建物の省エネに、SageGlass®が選ばれています。

建物のオーナーや建築家、施工業者がSageGlass®を選ぶ理由とは？

住宅やビルなど、建物の設計や管理において常に頭の痛い問題のひとつが窓ガラスです。従来の窓や天窓、カーテンウォールなどに使用されている静的（スタティック）ガラスは、自然光と共に、日射熱やまぶしい日差しを取り込んでしまいます。しかも従来の遮光機能では視界が損なわれるため、窓ガラスの機能が半減するなどの欠点がありました。SageGlass®はこの問題を解決し、建物の省エネとコスト削減に大きく役立ちます。

動的（ダイナミック）な電子的着色ガラスSageGlass®を使用することで、建物のオーナーや管理者は、屋内に入る光や太陽熱を積極的に調節することができ、居住性を向上させると同時に、省エネとコスト削減も実現することができます。また建築家は、SageGlass®によって、環境にやさしく見た目もスタイリッシュ、それでいて優れたエネルギー効率を備えた建物を設計することができます。

耐久性に優れた新技術

SageGlass®の特徴は、その取り付けやすさと揺るぎない信頼性です。SageGlass®の窓枠はコーティング後、業界標準の合わせ複層断熱ガラス（IGU）に組み立てたものを、それぞれ窓や天窓、カーテンウォールの枠材に取り付けます。

詳しいお問い合わせは、
下記までご連絡ください。

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SAGE

SageGlass®をご指名ください。

SageGlass®をご指名いただいた際には、弊社より様々なサービスを提供させていただきます。SageGlass®の施工には、次のサービスが含まれます。

- ガラス特性のモデリング
- 最適な窓ガラス仕様の決定とゾーン設計
- 窓、天窓、カーテンウォールメーカーとの詳細施工検討
- 枠材の配線設計と仕様決め
- 枠材の選定と評価アシスト
- 制御システムの配線図設計
- SageGlass®の制御システムとビルのオートメーションシステムの統合サポート
- 制御システムの構成の仕様決めと設計アシスト
- 窓施工業者と低電気取扱者の現場研修

SAGE

SAINT-GOBAIN GLASS

SageGlass® 製品ガイド

これからの時代に、
ダイナミックな複層ガラス
オフィスビルから住宅まで、
超高効率 SageGlass® は、
最高の性能と確かな信頼を
お届けします。

カリフォルニア州ヘイワードにあるシャボー・カレッジでは、「スマートビル計画」の一環でSageGlass®が使われています。

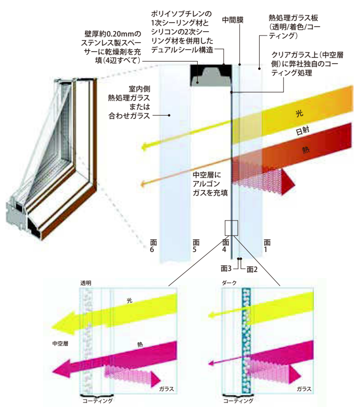
目的に合わせた製品選び

SageGlass® は、標準仕様として二層ならびに三層構造のタイプを、様々な寸法や形状、色でご用意しており、ほとんどの枠材に取り付けることができます。弊社製品はすべて、最高品質のシーリング材と部材を用いた自社生産品です。

二層ガラス

下図は、弊社標準の二層ガラスを一般的な工法で取り付けた場合の特徴を示したものです。弊社IGUの標準総厚は約25mmですが、室外側・室内側ガラス板共に、お客様のご要望に応じて厚みを変えることができます。

SageGlass®の合わせ複層断熱ガラス（IGU）- 着色時

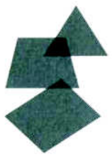


三層ガラス

三層構造のSageGlass® を使えば、エネルギー効率がさらにアップ。弊社の三層ガラスは、業界トップのエネルギー効率を誇っています。

寸法と形状

新築や改築で一般的に取り付けられる矩形の窓ガラスの場合は、最大寸法1524x3048mmまでご用意しています。また平行四辺形や台形、三角形など、意匠性の高い特殊形状にも対応可能です。



SageGlass®なら、あらゆる角形の形状に対応

色

建物の外観に合わせて、様々な着色・コーティングを施すことができます。

枠材

SageGlass® は、ほぼすべての枠材に取り付けることができます。弊社は有数の窓メーカーや天窓、カーテンウォールメーカーと密接な関係を築いており、様々な枠材に対応した施工説明書を準備しています。

バスバー

1辺が1016mm以下のIGUの場合は、2本のバスバーが窓の長手方向に沿って平行に走ります。短手方向の寸法が1016mmを超える場合は、窓の中央を3mm幅のコンダクター（導管）が通ります。このコンダクターのいずれかの面に施した複数のコーティングを独自に制御することで、窓内に2つのゾーンを作って部分的に日差しを防ぎ、日光を有効に取り入れることが可能です。

センター・バスバー付の天窓

優れた断熱・遮熱性

SageGlass® は、お選びいただいた構成と色によって異なる性能を発揮します。取り入れたい可視光と日射熱の量やカットしたい日差しの量に応じて、二層ガラスあるいは三層ガラスをお選びください。

二層ガラスの性能

二層タイプのSageGlass® は、外の視界は常に確保しながら、快適でコストの無駄をなくした環境を創り出します。米国エネルギー省ローレンスバークレー国立研究所の発表では、SageGlass® の二層タイプを使用することで冷房負荷が20％低減、ピーク時の電力需要は30％ダウン、さらに照明費が60％も削減されました。さらに、優れたエネルギー効率により、従来の静的ガラスが使用されていた建物に比べ、空調費を25％も節約することができます。

三層ガラスの性能

三層タイプのSageGlass® は、熱貫流率（U値）が0.7と、一般的なLow-E三層ガラスと同等レベルの低さです。それでいて省エネ性能はLow-Eガラスよりも高く、優れた断熱性と動的着色機能により、最新のLow-E三層ガラスよりも16％、従来の一枚ガラスに比べるとなんと50％以上も高い省エネ性能を発揮します。三層タイプのSageGlass® は、高い断熱性が必要とされる寒さの厳しい地域に理想の製品です。

初期投資比較

従来タイプ　SageGlass® 使用時

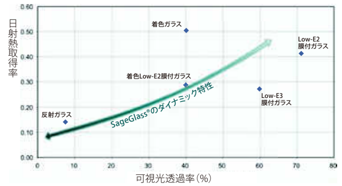
SageGlass®製品名	品種	光学的性能						熱的性能		
		可視光			日射			熱貫流率	遮蔽係数	日射熱取得率
		透過率（%）	反射率（%） OUT	反射率（%） IN	透過率（%）	反射率（%） OUT	反射率（%） IN	W/（m²k）	S.C	g
Classic 二層ガラス アルゴン	クリア＋ アルゴン12＋6	62	11	13	41	13	15	1.6	0.54	0.47
	半透1＋ アルゴン12＋6	21	6	10	10	8	14	1.6	0.18	0.16
	半透2＋ アルゴン12＋6	6	5	9	3	9	14	1.6	0.1	0.09
	フル着色＋ アルゴン12＋6	2	5	10	1	10	14	1.6	0.07	0.06
Classic 三層ガラス アルゴン	クリア＋アルゴン12＋6＋アルゴン12＋6	57	15	18	36	15	18	1.2	0.49	0.42
	半透1＋アルゴン12＋6＋アルゴン12＋6	19	6	16	9	8	18	1.2	0.15	0.13
	半透2＋アルゴン12＋6＋アルゴン12＋6	5	5	16	3	9	18	1.2	0.08	0.07
	フル着色＋アルゴン12＋6＋アルゴン12＋6	1	5	16	1	10	18	1.2	0.06	0.05
Classic 三層ガラス クリプトン	クリア＋クリプトン9＋6＋クリプトン9＋6	57	15	18	35	15	17	1.1	0.49	0.42
	半透1＋クリプトン9＋6＋クリプトン9＋6	19	6	16	9	8	17	1.1	0.15	0.13
	半透2＋クリプトン9＋6＋クリプトン9＋6	5	5	16	3	9	17	1.1	0.07	0.07
	フル着色＋クリプトン9＋6＋クリプトン9＋6	1	5	16	1	10	17	1.1	0.05	0.05
Classic 三層ガラス アルゴン ダブルコーティング	クリア＋アルゴン12＋6＋アルゴン12＋LE6	55	13	16	30	16	26	0.8	0.44	0.38
	半透1＋アルゴン12＋6＋アルゴン12＋LE6	19	6	13	8	8	26	0.8	0.14	0.12
	半透2＋アルゴン12＋6＋アルゴン12＋LE6	5	5	13	2	9	26	0.8	0.06	0.06
	フル着色＋アルゴン12＋6＋アルゴン12＋LE6	1	5	13	1	10	26	0.8	0.04	0.04
Classic 三層ガラス クリプトン ダブルコーティング	クリア＋クリプトン9＋6＋クリプトン9＋LE6	55	13	16	30	16	26	0.7	0.43	0.38
	半透1＋クリプトン9＋6＋クリプトン9＋LE6	19	6	13	8	8	26	0.7	0.13	0.12
	半透2＋クリプトン9＋6＋クリプトン9＋LE6	5	5	13	2	9	26	0.7	0.06	0.05
	フル着色＋クリプトン9＋6＋クリプトン9＋LE6	1	5	13	1	10	26	0.7	0.04	0.03

EN410-2011 及び EN673-2011のデータによる
Low-E：Planitherm UNII
充填率：アルゴン90%、クリプトン95%とする

これまでにない特性

SageGlass® は、可視光透過率と日射熱取得率を幅広くコントロールすることができます。建物の設計時、日射熱取得率と可視光透過率のどちらかに妥協する必要はありません。SageGlass® は、天候や差し込む日光の量に関係なく光と熱の理想的なバランスを実現することにより、エネルギーコストを低減し、居住者に快適な環境を提供します。

SageGlass® のダイナミックな透過・日射熱取得特性と従来の窓ガラスの比較



SageGlass®特性一覧

	可視光透過率	日射熱取得率	遮蔽係数	変色・退色保護
SageGlass®（クリア～フル着色）の特性	62% － 2%	0.47 － 0.06	0.54 － 0.07	－
特色	静的ガラスは対象となる日射条件が1点なのに対し、SageGlass®は広範囲の日射条件に対応。	SageGlass®にはクリアタイプと着色タイプがあり、必要に応じて日射熱を取り込んだり遮蔽したりすることができる。	SageGlass®の最大UV透過率は、静的クリアLow-Eガラスの最小UV透過率よりも低い。	SageGlass®は、変色・退色保護率がほぼ100%。最小値ですら従来タイプのガラスの最大値をはるかに超える。

上記の数値はClassic二層ガラスアルゴンのものです。

施工例
ウィスコンシン州ウォキショー郡
ボルティ チェッロ クラブ

Performance Assessment of SageGlass® Electrochromic Coatings and Control Scenarios

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PERFORMANCE ASSESSMENT OF SAGEGLASS® ELECTROCHROMIC COATINGS AND CONTROLS

EXECUTIVE SUMMARY

SAGE Electrochromics, Inc. has developed an electronically switchable window glazing that saves energy, cuts CO_2 emissions and contributes to occupant comfort and productivity in buildings.

SAGE commissioned a study by Paladino and Co., an internationally recognized green building consulting firm, to compare the energy performance of windows incorporating dynamic SageGlass® glazings with other conventional and high performance static glazings. Each window type was modeled in a standard eight-story office building using eQuest computer simulations based on the ASHRAE 90.1-2007 national energy code. Analysis was conducted for three different climates: Minneapolis, which is very cold in the winter; Phoenix, which is hot and dry; and Washington, DC, which has a mixed hot/cold climate.

SageGlass glazing performance was evaluated by comparing annual energy use and operating costs against the performance of static window options. The research also captured first cost savings due to down-sized cooling equipment and estimated reductions in annual CO_2 emissions.

Several key assumptions were made during performance modeling:

(1) ASHRAE 90.1-2007 was used to define the performance of a standard code-compliant building, including minimum insulation levels, occupant load, equipment efficiencies and schedules. The only modifications made between modeling runs were revisions of glazing parameters enabling the comparison of SageGlass glazings to static window options. ASHRAE standard glazings were used as the base case in each climate zone.

(2) Each window system must be capable of blocking uncomfortable glare. The SAGE glazing system can be electronically tinted to block glare when needed, and requires no shades or blinds. Commercial static glazing systems must include shading devices to reduce glare.

(3) SageGlass operation was modeled using integrated controls connected to building management systems for optimum energy performance and glare management. Static glazing systems were assumed to have manual shading devices that are pulled by building occupants when glare becomes uncomfortable.

(4) Daylight controls and electronic dimming were included in all results (SageGlass and static options) except for comparisons to single and double pane clear glazings, which represent older, less energy-efficient building stock.

SAGEGLASS PERFORMANCE SUMMARY

SageGlass glazings generate substantial energy savings and dramatically reduce a building's peak cooling load, reducing both annual operating costs and first costs associated with HVAC peak capacity for all U.S. climate zones. Significant reductions in CO_2 emissions correlate with building energy savings.

ENERGY SAVINGS: Table I shows minimum annual energy savings across all climate zones of SageGlass double and triple pane glazings when compared to (1) single pane glass (common in existing building stock), (2) baseline ASHRAE 90.1-2007 glazing, and (3) high performance commercial static triple panes.

Table I.

Minimum Annual Energy Savings for SAGE Dynamic Glazings
Compared to Static Commercial Glazing Types

	Static Single Pane (no daylighting controls)	ASHRAE 90.1-2007	Commercial Triple
SageGlass Double	45%	20%	NA
SageGlass Triple	53%	34%	14%

Eight story office building, 160,000 total sq. ft., 60% window-to-wall ratio

PEAK REDUCTION: SageGlass glazing dynamically controls the amount of solar energy entering a building, reducing air conditioning electricity demand during the hottest times of the day. Because cooling equipment is sized to exceed peak load conditions, SageGlass can reduce cooling equipment costs. In new construction, SageGlass can save 30 - 35% in cooling equipment costs, and in older building retrofits with single pane glazings, SageGlass can cut equipment costs 40 - 50%.

CO_2 REDUCTION: Utility companies run their most efficient power plants to meet base load demand and slowly bring on less efficient, more CO_2-emitting plants as demand increases. Since SageGlass glazings reduce the load on a building during peak utility times, their use exponentially reduces power plant emissions. SageGlass reduces peak load carbon emissions by as much as 35% in new construction and 50% in renovation projects.

THE TECHNOLOGICAL FUNDAMENTALS OF SAGEGLASS

SageGlass electrochromic (EC) coatings are applied to a single piece of glass, which is then fabricated into an architectural insulating glass unit (IGU). The coating can be tinted or cleared electronically to control solar heat gain and glare in buildings without ever blocking the view to the outside. SageGlass IGUs are nearly identical in form factor to a standard IGU, except that they have a wire exiting the IGU for electrical interconnections. The glazing can be controlled in a variety of ways, including integrating it into the building energy management system. It takes less electricity to operate 1500 sq.ft. of SageGlass windows than is needed to power a single 60-Watt light bulb.

Figure 1 shows what happens when electricity is applied to SageGlass glazing. The EC coating, which is made up of five layers, darkens as lithium ions and associated electrons transfer from the counter electrode (CE) to the electrochromic electrode(EC) layer. Reversing the voltage polarity causes the ions and associated electrons to return to their original layer, the CE, and the glass returns to a clear state. This solid state electrochromic reaction is controlled through a low voltage DC power supply. It takes less than 5V to switch the glazing.

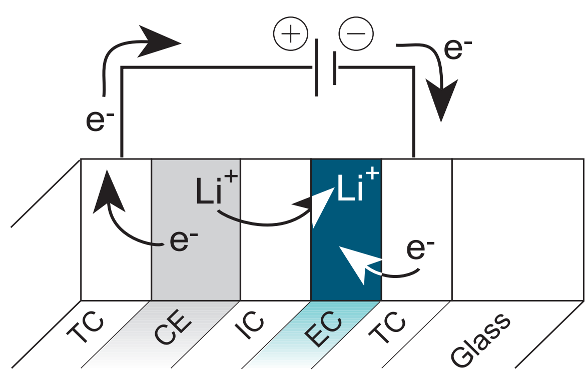

Figure 1. SAGE thin film electrochromic stack on glass.

TC: transparent conductor, CE: counter electrode, EC: electrochromic electrode, IC: ion conductor

Figure 2 illustrates how SageGlass IGUs modulate sunlight and solar heat. In the clear state, the SageGlass glazing has a visible light transmission of 62% and passes 48% of the incident solar energy to the building interior. When a low DC voltage is applied to tint the films, the amount of incident solar energy allowed into the building is reduced by 81%.

Today's static glazings do not approach the energy savings possible with SageGlass glazings. Each static glazing offers the architect a single fixed light transmission with associated fixed energy transmission. At one extreme, the choice of high transparency allows daylight to enter the building at the cost of high solar heat gain and high cooling loads. Low transparency static glazings reduce solar heat gain but also restrict natural daylighting. SageGlass performance is shown in Figure 3 which compares the individual solar control coordinates of static glazings with the wide range of SageGlass glazing—that can tint or clear according to changing environmental conditions to achieve optimum energy performance.

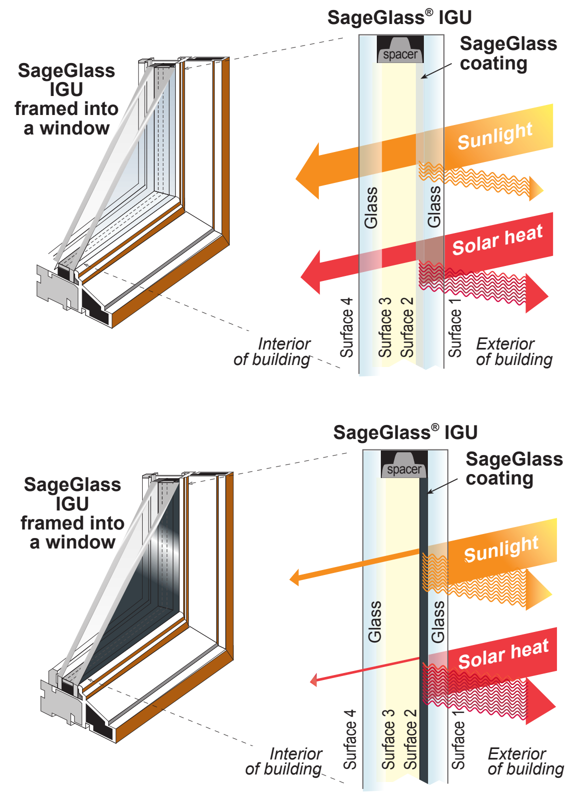

Figure 2. SageGlass technology in clear and tinted states.

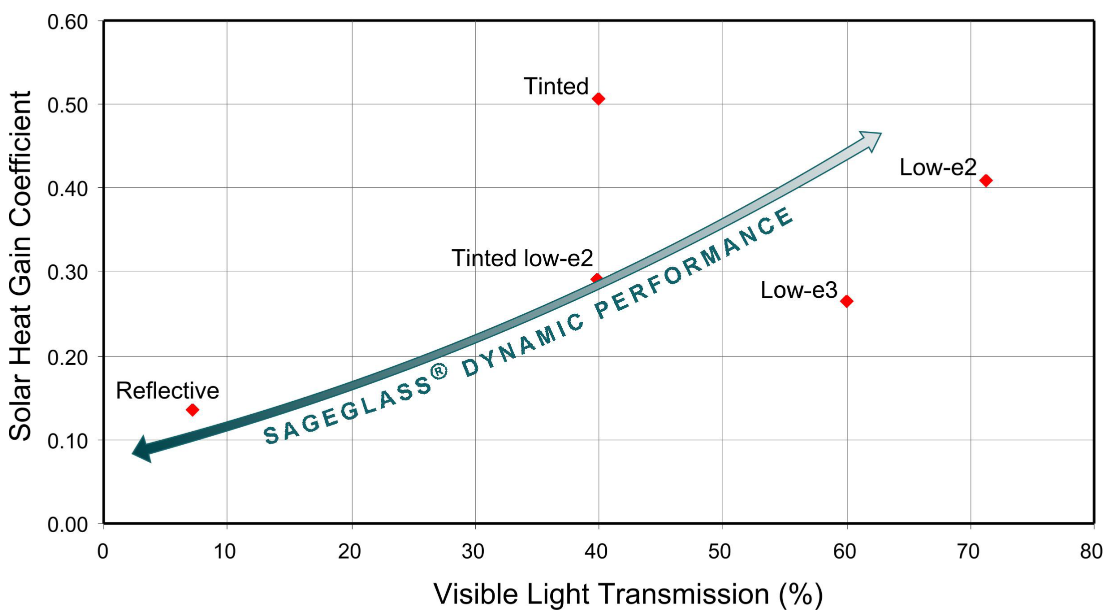

Figure 3. SageGlass – SHGC to VLT relationship: SageGlass glazing can be tinted from a highly transmitting state to a very dark state to adapt to a wide range of sunlight conditions. Today's static glazing (the individual points on the chart) are specific to one condition and cannot be changed.

SAGEGLASS CONTROL STRATEGIES

For optimum performance there are a number of control strategies for determining when the EC glazing should be in its darkened, clear or intermediate tinted state. The most logical means to control tint level is to link it directly to the amount of daylight that is needed within the space. Work at Lawrence Berkeley National Laboratory (LBNL) has shown that control algorithms based on daylight illuminance result in the best overall annual energy performance.[1] For purposes of this modeling exercise, a 30-footcandle[2] level delivered at the work surface (30" above the floor) was determined to be ideal for an office environment where computer screens are in use.

DAYLIGHT CONTROL: Daylighting is the synergistic control of dimmable electric lighting and natural light from windows for maximum natural daylight and optimum energy management. Depending on sky conditions (cloudy vs. clear), sun position and glass, a daylight sensor can control tint level to achieve the optimum footcandle level. With overcast skies, the glass may be cleared to admit enough daylight to achieve optimum illumination within the space. With clear skies, the daylight sensors can darken or partially tint the IGUs to limit daylight to obtain the same 30-footcandle target, while concurrently reducing solar gain.

SCHEDULE CONTROL: SageGlass glazing can also be controlled based on the time of year and amount of solar energy that is desired to pass into the space. During summer, blocking solar gain may reduce the load on building air conditioning systems. Conversely, allowing needed solar gain during winter will reduce energy needed to heat the building. Thus, seasonal variation in combination with daylighting controls can secure an optimal energy performance of the glass façade with SageGlass glazing.

GLARE CONTROL: SageGlass glazing can directly control glare in a space. Glare causes visual discomfort and reduces contrast at the workplane or on a computer screen due to direct solar irradiation. Tinting the glass fully (to 3.5% VLT or less) will achieve occupant comfort in direct sunlight or when exposed to intense reflected light. By allowing the user to control SageGlass glazing through a timed override, the offending window zone can be tinted while allowing other panes to permit daylighting in the space and/or heat the building during the winter (Figure 4.).

SageGlass glazing's electronic control can automatically adjust the tint when conditions change, unlike manual blinds that are rarely optimally controlled by users. For this reason, manual blinds cannot be adequately deployed for energy efficiency, while electronically controlled systems, such as SageGlass, can be optimally set by building management systems.

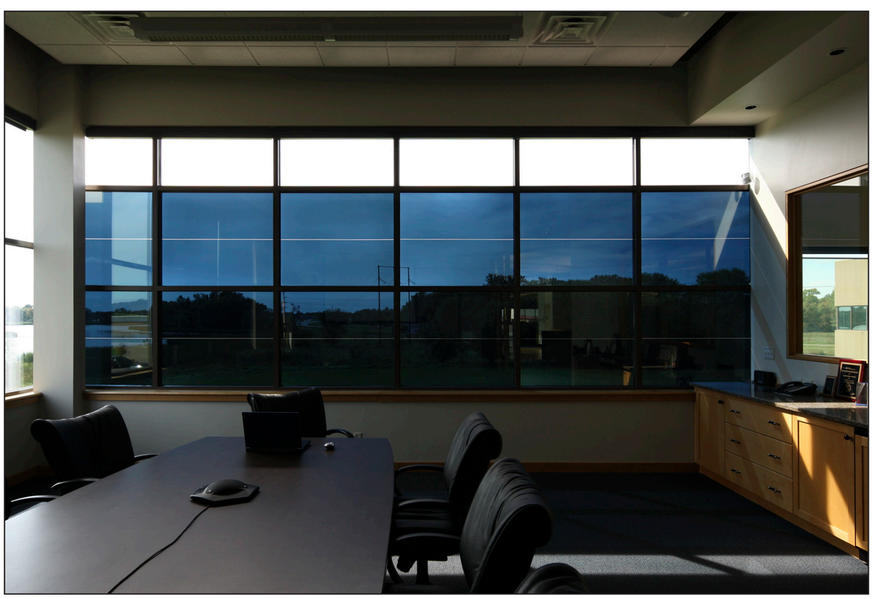

Figure 4. Conference room with zoned SageGlass windows block the sun's glare but allow in sufficient daylight to illuminate the room without the use of artificial lights.

1 R. Sullivan, E.S. Lee, K. Papamichael, M. Rubin, and S. Selkowitz, "Effect of Switching Control Strategies on the Energy Performance of Electrochromic Windows", LBL-35453, April 1994.

2 Horizontal Illuminance level for spaces with intense VDT usage - IESNA Lighting Handbook 9th Edition

SageGlass glazing can also use the input from occupancy sensors in offices and conference rooms to override other control strategies (such as glare control or daylighting control). When spaces are vacant, sensors can, in addition to switching off lights, reset SageGlass from glare control mode to energy savings mode (based on schedule control): clear in winter and fully tinted in summer.

In this study, the SageGlass glazings were optimally controlled in each of the climate models for maximum energy performance by combining daylight control and seasonal schedule. When glare control is added to the control sequence, there are times of year in which glare overrides optimal tinting of the glass. This occurs mainly in the seasons when the glass should be clear or partially tinted to optimize daylighting, but sometimes needs to be completely tinted to control glare. Per simulation results, the energy use impact of adding glare control ranges from +2% to -0.4% based on climate. By comparison, static glazings with manual shades for glare control increase building energy use 5-6%. This is described in more detail below.

ENERGY IMPACT FROM GLARE CONTROL: To determine the energy impact of glare on a space when using SageGlass, the number of hours that glare control is required was determined based on the hours that direct sun was incident on the work surface. The table below indicates the total number of winter and summer hours that require glare control with SageGlass per zone of the building for different climates. The corresponding energy impact from glare control is also listed in Table 2 below.

Table 2.

Calculated impact of glare control for SageGlass glazing.

Climate	Zones	No: of hours with glare control		Increase in Energy Use	Increase in Energy Cost
		Summer	Winter		
Washington DC	East/ West	25	20	1%	0.60%
	South	59	191		
Minnesota	East/ West	40	230	2.0%	2.3%
	South	122	450		
Phoenix	East/ West	48	324	-0.4%	-0.6%
	South	138	323		

ENERGY IMPACT FROM MANUAL BLINDS: Similarly, the energy impact of using manual blinds was determined based on the findings from the study Manual vs. Optimal Control of Interior and Exterior Blinds carried out by the Department of Architectural Engineering, SungKyunKwan University of South Korea, authored by Deuk-Woo Kim and Cheol-Soo Park[3].

This study shows that user-controlled manual blinds have a substantial impact on daylight energy savings[4]. As blinds are typically controlled manually, they are deployed based on extreme conditions, such as being closed when glare is present, and are rarely re-opened at the optimized time when glare control is no longer needed. The study indicates that manual blinds can negatively impact the energy savings associated with daylighting strategies from 0% (blinds completely raised) to 100% (blinds down and closed), depending on the number of open or closed blinds, and the angle of the blinds. In other words, maximum daylight energy savings is achieved when the manual blinds are completely raised, and zero daylight energy savings result when the manual blinds are completely lowered and closed.

3 Kim, D-W, and Park, C-S, "Manual vs. Optimal Control of Exterior and Interior Blind Systems", Eleventh International IBPSA Conference, Glasgow, Scotland, July 27-30, 2009.

4 Daylight energy savings: when daylight strategies are employed, energy is saved from reduced artificial lighting and the associated reduction in cooling energy.

To determine the impact of blinds, a control strategy was assumed in energy modeling runs that there was an equal percentage of down and closed blinds, raised blinds, and down blinds with the vanes open at various angles. Using this control assumption, the mid-point in lighting and cooling energy use from a modeling run that contains no daylighting control savings and a modeling run with daylighting control savings was used to determine the energy impact from glare control using manual blinds. This indicates a 50% reduction in daylighting energy savings (lighting and cooling energy savings associated with reduced artificial light use) and a slight increase in heating energy savings. We estimate 5-6% more energy consumption for static glass with manual blinds compared to the case of static glass with no blinds. There will be little to no change in the cooling energy use in the space due to manual blinds (unlike exterior shades or integrated blind systems)5 as the heat is already in the space.

ENERGY ANALYSIS PARAMETERS

Model Configuration

The energy model developed for this study assumed a standard U.S. office building configuration. The building model assumes a 15-ft. perimeter open office space surrounding a 40-ft. deep core. The resulting section of 70 feet allows for the maximum amount of workers to be located within the daylight zone of the building, while elevators, restrooms, stairways, equipment rooms, and conference areas are located within the non-daylit core of the building. The building consists of 20,000-sq.-ft. floor plates, contains eight total floors and has 160,000 total sq. ft. The total glazing area was 37,500 sq. ft. Building orientation was set such that the long side faced east/west with a window-to-wall ratio of 60%. Total plug loads for an office building were assumed to be 0.75 watts per sq. ft, representing typical office loads of computers, task lamps, copiers and other standard office equipment.

The national energy code, ASHRAE 90.1-2007, was used to define the minimum code compliant baseline, as it is the most widely adopted energy code standard. It provides minimum insulation levels for the envelope, mechanical efficiency requirements and maximum lighting power densities. Thus, the building modeled represents the minimum code compliant building that can be constructed today. This energy code represents a leap forward in energy performance compared to the typical building stock today. Several studies indicate that the ASHRAE 90.1-2007 is roughly 20-30% more efficient than buildings constructed 20 years ago. For a complete list of modeling assumptions, please see Appendix A.

Climate Zone Modeling Impact

The maximum energy impact of SageGlass is determined by the climate zone in which the building is located. Three climate zones were simulated to show the extreme conditions found within the U.S. to demonstrate the range of performance offered by the use of SageGlass and associated daylighting controls.

Phoenix, Ariz., was simulated to represent a hot, dry climate in which daylight is prevalent and a cooling load is dominant throughout the year. Minneapolis, Minn., was simulated to represent a cold climate that is heating load dominated. Washington, D.C., was used to represent a composite climate that has both extreme heating and cooling seasons.

Glazing Performance

ASHRAE 90.1-2007 offers various minimum performance values for glass for each climate zone located within the U.S. These performance values are determined by the needs of the climate and are

5 In case of interior blinds, solar radiation passing through the window is distributed on internal surfaces (wall, floor, ceiling, slats, furniture), and the effect of blocking solar radiation is not significant compared to the exterior blinds.

established as the optimal static level. The critical values that are set by ASHRAE include both the solar heat gain coefficient (SHGC) and the U-value of the glass. The SHGC is the fraction of incident solar radiation allowed to pass through the glass while the U-factor expresses the overall heat flow through the IGU (Btu/hr.-sq.-ft.-°F) for a 1-degree-Farenheit difference between indoor and outdoor temperatures.

In a cold climate like Minneapolis', a lower U-value is desired to offset heat loss through direct conduction, though a high SHGC is also desired, as solar gain helps passively heat the building. In Phoenix, a low SHGC is required to attenuate the intense sun and limit solar gain, though a higher U-value is allowed as the temperature difference between the interior and exterior is relatively small when compared to cold climates. For Washington D.C., the code offers the best static condition between both solar gain and conduction, though neither is suited ideally for the extremes of the climate.

The third performance target desired by architects and engineers is Visual Light Transmission (VLT). The higher the VLT percentage, the greater amount of natural daylight allowed to enter the space and the clearer the views to the outside. High VLT values exhibited by clear glass are optimal to daylight a building. Low VLT values are the result of tinting, reflectance, or low-e coatings that have been applied to the glass to limit solar heat gain or decrease the U-value of the glass.

Thus, in ASHRAE 90.1-2007 code performance targets for both SHGC and U-value impact the specification of clear glass desired to daylight a building. Architects often specify clear glass to maximize views to the outside at the expense of an energy penalty in either SHGC or U-value that must be offset by other systems in the building. VLT values for each of the climates modeled in this study represent values that can be achieved with static glass while hitting the SHGC and U-values dictated by ASHRAE 90.1-2007.

Table 3 shows the Center of Glass (COG) performance levels for ASHRAE 90.1-2007 code specified static glass per climate zone and SageGlass performance for both tinted and clear states used in the eQuest energy modeling.

Table 3.

Glazing performance per ASHRAE 90.1-2007 and actual SageGlass characteristics

		SHGC	U-Value	VLT
Phoenix, AZ		0.25	0.75	40%
Washington, DC		0.4	0.55	40%
Minneapolis, MN		0.4	0.55	40%
SageGlass Double Pane (Argon)	Clear	0.48	0.29	62%
	Tinted	0.09	0.29	3.5%
SageGlass Triple Pane (Argon)	Clear	0.38	0.14	52%
	Tinted	0.05	0.14	2.9%

ENERGY MODELING PROTOCOL

ASHRAE 90.1-2007 Appendix G represents the most prevalent standard for determining building energy performance. The code requires that two models are run to compare a minimum code compliant building (a baseline model) against a proposed building (design case). The protocol requires that occupancy, plug loads and annual operating hours remain constant. All results indicated in this report were validated using eQuest v3.63 that is a DOE-2 compliant modeling program allowed by Appendix G.

Various parametric modeling simulation runs were completed to demonstrate performance levels for different control strategies of SAGE EC windows. Table 4 below describes the variances between the modeling runs as allowed by Appendix G. As daylighting and glare controls are integrated into all SageGlass results, data for static glazings should include these options where appropriate. For runs 1 and 2 in Table 4 below, it is assumed that single and double pane clear glass are only used in older buildings without daylighting controls. ASHRAE 90.1-2007 glazings in runs 3 and 4 were analyzed with and without daylighting controls and manual blinds. Higher performing static glazings in modeling runs 5 and 7 also included daylighting controls and interior manual shading devices.

Table 4.

Performance modeling simulations runs.

Modeling Run	Application of ASHRAE Standard	Glazing Characteristics
Run 1: Single pane clear	Based on climate specific ASHRAE requirements for an office occupancy except glazing	COG U-val=1.03, SHGC=0.82, Tvis=0.89
Run 2: Double pane clear	Same as Run 1	COG U-val=0.48, SHGC=0.76, Tvis=0.81
Run 3: ASHRAE	Based on climate specific ASHRAE requirements for an office occupancy including glazing	Washington DC: COG U-val=0.55, SHGC=0.40, Tvis=0.4 Minneapolis: COG U-val=0.55, SHGC=0.40, Tvis=0.4 Phoenix: COG U-val=-0.75, SHGC=0.40, Tvis=0.4
Run 4: ASHRAE + DL + manual blinds	Same as Run 3 with daylight controls and manual blinds for glare control	Washington DC: COG U-val=0.55, SHGC=0.40, Tvis=0.4 Minneapolis: COG U-val=0.55, SHGC=0.40, Tvis=0.4 Phoenix: COG U-val=-0.75, SHGC=0.40, Tvis=0.4
Run 5: Commercial static double (air) + DL + manual blinds	Same as Run 1 with daylight controls and manual blinds for glare control	Washington DC: COG U-val=0.29, SHGC=0.38, Tvis=0.71 Minneapolis: COG U-val=0.29, SHGC=0.38, Tvis=0.71 Phoenix: COG U-val=-0.29, SHGC=0.28, Tvis=0.62
Run 6: SAGE double with argon + DL + manual blinds	SageGlass double-pane with daylight + glare controlling the glass during the summer and only glare controlling the glass during the winter	Clear state: COG U-val=0.29, SHGC=0.48, Tvis=0.62 Tint State: COG U-val=0.29, SHGC=0.09, Tvis=0.035
Run 7: Commercial static triple, argon + DL + manual blinds	Same as Run 1 with daylight controls and manual blinds for glare control	COG U-value=0.12, SHGC=0.33, Tvis=0.55
Run 8: SAGE triple with argon + DL + glare control	SageGlass triple-pane with daylight + glare controlling the glass during the summer and only glare controlling the glass during the winter	Clear state: COG U-val=0.136, SHGC=0.382, Tvis=0.523 Tint State: COG U-val=0.136, SHGC=0.053 Tvis=0.029

CONCLUSIONS

In conclusion, this study shows that windows with SageGlass glazings:

- generate substantial energy savings;
- dramatically reduce the peak cooling load of a building;
- provide glare control that improves occupant comfort without a significant energy penalty;
- significantly reduce CO_2 emissions; and
- outperform high performance double and triple static glazing options.

The following graphs illustrate the level of energy and chiller cost reduction (for a large office building with 60% window-to-wall ratio) that can be achieved using SageGlass in comparison to current commonly specified glass types in commercial buildings.

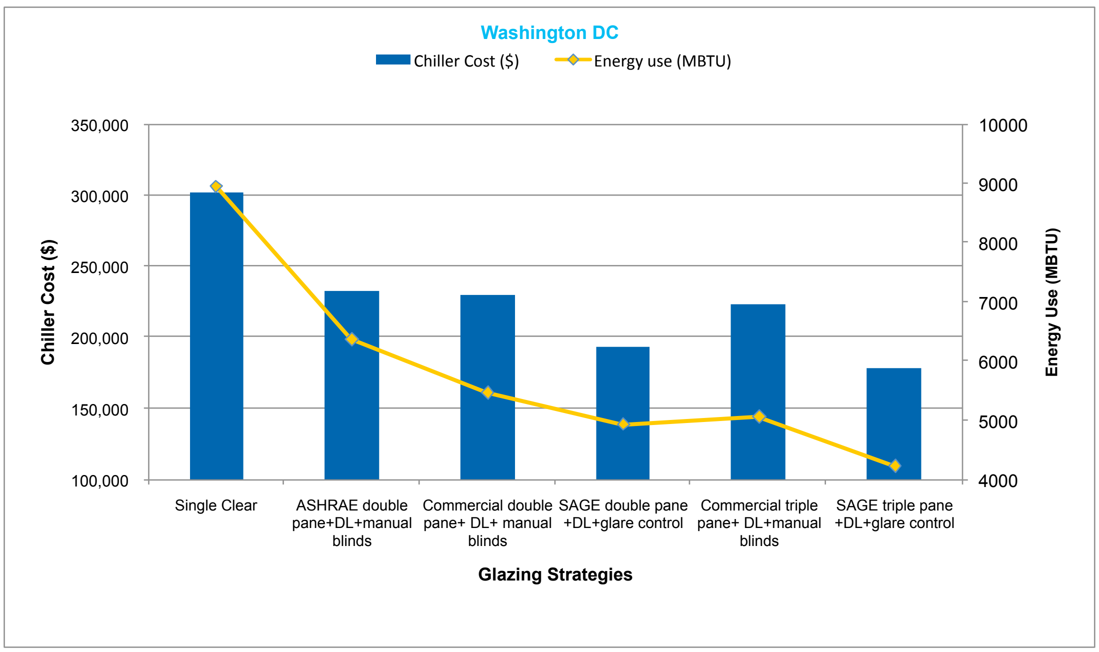

Figure 5. Washington, D.C. - Energy use and chiller cost for different glass types.

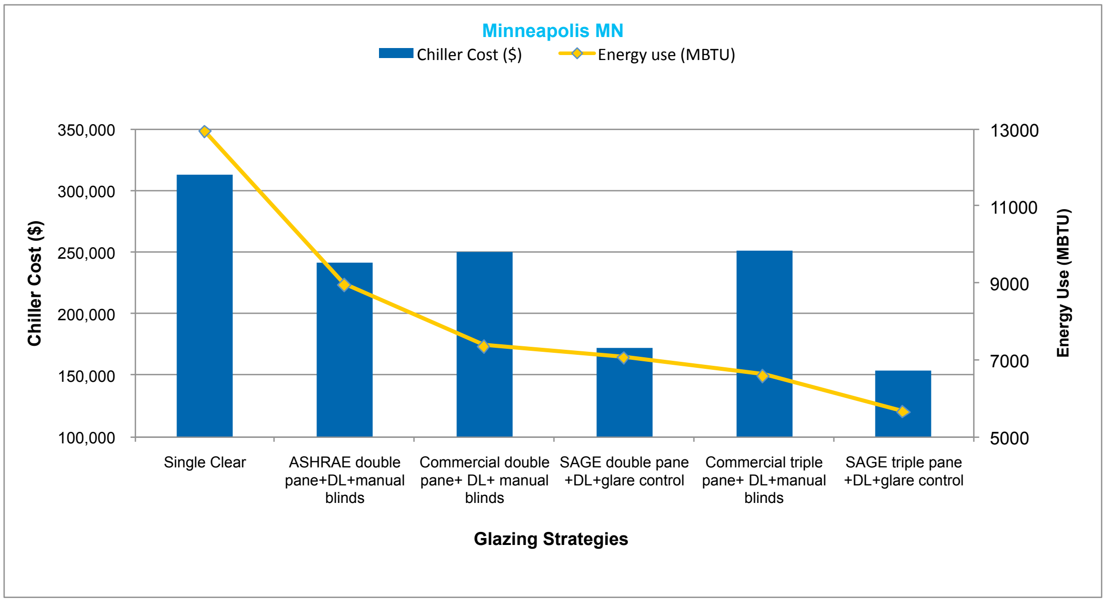

Figure 6. Minneapolis, Minn. - Energy use and chiller cost for different glass types.

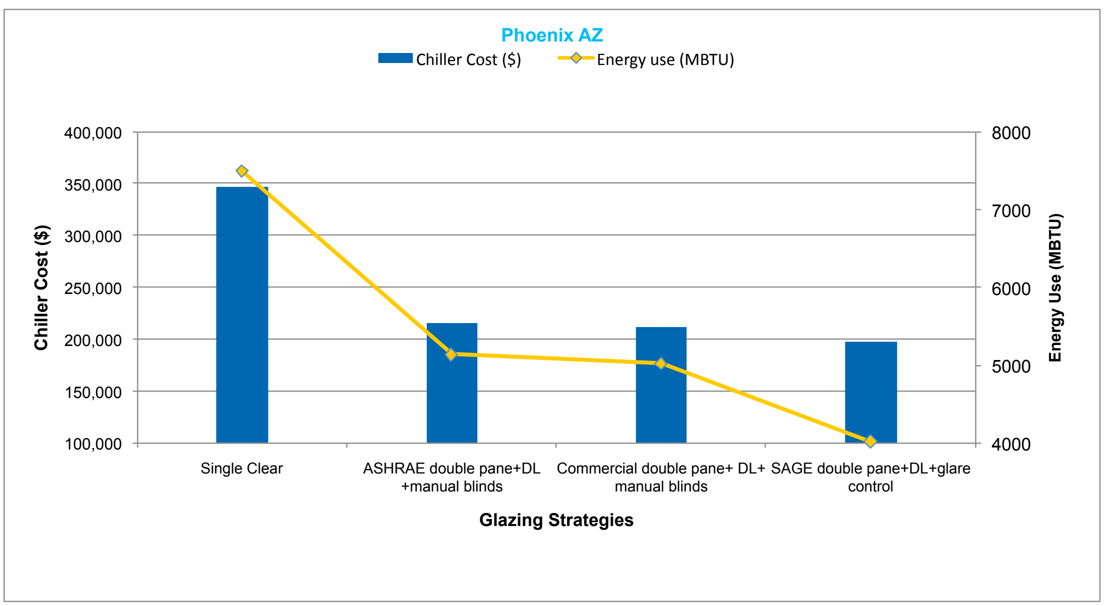

Figure 7. Phoenix, Ariz. - Energy use and chiller cost for different glass types.

APPENDIX A: DETAILED SIMULATION INPUT VALUES: OFFICE BUILDING

Category	Description	Reference in ASHRAE Standard 90.1-2007
Building Envelope		
# of floors	8	-
Floor dimension	70' by 285'	-
Building gross floor area	159,600 sq. ft.	-
Floor-to-floor height	12'	-
Floor-to-ceiling height	9'	-
Window height	7.2'	-
Window sill height	1.6'	-
Window-exterior wall-ratio	60%, at all levels and four elevations	-
Roof U-value	0.048 for DC (Zone 4A) Phoenix (Zone 2B) and Minneapolis (Zone 6A), insulation entirely above deck	Table 5.5 and Table G3.1 (5)
Exterior wall U-value	0.064 for DC (Zone 4A) 0.124 for Phoenix (Zone 2B), and 0.064 for Minneapolis (Zone 6A), steel-framed exterior walls	
Floor U-value	0.038 for DC (Zone 4A) and 0.052 for Phoenix (Zone 2B), 0.038 for Minneapolis (Zone 6A), steel-joist floors	
Slab-on-grade floor F-factor	0.73, 6" concrete with no insulation for DC (Zone 4A) and Phoenix (Zone 2B), 0.54, 6" concrete with no insulation for Minneapolis (Zone 6A)	
Window assembly U-value	0.55 for both DC (Zone 4A) and Minneapolis (Zone 6A), and 0.75 for Phoenix (Zone 2B)	
Window assembly SHGC	0.40 for both DC (Zone 4A) and Minneapolis (Zone 6A), and 0.25 for Phoenix (Zone 2B)	
Shading devices	None	

Category	Description	Reference in ASHRAE Standard 90.1-2007
HVAC systems		
System Type	#7 – VAV with reheat	Table G3.1.1
Fan control	VAV	
Cooling type	Chilled water	
Heating type	Hot water gas boiler	
Economizers	Included for and Phoenix (Zone 2B), 0.038 for Minneapolis (Zone 6A), not included for DC (Zone 4A)	G3.1.2.6
Economizer high-limit shut-off	75 F (Zone 2B) and 70 F (Zone 6A)	
Supply air temperature	55F/95F, reset based on minimum cooling conditions; Delta 5F	G3.1.2.8 and G3.1.3.12
Fan system operation	Continuous whenever spaces are occupied; Cycled on to meet heating and cooling loads during unoccupied hours	G3.1.2.4
Supply fan volume	Calculated by eQuest	-
Fan power	Calculated based on supply/return air volume	G3.1.2.9
VAV minimum flow set point	0.4 cfm/sq. ft.	G3.1.3.13
VAV fan part-load performance	Using part-load fan power equation	Table G3.1.3.15
Number and type of chillers	2 screw chillers	Table G3.1.3.7
Chiller capacity	Sized by eQuest	-
Chiller efficiency	4.9 COP	Table 6.8.1C for screw chillers of 150 ton to 300 ton capacity each

Category	Description	Reference in ASHRAE Standard 90.1-2007
Chilled water supply /return temperature	44 F/56 F, supply temperature reset based on outdoor dry-bulb temperature	G3.1.3.8 & G3.1.3.9
Chilled water pumps	Primary/secondary system, two primary pumps and one secondary loop pump VSD on the secondary loop pump Pump power = 22W/gpm	G3.1.3.10
Number and type of Boilers	2 gas boilers	G3.1.3.2
Boiler capacity	Sized by eQuest	-
Boiler efficiency	80% for capacity more than 2,500 kBtu/h	Table 6.8.1F
Hot water supply/return temperature	180 F/130 F, supply temperature reset based on outdoor dry-bulb temperature	G3.1.3.3 & G3.1.3.4
Hot water pumps	Primary-only system 2 primary pumps with VSD Pump power = 19 W/gpm	G3.1.3.5
Heat rejection	One axial fan cooling tower, 2-speed fans	G3.1.3.11
Condenser water loop	Tower water entering temperature: 85F leaving temperature: 70 F	
Condenser water pump	One single-speed pump for each chiller Pump power = 19W/gpm	
Occupant density	ASHRAE 62.1-2004 default occupant densities	-
Outdoor air rate	20 cfm/person	-
Heating set point	70 F, and 64 F during unoccupied hours	Assumed
Cooling set point	76 F, and 82 F during unoccupied hours	Assumed

Category	Description	Reference in ASHRAE Standard 90.1-2007
Lighting and Receptacle loads		
LPD	1.1 w/sq. ft	Space-by-space method in Table 9.6.1
	1.5 W/sq. ft. for mechanical/electric rooms	
	0.9 W/sq. ft. for rest rooms	
	1.3 W/sq. ft. for lobbies	
Receptacle loads	0.75 W/sq. ft.	Table G-B of ASHRAE 90.1-2004 User's Manual
Domestic Hot Water System		
Water heating equipment	Four 100-gal gas storage water heaters, one for two floors	Assumed
Heating capacity/ Tank volume	Sized by eQuest based on the water use assumption of 1 gal/person/day	-
Thermal efficiency	80%	Table 7.8
Tank standby loss	1.27 kBtu/h	Table 7.8 for heater capacity more than 75,000 Btu/h

APPENDIX B: MODELING RESULTS BY CLIMATE

WASHINGTON, D.C.

Energy Analysis: Energy, Cost and Emissions Data

Run no	Runs	Annual site Energy		Annual Operating Cost ($)[2]	Peak Demand		Chiller Cost ($)*	Annual CO_2 Emissions (kG) **	Annual site		Lighting	Misc Equip	HVAC		
		Total Mbtu	EUI kBtu/sf/yr		Elec kW	Cooling tons			Elect kWh	Nat Gas Therms	Electric kWh	Electric kWh	Electric kWh	Nat Gas Therms	Total Mbtu
1	Single-pane clear	8949	55.9	$ 384,095	873	465	$ 302,250	1016151.4	1,597,522	34,981	394,679	383,439	819,400	32,768	6,073
2	Double-pane clear	6645	41.5	$ 333,954	821	429	$ 278,850	855411.0	1,484,604	15,795	394,679	383,439	706,481	13,592	3,770
3	ASHRAE	6532	40.8	$ 298,840	725	366	$ 237,900	774638.2	1,263,476	22,209	394,679	383,439	485,353	19,996	3,656
4	ASHRAE + DL + Manual Blinds	6363	39.8	$ 284,622	689	359	$ 233,025	740322.7	1,188,484	23,083	332,297	383,439	472,745	20,870	3,701
5	Commercial static double glazing (SHGC=0.38) + DL + Manual Blinds	5460	34.1	$ 269,162	681	354	$ 229,775	686755.3	1,172,244	14,600	331,247	383,439	457,554	12,396	2,802
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	4932	30.8	$ 222,526	564	297	$ 192,977	573667.7	928,486	17,150	268,064	383,439	276,983	14,930	2,438
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	5055	31.6	$ 259,555	666	343	$ 222,950	657234.2	1,148,663	11,354	331,510	383,439	433,711	9,153	2,396
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	4231	26.4	$ 205,857	527	274	$ 177,982	522477.4	886,238	11,654	269,077	383,439	233,721	9,441	1,742

* Includes chiller, cooling tower with pump, piping and installation cost

* Source: Tri-State Generation and Transmission Association - http://tristate.apogee.net/cool/cmnch.asp

** Calculated using Portfolio Manger's Emissions calculation methodology

RESULTS (Washington D.C.): Savings from Various Glass Types

Baseline: Single Clear (Run 1)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[2]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
1	Single Pane Clear	–	–	–	–	–	–	–
2	Double-pane clear	2304	26%	$ 50,141	13%	36	$ 23,400	160,740.4
3	ASHRAE	2417	27%	$ 85,255	22%	99	$ 64,350	241,513.2
4	ASHRAE + DL + Manual Blinds	2585	29%	$ 99,474	26%	107	$ 69,225	275,828.7
5	Commercial static double glazing (SHGC=0.38) + DL + Manual Blinds	3489	39%	$ 114,934	30%	112	$ 72,475	275,828.7
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	4017	45%	$ 161,569	42%	168	$ 109,273	329,396.1
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	3894	44%	$ 124,541	32%	122	$ 79,300	358,917.2
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	4718	53%	$ 178,238	46%	191	$ 124,268	493,673.9

Baseline: ASHRAE +DL+ Manual Blinds (Run 4)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[2]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
4	ASHRAE + DL + Manual Blinds	–	–	–	–	–	–	–
5	Commercial static double glazing (SHGC=0.38) + DL + Manual Blinds	904	14%	$ 15,460	5%	5	$ 3,250	53,567.4
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	1432	22%	$ 62,095	22%	62	$ 40,048	166,655.0
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	1309	21%	$ 25,067	9%	16	$ 10,075	83,088.6
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	2132	34%	$ 78,765	28%	85	$ 55,043	217,845.3

Baseline: Commercial static triple glazing +DL+ Manual Blinds (Run 7)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[2]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	–	–	–	–	–	–	–
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	123	2%	$ 37,028	14%	46	$ 29,973	83,566.5
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	824	16%	$ 53,698	21%	69	$ 44,968	134,756.7

MINNEAPOLIS, MINN.

Energy Analysis: Energy, Cost and Emissions Data

Run no	Runs	Annual site Energy		Annual Operating Cost ($)[1]	Peak Demand		Chiller Cost ($)*	Annual CO2 Emissions (kG) **	Annual site		Lighting	Misc Equip	HVAC		
		Total Mbtu	EUI kBtu/sf/yr		Elec kW	Cooling tons			Elect kWh	Nat Gas Therms	Electric kWh	Electric kWh	Electric kWh	Nat Gas Therms	Total Mbtu
1	Single-pane clear	12936	80.8	$ 232,878	917	482	$ 313,300	1780577.1	1,682,081	71,965	394,679	383,439	903,956	69,541	10,039
2	Double-pane clear	8810	55.1	$ 160,936	847	448	$ 291,200	1452882.1	1,515,430	36,398	394,679	383,439	737,308	33,985	5,915
3	ASHRAE	9076	56.7	$ 169,246	734	385	$ 250,250	1323216.0	1,293,978	46,614	394,679	383,439	515,854	44,191	6,180
4	ASHRAE + DL + Manual Blinds	8959	56.0	$ 167,246	701	373	$ 242,125	1271314.2	1,223,655	47,842	331,487	383,439	508,725	45,419	6,279
5	Commercial static double glazing (SHGC=0.38) + DL + Manual Blinds	7355	46.0	$ 137,864	689	385	$ 250,250	1153714.9	1,173,992	33,494	330,947	383,439	459,602	31,078	4,677
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	7069	44.2	$ 132,613	550	265	$ 171,976	970924.3	927,290	37,668	267,324	383,439	276,525	35,236	4,467
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	6591	41.2	$ 124,565	677	387	$ 251,225	1087831.1	1,135,116	27,182	331,070	383,439	420,604	24,770	3,913
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	5627	35.2	$ 106,925	501	237	$ 154,320	841008.0	843,110	26,396	267,823	383,439	191,848	23,971	3,052

* Includes chiller, cooling tower with pump, piping and installation cost

* Source: Tri-State Generation and Transmission Association - http://tristate.apogee.net/cool/cmnch.asp

** Calculated using Portfolio Manger's Emissions calculation methodology

RESULTS (Minneapolis, Minn.): Savings from Various Glass Types

Baseline: Single Clear (Run 1)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[1]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
1	Single Pane Clear	–	–	–	–	–	–	–
2	Double-pane clear	4125	32%	$ 71,942	31%	34	$ 22,100	327,695.0
3	ASHRAE	3859	30%	$ 63,632	27%	97	$ 63,050	457,361.1
4	ASHRAE + DL + Manual Blinds	3976	31%	$ 65,632	28%	110	$ 71,175	509,262.9
5	Commercial static double glazing (SHGC=0.38) + DL + Manual Blinds	5581	43%	$ 95,014	41%	97	$ 63,050	509,262.9
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	5866	45%	$ 100,265	43%	217	$ 141,324	626,862.2
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	6345	49%	$ 108,313	47%	96	$ 62,075	692,746.0
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	7309	57%	$ 125,953	54%	245	$ 158,980	939,569.1

Baseline: ASHRAE +DL+ Manual Blinds (Run 4)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[1]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
4	ASHRAE + DL + Manual Blinds	–	–	–	–	–	–	–
5	Commercial static double glazing (SHGC=0.38) + DL + Manual Blinds	1604	18%	$ 29,382	18%	-13	$ (8,125)	117,599.2
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	1890	21%	$ 34,633	21%	108	$ 70,149	300,389.8
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	2368	26%	$ 42,681	26%	-14	$ (9,100)	183,483.1
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	3333	37%	$ 60,321	36%	135	$ 87,805	430,306.2

Baseline: Commercial static triple glazing +DL+ Manual Blinds (Run 7)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[1]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction (kW)	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
7	Commercial static triple glazing (SHGC=0.33) + DL + Manual Blinds	–	–	–	–	–	–	–
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	-478	-7%	$ (8,048)	-6%	122	$ 79,249	116,906.8
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	965	15%	$ 17,640	16%	149	$ 96,905	246,823.1

PHOENIX, ARIZ.

Run no	Runs	Annual site Energy		Annual Operating Cost ($)[3]	Peak Demand		Chiller Cost ($)*	Annual CO2 Emissions (kG) **	Annual site		Lighting	Misc Equip	HVAC		
		Total Mbtu	EUI kBtu/sf/yr		Elec kW	Cooling tons			Elect kWh	Nat Gas Therms	Electric kWh	Electric kWh	Electric kWh	Nat Gas Therms	Total Mbtu
1	Single-pane clear	7495	46.8	$ 213,013	968	534	$ 347,100	1304687.1	2,049,945	5,004	394,679	383,439	1,271,826	3,169	4,658
2	Double-pane clear	6830	42.7	$ 198,840	871	465	$ 302,250	1166733.2	1,931,933	2,381	394,679	383,439	1,153,810	554	3,993
3	ASHRAE	5375	33.6	$ 157,511	719	336	$ 218,400	873771.8	1,413,616	5,513	394,679	383,439	635,494	3,676	2,536
4	ASHRAE + DL + Manual Blinds	5131	32.1	$ 149,570	686	334	$ 216,775	889527.9	1,331,492	5,880	330,097	383,439	617,954	4,042	2,513
5	Commercial static double glazing (SHGC=0.28) + DL + Manual Blinds	5019	31.4	$ 151,083	674	327	$ 212,550	898828.9	1,391,521	2,708	329,840	383,439	678,240	882	2,403
6	SageGlass double pane -12mm Argon (Summer-switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	4018	25.1	$ 125,728	592	304	$ 197,595	702625.4	1,110,298	2,459	265,060	383,439	461,797	628	1,639
7	Commercial static triple glazing (SHGC=0.25) + DL + Manual Blinds	4841	30.3	$ 146,707	642	299	$ 194,350	817910.6	1,347,578	2,428	329,908	383,439	634,156	604	2,225
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	3780	23.6	$ 118,500	548	281	$ 182,967	661261.1	1,049,738	2,135	265,306	383,439	400,992	306	1,399

* Includes chiller, cooling tower with pump, piping and installation cost

* Source: Tri-State Generation and Transmission Association - http://tristate.apogee.net/cool/cmnch.asp

** Calculated using Portfolio Manger's Emissions calculation methodology

RESULTS (Phoenix, Ariz.): Savings from Various Glass Types

Baseline: Single Clear (Run 1)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[3]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
1	Single Pane Clear	–	–	–	–	–	–	–
2	Double-pane clear	665	9%	$ 14,173	7%	69	$ 44,850	137,953.9
3	ASHRAE	2120	28%	$ 55,502	26%	198	$ 128,700	430,915.3
4	ASHRAE + DL + Manual Blinds	2364	32%	$ 63,444	30%	201	$ 130,325	415,159.3
5	Commercial static double glazing (SHGC=0.28) + DL + Manual Blinds	2476	33%	$ 61,930	29%	207	$ 134,550	415,159.3
6	SageGlass double pane -12mm Argon (Summer- switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	3477	46%	$ 87,285	41%	230	$ 149,505	405,858.3
7	Commercial static triple glazing (SHGC=0.25) + DL + Manual Blinds	2654	35%	$ 66,306	31%	235	$ 152,750	486,776.5
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	3715	50%	$ 94,513	44%	253	$ 164,133	643,426.0

Baseline: ASHRAE +DL+ Manual Blinds (Run 4)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[3]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
4	ASHRAE + DL + Manual Blinds	–	–	–	–	–	–	–
5	Commercial static double glazing (SHGC=0.28) + DL + Manual Blinds	112	2%	$ (1,514)	-1%	7	$ 4,225	-9,301.0
6	SageGlass double pane -12mm Argon (Summer- switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	1113	22%	$ 23,841	16%	30	$ 19,180	186,902.5
7	Commercial static triple glazing (SHGC=0.25) + DL + Manual Blinds	290	6%	$ 2,863	2%	35	$ 22,425	71,617.3
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	1351	26%	$ 31,070	21%	52	$ 33,808	228,266.8

Baseline: Commercial static triple glazing +DL+ Manual Blinds (Run 7)

Run no	Runs	Annual Energy Savings (MBTUs)	Annual % Energy Savings	Annual Op. Cost Savings ($)[3]	Annual % Op. Cost Energy Savings	Peak Cooling Ton Reduction	Chiller First Cost Savings ($)*	Annual CO2 Emissions Savings (kG) **
7	Commercial static triple glazing (SHGC=0.25) + DL + Manual Blinds	–	–	–	–	–	–	–
6	SageGlass double pane -12mm Argon (Summer- switching controlled by daylight lvl; Winter - switching OFF)+DL + Glare Control	823	17%	$ 20,979	14%	-5	$ (3,245)	115,285.2
8	SageGlass triple pane-12mm Argon (Summer - switching controlled by daylight lvl; Winter - switching OFF)+ DL + Glare control	1061	22%	$ 28,207	19%	18	$ 11,383	156,649.5

1- Minneapolis Utility Tariff

Electricity - Northern States Power company, large general service

Summer	Winter
Energy = $0.02169/ kWh	Energy = $0.02169/ kWh
Demand = $10.15/kW	Demand = $6.81/kW
Monthly Charges = $22.00	Monthly Charges = $22.00

Gas - Northern States Power Company, commercial firm service

Summer	Winter
Distribution charge = $0.13103/ therm	Distribution charge = $0.13103/ therm
Energy = $0.8360/ therm	Energy = $0.77774/ therm
Monthly Charges = $40.00	Monthly Charges = $40.00

2- DC Utility Tariff

Electricity - PEPCO GS3A

Summer	Winter
Energy 1-6000 kWh = $0.2048/ kWh	Energy 1-6000 kWh = $0.1934/ kWh
Energy >6000 kwh = $0.168262/ kWh	Energy >6000 kwh = $0.176926/ kWh
Demand 1-25 kW = $0/kW	Demand 1-25 kW = $0/kW
Demand >25kW =$7.93/kW	Demand >25kW =$7.64/kW
Monthly Charges = $14.93	Monthly Charges = $14.93

Gas - Washington Gas

Energy = $1.4707/ therm
Monthly Charges = $26.40

3-Phoenix Utility Tariff

Electricity - APS E-32

Summer	Winter
Energy 1-200 kWh/kW = $0.09115/ kWh	Energy 1-200 kWh/kW = $0.07613/ kWh
Energy >200kwh/kW = $0.05330/ kWh	Energy >200kwh/kW = $0.03828/ kWh
Demand 1-100 kW = $8.477/kW	Demand 1-100 kW = $8.477/kW
Demand >100kW =$4.509/kW	Demand >100kW =$4.509/kW
Monthly Charges = $34.02	Monthly Charges = $34.02

Gas - SGC G-25 Medium

Energy = $1.2466/ therm
Monthly Charges = $43.50