17.64%	29.31%			17.44%			44.36%	x		17.44%		
1018	133.26	618596	1122134	982331	843147	1.47%	13.75%	25.97%			13.54%			41.73%	x		13.54%		
1017	132.80	616468	1118273	978951	840246	1.81%	14.04%	26.22%			13.84%			41.93%	x		13.84%		
1028	135.97	631185	1144970	1002322	860305	-0.53%	11.99%	24.46%			11.78%			40.54%	x		11.78%		
1019	137.57	638634	1158482	1014151	870458	-1.72%	10.95%	23.57%			10.74%			39.84%	x		10.74%		
1020	137.69	639169	1159453	1015001	871188	-1.80%	10.88%	23.51%			10.66%			39.79%	x		10.66%		

Table 21 continued.

SUMMARY OF FINDINGS

This analysis to find the optimum window is about performance—specifically the energy performance of window design options in a commercial building. The performance attributes are measured in terms of annual energy use and peak demand with human-centered issues such as a glare and thermal comfort taken into account.

Energy use and peak demand have a direct relationship to the annual energy performance of the building and these measurable parametrics play an important role in the determination of the optimum design. The human-centered issues of glare and thermal comfort are also important, and to a lesser degree, also aid in the determination of the optimum design. The findings follow the methodology of first identifying the top performers for each climate in the entire database. The top performing design options are then analyzed to determine the optimum window-to-wall ratio (WWR), optimum shading condition, and optimum glazing condition—all used to determine the optimum design option.

Top Performers in Data Set

The query and analysis of the data set recognizes the best window design options in each climate (per orientation) based on performance metrics and recognizes and documents if best performers are outside the acceptable ranges for glare and thermal comfort. The top 50 performing windows in the database are identified in terms of annual energy (kBtu/sf) and the corresponding peak demand (W/sf).

Key Findings for Top Performers in Phoenix, Arizona

All the top performing options have high-performance glass found in window F (double spectrally selective tint), window G (double spectrally selective low-E), window H (triple glazed low-E), or window I (quadruple low-E). These 4 glazing types not only provide a low U-factor, but most importantly for a warm climate, they provide a low solar heat gain coefficient (SHGC). A combination of interior shades and exterior shades are prevalent in the results, mostly using some sort of exterior shading device with or without interior shades. See Figures 5–8 for the top performing design options per orientation.

Key findings:

- For the north and east orientations, many of the top performers for annual energy are also the top performers in terms of peak demand, mostly used in combination with shading devices.
- For the east and west orientations, window options were removed due to poor performance in terms of glare. These window options have a large WWR.
- For the east, south, and west orientations, all top performers use some sort of external shading device. Exterior shading of overhangs and fins (ov2f) dominates which blocks the extreme sun angles.
- The design options in the north orientation have the lowest annual energy use compared to the other orientations resulting from the lack of direct solar gain.

- For the north orientation, a large WWR with triple (window H) or quad (window I) glazing performs best and demonstrates there is little or no performance penalty for using high-performing glazing with a large window area.
- For the north orientation, no external shading or shallow devices are preferred, allowing for ample indirect light.
- For the east orientation, to reduce peak demand, WWR must also be reduced.
- For the east, south and west orientations, double tint (window F) and double clear (window G) glazing are used in combination with a small or moderate WWR and an external shading device.
- For the south and west orientations, large WWR is used in combination with deep shading devices.

Key Findings for Top Performers in Minneapolis, Minnesota
All the top performing options have high-performance glass found in window G (double spectrally selective low-E), window H (triple glazed low-E), or window I (quadruple low-E). These 3 glazing types provide a low U-factor which is necessary for reducing heat loss in a cold climate. A combination of no shading and of interior and exterior shades are prevalent in the results. See Figures 9–12 for the top performing design options per orientation.

Key findings:

- For all orientations, the best performers for annual energy are often the worst performers for peak demand. Peak demand is not as critical of an energy-performance attribute in a heating climate as it is in a cooling climate.
- For the north orientation, a large WWR with triple (window H) or quad (window I) glazing performs best allowing for ample indirect light and illustrating the impact of a very low U-factor on reducing annual energy. This also demonstrates there is little or no performance penalty for using high-performing glazing with a large window area.
- For the north orientation, no external shading or shallow devices are preferred.
- For the east orientation, 0.30 WWR dominates.
- For the east and south orientations, double clear glazing (window G) is used in combination with a small or moderate WWR with no external shading devices.
- For the east orientation, window options were removed due to poor performance in terms of glare. These window options have a large WWR with no external shading, shallow overhangs (ov1), deep overhangs (ov2) or setback.
- The design options in the south orientation have the lowest annual energy use compared to the other orientations resulting from the benefits of passive solar gain.
- For the south orientation, shallow shading devices are used with moderate WWR and deep shading devices are used with large WWR, both of which limit exposure to the southern sun.
- For the west orientation, moderate to large WWR used in combination with various shading devices is prevalent.

The analysis of the top performers found that there is no single optimum window design for Phoenix and Minneapolis due to the importance of orientation and how window area, shading device and glazing type perform (separate or in combination) in each of the 4 orientations.

Optimum WWR

The study of the top 50 performers to find the optimum window-to-wall ratio (WWR), given all the parameters, determined there was no optimum WWR for each climate and orientation due to the fact that glazing type and shading devices play a significant role in the performance of the window design. Finding the optimum WWR for each orientation in each climate requires fixing various parametrics (shading and glazing type) to allow optimum shading device to be revealed for specific design conditions.

Key WWR Findings in Phoenix, Arizona

- A moderate or large WWR in combination with triple (window H) or quad (window I) glazing using no exterior shading or a shallow shading device makes up the very top performers for the north orientation—showing the benefit of window area on daylighting strategies as well as showing that heat loss and/or gain is not increased with a larger window area when using high-performing glass.
- A moderate WWR in combination with triple (window H) or quad (window I) glazing with deep overhangs (ov2) or overhangs with fins (ov2f) make up the very top performers for the east orientation. For double glazing (window F or G), a small WWR is used with the larger WWR requiring more extreme shading.
- A moderate to large WWR in combination with triple (window H) or quad (window I) glazing using overhangs with fins (ov2f) as the exterior shading device make up the very top performers for the south orientation
- A moderate to large WWR in combination with triple (window H) or quad (window I) glazing using deep overhangs (ov2) or overhangs with fins (ov2f) as the shading device make up the very top performers for the west orientation.

Key WWR Findings in Minneapolis, Minnesota

- A moderate to large WWR in combination with triple (window H) or quad (window I) glazing with either no shading or a shallow shading device make up the very top performers for the north orientation—showing the benefit of WWR on daylighting strategies as well that showing that heat loss and/or gain is not increased with the increase of window area when using high-performing glass.
- A moderate WWR in combination with triple (window H) or quad (window I) glazing with either no shading or a shallow shading device make up the very top performers for the east orientation.
- A moderate WWR in combination with triple (window H) or quad (window I) glazing with either no shading or a shallow shading device make up the very top performers for the south orientation.
- A moderate WWR in combination with triple (window H) or quad (window I) glazing with either overhangs or setback make up the very top performers for the west orientation.

Optimum Shading Device

The study of the top 50 performers to find the optimum shading device, given all the parameters, determined there was no optimum shading device for each climate and orientation due to the fact that glazing type and window area play a significant role in the performance of the window design. Finding the optimum shading device for each orientation in each climate requires fixing various parametrics (WWR and glazing type) to allow optimum shading device to be revealed for specific design conditions.

Key Shading Device Findings in Phoenix, Arizona

- No exterior shading device or shallow devices (ov1, fins, or setback) used with a moderate to large WWR with quad glazing (window I) make up the very top performers for the north orientation.
- Overhangs with fins (ov2f) or deep overhangs (ov2) used with moderate WWR with triple (window H) or quad (window I) glazing make up the very top performers in the east orientation—showing the benefit of shading devices to block the extreme angles of the sun allowing for a large window area when using high-performing glass.
- Overhangs with fins (ov2f) or deep overhangs (ov2) used with moderate to large WWR with triple (window H) or quad (window I) glazing make up the very top performers in the south orientation—showing the benefit of shading devices to block the extreme angles of the sun which allows for a large window area when using high-performing glass.
- Overhangs with fins (ov2f) or deep overhangs (ov2) used with moderate to large WWR with triple (window H) or quad (window I) glazing make up the very top performers in the west orientation—showing the benefit of shading devices to block the extreme angles of the sun which allows for large window area when using high-performing glass.

Key Shading Device Findings in Minneapolis, Minnesota

- No exterior shading device or shallow devices (ov1, fins, or setback) used with a moderate to large WWR with quad glazing (window I) make up the very top performers for the north orientation.
- No exterior shading device or shallow devices (ov1, fins, or setback) used with a 0.30 WWR with triple (window H) or quad (window I) glazing make up the very top performers for the east orientation.
- Overhangs (ov1 and ov2) and setback used with a moderate or large WWR with triple (window H) or quad (window I) glazing make up the very top performers for the south orientation.
- Overhangs (ov1 and ov2) and setback used with a moderate or large WWR with triple (window H) or quad (window I) glazing make up the very top performers for the west orientation.

Optimum Glazing Type

The study of the top 50 performers to find the optimum glazing type, given all the parameters, determined there was no optimum glazing for each climate and orientation due to the fact that window-to-wall ratio (WWR) and shading devices play a significant role in the performance of the window design. Finding the optimum glazing type for each orientation in each climate requires fixing various parametrics (WWR and shading type) to allow the optimum glazing to be revealed for specific design conditions.

Key Glazing Findings in Phoenix, Arizona

- Quad glazing (window I) used with a moderate or large WWR and either no exterior shading device or a shallow device (fins or setback) make up the very top performers for the north orientation.
- Triple (window H) or quad (window I) glazing used with a moderate WWR with a deep shading device (ov2 or ov2f) make up the very top performers in the east orientation.
- Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a deep shading device (ov2 or ov2f) make up the very top performers in the south orientation.
- Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a deep shading device (ov2 or ov2f) make up the very top performers in the west orientation.

Key Glazing Findings in Minneapolis, Minnesota

- Quad glazing (window I) used with a moderate or large WWR and either no exterior shading device or a shallow device (ov1, fins or setback) make up the very top performers for the north orientation.
- Triple (window H) or quad glazing (window I) used with a moderate WWR and either no exterior shading device or a shallow device (ov1, fins or setback) make up the very top performers for the east orientation.
- Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a shading device (ov1, ov2 or setback) make up the very top performers for the south orientation.
- Triple (window H) or quad (window I) glazing used with a moderate or large WWR with a shading device (ov1, ov2 or setback) make up the very top performers for the west orientation.

Optimum Window

This study to find the optimum window determined there was no single optimum window design for each climate due to the conditions of:

- orientation;
- glazing type;
- daylighting strategies;
- window area;
- interior and exterior shading devices;
- and the focus on reducing annual; energy use, peak demand, and/or carbon emissions.

The results provided for the top performers, the optimum WWR, optimum shading device, optimum glazing type, and the optimum design options based on certain fixed parametrics help the decision-maker to determine the optimum window for specific design criteria such as:

- What is the optimum design option in terms of energy?
- What is the best window area to use with a shallow overhang?

WHAT WAS DISCOVERED

Performance targets of 30% and 50% (for both energy and carbon emissions) cannot be reached by looking at just a single attribute of a building facade design. The 50% targets were not met in any condition. The reduction of energy demand and consumption requires attention to an integrated design process which includes the building facade, infrastructure, materials, and mechanical systems. Then attention to occupancy, operations, and maintenance is required.

The reduction of annual energy and peak demand does not have a direct correlation to the reduction of carbon emissions. For example in Phoenix in the east orientation, window option 1115 has a 37.91% reduction in annual energy use compared to the baseline window option, but the same comparison produces a 25.08% reduction in annual carbon emissions.

It was assumed that triple (window H) and quad (window I) glazing would be top performers in the heating climate due to the low U-factor. But with the low SHGC, these windows are also the top performers in the cooling climate. These glazing types have a higher visible transmittance allowing for more "clear" glazing in a climate where tinted glazing is often used to reduce solar gain.

There are a number of issues that would prove beneficial for further study. These issues are:

- What is the impact of peak demand reduction when using actual utility cost data, specifically in the cooling climate.
- Study the difference in perimeter zone versus whole building performance. Original study using perimeter zones came back with some confusing results because the annual energy use of a particular perimeter zone may perform very well on one particular orientation but not necessarily on the others. Determine if there is some sort of direct relationship between the perimeter zone performance and the whole building performance.
- Do a life-cycle costing analysis (LCCA) of the window design options to determine the economic effects of alternative designs, to quantify these effects, and express them in dollar amounts.
- This analysis showed the importance of daylighting controls. Continuous dimming was the only daylighting control used. A study to show the effects of different daylighting control strategies would be beneficial.
- How do results and findings impact standards and ratings systems, such as LEED® or Green Globes®?

APPENDIX

Properties for windows used in Figures 11–14. See Appendix B for complete window property information.

Window	Outer Layer	Inner Layer	U-factor	SHGC	VT
A	Clear	-	1.25	0.72	0.71
B	Clear	Clear	0.60	0.60	0.63
C	Bronze Tint	Clear	0.60	0.42	0.38
D	Reflective Tint	Clear	0.54	0.17	0.10
E	Bronze Tint	Clear Low-E	0.49	0.39	0.36
F	Selective Tint	Clear SS Low-E	0.46	0.27	0.43
G	Clear SS Low-E	Clear	0.46	0.34	0.57
H	Clear Low-E +1 PET layer	Clear Low-E	0.20	0.22	0.37
I	Clear Low-E + 2 PET layers	Clear Low-E	0.14	0.20	0.34

Table 5. Ability for typical windows in Phoenix, Arizona to meet ASHRAE Standard 90.1-99. PF=Projection Factor (depth of overhang/height of window). PF=0.50+ means that glazing will meet the standard if there is a projection factor of 0.50 or more. The PF for overhangs modeled for the simulations are either 0.47 (shallow/OV1) or 0.70 (deep/OV2) for WWR=0.15–0.60 corresponding to profile angles of 55° or 65°. Although Window F with a SHGC of 0.27 requires a projection factor of 0.10 or more, there are many selective tints in this category that are below SHGC of 0.25 and do not require a projection. Source: Window Systems for High-performance Buildings and ASHRAE 90.1-99.

		Glazing	U-Factor	SHGC	WINDOW-TO-WALL RATIO				
Window		Layers	(Overall)	(Overall)	0-10%	10-20%	20-30%	30-40%	40-50%
A	Clear	1	1.25	0.72	no	no	no	no	no
B	Clear	2	0.60	0.60	no	no	no	no	no
C	Bronze Tint	2	0.60	0.42	PF=0.60+	PF=0.60+	PF=0.60+	PF=0.60+	no
D	Reflective	2	0.54	0.17	yes	yes	yes	yes	yes
E	Low-E Bronze Tint	2	0.49	0.39	PF=0.50+	PF=0.50+	PF=0.50+	PF=0.50+	no
F	Selective Low-E Tint	2	0.46	0.27	PF=0.10+	PF=0.10+	PF=0.10+	PF=0.10+	PF=0.50+
G	Clear SS Low-E	2	0.46	0.34	PF=0.40+	PF=0.40+	PF=0.40+	PF=0.40+	PF=0.80+
H	Clear 1 Low-E layer	3	0.20	0.22	yes	yes	yes	yes	PF=0.30+
I	Clear 2 Low-E layers	4	0.14	0.20	yes	yes	yes	yes	PF=0.20+

Table 6. Ability for typical windows in Minneapolis, Minnesota to meet ASHRAE Standard 90.1-99. PF=Projection Factor (depth of overhang/height of window). PF=0.50+ means that glazing will meet the standard if there is a projection factor of 0.50 or more. The PF for overhangs modeled for the simulations are either 0.47 (shallow/OV1) or 0.70 (deep/OV2) for WWR=0.15–0.60 corresponding to profile angles of 55° or 65°. Source: Window Systems for High-performance Buildings and ASHRAE 90.1-99.

		Glazing	U-Factor	SHGC	WINDOW-TO-WALL RATIO				
Window		Layers	(Overall)	(Overall)	0-10%	10-20%	20-30%	30-40%	40-50%
A	Clear	1	1.25	0.72	no	no	no	no	no
B	Clear	2	0.60	0.60	no	no	no	no	no
C	Bronze Tint	2	0.60	0.42	no	no	no	no	no
D	Reflective	2	0.54	0.17	yes	yes	yes	yes	no
E	Low-E Bronze Tint	2	0.49	0.39	yes	yes	yes	yes	no
F	Selective Low-E Tint	2	0.46	0.27	yes	yes	yes	yes	yes
G	Clear with SS Low-E	2	0.46	0.34	yes	yes	yes	yes	yes
H	Clear 1 Low-E layer	3	0.20	0.22	yes	yes	yes	yes	yes
I	Clear 2 Low-E layers	4	0.14	0.20	yes	yes	yes	yes	yes

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