Glazing Alternatives

Background / Goals

When initially investigating the current glazing system used in the building, it became apparent that for sustainability purposes, the most efficient glazing type was not being utilized. The glazing manufacturer, Viracon, Inc., recommends specific glass types to help achieve Energy and Atmosphere Credit 1.0, *Optimize Energy Performance*. U-value and solar heat gain coefficients (SHGC) are maximized within these recommended glass types to help achieve a minimum 14% energy savings compared to an ASHRAE/IESNA Standard 90.1-2004 baseline building performance model. The manufacturer does not suggest that by solely incorporating these glazing types Energy and Atmosphere Credit 1.0 will be achieved. It will help contribute significant savings to the building though.

The purpose of this breadth study is to perform a value engineering assessment to determine the implications of changing the exterior glazing within the building envelope. Of note, the study focuses on the glass on floors three through eleven.

Analysis Methodology

1. Select Viracon glazing alternatives.
2. Investigate an appropriate methodology for fenestration analysis using <u>ASHRAE Handbook of Fundamentals 2005</u>.
3. Determine daily temperature gradients for the Washington, DC area for calculating conductive heat transfer.
4. Calculate total solar irradiance on each building face throughout the year.
5. Perform energy analysis to compare total energy transfer savings through each glazing type compared to the existing condition.
6. Investigate initial cost implications and life-cycle savings of incorporating each glass type.
7. Evaluate impact on LEED accreditation.

Resources and Tools

To begin this study, a consultation meeting was set up with Andreas Phelps. His extensive knowledge of building envelope design was able to direct me to an appropriate methodology for calculating energy transfer through a fenestration system. After researching methods to estimate solar energy transfer, a meeting was made with Moses Ling to confirm that indeed I was approaching the design problem correctly. Moses was also able to assist in determining the appropriate means for estimating energy savings that would occur as a result of reduced heating and cooling loads.

Alissa Schmidt, a design associate at Viracon, was helpful in providing cost estimates of various glazing types. The 2005 edition of <u>ASHRAE Handbook of Fundamentals</u> was also extensively used to perform necessary heating and cooling load calculations.

Viracon Glazing Options

Glass Type	Transmittance			Reflectance			U-Value		SHGC	$/SF
	Visible	Solar	U-V	Vis-Out	Vis-In	Solar	Winter	Summer		
VE 1-85	76%	47%	26%	12%	13%	21%	0.31	0.29	0.54	$13.30
VRE 1-67	60%	32%	20%	29%	25%	35%	0.30	0.27	0.37	$13.30
VNE 1-63	62%	23%	4%	10%	11%	36%	0.29	0.25	0.28	$14.80

Figure 5.1: Glazing Properties

Existing Glazing (VE 1-85)

The existing glazing on floors three through eleven is a low-emissivity insulating glass unit which is composed of two ¼" lites of glass with a ½" air space between. The low-e coating applied to the number two surface, as seen in Figure 5.2, provides an effective balance between reducing solar transfer and maximizing light transmittance. When short-wave solar energy , as shown in Figure 5.3, strikes the exterior ply it is absorbed and converted into long-wave infrared energy. The low-e coating on the interior side of the exterior ply then serves to reflect the long-wave radiation back outdoors.

Brown Center: Baltimore, MD
Glass Type: VE 1-85
(Source: Viracon)

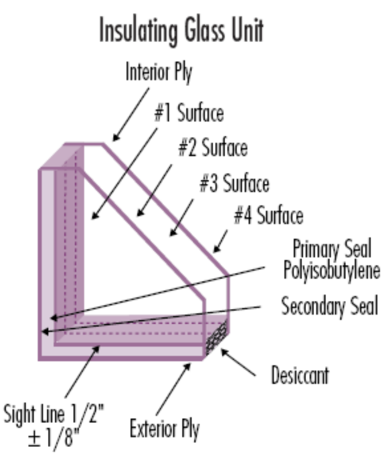

Figure 5.2: IGU Detail
(Source: Viracon)

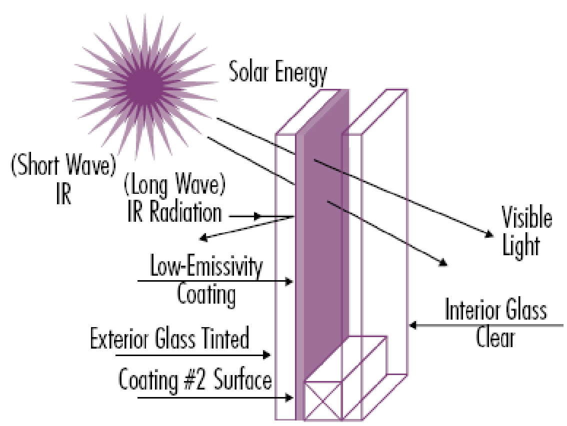

Figure 5.3: Glazing Detail
(Source: Viracon)

It is important to note that the current design incorporates a clear exterior ply with relatively high visible transmittance. This leads to more day lighting within the interior space. It was important to be mindful of the architect's desire to use clear vision glass with high visible transmittance. These two criteria were considered in the selection of alternative insulating glass unit. By using a tinted glass or a clear glass with less visible transmittance, additional energy savings could be achieved.

Design Alternative #1 (VRE 1-67)

Viracon's radiant low-emissivity coating, also applied to the number 2 surface, is a hybrid coating that combines the performance of traditional low-emissivity glass with reduced solar heat gain. Though conductance is reduced, the primary advantage is achieved through a reduction in the solar heat gain coefficient. The glazing type that was selected has clear interior and exterior lites and also the highest visible transmittance of any of the VRE glazing types.

WSFS Bank Center: Wilmington, DE
Glass Type: VRE 1-67
(Source: Viracon)

Design Alternative #2 (VNE 1-63)

Viracon's VNE coating combines the solar performance of their hybrid, radiant low-e glass (VRE) with the low reflectance experienced with traditional low-emissivity glass (VE). Low interior and exterior reflectance correlates to high visible light transmittance. The VNE coating system is recommended for buildings incorporating sustainable design practices. Therefore, the VNE glazing is ideal for the 77 K Street project if it were to seek LEED accreditation. Though this glazing type alone will not allow the building to achieve Energy and Atmosphere Credit 1.0, it will significantly contribute to a reduction in energy demands. If the architect were willing to accept a tinted glazing system or reduce the visible transmittance, the glazing system chosen could potentially account for a 14% reduction in total building demand.

Fenestration Heat Gain Analysis

The governing equation for instantaneous heat transfer through a fenestration system as outlined on page 31.3, equation 1 of the 2005 ASHRAE Handbook of Fundamentals is:

$$Q = Q_{cond} + Q_{sol}$$

$$Q = UA(t_{out} - t_{in}) + SHGC(A)(E_t)$$

where,

Q = Instantaneous Energy Transfer, BTU/hr
U = Overall Coefficient of Heat Transfer (U-Factor), BTU / $(hr*ft^2*{}^\circ F)$
A = Area of Fenestration
t_{out}, t_{in} = Exterior and Interior Temperatures, °F
SHGC = Solar Heat Gain Factor
E_t = Incident Total Irradiance, BTU / $(hr*ft^2)$

Area, u-value, and solar heat gain coefficient are properties of the glazing in question and have a constant, or relatively constant, value. t_{out} and t_{in} are environmental properties that vary throughout the year. Incident total irradiance also is an environmental property that is dependent on the incident angle of the sun against a given surface, as shown in figure 5.4.

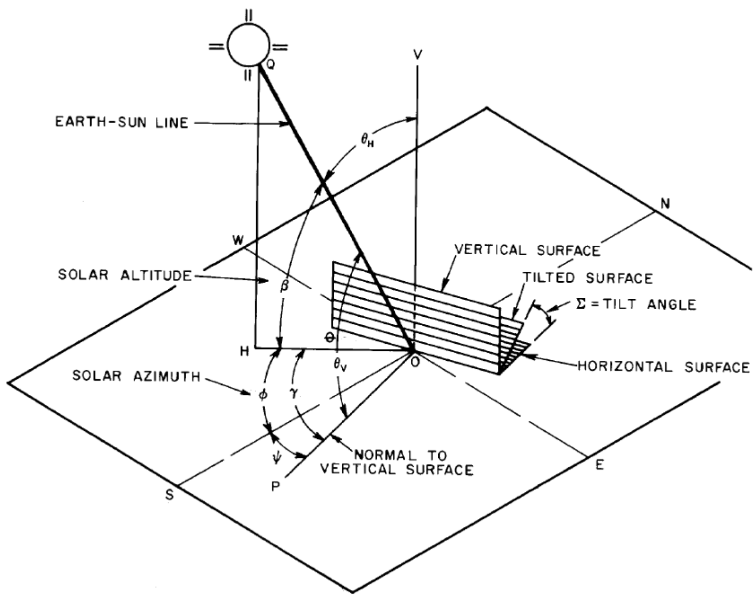

Figure 5.4: Solar Angles
(Source: ASHRAE 2005 Handbook of Fundamentals)

Estimation of Exterior Temperature

In order to calculate the conductive heat transfer, the outdoor air temperature had to be estimated as well. In order to estimate the exterior temperature at each hour of the day of each month, sunrise and sunset data was collected from the United States Naval Observatory's (USNO) Astronomical Application Department. Additionally maximum, minimum, and mean temperatures were collected for each month from the National Oceanic and Atmospheric Administration (NOAA). These two sets of data were used to produce monthly temperature gradients knowing that the maximum daily temperature occurs approximately four hours before sunset and the minimum temperature occurs one hour before sunrise. Figure 5.5, shows the daily temperature gradients for the Washington, DC area.

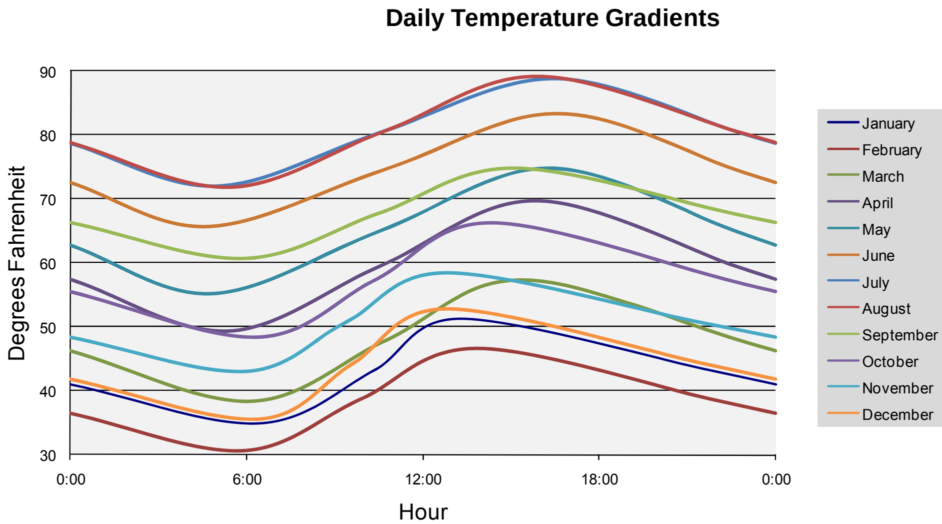

Figure 5.5: Daily Temperature Gradients

Calculation of Total Surface Irradiance

As a result of the continuous change in incident angle, the value of incident total irradiance (E_t) changes throughout the year and also varies based on the orientation of a surface. For the purpose of this study, the value of E_t was calculated hourly for one day per month and for each of the four orientations of the building (north, south, east, and west). The calculation of E_t is governed by the equations listed in Table 14 of the AHRAE handbook in Appendix C.1. The hourly tabulation of total direct irradiance per square foot for each month and each surface orientation can be found in Appendix C.2 but a daily summary graph can be seen below in Figure 5.6.

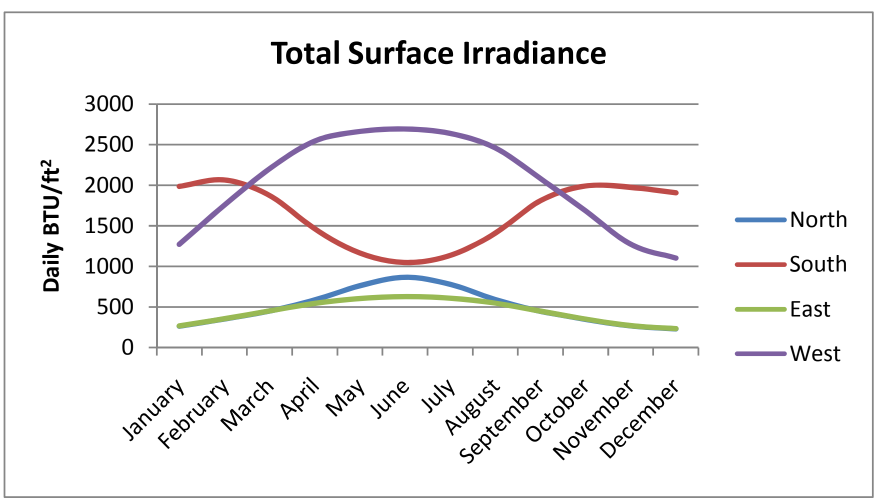

Figure 5.6: Annual Total Surface Irradiance

Cooling Load Analysis

Once the exterior temperature and total surface irradiance is calculated, all variables are known and the heat transfer analysis can be performed. A number of assumptions were made to complete the analysis.

1. Only heat gain, cooling load is considered in the energy transfer analysis. Net heat loss, heating load is ignored as there are other variables within the building that can potentially counter the effect of heat loss. These include heat gain from computers and other equipment, people, etc. This only occurs in the nighttime hours when conductive transfer dominates and solar transfer is not present. Additionally, the glazing alternatives offer only minor incremental improvements in conductive energy transfer so such savings would be relatively insignificant anyway. Solar heat gain is the dominant form of energy transfer and the most important area to consider when selecting glazing for its thermal performance.
2. Indoor temperature is assumed to be set at 70°F between the working hours of 6:00 a.m. and 10:00 p.m. each day. There is an evening setback temperature of 60°F during the heating months of September through May and 78°F during the cooling summer months.
3. Only vision glass is considered in the calculation.

Appendix C.3 contains a detailed month by month analysis that includes both conductive and solar heat transfer through the glazing. Figure 5.7 below shows a summary of the energy loads and energy savings of the three glazing systems. Each glazing type is color coated and corresponds with color coding in the detailed analysis in the appendix. Cooling savings are relative to the existing VE 1-85 glazing system. Figures 5.8 and 5.9 graphically illustrate the monthly cooling loads and expected savings in cooling load compared to the baseline, existing VE 1-85 glazing type.

Energy Analysis Summary Table

	Days	Daily Cooling Load (BTU)			Monthly Cooling Load (BTU)			Cumulative Cooling Savings (BTU)	
		VE 1-85	VRE 1-67	VNE 1-63	VE 1-85	VRE 1-67	VNE 1-63	VRE 1-67	VNE 1-63
January	31	8296813	4958938	2547364	257201206	153727091	78968269	103474115	178232937
February	28.25	9978682	5985312	3099639	281897754	169085071	87564801	216286797.6	372565889
March	31	13141832	8679506	5447523	407396784	269064695	168873221	354618887	611089452
April	30	15808048	11194399	7816540	474241447	335831966	234496201	493028367	850834698
May	31	16770005	12046713	8584296	519870149	373448104	266113185	639450412	1104591661
June	30	17948427	13114045	9555507	538452796	393421357	286665222	784481851	1356379235
July	31	18428671	13602049	10040575	571288790	421663532	311257820	934107109	1616410206
August	31	17963971	13266104	9799110	556883092	411249214	303772420	1079740988	1869520878
September	30	15757874	11370395	8153816	472736223	341111845	244614494	1211365366	2097642607
October	31	12857872	8892437	5998249	398594044	275665550	185945711	1334293860	2310290939
November	30	9692017	6315484	3863335	290760498	189464508	115900053	1435589850	2485151385
December	31	7503122	4445222	2236877	232596786	137801884	69343187	1530384753	2648404984

Figure 5.7: Annual Cooling Analysis

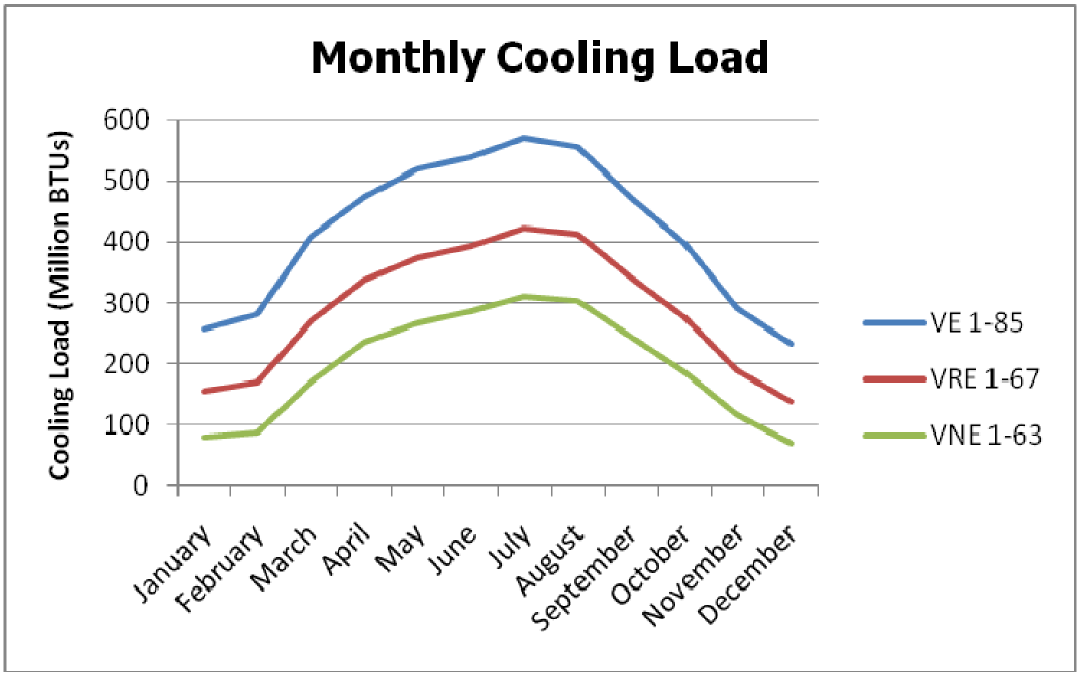

Figure 5.8: Monthly Cooling Loads

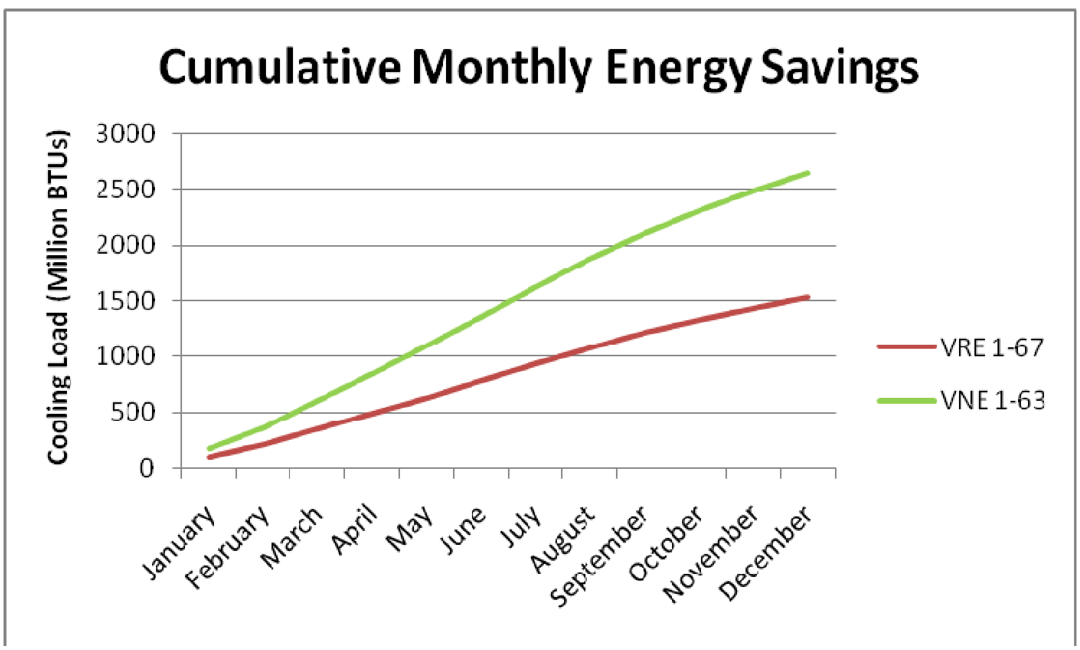

Figure 5.9: Cumulative Energy Savings

Cooling Load Cost Savings Calculation

Once it has been determined how much energy will be saved each year by each of the glazing alternatives, one can determine the financial savings. The financial savings will include both the initial glazing system cost as well as the operational cost.

The cost of cooling can be calculated using the following equation:

$$\$/yr = \frac{(BTU/yr)(\$/kWh)}{(SEER)(1{,}000\ \text{W/kW})}$$

The Seasonal Energy Efficiency Rating, or SEER value, is a rating of the efficiency of the equipment being used to cool a space. The SEER units are BTUs per watt. The higher the SEER rating, the more efficient the cooling operation and the cheaper the cooling cost will be. The McQuay self-contained air handling units that cool the air on floors three through eleven have a SEER rating of approximately 14.

Glass Type	$/SF	Initial Cost	Annual Cooling Cost	Annual Cooling Savings
VE 1-85	$13.30	$322,924	$24,009.21	----
VRE 1-67	$13.30	$322,924	$16,663.37	$7,346
VNE 1-63	$14.80	$359,344	$11,296.87	$12,712

Figure 5.10: Glazing Cost Evaluation

As shown in Figure 5.10, the square foot cost for both glass types VE 1-85 and VRE 1-67 is $13.30. The cost for glass type VNE 1-63 is more expensive with a cost of $14.80/SF. A rudimentary ten year cost analysis considering both the initial material cost and cooling load costs is shown in Figure 5.11.

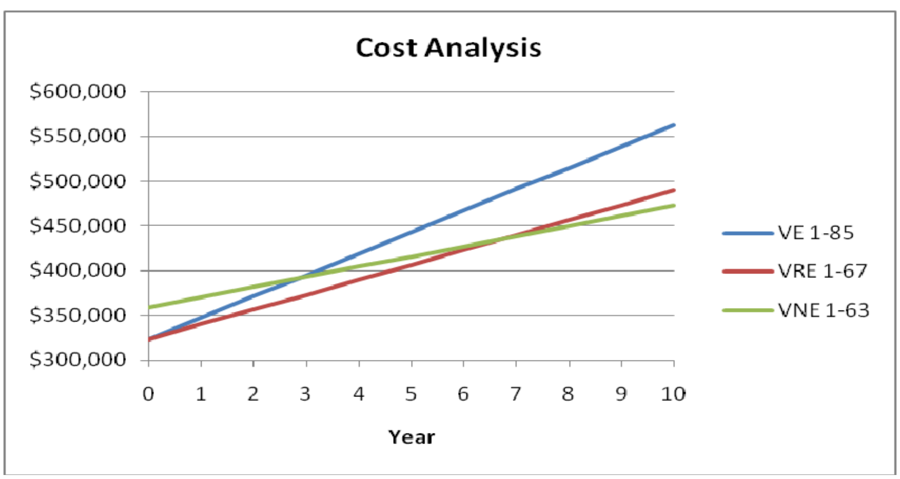

Figure 5.11: Ten Year Cost Analysis

Recommendation

Based on the above analysis, the radiant low-emissivity glazing type VRE 1-67 (alternative #1) has an instantaneous payback period because it has the same upfront cost as the existing glazing type. The hybrid low-emissivity glazing type VNE 1-63 (alternative # 2) has a payback period of just over two years, eleven months as compared to the existing glazing. It takes this period of time for the owner to reach a utility savings that would offset the initial higher material cost. In comparison to the VRE 1-67 glazing, the VNE 1-63 glass has a payback period of six years, ten months.

It is clear that it seems to be a wise investment to change the glazing to at least the radiant low-e glass type. The owner still pays the same upfront cost and receives a utility energy savings. Based on the theme of this report, I would recommend that the owner change the glazing to design alternative #2 though. If the owner wishes to maintain and operate the facility for at least seven years, then the decision is quite clear. Even if the owner wishes to sell the building, I would still encourage them to consider accepting the slightly higher construction cost. The energy savings from the hybrid glass is quite substantial and will help contribute significantly to the overall energy savings of the building and thus help the building achieve Energy and Atmosphere Credit 1.0, *Optimize Energy Performance*.

LEED Impact

The improved glazing system has the potential to contribute to four categories of the LEED rating system as outlined below.

# of Credits	LEED Credit	Likely	Possibly	Contributor
2-8	Energy and Atmosphere 1.0 *Optimizing Energy Performance*			X
1-2	Materials and Resources 4.1, 4.2 *Recycled Content*			X
1	Indoor Environmental Quality 8.1 *Daylight and Views*	X		
1	Indoor Environmental Quality 8.2 *Daylight and Views*	X		
1-4	Innovation & Design Process 1.1-1.4 *Innovation in Design*		X	

Energy and Atmosphere Credit 1.0,
Achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.

Total building energy cost savings must equal 14% at minimum to receive the required 2 credits for certification. Incremental increases in building performance will lead to accruing more credits. The improved glazing system will undoubtedly help contribute to this overall energy savings as shown in the energy analysis

portion of this report. The VNE 1-63 glazing has a 53% reduction in heat gain as compared to the existing VE 1-83 glass.

Materials and Resources Credits 4.1, 4.2

Increase demand for building products that incorporate recycled content materials, thereby reducing impacts resulting from extraction and processing of virgin materials.

Post-consumer content plus one-half pre-consumer content constitutes at least 10% of the total material value of the project to receive credit 4.1. By adding an additional 10% of the material value, the project will receive an additional credit under credit 4.2. According to their product data, Viracon float glass contains approximately 20% pre-consumer and 0% post-consumer recycled content.

Indoor Environment Quality Credit 8.1,

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Illumination levels must be modeled to determine whether or not 75% of all occupied spaces achieve a daylight illumination level of 25 footcandles. According to their product data, glass types VRE 1-67 and VNE 1-63, will far exceed the minimum requirements based on the calculation methodology for achieving this credit.

Indoor Environment Quality Credit 8.2,

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

A tenant space layout must be developed to determine whether 90% of occupied spaces have direct lines of sight to the outdoors via vision glass. With an open floor layout, this credit will be achieved using the selected glazing type.

Innovation and Design Process Credits 1.1-1.4,

To provide design teams and projects the opportunity to be awarded points for exceptional performance above the requirements set by the LEED for Core & Shell Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED for Core & Shell Green Building Rating System.

It is quite possible that through the use of the hybrid low-emissivity glazing, energy models will far exceed required ASHRAE levels. This opens the opportunity for achieving innovation credits for "exceptional performance above the requirements set by the LEED for Core & Shell Green Building Rating System."