

A Comparison of Energy, Economic and Environmental Benefits of Transparent Low-E Glasses



In November 2005, PPG Performance Glazings introduced *Solarban 70XL* glass, a transparent, coated solar control, low-emissivity (low-e) architectural glass with superior solar control characteristics.

Recently, PPG commissioned a study by the Architectural Energy Corporation (AEC) comparing the energy performance of *Solarban 70XL* Glass to dual pane tinted glass and several commonly specified high-performance architectural glasses. The study showed that, depending on the size, type and climate of a prospective building, *Solarban 70XL* glass has the potential to save architects and building owners hundreds of thousands of dollars in upfront capital cooling equipment costs when it is specified instead of competing products. *Solarban 70XL* glass also can produce annual energy savings of up to 13 percent.

Finally, and perhaps most importantly for environmentally-focused architects, the study also showed that the specifying *Solarban 70XL* glass for a typical commercial building can reduce CO₂ emissions by thousands of tons over its lifetime.

This following paper summarizes the energy and environmental performance of *Solarban 70XL* glass, dual-pane tinted glass and other commonly specified architectural glasses with similar aesthetic qualities. It also quantifies the potential cost savings *Solarban 70XL* glass can provide, as well as the positive impact this glass can have for architects seeking to reduce the carbon footprint of their buildings.

KEY FINDINGS:

“Cost savings for Solarban 70XL glass are even greater when measured against other glazing options, such as double-paned tinted or tinted Solar Control Low-E glass.”

Initial HVAC Equipment Cost Savings

Solarban 70XL glass has the potential to produce dramatic savings in upfront capital cooling equipment expenses for commercial buildings incorporating large areas of glass.

This is demonstrated clearly in the chart (next page), which compares the potential HVAC equipment costs for two prototypical window-walled eight-story office buildings — one specified with dual-pane tinted glass and the other with *Solarban 70XL* glass — in 12 North American cities.

When compared to dual-pane tinted glass, a commonly specified glazing for commercial buildings, the study showed that prototypical buildings in warm climates such as Atlanta and Los Angeles glazed with *Solarban 70XL* glass can yield more than \$400,000 in HVAC capital equipment cost savings, a cost reduction of nearly 20 percent.

The cost savings are similar in cooler climates. For instance, the same eight-story building owner could save more than \$400,000 in Chicago by specifying *Solarban 70XL* glass over dual pane tinted glass. Savings in Boston, Philadelphia, Ottawa and St. Louis are comparable. In every

city measured in the study, the building owners would realize equipment costs savings of 15 to 20 percent.

Year to Year Energy Savings

While these upfront savings are significant, the greatest return on investment can be realized through the year-to-year energy cost savings *Solarban 70XL* glass provides. Again, referring to chart (next page), annual energy costs savings on a glass-walled, eight-story office building can range from \$43,000 in Seattle to more than \$97,000 in Boston. Overall, annual energy costs savings measured from 11.4 percent in Boston to 12.9 percent in Seattle.

Over the life of a building, these savings can amount to millions of dollars.

Together, these findings indicate that architects and building owners who invest in the superior performance characteristics of *Solarban 70XL* glass can anticipate quick and substantial returns on their investment over both the short term (equipment savings) and long term (annual energy savings).

Example 1 Building Type: Eight-story office building, window wall
Total Glass Area: 50,976 ft² Total Floor Area: 270,000 ft²

City	Annual HVAC Operating Expenses		Annual Savings	Total HVAC Equipment Cost		Immediate Equipment Savings	1st Year Savings
	Dual-Pane Tinted	Solarban 70XL		Dual-Pane Tinted	Solarban 70XL		
Atlanta	\$680,456	\$597,772	\$82,684	\$2,115,464	\$1,697,868	\$417,597	\$500,281
Boston	\$853,450	\$756,001	\$97,539	\$2,326,967	\$1,928,086	\$398,881	\$496,420
Chicago	\$417,775	\$361,429	\$56,346	\$2,113,620	\$1,710,275	\$403,345	\$459,691
Denver	\$445,402	\$383,584	\$61,818	\$2,170,145	\$1,772,006	\$398,139	\$459,597
Houston	\$846,757	\$753,455	\$93,302	\$2,137,152	\$1,760,175	\$376,977	\$470,279
Los Angeles	\$684,484	\$608,756	\$75,728	\$2,237,643	\$1,819,144	\$418,499	\$494,227
Mexico City	\$758,724	\$680,368	\$78,356	\$2,023,150	\$1,655,745	\$367,405	\$445,761
Ottawa	\$472,397	\$422,118	\$50,279	\$2,045,396	\$1,695,981	\$349,415	\$399,694
Philadelphia	\$432,511	\$381,160	\$51,351	\$2,107,615	\$1,713,032	\$394,583	\$445,943
Phoenix	\$436,554	\$390,781	\$45,773	\$2,178,115	\$1,796,710	\$381,404	\$427,177
St. Louis	\$357,048	\$304,899	\$52,149	\$2,209,526	\$1,793,386	\$416,140	\$468,289
Seattle	\$337,361	\$293,506	\$43,855	\$1,937,682	\$1,591,412	\$346,269	\$390,124

Solarban 70XL Glass Dramatically Reduces CO₂ Emissions

Beyond its energy and equipment cost-savings, *Solarban 70XL* glass can also dramatically reduce the level of CO₂ emissions associated with the heating and cooling of commercial buildings.

As the chart (next page) demonstrates, according to calculators provided by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), specifying *Solarban 70XL* glass reduces CO₂ emissions in a standard window-walled, eight-story office building by more than 500 tons per year compared to dual pane tinted glass. That’s the yearly equivalent of removing almost 100 passenger cars from the road. Over a 40-year life-cycle, just one building of this type glazed with *Solarban 70XL* glass can reduce CO₂ emissions by more than 20,000 tons.

As the architectural industry in the U.S. strives to achieve carbon-neutral buildings, advanced architectural glasses such as *Solarban 70XL* glass can play a key role in balancing the desire for the aesthetics of clear glass, occupant comfort and the diminution of greenhouse gas emissions.

Example: CO₂ Reduction: Solarban 70XL Glass vs. Dual-Pane Tinted Glass

Eight-story office building, window wall *Total Glass Area: 50,976 ft² Total Floor Area: 270,000 ft²*

City	Electricity (Kwh savings)	Gas (Therms savings)	Annual CO ₂ Reduction (Tons)	40-Year CO ₂ Reduction (Tons)
Atlanta	455,841	18,829	417	16,669
Boston	432,301	26,618	354	14,163
Chicago	434,777	29,644	502	20,087
Denver	443,651	22,871	483	19,302
Houston	473,971	14,199	422	16,889
Los Angeles	413,247	14,162	188	7,529
Mexico City	389,927	12,524	352	14,080
Ottawa	411,276	36,361	416	16,651
Philadelphia	435,848	24,243	363	14,502
Phoenix	469,246	6,170	411	16,451
St. Louis	478,153	24,815	538	21,527
Seattle	328,567	29,588	250	10,018

All CO₂ emission calculations based on multipliers provided by Carbon Dioxide Emissions for the Generation of Electric Power in the United States, a report published in July 2000 by the U.S. Department of Energy. For addition details, see Appendix E.

Measuring the Environmental Performance of Architectural Glass

While the energy performance of architectural glass has long been a factor for specifying architects, the significance of these values has risen in tandem with the advent of the “green” building revolution. In recent years, a number of organizations have established standards to quantify the environmental performance of buildings according to the products and processes (and sites) used in their construction.

Increasingly, these standards — typified by the *U.S. Green Building Council’s LEED Green Building Rating System* — are being incorporated into the building codes for local and state municipalities and the federal government.

Thanks to its aesthetic diversity and relatively low cost, architectural glass is a major component for most large commercial and municipal buildings. As a result, its environmental performance is of increasing importance to specifying architects.

The Spectral Ideal

The concept of spectrally selective glazing is nothing new to the architectural community. However, with the release of *Solarban 70XL*

glass, the glass industry is now one step closer to giving the architectural community what it has been seeking for years: a glazing product that transmits the highest percentage of visible light while blocking the greatest possible amount of solar energy. The first attribute minimizes the need for artificial lighting while the second helps to manage the spiraling energy costs related to HVAC operations.

The three common glass performance characteristics that Architects and Mechanical Engineers use to compare various glass products and gauge a glass’s potential environmental impact and performance are:

1. *Visible Light Transmittance (VLT)*, which measures the percentage of visible light a glass transmits.
2. *Solar Heat Gain Coefficient (SHGC)*, quantifies the amount of solar energy (heat) that passes directly through or is absorbed into a building through the glass.
3. *Light to Solar Gain ratio (LSG)* which is derived by dividing a glass’ VLT by its SHGC.

PPG makes *Solarban 60* and *Solarban 80* coated solar control low-e glasses. With LSG* ratios of 1.84 and 1.96, respectively, these two products had previously set the standard as the industry’s highest performing coated solar control low-e glasses.

Now, with *Solarban 70XL* glass and its 2.37 LSG ratio, PPG has raised the standard of performance for advanced architectural glass. The following pages quantify the potential cost savings this breakthrough technology can generate by comparing the energy performance of *Solarban 70XL* against five other high-performance architectural glazings.

**Denotes LSG ratios for Solarban 60 and Solarban 80 when used with conventional clear glass as part of a one-inch (1”) insulating glass unit (IGU).*

Potential Energy Savings from Solarban 70XL Glass

In many of the scenarios examined by AEC, *Solarban 70XL* glass lowered overall energy and equipment costs so dramatically that an investment in this technology was returned in less than six months.

Following is an example of the energy and capital equipment cost savings generated through the specification of *Solarban 70XL* glass versus the leading transparent solar control low-e coating in a one-story middle school with punched windows in 12 different North American cities.

Complete cost data for all building prototypes in each architectural scenario in each city is included in Appendix B.

Example 1 Building Type: One-story middle school, punched windows
 Total Glass Area: 18,863 ft²

City	Annual HVAC Operating Expenses		Annual Savings	Total HVAC Equipment Cost		Immediate Equipment Savings	1st Year Savings
	Dual-Pane Tinted	Solarban 70XL		Dual-Pane Tinted	Solarban 70XL		
Atlanta	\$316,707	\$300,697	\$16,010	\$1,002,400	\$924,720	\$77,681	\$93,691
Boston	\$314,291	\$301,932	\$12,360	\$1,074,938	\$957,141	\$117,797	\$130,157
Chicago	\$225,832	\$215,885	\$9,947	\$1,057,460	\$972,272	\$85,188	\$95,065
Denver	\$224,531	\$215,816	\$8,715	\$924,776	\$829,705	\$95,070	\$103,785
Houston	\$318,447	\$300,797	\$17,650	\$1,106,749	\$1,011,068	\$95,682	\$113,332
Los Angeles	\$254,478	\$240,793	\$13,685	\$925,201	\$798,596	\$126,605	\$140,290
Mexico City	\$275,027	\$260,707	\$14,320	\$859,133	\$767,752	\$91,381	\$105,701
Ottawa	\$188,424	\$182,372	\$6,052	\$966,525	\$876,202	\$90,323	\$96,375
Philadelphia	\$242,368	\$234,793	\$7,845	\$1,012,224	\$928,255	\$83,969	\$91,814
Phoenix	\$192,391	\$181,203	\$11,188	\$1,073,806	\$967,007	\$106,799	\$117,987
St. Louis	\$138,926	\$132,662	\$6,264	\$651,770	\$584,157	\$67,613	\$73,877
Seattle	\$131,042	\$125,750	\$5,292	\$1,176,186	\$1,062,659	\$113,527	\$118,819

Daylighting and Visible Light Transmittance: A Source of Undocumented Energy Savings

In addition to the energy cost savings associated with heating and cooling, *Solarban 70XL* glass can also provide significant savings related to daylighting thanks to its high levels of visible light transmittance (VLT). For more information

on the visible light transmittance for *Solarban 70XL* glass and other products highlighted in this study, see the performance characteristic chart in Appendix A.

APPENDIX A: Testing Parameters and Simulation Criteria

To determine the potential energy and cost-savings from the installation of *Solarban 70XL* glass, PPG commissioned Architectural Energy Corporation (AEC) of Boulder, Colorado to analyze its energy performance against the five high-performance glazings listed below:

- *Dual Pane Tinted Glass*
- *Solarban® 60 (2) Clear Glass*
- *Solarban® 80 (2) Clear Glass*
- *VE2-2M (2) Clear Glass*
- *Sungate® 500 (3) Solexia® Glass*

The performance glazings were tested in two architectural scenarios. One consisted of punched windows; the other featured an entire window wall on each exposure. There were two building prototypes, as follows:

- *Single-Story Middle School*
- *Eight-Story Office Building*

Finally, all six glazing types were simulated for both building types in 12 selected locations across North America:

- *Atlanta, GA*
- *Boston, MA*
- *Chicago, IL*
- *Denver, CO*
- *Houston, TX*
- *Los Angeles, CA*
- *Mexico City, Mexico*
- *Ottawa, Ontario, Canada*
- *Philadelphia, PA*
- *Phoenix, AZ*
- *St. Louis, MO*
- *Seattle, WA*

The performance characteristics for *Solarban 70XL* glass and the other five performance glazings are defined in the table below:

Window Glazing	Tvis	Rfvis	Tsol	Rfsol	U-Value	Shading Coefficient (SC)	Solar Heat Gain Coefficient (SHGC)
Dual Pane Tinted	0.690	0.130	0.390	0.080	0.470	0.570	0.490
Solarban 60(2) Clear	0.704	0.112	0.328	0.293	0.291	0.438	0.380
Solarban 70XL(2) Clear	0.640	0.108	0.227	0.347	0.286	0.311	0.270
Solarban 80(2) Clear	0.470	0.330	0.200	0.380	0.290	0.280	0.240
VE2-2M(2) Clear	0.600	0.090	0.240	0.100	0.290	0.360	0.310
Solexia / SG 500(3)	0.640	0.140	0.330	0.090	0.350	0.510	0.450

Figures may vary due to manufacturing tolerances. All tabulated data is based on NFRC methodology using the LBL 5.2 software. Variations from previously published data are due to minor changes in the LBL Window 5.2 software versus Version 4.1.

Building Energy Simulation Criteria:

DOE 2.2 Building Energy Analysis Simulation Tool

Energy simulations were conducted with the DOE 2.2 *Building Energy Analysis Simulation Tool* developed at Lawrence Berkeley National Laboratory and Los Alamos National Laboratory. It is the most accurate and well-documented energy modeling program currently available in the U.S.

DOE-2 calculates hour-by-hour energy consumption by the prototype facility over an entire year (8,760 hours) using hourly climate data for

the location under consideration. Input into the DOE-2 Model consists of detailed descriptions of the buildings being analyzed, including the hourly scheduling of occupants, lighting, equipment and thermostat settings.

The DOE-2 Model provides accurate simulation of building features such as shading, fenestration, interior building mass, envelope building mass, and the dynamic response of differing heating and air conditioning system types and controls.

Building Prototype Descriptions and Characteristics

Characteristics for both building types — middle school and office building — were developed in a study conducted by Lawrence Berkeley Laboratory's Applied Science Division, based on

regional and national criteria. The building types were adjusted to be compliant with ASHRAE 90.1-1999. The table below identifies the main characteristics of each building prototype.

	Office	School
Geometry and U-Values		
Floor Area (sq ft)	270,000	200,00
Number of Stories	8	1
Punch Window to Wall Ratio ¹	59%	30%
Window Wall to Wall Ratio ²	90%	71%
Wall U-Value (Btu/ft ² -hr-F) ³	0.124	0.124
Roof U-Value (Btu/ft ² -hr-F) ⁴	0.065	0.065
Glazing Type	Dual Pane Tint	Dual Pane Tint
	Solarban-60	Solarban-60
	Solarban-70XL	Solarban-70XL
	Solarban-80	Solarban-80
	VE 2-2M	VE 2-2M
	Solexia / SG 500	Solexia / SG 500
Operating Conditions		
Cooling Temp Setpoint (F)	75	76
Heating Temp Setpoint (F)	70	72
Standard Day Schedule	7 AM-6 PM Wkdays 8 AM-12 PM Wkends Wkdays	7 AM-9 PM Wkdays 10 AM-3 PM Summer
	All Year	Summer: Jul-Aug
HVAC Equipment		
Air Handling System	VAV	Packaged VAV
Cooling Plant Type	Centrifugal Chiller	DX Coils
Economizer	Yes	Yes
Heating Plant Type	Hot Water Boilers	Hot Water Boilers
Service Hot Water	Hot Water Boilers	Gas Water Heater
Internal Loads (Peak)		
Occupants (ft ² /person)	448	125
Lighting (W/ft ²)	1.3	1.1
Equipment (W/ft ²)	0.75	0.45

¹ Punch Window to Wall Ratio is based on most of the walls being window

² Wall Window to Wall Ratio is based on the national building prototype

³ Wall U-Values are based on ASHRAE 90.1-1999

⁴ Roof U-Values are based on ASHRAE 90.1-1999

Technical Approach

Detailed DOE-2 energy simulations were developed for each building prototype, according to their unique building characteristics. Components of the building prototype that were specific to a particular location were altered in the simulation macro. This macro ran a DOE-2 simulation for both building types, for all glazing types, in all listed locations for two architectural scenarios (punched windows and window walls).

These DOE-2 energy simulations were used to calculate the effect of the six high-performance glazings on the following variables:

- *Building Loads*
- *Cooling Equipment Size*
- *Building Energy Costs*
- *HVAC Cooling Costs (based on cooling size in tons and total supply air flow into the building)*

Calculating HVAC Capital Cooling Costs

The DOE-2 simulations provided estimates of the cooling peak loads for both prototype buildings, which were then used to develop estimates of the associated HVAC cooling equipment capital costs.

The cooling equipment costs were calculated based on the peak cooling load, in tons. The HVAC equipment costs were calculated based on the total supply airflow to the building. Cooling equipment costs were estimated at \$1,200 per ton of cooling. The HVAC equipment costs for both buildings were estimated at \$3.50 per cfm airflow.

Utility Rate Calculations

Utility companies for each of the 12 cities included in the study were contacted to obtain the latest rate tariffs for electricity and natural gas. Details are provided in Appendix D.

The analyses of the two building prototypes — each with a punched window and window wall scenario — were run with six different high performance glazing types. This produced 288 separate simulation results measuring the following variables:

- *Total Electric Consumption (kWh)*
- *Total Natural Gas Consumption (therms)*
- *Peak Cooling Load (tons)*
- *Peak Heating Loads (kBtu/hr)*
- *Total Supply Airflow (cfm)*
- *Total Electric Cost (\$)*
- *Total Natural Gas Cost (\$)*
- *Total Building Energy Consumption Cost (\$)*
- *Cooling Equipment Capital Cost (\$)*
- *HVAC Equipment Capital Cost (\$)*
- *Total Cooling HVAC Capital Cost (\$)*

APPENDIX B:

Table 1-1: Results for the Office Building Prototype with Wall Windows (Atlanta-Los Angeles)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Atlanta	4,736,231	71,094	\$615,632	\$64,824	\$680,456	\$2,115,464	\$0	\$0	0	0
Solarban 60	Atlanta	4,494,860	57,239	\$580,820	\$52,288	\$633,108	\$1,894,098	\$47,348	\$221,367	242	9,680
Solarban 70XL	Atlanta	4,280,390	52,256	\$549,993	\$47,779	\$597,772	\$1,697,868	\$82,684	\$417,597	417	16,669
Solarban 80	Atlanta	4,227,423	51,277	\$542,633	\$46,894	\$589,527	\$1,651,357	\$90,929	\$464,107	458	18,340
VE22	Atlanta	4,359,188	53,918	\$561,617	\$49,283	\$610,900	\$1,772,350	\$69,556	\$343,114	353	14,138
Solexia Sungate 500	Atlanta	4,623,437	63,127	\$599,298	\$57,615	\$656,913	\$2,008,848	\$23,543	\$106,617	121	4,852
Dual Pane Tinted (DT)	Boston	4,592,593	126,515	\$704,648	\$148,892	\$853,540	\$2,326,967	\$0	\$0	0	0
Solarban 60	Boston	4,360,494	105,299	\$669,048	\$124,018	\$793,066	\$2,123,627	\$60,474	\$203,341	228	9,125
Solarban 70XL	Boston	4,160,292	99,879	\$638,336	\$117,665	\$756,001	\$1,928,086	\$97,539	\$398,881	354	14,163
Solarban 80	Boston	4,115,446	99,384	\$631,466	\$117,084	\$748,550	\$2,008,220	\$104,990	\$444,747	378	15,133
VE22	Boston	4,236,450	102,060	\$650,020	\$120,221	\$770,241	\$2,003,328	\$83,299	\$323,639	306	12,220
Solexia Sungate 500	Boston	4,479,361	113,037	\$687,272	\$133,090	\$820,362	\$2,234,464	\$33,178	\$92,503	128	5,140
Dual Pane Tinted (DT)	Chicago	4,565,157	119,166	\$307,776	\$109,999	\$417,775	\$2,113,620	\$0	\$0	0	0
Solarban 60	Chicago	4,316,297	95,323	\$291,422	\$88,062	\$379,484	\$1,898,094	\$38,291	\$215,526	325	13,010
Solarban 70XL	Chicago	4,130,380	89,522	\$278,705	\$82,724	\$361,429	\$1,710,275	\$56,346	\$403,345	502	20,087
Solarban 80	Chicago	4,085,886	88,450	\$275,670	\$81,739	\$357,409	\$1,669,254	\$60,366	\$444,366	543	21,711
VE22	Chicago	4,204,254	92,043	\$283,604	\$85,045	\$368,649	\$1,783,050	\$49,126	\$330,570	431	17,227
Solexia Sungate 500	Chicago	4,442,264	104,988	\$299,828	\$96,955	\$396,783	\$2,008,301	\$20,992	\$105,319	174	6,953
Dual Pane Tinted (DT)	Denver	4,471,508	81,162	\$365,687	\$79,715	\$445,402	\$2,170,145	\$0	\$0	0	0
Solarban 60	Denver	4,233,193	61,798	\$344,901	\$60,595	\$405,496	\$1,967,146	\$39,906	\$202,999	298	11,926
Solarban 70XL	Denver	4,027,857	58,291	\$326,192	\$57,392	\$383,584	\$1,772,006	\$61,818	\$398,139	483	19,302
Solarban 80	Denver	3,980,439	58,040	\$321,877	\$57,186	\$379,063	\$1,729,002	\$66,339	\$441,143	522	20,882
VE22	Denver	4,107,866	59,835	\$333,254	\$58,781	\$392,035	\$1,847,240	\$53,367	\$322,905	410	16,389
Solexia Sungate 500	Denver	4,358,684	68,741	\$355,909	\$67,399	\$423,308	\$2,072,660	\$22,094	\$97,485	159	6,362
Dual Pane Tinted (DT)	Houston	5,039,323	45,236	\$782,070	\$64,687	\$846,757	\$2,137,152	\$0	\$0	0	0
Solarban 60	Houston	4,785,198	35,512	\$742,926	\$50,782	\$793,708	\$1,939,184	\$53,049	\$197,968	238	9,520
Solarban 70XL	Houston	4,565,352	31,037	\$709,072	\$44,383	\$753,455	\$1,760,175	\$93,302	\$376,977	422	16,889
Solarban 80	Houston	4,511,205	30,160	\$700,733	\$43,128	\$743,861	\$1,719,355	\$102,896	\$417,796	466	18,655
VE22	Houston	4,648,898	32,720	\$721,937	\$46,790	\$768,727	\$1,827,679	\$78,030	\$309,473	352	14,093
Solexia Sungate 500	Houston	4,918,261	39,813	\$763,427	\$56,933	\$820,360	\$2,050,388	\$26,397	\$86,764	118	4,709
Dual Pane Tinted (DT)	Los Angeles	4,577,656	53,170	\$632,740	\$51,744	\$684,484	\$2,237,643	\$0	\$0	0	0
Solarban 60	Los Angeles	4,386,679	44,542	\$603,379	\$43,370	\$646,749	\$2,027,546	\$37,735	\$210,097	98	3,938
Solarban 70XL	Los Angeles	4,164,409	39,008	\$570,756	\$38,000	\$608,756	\$1,819,144	\$75,728	\$418,499	188	7,529
Solarban 80	Los Angeles	4,103,992	37,423	\$562,279	\$36,462	\$598,741	\$1,767,719	\$85,743	\$469,924	213	8,523
VE22	Los Angeles	4,250,733	41,150	\$583,388	\$40,078	\$623,466	\$1,899,559	\$61,018	\$338,083	153	6,136
Solexia Sungate 500	Los Angeles	4,496,078	48,430	\$620,048	\$47,144	\$667,192	\$2,142,989	\$17,292	\$94,654	48	1,914

Double Pane Tinted Tvis - 0.690, U-Value - 0.470, SC - 0.570
 Solarban 60 (2) Tvis - 0.704, U-Value - 0.291, SC - 0.438
 Solarban 70XL (2) Tvis - 0.640, U-Value - 0.286, SC - 0.311
 Solarban 80 (2) Tvis - 0.470, U-Value - 0.290, SC - 0.280
 VE2-2M (2) Tvis - 0.600, U-Value - 0.290, SC - 0.360
 Solexia Sungate 500 (3) Tvis - 0.640, U-Value - 0.350, SC - 0.510

Electric Costs based on utility electric rates for each selected city
 Natural Gas Costs based on utility gas rates for each selected city
 Capital Cooling Costs based on \$1,200 per ton for Office Buildings
 Capital HVAC Costs based on \$3.50 per cfm for Office Buildings

Cabon Multiplier (lbs CO₂/kwh) 2.095
 DOE and EPA Report 1.321
 1.969
 lbs CO₂/therm 11.00
 EPA Workbook 1995

Table 1-1: Results for the Office Building Prototype with Wall Windows (Mexico City-Seattle)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Mexico City	4,344,683	25,143	\$749,546	\$9,178	\$758,724	\$2,023,150	\$0	\$0	0	0
Solarban 60	Mexico City	4,163,200	16,623	\$713,994	\$6,296	\$720,290	\$1,837,343	\$38,434	\$185,808	179	7,145
Solarban 70XL	Mexico City	3,954,756	12,619	\$675,426	\$4,942	\$680,368	\$1,655,745	\$78,356	\$367,405	352	14,080
Solarban 80	Mexico City	3,901,994	11,654	\$665,900	\$4,612	\$670,512	\$1,608,947	\$88,212	\$414,203	396	15,825
VE22	Mexico City	4,036,070	14,288	\$690,352	\$5,506	\$695,858	\$1,725,694	\$62,866	\$297,457	284	11,351
Solexia Sungate 500	Mexico City	4,270,301	20,470	\$734,421	\$7,597	\$742,018	\$1,938,516	\$16,706	\$84,634	80	3,188
Dual Pane Tinted (DT)	Ottawa	4,543,148	151,811	\$413,156	\$59,241	\$472,397	\$2,045,396	\$0	\$0	0	0
Solarban 60	Ottawa	4,316,490	121,218	\$392,956	\$48,034	\$440,990	\$1,866,329	\$31,407	\$179,067	287	11,498
Solarban 70XL	Ottawa	4,131,872	115,450	\$376,266	\$45,852	\$422,118	\$1,695,981	\$50,279	\$349,415	416	16,651
Solarban 80	Ottawa	4,085,991	114,481	\$372,049	\$45,477	\$417,526	\$1,654,550	\$54,871	\$390,846	446	17,829
VE22	Ottawa	4,204,901	118,027	\$382,806	\$46,822	\$429,628	\$1,761,703	\$42,769	\$283,692	364	14,548
Solexia Sungate 500	Ottawa	4,437,972	132,697	\$403,787	\$52,249	\$456,036	\$1,963,457	\$16,361	\$81,939	160	6,418
Dual Pane Tinted (DT)	Philadelphia	4,668,441	106,206	\$289,615	\$142,896	\$432,511	\$2,107,615	\$0	\$0	0	0
Solarban 60	Philadelphia	4,357,313	87,585	\$275,926	\$118,215	\$394,141	\$1,903,811	\$38,370	\$203,804	266	10,642
Solarban 70XL	Philadelphia	4,232,593	81,963	\$270,438	\$110,722	\$381,160	\$1,713,032	\$51,351	\$394,583	363	14,502
Solarban 80	Philadelphia	4,188,706	81,528	\$268,506	\$110,131	\$378,637	\$1,667,658	\$53,874	\$439,957	388	15,521
VE22	Philadelphia	4,313,646	84,398	\$274,003	\$113,967	\$387,970	\$1,786,403	\$44,541	\$321,212	307	12,261
Solexia Sungate 500	Philadelphia	4,480,418	95,400	\$281,344	\$128,579	\$409,923	\$2,013,789	\$22,588	\$93,826	158	6,333
Dual Pane Tinted (DT)	Phoenix	5,060,402	24,466	\$407,392	\$29,162	\$436,554	\$2,178,115	\$0	\$0	0	0
Solarban 60	Phoenix	4,800,492	19,275	\$385,722	\$23,344	\$409,066	\$1,972,002	\$27,488	\$206,113	238	9,502
Solarban 70XL	Phoenix	4,591,156	18,296	\$368,534	\$22,247	\$390,781	\$1,796,710	\$45,773	\$381,404	411	16,451
Solarban 80	Phoenix	4,558,432	18,028	\$365,572	\$21,947	\$387,519	\$1,753,147	\$49,035	\$424,968	439	17,563
VE22	Phoenix	4,673,118	18,758	\$375,251	\$22,765	\$398,016	\$1,864,399	\$38,538	\$313,716	343	13,713
Solexia Sungate 500	Phoenix	4,932,786	21,066	\$396,744	\$25,351	\$422,095	\$2,076,319	\$14,459	\$101,796	121	4,853
Dual Pane Tinted (DT)	St Louis	4,855,723	105,771	\$233,735	\$123,313	\$357,048	\$2,209,526	\$0	\$0	0	0
Solarban 60	St Louis	4,587,047	85,600	\$220,239	\$100,450	\$320,689	\$1,994,961	\$36,359	\$214,565	337	13,466
Solarban 70XL	St Louis	4,377,570	80,956	\$209,870	\$95,029	\$304,899	\$1,793,386	\$52,149	\$416,140	538	21,527
Solarban 80	St Louis	4,325,772	79,840	\$207,382	\$93,727	\$301,109	\$1,747,709	\$55,939	\$461,817	588	23,513
VE22	St Louis	4,458,294	82,758	\$213,802	\$97,124	\$310,926	\$1,866,712	\$46,122	\$342,814	460	18,418
Solexia Sungate 500	St Louis	4,726,981	93,677	\$227,191	\$109,645	\$336,836	\$2,105,527	\$20,212	\$103,999	175	6,987
Dual Pane Tinted (DT)	Seattle	4,023,627	111,151	\$247,605	\$89,756	\$337,361	\$1,937,682	\$0	\$0	0	0
Solarban 60	Seattle	3,835,296	88,392	\$235,880	\$71,894	\$307,774	\$1,759,554	\$29,587	\$178,128	175	7,018
Solarban 70XL	Seattle	3,695,060	81,563	\$226,972	\$66,534	\$293,506	\$1,591,413	\$43,855	\$346,269	250	10,018
Solarban 80	Seattle	3,663,085	80,401	\$224,927	\$65,622	\$290,549	\$1,550,431	\$46,812	\$387,251	265	10,615
VE22	Seattle	3,751,828	84,524	\$230,555	\$68,858	\$299,413	\$1,656,023	\$37,948	\$281,660	219	8,760
Solexia Sungate 500	Seattle	3,929,659	97,545	\$241,779	\$79,078	\$320,857	\$1,859,058	\$16,504	\$78,624	100	3,997

Double Pane Tinted	Tvis - 0.690, U-Value - 0.470, SC - 0.570	Electric Costs based on utility electric rates for each selected city	Cabon Multiplier	2.095
Solarban 60 (2)	Tvis - 0.704, U-Value - 0.291, SC - 0.438	Natural Gas Costs based on utility gas rates for each selected city	(lbs CO ₂ /Kwh)	1.321
Solarban 70XL (2)	Tvis - 0.640, U-Value - 0.286, SC - 0.311	Capital Cooling Costs based on \$1,200 per ton for Office Buildings	DOE and EPA	1.969
Solarban 80 (2)	Tvis - 0.470, U-Value - 0.290, SC - 0.280	Capital HVAC Costs based on \$3.50 per cfm for Office Buildings	Report	
VE2-2M (2)	Tvis - 0.600, U-Value - 0.290, SC - 0.360			
Solexia Sungate 500 (3)	Tvis - 0.640, U-Value - 0.350, SC - 0.510		lbs CO ₂ /therm	11.00
			EPA Workbook 1995	

Table 1-2: Results for the Office Building Prototype with Punched Windows (Atlanta-Los Angeles)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Atlanta	4,277,723	49,148	\$563,301	\$44,967	\$608,268	\$1,798,119	\$0	\$0	0	0
Solarban 60	Atlanta	4,123,407	40,128	\$541,647	\$36,806	\$578,453	\$1,674,573	\$29,815	\$123,546	156	6,224
Solarban 70XL	Atlanta	3,974,617	36,740	\$522,134	\$33,740	\$555,874	\$1,566,777	\$52,394	\$231,342	276	11,058
Solarban 80	Atlanta	3,971,399	36,276	\$520,183	\$33,320	\$553,503	\$1,551,946	\$54,765	\$246,173	281	11,248
VE22	Atlanta	4,032,993	38,035	\$529,686	\$34,912	\$564,598	\$1,598,924	\$43,670	\$199,195	229	9,169
Solexia Sungate 500	Atlanta	4,205,726	43,818	\$553,197	\$40,144	\$593,341	\$1,740,468	\$14,927	\$57,651	79	3,151
Dual Pane Tinted (DT)	Boston	4,154,617	98,670	\$637,476	\$116,246	\$753,722	\$2,037,554	\$0	\$0	0	0
Solarban 60	Boston	3,996,455	84,621	\$613,209	\$99,776	\$712,985	\$1,904,120	\$40,737	\$133,434	153	6,128
Solarban 70XL	Boston	3,870,238	82,148	\$593,848	\$96,876	\$690,724	\$1,794,554	\$62,998	\$243,001	227	9,097
Solarban 80	Boston	3,848,253	82,590	\$590,475	\$97,395	\$687,870	\$1,790,025	\$65,852	\$247,530	236	9,422
VE22	Boston	3,914,587	82,691	\$600,649	\$97,513	\$698,162	\$1,828,334	\$55,560	\$209,221	203	8,125
Solexia Sungate 500	Boston	4,079,102	90,311	\$625,885	\$106,446	\$732,331	\$1,976,778	\$21,391	\$60,777	82	3,289
Dual Pane Tinted (DT)	Chicago	4,140,306	89,267	\$283,556	\$82,490	\$366,046	\$1,768,838	\$0	\$0	0	0
Solarban 60	Chicago	3,970,889	73,562	\$273,176	\$68,041	\$341,217	\$1,642,865	\$24,829	\$125,973	219	8,741
Solarban 70XL	Chicago	3,850,679	70,431	\$265,484	\$65,161	\$330,645	\$1,541,234	\$35,401	\$227,604	330	13,180
Solarban 80	Chicago	3,831,366	70,875	\$264,119	\$65,569	\$329,688	\$1,530,920	\$36,358	\$237,918	342	13,685
VE22	Chicago	3,896,421	71,632	\$268,464	\$66,266	\$334,730	\$1,570,726	\$31,316	\$198,112	287	11,489
Solexia Sungate 500	Chicago	4,054,026	79,596	\$278,363	\$73,592	\$351,955	\$1,710,476	\$14,091	\$58,362	120	4,820
Dual Pane Tinted (DT)	Denver	4,059,047	57,802	\$334,303	\$57,381	\$391,684	\$1,920,398	\$0	\$0	0	0
Solarban 60	Denver	3,881,978	44,220	\$320,281	\$43,777	\$364,058	\$1,792,184	\$27,626	\$128,214	217	8,684
Solarban 70XL	Denver	3,740,209	41,811	\$308,704	\$41,616	\$350,320	\$1,667,675	\$41,364	\$252,723	344	13,774
Solarban 80	Denver	3,712,219	42,109	\$306,243	\$41,985	\$348,228	\$1,647,988	\$43,456	\$272,410	365	14,608
VE22	Denver	3,792,647	42,605	\$313,004	\$42,314	\$355,318	\$1,716,223	\$36,366	\$204,174	298	11,912
Solexia Sungate 500	Denver	3,969,188	49,269	\$327,537	\$48,811	\$376,348	\$1,862,785	\$15,336	\$57,613	119	4,768
Dual Pane Tinted (DT)	Houston	4,537,482	26,904	\$704,778	\$38,473	\$743,251	\$1,843,796	\$0	\$0	0	0
Solarban 60	Houston	4,383,447	21,394	\$681,063	\$30,594	\$711,657	\$1,718,456	\$31,594	\$125,340	142	5,686
Solarban 70XL	Houston	4,233,000	19,273	\$657,891	\$27,560	\$685,451	\$1,621,425	\$57,800	\$222,370	263	10,522
Solarban 80	Houston	4,188,345	18,697	\$651,011	\$26,736	\$677,747	\$1,610,517	\$65,504	\$233,278	299	11,945
VE22	Houston	4,286,275	19,720	\$666,094	\$28,200	\$694,294	\$1,648,708	\$48,957	\$195,088	222	8,876
Solexia Sungate 500	Houston	4,467,101	23,727	\$693,944	\$33,929	\$727,873	\$1,785,014	\$15,378	\$58,781	69	2,743
Dual Pane Tinted (DT)	Los Angeles	4,127,536	31,357	\$573,956	\$30,575	\$604,531	\$1,940,249	\$0	\$0	0	0
Solarban 60	Los Angeles	3,994,220	25,291	\$554,284	\$24,688	\$578,972	\$1,802,037	\$25,559	\$138,212	69	2,758
Solarban 70XL	Los Angeles	3,827,893	20,616	\$531,781	\$20,151	\$551,932	\$1,684,013	\$52,599	\$256,236	139	5,563
Solarban 80	Los Angeles	3,781,718	19,136	\$525,784	\$18,715	\$544,499	\$1,661,993	\$60,032	\$278,256	160	6,382
VE22	Los Angeles	3,894,583	22,653	\$540,529	\$22,128	\$562,657	\$1,717,159	\$41,874	\$223,090	110	4,403
Solexia Sungate 500	Los Angeles	4,078,830	28,434	\$566,256	\$27,739	\$593,995	\$1,878,535	\$10,536	\$61,714	29	1,163

Double Pane Tinted Tvis - 0.690, U-Value - 0.470, SC - 0.570
 Solarban 60 (2) Tvis - 0.704, U-Value - 0.291, SC - 0.438
 Solarban 70XL (2) Tvis - 0.640, U-Value - 0.286, SC - 0.311
 Solarban 80 (2) Tvis - 0.470, U-Value - 0.290, SC - 0.280
 VE2-2M (2) Tvis - 0.600, U-Value - 0.290, SC - 0.360
 Solexia Sungate 500 (3) Tvis - 0.640, U-Value - 0.350, SC - 0.510

Electric Costs based on utility electric rates for each selected city
 Natural Gas Costs based on utility gas rates for each selected city
 Capital Cooling Costs based on \$1,200 per ton for Office Buildings
 Capital HVAC Costs based on \$3.50 per cfm for Office Buildings

Cabon Multiplier (lbs CO₂/kwh) 2.095
 DOE and EPA Report 1.321
 Report 1.969
 lbs CO₂/therm 11.00
 EPA Workbook 1995

Table 1-2: Results for the Office Building Prototype with Punched Windows (Mexico City-Seattle)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Mexico City	3,930,065	9,837	\$685,683	\$3,973	\$689,656	\$1,826,178	\$0	\$0	0	0
Solarban 60	Mexico City	3,823,645	6,338	\$665,488	\$2,639	\$668,127	\$1,712,248	\$21,529	\$113,930	97	3,861
Solarban 70XL	Mexico City	3,684,058	5,295	\$642,198	\$2,228	\$644,426	\$1,621,104	\$45,230	\$205,074	204	8,144
Solarban 80	Mexico City	3,647,675	5,158	\$636,119	\$2,174	\$638,293	\$1,610,489	\$51,363	\$215,690	231	9,231
VE22	Mexico City	3,734,214	5,553	\$650,911	\$2,329	\$653,240	\$1,648,560	\$36,416	\$177,618	166	6,631
Solexia Sungate 500	Mexico City	3,888,719	7,606	\$677,327	\$3,139	\$680,466	\$1,773,149	\$9,190	\$53,029	42	1,692
Dual Pane Tinted (DT)	Ottawa	4,152,465	116,401	\$379,777	\$46,038	\$425,815	\$1,818,667	\$0	\$0	0	0
Solarban 60	Ottawa	3,978,789	96,242	\$365,165	\$38,411	\$403,576	\$1,703,776	\$22,239	\$114,891	202	8,088
Solarban 70XL	Ottawa	3,862,079	93,227	\$354,880	\$37,236	\$392,116	\$1,610,198	\$33,699	\$208,469	280	11,207
Solarban 80	Ottawa	3,846,429	93,886	\$353,435	\$37,485	\$390,920	\$1,597,162	\$34,895	\$221,504	285	11,391
VE22	Ottawa	3,905,005	94,380	\$358,544	\$37,684	\$396,228	\$1,635,104	\$29,587	\$183,563	251	10,050
Solexia Sungate 500	Ottawa	4,064,230	103,904	\$372,398	\$41,376	\$413,774	\$1,765,114	\$12,041	\$53,553	115	4,605
Dual Pane Tinted (DT)	Philadelphia	4,227,796	80,139	\$270,227	\$108,093	\$378,320	\$1,772,085	\$0	\$0	0	0
Solarban 60	Philadelphia	3,994,281	67,312	\$259,954	\$91,054	\$351,008	\$1,652,488	\$27,312	\$119,597	193	7,734
Solarban 70XL	Philadelphia	3,937,998	64,914	\$257,477	\$87,809	\$345,286	\$1,556,917	\$33,034	\$215,169	236	9,446
Solarban 80	Philadelphia	3,916,355	65,265	\$256,524	\$88,247	\$344,771	\$1,551,027	\$33,549	\$221,059	246	9,824
VE22	Philadelphia	3,980,163	65,311	\$259,332	\$88,358	\$347,690	\$1,580,829	\$30,630	\$191,257	212	8,471
Solexia Sungate 500	Philadelphia	4,078,747	72,311	\$263,670	\$97,705	\$361,375	\$1,718,370	\$16,945	\$53,715	121	4,858
Dual Pane Tinted (DT)	Phoenix	4,583,051	14,501	\$369,989	\$17,993	\$387,982	\$2,003,451	\$0	\$0	0	0
Solarban 60	Phoenix	4,413,926	11,239	\$356,048	\$14,337	\$370,385	\$1,873,725	\$17,597	\$129,726	154	6,158
Solarban 70XL	Phoenix	4,282,582	10,143	\$345,300	\$13,108	\$358,408	\$1,771,815	\$29,574	\$231,636	266	10,624
Solarban 80	Phoenix	4,247,052	9,949	\$342,473	\$12,891	\$355,364	\$1,749,409	\$32,618	\$254,043	295	11,809
VE22	Phoenix	4,324,268	10,529	\$348,821	\$13,541	\$362,362	\$1,810,142	\$25,620	\$193,309	230	9,198
Solexia Sungate 500	Phoenix	4,498,523	12,463	\$363,034	\$15,709	\$378,743	\$1,942,929	\$9,239	\$60,522	79	3,167
Dual Pane Tinted (DT)	St Louis	4,388,382	79,228	\$213,913	\$92,800	\$306,713	\$1,849,239	\$0	\$0	0	0
Solarban 60	St Louis	4,209,813	66,610	\$205,401	\$78,507	\$283,908	\$1,711,663	\$22,805	\$137,575	219	8,777
Solarban 70XL	St Louis	4,066,356	63,301	\$198,696	\$74,633	\$273,329	\$1,598,878	\$33,384	\$250,361	358	14,325
Solarban 80	St Louis	4,038,845	63,438	\$197,372	\$74,766	\$272,138	\$1,584,188	\$34,575	\$265,050	380	15,220
VE22	St Louis	4,119,295	64,405	\$201,207	\$75,932	\$277,139	\$1,639,293	\$29,574	\$209,946	308	12,304
Solexia Sungate 500	St Louis	4,300,530	71,452	\$209,710	\$84,026	\$293,736	\$1,783,764	\$12,977	\$65,475	117	4,663
Dual Pane Tinted (DT)	Seattle	3,719,896	82,469	\$228,921	\$67,245	\$296,166	\$1,686,500	\$0	\$0	0	0
Solarban 60	Seattle	3,583,989	66,523	\$220,303	\$54,730	\$275,033	\$1,577,492	\$21,133	\$109,008	124	4,959
Solarban 70XL	Seattle	3,492,080	62,025	\$214,507	\$51,200	\$265,707	\$1,486,174	\$30,459	\$200,326	173	6,931
Solarban 80	Seattle	3,479,396	62,215	\$213,725	\$51,350	\$265,075	\$1,484,259	\$31,091	\$202,241	176	7,024
VE22	Seattle	3,523,113	63,151	\$216,225	\$52,084	\$268,309	\$1,513,109	\$27,857	\$173,390	159	6,351
Solexia Sungate 500	Seattle	3,648,221	72,415	\$224,311	\$59,354	\$283,665	\$1,635,890	\$12,501	\$50,610	74	2,977

Double Pane Tinted	Tvis - 0.690, U-Value - 0.470, SC - 0.570	Electric Costs based on utility electric rates for each selected city	Cabon Multiplier	
Solarban 60 (2)	Tvis - 0.704, U-Value - 0.291, SC - 0.438	Natural Gas Costs based on utility gas rates for each selected city	(lbs CO ₂ /Kwh)	2.095
Solarban 70XL (2)	Tvis - 0.640, U-Value - 0.286, SC - 0.311	Capital Cooling Costs based on \$1,200 per ton for Office Buildings	DOE and EPA	1.321
Solarban 80 (2)	Tvis - 0.470, U-Value - 0.290, SC - 0.280	Capital HVAC Costs based on \$3.50 per cfm for Office Buildings	Report	1.969
VE2-2M (2)	Tvis - 0.600, U-Value - 0.290, SC - 0.360			
Solexia Sungate 500 (3)	Tvis - 0.640, U-Value - 0.350, SC - 0.510		lbs CO ₂ /therm	11.00
			EPA Workbook 1995	

Table 2-1: Results for Middle School Building Prototype with Wall Windows (Atlanta-Los Angeles)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Atlanta	1,672,083	59,413	\$308,768	\$54,257	\$363,025	\$1,229,811	\$0	\$0	0	0
Solarban 60	Atlanta	1,571,694	53,624	\$290,552	\$49,019	\$339,571	\$1,125,734	\$23,454	\$104,077	101	4,032
Solarban 70XL	Atlanta	1,478,648	55,613	\$273,400	\$50,820	\$324,220	\$1,036,819	\$38,805	\$192,992	154	6,151
Solarban 80	Atlanta	1,456,820	56,489	\$269,363	\$51,612	\$320,975	\$1,014,104	\$42,050	\$215,706	164	6,558
VE22	Atlanta	1,514,515	54,959	\$279,933	\$50,227	\$330,160	\$1,069,982	\$32,865	\$159,829	133	5,309
Solexia Sungate 500	Atlanta	1,625,958	55,197	\$300,000	\$50,443	\$350,443	\$1,178,485	\$12,582	\$51,326	55	2,195
Dual Pane Tinted (DT)	Boston	1,481,195	112,488	\$227,381	\$132,449	\$359,830	\$1,349,700	\$0	\$0	0	0
Solarban 60	Boston	1,398,999	100,020	\$214,773	\$117,832	\$332,605	\$1,227,531	\$27,225	\$122,169	108	4,322
Solarban 70XL	Boston	1,336,193	101,429	\$205,139	\$119,484	\$324,623	\$1,120,107	\$35,207	\$229,593	130	5,218
Solarban 80	Boston	1,321,950	102,165	\$202,954	\$120,347	\$323,301	\$1,093,767	\$36,529	\$255,933	133	5,329
VE22	Boston	1,357,816	100,668	\$208,455	\$118,592	\$327,047	\$1,161,972	\$32,783	\$187,728	124	4,970
Solexia Sungate 500	Boston	1,440,838	103,918	\$221,190	\$122,402	\$343,592	\$1,291,052	\$16,238	\$58,648	67	2,660
Dual Pane Tinted (DT)	Chicago	1,499,964	117,532	\$147,686	\$108,498	\$256,184	\$1,279,552	\$0	\$0	0	0
Solarban 60	Chicago	1,420,816	104,928	\$139,887	\$96,902	\$236,789	\$1,182,919	\$19,395	\$96,632	131	5,242
Solarban 70XL	Chicago	1,355,759	105,442	\$133,635	\$97,376	\$231,011	\$1,096,949	\$25,173	\$182,602	179	7,159
Solarban 80	Chicago	1,340,867	107,127	\$132,218	\$98,926	\$231,144	\$1,074,109	\$25,040	\$205,443	181	7,253
VE22	Chicago	1,379,874	104,914	\$136,039	\$96,881	\$232,920	\$1,131,786	\$23,264	\$147,766	163	6,523
Solexia Sungate 500	Chicago	1,462,124	109,102	\$144,155	\$100,742	\$244,897	\$1,296,080	\$11,287	\$43,472	76	3,035
Dual Pane Tinted (DT)	Denver	1,472,574	88,115	\$166,852	\$88,232	\$255,084	\$1,166,992	\$0	\$0	0	0
Solarban 60	Denver	1,389,759	79,204	\$157,270	\$79,245	\$236,515	\$1,059,175	\$18,569	\$107,817	116	4,624
Solarban 70XL	Denver	1,324,687	82,680	\$149,270	\$82,505	\$231,775	\$963,447	\$23,309	\$203,545	149	5,953
Solarban 80	Denver	1,308,417	84,516	\$147,020	\$84,314	\$231,334	\$936,231	\$23,750	\$230,761	152	6,072
VE22	Denver	1,352,110	81,301	\$152,858	\$81,218	\$234,076	\$1,000,491	\$21,008	\$166,500	134	5,374
Solexia Sungate 500	Denver	1,434,150	81,593	\$162,548	\$81,682	\$244,230	\$1,117,566	\$10,854	\$49,426	67	2,671
Dual Pane Tinted (DT)	Houston	1,993,815	40,321	\$313,044	\$57,664	\$370,708	\$1,343,110	\$0	\$0	0	0
Solarban 60	Houston	1,860,525	36,456	\$292,517	\$52,137	\$344,654	\$1,230,134	\$26,054	\$112,976	118	4,721
Solarban 70XL	Houston	1,742,935	37,461	\$274,408	\$53,573	\$327,981	\$1,145,061	\$42,727	\$198,050	198	7,915
Solarban 80	Houston	1,714,691	37,900	\$270,059	\$54,201	\$324,260	\$1,125,438	\$46,448	\$217,672	216	8,639
VE22	Houston	1,788,068	37,071	\$281,359	\$53,016	\$334,375	\$1,179,451	\$36,333	\$163,660	167	6,690
Solexia Sungate 500	Houston	1,928,087	37,537	\$302,922	\$53,682	\$356,604	\$1,280,635	\$14,104	\$62,476	63	2,521
Dual Pane Tinted (DT)	Los Angeles	1,551,157	38,332	\$256,556	\$37,346	\$293,902	\$1,199,877	\$0	\$0	0	0
Solarban 60	Los Angeles	1,461,570	34,611	\$241,995	\$33,734	\$275,729	\$1,084,313	\$18,173	\$115,564	44	1,775
Solarban 70XL	Los Angeles	1,375,992	36,032	\$227,033	\$35,114	\$262,147	\$969,958	\$31,755	\$229,919	59	2,377
Solarban 80	Los Angeles	1,356,492	36,700	\$223,343	\$35,762	\$259,105	\$933,452	\$34,797	\$266,425	61	2,438
VE22	Los Angeles	1,407,915	35,522	\$232,767	\$34,619	\$267,386	\$1,017,664	\$26,516	\$182,213	54	2,148
Solexia Sungate 500	Los Angeles	1,510,973	35,572	\$250,106	\$34,667	\$284,773	\$1,144,682	\$9,129	\$55,195	26	1,036

Double Pane Tinted Tvis - 0.690, U-Value - 0.470, SC - 0.570
 Solarban 60 (2) Tvis - 0.704, U-Value - 0.291, SC - 0.438
 Solarban 70XL (2) Tvis - 0.640, U-Value - 0.286, SC - 0.311
 Solarban 80 (2) Tvis - 0.470, U-Value - 0.290, SC - 0.280
 VE2-2M (2) Tvis - 0.600, U-Value - 0.290, SC - 0.360
 Solexia Sungate 500 (3) Tvis - 0.640, U-Value - 0.350, SC - 0.510

Electric Costs based on utility electric rates for each selected city
 Natural Gas Costs based on utility gas rates for each selected city
 Capital Cooling Costs based on \$1,200 per ton for Middle Schools
 Capital HVAC Costs based on \$3.50 per cfm for Middle Schools

Cabon Multiplier (lbs CO₂/kwh) 2.095
 DOE and EPA Report 1.321
 Report 1.969
 lbs CO₂/therm 11.00
 EPA Workbook 1995

Table 2-1: Results for Middle School Building Prototype with Wall Windows (Mexico City- Seattle)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Mexico City	1,435,787	23,723	\$309,039	\$8,624	\$317,663	\$1,121,503	\$0	\$0	0	0
Solarban 60	Mexico City	1,363,242	21,696	\$293,482	\$7,937	\$301,419	\$1,016,791	\$16,244	\$104,713	64	2,553
Solarban 70XL	Mexico City	1,278,744	22,435	\$273,059	\$8,190	\$281,249	\$893,898	\$36,414	\$227,605	121	4,844
Solarban 80	Mexico City	1,258,232	22,774	\$268,350	\$8,307	\$276,657	\$864,699	\$41,006	\$256,804	134	5,365
VE22	Mexico City	1,310,578	22,151	\$280,826	\$8,092	\$288,918	\$940,342	\$28,745	\$181,162	100	3,982
Solexia Sungate 500	Mexico City	1,407,554	22,205	\$303,135	\$8,109	\$311,244	\$1,079,368	\$6,419	\$42,136	29	1,154
Dual Pane Tinted (DT)	Ottawa	1,426,700	150,171	\$150,635	\$58,426	\$209,061	\$1,202,163	\$0	\$0	0	0
Solarban 60	Ottawa	1,358,298	136,587	\$143,832	\$53,574	\$197,406	\$1,103,803	\$11,655	\$98,359	111	4,427
Solarban 70XL	Ottawa	1,303,658	141,242	\$137,916	\$55,218	\$193,134	\$1,005,234	\$15,927	\$196,928	114	4,553
Solarban 80	Ottawa	1,290,480	142,601	\$136,421	\$55,710	\$192,131	\$980,554	\$16,930	\$221,608	113	4,531
VE22	Ottawa	1,325,189	140,122	\$140,100	\$54,816	\$194,916	\$1,041,852	\$14,145	\$160,311	109	4,346
Solexia Sungate 500	Ottawa	1,393,659	140,669	\$147,349	\$55,043	\$202,392	\$1,157,658	\$6,669	\$44,505	70	2,785
Dual Pane Tinted (DT)	Philadelphia	1,543,305	97,630	\$142,219	\$131,123	\$273,342	\$1,224,329	\$0	\$0	0	0
Solarban 60	Philadelphia	1,458,842	87,355	\$135,961	\$117,515	\$253,476	\$1,128,609	\$19,866	\$95,720	101	4,037
Solarban 70XL	Philadelphia	1,386,094	88,959	\$130,566	\$119,639	\$250,205	\$1,049,947	\$23,137	\$174,382	130	5,215
Solarban 80	Philadelphia	1,369,070	89,680	\$129,308	\$120,595	\$249,903	\$1,029,137	\$23,439	\$195,192	135	5,414
VE22	Philadelphia	1,414,359	88,556	\$132,662	\$119,106	\$251,768	\$1,084,330	\$21,574	\$139,999	118	4,709
Solexia Sungate 500	Philadelphia	1,503,026	90,560	\$139,265	\$121,760	\$261,025	\$1,176,681	\$12,317	\$47,648	60	2,403
Dual Pane Tinted (DT)	Phoenix	2,147,948	36,218	\$183,071	\$42,337	\$225,408	\$1,353,262	\$0	\$0	0	0
Solarban 60	Phoenix	1,987,023	33,179	\$169,381	\$38,930	\$208,311	\$1,219,091	\$17,097	\$134,170	146	5,845
Solarban 70XL	Phoenix	1,854,784	34,602	\$157,916	\$40,525	\$198,441	\$1,113,870	\$26,967	\$239,392	245	9,785
Solarban 80	Phoenix	1,823,691	35,144	\$155,544	\$41,132	\$196,676	\$1,089,063	\$28,732	\$264,199	267	10,666
VE22	Phoenix	1,905,961	34,094	\$162,400	\$39,956	\$202,356	\$1,154,851	\$23,052	\$198,411	206	8,251
Solexia Sungate 500	Phoenix	2,070,208	33,955	\$176,428	\$39,800	\$216,228	\$1,286,575	\$9,180	\$66,686	75	2,998
Dual Pane Tinted (DT)	St Louis	1,673,401	19,038	\$123,004	\$23,126	\$146,130	\$1,432,659	\$0	\$0	0	0
Solarban 60	St Louis	1,564,613	19,208	\$115,597	\$23,329	\$138,926	\$1,307,569	\$7,204	\$125,090	90	3,618
Solarban 70XL	St Louis	1,463,738	19,403	\$109,099	\$23,563	\$132,662	\$1,208,378	\$13,468	\$224,281	174	6,965
Solarban 80	St Louis	1,440,689	19,457	\$107,007	\$23,628	\$130,635	\$1,185,360	\$15,495	\$247,299	193	7,728
VE22	St Louis	1,501,864	19,323	\$110,679	\$23,468	\$134,147	\$1,246,965	\$11,983	\$185,694	143	5,702
Solexia Sungate 500	St Louis	1,622,360	19,106	\$118,663	\$23,207	\$141,870	\$1,375,509	\$4,260	\$57,150	43	1,700
Dual Pane Tinted (DT)	Seattle	1,324,941	103,771	\$84,944	\$83,925	\$168,869	\$1,099,689	\$0	\$0	0	0
Solarban 60	Seattle	1,264,672	91,660	\$80,941	\$74,418	\$155,359	\$994,434	\$13,510	\$105,255	83	3,308
Solarban 70XL	Seattle	1,219,613	91,280	\$78,038	\$74,131	\$152,169	\$898,312	\$16,700	\$201,378	97	3,873
Solarban 80	Seattle	1,210,187	91,714	\$77,360	\$74,475	\$151,835	\$874,790	\$17,034	\$224,899	97	3,878
VE22	Seattle	1,236,260	91,543	\$79,093	\$74,335	\$153,428	\$937,800	\$15,441	\$161,890	91	3,637
Solexia Sungate 500	Seattle	1,294,765	95,759	\$82,983	\$77,632	\$160,615	\$1,053,373	\$8,254	\$46,316	52	2,085

Double Pane Tinted	Tvis - 0.690, U-Value - 0.470, SC - 0.570	Electric Costs based on utility electric rates for each selected city	Cabon Multiplier	2.095
Solarban 60 (2)	Tvis - 0.704, U-Value - 0.291, SC - 0.438	Natural Gas Costs based on utility gas rates for each selected city	(lbs CO ₂ /Kwh)	1.321
Solarban 70XL (2)	Tvis - 0.640, U-Value - 0.286, SC - 0.311	Capital Cooling Costs based on \$1,200 per ton for Middle Schools	DOE and EPA	1.969
Solarban 80 (2)	Tvis - 0.470, U-Value - 0.290, SC - 0.280	Capital HVAC Costs based on \$3.50 per cfm for Middle Schools	Report	
VE2-2M (2)	Tvis - 0.600, U-Value - 0.290, SC - 0.360			
Solexia Sungate 500 (3)	Tvis - 0.640, U-Value - 0.350, SC - 0.510		lbs CO ₂ /therm	11.00
			EPA Workbook 1995	

Table 2-2: Results for the Middle School Building Prototype with Punched Windows (Atlanta-Los Angeles)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Atlanta	1,441,120	53,182	\$268,087	\$48,620	\$316,707	\$1,002,400	\$0	\$0	0	0
Solarban 60	Atlanta	1,399,065	50,839	\$259,326	\$46,500	\$305,826	\$956,272	\$10,881	\$46,128	42	1,671
Solarban 70XL	Atlanta	1,367,728	52,411	\$252,775	\$47,922	\$300,697	\$924,720	\$16,010	\$77,681	55	2,186
Solarban 80	Atlanta	1,360,093	53,002	\$250,933	\$48,456	\$299,389	\$914,314	\$17,318	\$88,087	57	2,266
VE22	Atlanta	1,381,269	51,858	\$255,745	\$47,422	\$303,167	\$938,687	\$13,540	\$63,713	48	1,936
Solexia Sungate 500	Atlanta	1,421,588	51,340	\$263,649	\$46,953	\$310,602	\$981,109	\$6,105	\$21,291	24	942
Dual Pane Tinted (DT)	Boston	1,302,076	97,081	\$199,905	\$114,386	\$314,291	\$1,074,938	\$0	\$0	0	0
Solarban 60	Boston	1,269,351	92,018	\$194,885	\$108,441	\$303,326	\$1,015,973	\$10,965	\$58,965	44	1,742
Solarban 70XL	Boston	1,244,004	94,133	\$190,998	\$110,933	\$301,931	\$957,141	\$12,360	\$117,797	44	1,764
Solarban 80	Boston	1,238,872	94,715	\$190,210	\$111,615	\$301,825	\$943,144	\$12,466	\$131,793	43	1,734
VE22	Boston	1,253,041	93,377	\$192,384	\$110,047	\$302,431	\$980,018	\$11,860	\$94,920	44	1,757
Solexia Sungate 500	Boston	1,284,455	93,313	\$197,203	\$109,969	\$307,172	\$1,045,962	\$7,119	\$28,976	29	1,167
Dual Pane Tinted (DT)	Chicago	1,323,036	102,314	\$131,333	\$94,499	\$225,832	\$1,057,460	\$0	\$0	0	0
Solarban 60	Chicago	1,288,178	97,060	\$128,326	\$89,665	\$217,991	\$1,013,983	\$7,841	\$43,476	56	2,243
Solarban 70XL	Chicago	1,262,168	98,550	\$124,857	\$91,028	\$215,885	\$972,272	\$9,947	\$85,188	68	2,727
Solarban 80	Chicago	1,257,214	99,391	\$124,123	\$91,802	\$215,925	\$961,897	\$9,907	\$95,562	67	2,697
VE22	Chicago	1,272,505	97,897	\$125,963	\$90,427	\$216,390	\$990,156	\$9,442	\$67,304	64	2,548
Solexia Sungate 500	Chicago	1,303,933	98,280	\$129,602	\$90,787	\$320,389	\$1,039,097	\$5,443	\$18,363	37	1,483
Dual Pane Tinted (DT)	Denver	1,289,171	79,474	\$145,119	\$79,412	\$224,531	\$924,776	\$0	\$0	0	0
Solarban 60	Denver	1,254,217	76,014	\$140,978	\$75,913	\$216,891	\$878,029	\$7,640	\$46,747	47	1,886
Solarban 70XL	Denver	1,226,827	78,786	\$137,269	\$78,547	\$215,816	\$829,705	\$8,715	\$95,070	54	2,157
Solarban 80	Denver	1,220,780	79,662	\$136,419	\$79,392	\$215,811	\$817,825	\$8,720	\$106,950	54	2,158
VE22	Denver	1,236,741	77,311	\$138,631	\$77,091	\$215,722	\$846,289	\$8,809	\$78,487	54	2,162
Solexia Sungate 500	Denver	1,271,788	76,613	\$143,105	\$76,544	\$219,649	\$902,672	\$4,882	\$22,104	30	1,189
Dual Pane Tinted (DT)	Houston	1,699,590	35,461	\$267,733	\$50,714	\$318,447	\$1,106,749	\$0	\$0	0	0
Solarban 60	Houston	1,641,784	34,015	\$258,831	\$48,645	\$307,476	\$1,056,304	\$10,971	\$50,445	50	1,997
Solarban 70XL	Houston	1,590,309	34,888	\$250,903	\$49,894	\$300,797	\$1,011,068	\$17,650	\$95,682	82	3,300
Solarban 80	Houston	1,578,634	35,202	\$249,106	\$50,343	\$299,449	\$1,002,044	\$18,998	\$104,705	89	3,570
VE22	Houston	1,610,691	34,572	\$254,043	\$49,443	\$303,486	\$1,030,820	\$14,961	\$75,930	69	2,777
Solexia Sungate 500	Houston	1,672,409	34,331	\$263,548	\$49,098	\$312,646	\$1,081,077	\$5,801	\$25,672	26	1,038
Dual Pane Tinted (DT)	Los Angeles	1,339,744	34,107	\$221,233	\$33,245	\$254,478	\$925,201	\$0	\$0	0	0
Solarban 60	Los Angeles	1,302,130	32,678	\$214,818	\$31,859	\$246,677	\$862,188	\$7,801	\$63,013	18	716
Solarban 70XL	Los Angeles	1,268,245	33,629	\$208,011	\$32,782	\$240,793	\$798,596	\$13,685	\$126,605	22	869
Solarban 80	Los Angeles	1,260,465	34,019	\$206,464	\$33,161	\$239,625	\$784,549	\$14,853	\$140,652	22	866
VE22	Los Angeles	1,281,068	33,257	\$210,520	\$32,421	\$242,941	\$822,121	\$11,537	\$103,081	20	814
Solexia Sungate 500	Los Angeles	1,322,229	32,955	\$218,272	\$32,127	\$250,399	\$897,454	\$4,079	\$27,747	11	440

Double Pane Tinted Tvis - 0.690, U-Value - 0.470, SC - 0.570
 Solarban 60 (2) Tvis - 0.704, U-Value - 0.291, SC - 0.438
 Solarban 70XL (2) Tvis - 0.640, U-Value - 0.286, SC - 0.311
 Solarban 80 (2) Tvis - 0.470, U-Value - 0.290, SC - 0.280
 VE2-2M (2) Tvis - 0.600, U-Value - 0.290, SC - 0.360
 Solexia Sungate 500 (3) Tvis - 0.640, U-Value - 0.350, SC - 0.510

Electric Costs based on utility electric rates for each selected city
 Natural Gas Costs based on utility gas rates for each selected city
 Capital Cooling Costs based on \$1,200 per ton for Middle Schools
 Capital HVAC Costs based on \$3.50 per cfm for Middle Schools

Cabon Multiplier (lbs CO₂/Kwh) 2.095
 DOE and EPA Report 1.321
 Report 1.969
 lbs CO₂/therm 11.00
 EPA Workbook 1995

Table 2-2 Results for the Middle School Building Prototype with Punched Windows (Mexico City- Seattle)

Glazing	Location	Electricity (kWh)	Gas (therms)	Total Operating Electric Cost (US\$)	Total Operating Gas Cost (US\$)	Total Operating Cost (US\$)	Total Capital Cooling HVAC Cost (US\$)	Annual Operating Cost Savings of Low-E Coatings vs. DT (US\$)	Initial Capital Cost Savings of Low-E Coatings vs. DT (US\$)	Annual CO ₂ Savings of Low-E vs. DT (Tons)	40 Year Building Life CO ₂ Savings of Low-E vs. DT (Tons)
Dual Pane Tinted (DT)	Mexico City	1,249,515	21,076	\$267,300	\$7,727	\$275,027	\$859,133	\$0	\$0	0	0
Solarban 60	Mexico City	1,221,868	20,622	\$261,020	\$7,574	\$268,594	\$815,760	\$6,433	\$43,373	23	903
Solarban 70XL	Mexico City	1,189,493	21,457	\$252,847	\$7,860	\$260,707	\$767,752	\$14,320	\$91,381	41	1,659
Solarban 80	Mexico City	1,182,160	21,791	\$251,003	\$7,975	\$258,978	\$756,587	\$16,049	\$102,546	45	1,799
VE22	Mexico City	1,201,299	21,105	\$255,879	\$7,739	\$263,618	\$785,493	\$11,409	\$73,640	35	1,394
Solexia Sungate 500	Mexico City	1,238,402	20,625	\$264,932	\$7,574	\$272,506	\$840,767	\$2,521	\$18,366	11	422
Dual Pane Tinted (DT)	Ottawa	1,273,255	136,806	\$134,839	\$53,585	\$188,424	\$966,525	\$0	\$0	0	0
Solarban 60	Ottawa	1,244,040	132,255	\$131,670	\$51,914	\$183,584	\$920,905	\$4,840	\$45,620	40	1,616
Solarban 70XL	Ottawa	1,223,928	134,889	\$129,496	\$52,876	\$182,372	\$876,202	\$6,052	\$90,323	36	1,459
Solarban 80	Ottawa	1,219,166	135,806	\$128,944	\$53,208	\$182,152	\$865,245	\$6,272	\$101,280	34	1,358
VE22	Ottawa	1,231,462	133,910	\$130,381	\$52,522	\$182,903	\$893,369	\$5,521	\$73,156	38	1,516
Solexia Sungate 500	Ottawa	1,259,076	133,582	\$133,244	\$52,399	\$185,643	\$946,374	\$2,781	\$20,151	25	1,008
Dual Pane Tinted (DT)	Philadelphia	1,351,758	85,180	\$128,004	\$114,634	\$242,638	\$1,012,224	\$0	\$0	0	0
Solarban 60	Philadelphia	1,317,442	81,326	\$125,445	\$109,530	\$234,975	\$966,148	\$7,663	\$46,076	39	1,570
Solarban 70XL	Philadelphia	1,288,643	82,864	\$123,218	\$111,575	\$234,793	\$928,255	\$7,845	\$83,969	46	1,837
Solarban 80	Philadelphia	1,281,931	83,696	\$122,691	\$112,677	\$235,368	\$917,335	\$7,270	\$94,889	45	1,795
VE22	Philadelphia	1,300,999	81,806	\$124,188	\$110,159	\$234,347	\$946,647	\$8,291	\$65,577	45	1,810
Solexia Sungate 500	Philadelphia	1,335,840	82,517	\$126,814	\$111,107	\$237,921	\$990,502	\$4,717	\$21,722	23	921
Dual Pane Tinted (DT)	Phoenix	1,807,445	32,739	\$153,954	\$38,437	\$192,391	\$1,073,806	\$0	\$0	0	0
Solarban 60	Phoenix	1,734,045	31,530	\$147,707	\$37,082	\$184,789	\$1,012,504	\$7,602	\$61,302	66	2,627
Solarban 70XL	Phoenix	1,675,840	32,603	\$142,918	\$38,285	\$181,203	\$967,007	\$11,188	\$106,799	107	4,263
Solarban 80	Phoenix	1,662,014	32,986	\$141,454	\$38,714	\$180,168	\$956,091	\$12,223	\$117,715	116	4,624
VE22	Phoenix	1,698,536	32,251	\$144,711	\$37,890	\$182,601	\$984,670	\$9,790	\$89,136	90	3,610
Solexia Sungate 500	Phoenix	1,771,635	31,770	\$151,061	\$37,351	\$188,412	\$1,043,184	\$3,979	\$30,622	34	1,365
Dual Pane Tinted (DT)	St Louis	1,429,315	19,533	\$107,322	\$23,720	\$131,042	\$1,176,186	\$0	\$0	0	0
Solarban 60	St Louis	1,381,203	19,595	\$103,372	\$23,794	\$127,166	\$1,115,935	\$3,876	\$60,251	40	1,603
Solarban 70XL	St Louis	1,339,720	21,144	\$100,097	\$25,653	\$125,750	\$1,062,659	\$5,292	\$113,527	66	2,656
Solarban 80	St Louis	1,330,224	21,382	\$99,532	\$25,937	\$125,469	\$1,047,648	\$5,573	\$128,538	73	2,923
VE22	St Louis	1,355,722	20,741	\$101,155	\$25,169	\$126,324	\$1,084,747	\$4,718	\$91,439	55	2,207
Solexia Sungate 500	St Louis	1,406,445	18,841	\$105,545	\$22,890	\$128,435	\$1,150,303	\$2,607	\$25,883	23	921
Dual Pane Tinted (DT)	Seattle	1,194,495	86,793	\$76,337	\$70,605	\$146,942	\$860,895	\$0	\$0	0	0
Solarban 60	Seattle	1,170,198	81,636	\$74,805	\$66,559	\$141,364	\$811,783	\$5,578	\$49,111	35	1,394
Solarban 70XL	Seattle	1,154,684	82,073	\$73,792	\$66,910	\$140,702	\$756,249	\$6,240	\$104,645	37	1,464
Solarban 80	Seattle	1,151,191	82,438	\$73,510	\$67,200	\$140,710	\$741,982	\$6,232	\$118,913	36	1,421
VE22	Seattle	1,160,592	81,990	\$74,171	\$66,842	\$141,013	\$778,373	\$5,929	\$82,522	35	1,419
Solexia Sungate 500	Seattle	1,181,504	83,223	\$75,565	\$67,803	\$143,368	\$838,795	\$3,574	\$22,099	23	924

Double Pane Tinted	Tvis - 0.690, U-Value - 0.470, SC - 0.570	Electric Costs based on utility electric rates for each selected city	Cabon Multiplier	2.095
Solarban 60 (2)	Tvis - 0.704, U-Value - 0.291, SC - 0.438	Natural Gas Costs based on utility gas rates for each selected city	(lbs CO ₂ /Kwh)	1.321
Solarban 70XL (2)	Tvis - 0.640, U-Value - 0.286, SC - 0.311	Capital Cooling Costs based on \$1,200 per ton for Middle Schools	DOE and EPA	1.969
Solarban 80 (2)	Tvis - 0.470, U-Value - 0.290, SC - 0.280	Capital HVAC Costs based on \$3.50 per cfm for Middle Schools	Report	
VE2-2M (2)	Tvis - 0.600, U-Value - 0.290, SC - 0.360			
Solexia Sungate 500 (3)	Tvis - 0.640, U-Value - 0.350, SC - 0.510		lbs CO ₂ /therm	11.00
			EPA Workbook 1995	

APPENDIX C: Weather Data

	Atlanta	Boston	Chicago	Denver	Houston	Los Angeles	Mexico City	Ottawa	Philadelphia	Phoenix	St. Louis	Seattle
Average Drybulb Temperature (F)	60.6	50.6	50.3	51.0	68.1	62.0	61.5	42.7	53.6	72.5	55.1	50.5
Average Wetbulb Temperature (F)	54.1	45.1	44.9	42.0	62.4	55.8	51.6	36.9	47.9	54.8	49.3	46.2
Average Daily Max Temperature (F)	70.3	57.9	58.3	64.4	78.3	69.4	73	52.2	62.0	85.2	64.5	57.4
Average Daily Min Temperature (F)	51.6	43.6	42.2	39.4	58.6	56.1	49.1	32.3	45.4	59.4	45.9	44.2
Heating Degree Days (Base 65)	3,090	5,841	6,128	5,395	1,552	1,291	1,596	8,605	5,181	1,153	5,021	5,300
Cooling Degree Days (Base 65)	1,611	646	738	606	2,810	470	151	302	1,053	3,815	1,437	106
Maximum Temp (F)	97	92	99	94	97	95	87	92	95	115	101	87
Minimum Temp (F)	12	5	-8	-3	14	40	31	-20	11	27	0	20
No of Days Max Temp 90 and Above	17	2	12	13	70	1	0	1	12	164	33	0
No of Days Max Temp 32 and Below	4	26	37	13	0	0	0	77	19	0	31	3
No of Days Min Temp 32 and Below	52	106	111	142	26	0	1	169	99	2	101	36
No of Days Max Temp 0 and Below	0	0	3	1	0	0	0	31	0	0	1	0
Average Wind Speed (MPH)	8.8	12.1	9.9	9.7	8.4	8.0	5.7	8.0	9.6	6.7	9.8	9.1
Average Day Temp (F)	66.4	55.0	55.0	54.0	73.5	65.2	66.8	50.2	59.1	79.3	60.9	54.2
Average Night Temp (F)	55.9	45.8	45.3	47.9	63.3	58.7	57.2	35.2	48.1	66.7	49.3	47.0
Average RH at 4 AM	80.3	73.6	78.2	62.2	89.2	77.3	74.1	81.1	78.0	50.3	83.7	85.2
Average RH at 10 AM	67.9	62.2	69.7	65.3	68.9	60.3	59.3	62	63.1	35.6	67.7	75.8
Average RH at 4 PM	52.1	57.5	59.9	36.1	57.9	64.3	36.8	44.6	53.9	21.6	55.9	63.4
Average RH at 10 PM	71.1	68.4	71.8	47.6	82.3	74.6	58.1	65.5	71.2	36.3	74.1	76.5

APPENDIX D: Utility Rate Data by City
*Utility rates used in the PPG Window Analysis***Atlanta**

Electric Rates:	Georgia Power
<i>Monthly Charge:</i>	\$41.00
Energy Charge:	Time of Use Rate
• <i>Summer (June-September)</i>	
Off Peak	0.0678 \$/kWh
On Peak	0.1504 \$/kWh
	<i>(Weekday 2:00 p.m. - 7:00 p.m.)</i>
• <i>Winter (January-May, October-December)</i>	
Off Peak	0.0259 \$/kWh
On Peak	0.0678 \$/kWh
	<i>(Weekday 2:00 p.m. - 7:00 p.m.)</i>
Demand Charge:	
First 10 kW	4.30 \$/kW
Next 40 kW	8.50 \$/kW
Over 50 kW	26.40 \$/kW
Gas Rates:	Atlanta Gas Light
<i>Monthly Charge:</i>	\$41.50
<i>Energy Charge:</i>	0.9048 \$/Therm

Boston

Electric Rates:	Massachusetts Electric
<i>Monthly Charge:</i>	\$15.31
<i>Energy Charge:</i>	0.13395 \$/kWh
Gas Rates:	Boston Gas Company
<i>Monthly Charge:</i>	\$47.17
<i>Energy Charge:</i>	1.1724 \$/Therm

Chicago

Electric Rates:	Illinois Power Company
<i>Monthly Charge:</i>	\$39.93
Energy Charge:	
First 30,000 kWh	0.04247 \$/kWh
Next 470,000 kWh	0.03167 \$/kWh
Over 500,000 kWh	0.03118 \$/kWh
Demand Charge:	
11.13 \$/kW	Winter: Oct-May
14.24 \$/kW	Summer: June-Sept
Gas Rates:	Illinois Power Company
<i>Monthly Charge:</i>	\$30.00
<i>Energy Charge:</i>	0.92005 \$/Therm

Denver

Electric Rates:	Excel Energy
<i>Monthly Charge:</i>	\$25.00
<i>Energy Charge:</i>	0.04147 \$/kWh
Demand Charge:	
12.85 \$/kW	Winter: Oct-May
14.03 \$/kW	Summer: June-Sept
Gas Rates:	Excel Energy
<i>Monthly Charge:</i>	\$20.00
<i>Energy Charge:</i>	0.9289 \$/Therm

Houston

Electric Rates:	Reliant Energy
<i>Monthly Charge:</i>	\$500.00
<i>Energy Charge:</i>	0.154 \$/kWh
<i>Demand Charge:</i>	No Demand Charge
Gas Rates:	Energy Information Administration
	Average Rate for Texas (2005)
<i>Monthly Charge:</i>	\$0
<i>Energy Charge:</i>	1.43 \$/Therm

Los Angeles

Electric Rates:	Southern California Edison
<i>Monthly Charge:</i>	\$63.71
<i>Energy Charge:</i>	0.97047 \$/kWh
Demand Charge:	
9.68 \$/kW	Winter: Oct-May
17.05 \$/kW	Summer: June-Sept
Gas Rates:	Southern California Gas Company
<i>Monthly Charge:</i>	\$12.00
<i>Energy Charge:</i>	0.97047 \$/Therm

Mexico City

Electric Rates:	Luz Y Fuerza
<i>Monthly Charge:</i>	\$121.11
<i>Energy Charge:</i>	0.1149 \$/kWh
<i>Demand Charge:</i>	\$18.25 \$/kW
Gas Rates:	Metrogas (CRE)
<i>Monthly Charge:</i>	\$11.60
<i>Energy Charge:</i>	
First 793 Therms	0.39445 \$/Therm
Next 5,159 Therms	0.33819 \$/Therm
Next 8,054 Therms	0.27290 \$/Therm
Next 5,834 Therms	0.07467 \$/Therm
Over 19,840 Therms	0.02812 \$/Therm

Ottawa

Electric Rates:	Hydro Ottawa
<i>Monthly Charge:</i>	\$247.16
<i>Energy Charge:</i>	
First 750 kWh	0.0631 \$/kWh
Over 750 kWh	0.0711 \$/kWh
<i>Demand Charge:</i>	6.75 \$/kW
Gas Rates:	Enbridge Gas
<i>Monthly Charge:</i>	\$22.00
<i>Energy Charge:</i>	
First 17,600 Therms	0.3972 \$/Therm
Next 37,000 Therms	0.3390 \$/Therm
Over 54,600 Therms	0.2982 \$/Therm

Philadelphia

Electric Rates:	PECO Energy Company
<i>Monthly Charge:</i>	\$25.00
<i>Energy Charge:</i>	
First 100 kWh	0.2246 \$/kWh
Next 50,000 kWh	0.1145 \$/kWh
Next 100,000 kWh	0.0785 \$/kWh
Over 150,100 kWh	0.044 \$/kWh
<i>Demand Charge:</i>	No Demand Charge
Gas Rates:	PECO Energy Company
<i>Monthly Charge:</i>	\$14.40
<i>Energy Charge:</i>	
First 2,000 Therms	1.41095 \$/Therm
Over 2,000 Therms	1.32434 \$/Therm

Phoenix

Electric Rates:	Salt River Project
<i>Monthly Charge:</i>	\$25.00
<i>Energy Charge:</i>	
• <i>Summer (June-September)</i>	
First 350 kWh/kW	0.0814 \$/kWh
Next 180 kWh/kW	0.0814 \$/kWh
Next 135 kWh/kW	0.0663 \$/kWh
Remaining kWh/kW	0.0471 \$/kWh
• <i>Winter (January-May, October-December)</i>	
First 350 kWh/kW	0.0640 \$/kWh
Next 180 kWh/kW	0.0640 \$/kWh
Next 135 kWh/kW	0.0568 \$/kWh
Remaining kWh/kW	0.0394 \$/kWh

Demand Charge:

1.88 \$/kW	Winter: Oct-May
3.65 \$/kW	Summer: June-Sept

Gas Rates:	Southwest Gas Corporation
<i>Monthly Charge:</i>	\$145.00
<i>Energy Charge:</i>	1.12083 \$/Therm

St. Louis

Electric Rates:	Union Electric Company
<i>Monthly Charge:</i>	\$100.00
<i>Energy Charge:</i>	0.02181 \$/kWh
<i>Demand Charge:</i>	
7.00 \$/kW	Winter: Oct-May
14.00 \$/kW	Summer: June-Sept
Gas Rates:	Union Electric Company
<i>Monthly Charge:</i>	\$24.00
<i>Energy Charge:</i>	
First 7,000 Therms	1.1996 \$/Therm
Over 7,000 Therms	1.1132 \$/Therm

Seattle

Electric Rates:	Seattle City Light
<i>Monthly Charge:</i>	\$100.00
<i>Energy Charge:</i>	
On Peak kWh	0.0586 \$/kWh
Off Peak kWh	0.0512 \$/kWh
<i>Demand Charge:</i>	
On Peak kW	0.40 \$/kW
Off Peak kW	0.17 \$/kW
Gas Rates:	Avista Utilities
<i>Monthly Charge:</i>	\$131.13
<i>Energy Charge:</i>	
First 200 Therms	0.9175 \$/Therm
Next 800 Therms	0.85036 \$/Therm
Over 1,000 Therms	0.78483 \$/Therm

APPENDIX E: Calculating Carbon Emissions

Calculations for CO₂ emission were derived using the multipliers derived *Carbon Dioxide Emissions for the Generation of Electric Power*

in the United States, a report published in July 2000 by the U.S. Department of Energy (DOE).

Example: Local Fuel Sources and EPA Multipliers for Electrical Power Generation

City	Electrical Power Generation Fuel %								Heat	
	Coal	EPA Multiplier (lbs/CO ₂ /Kwh)	Gas	EPA Multiplier (lbs/CO ₂ /Kwh)	Oil	EPA Multiplier (lbs/CO ₂ /Kwh)	Other	EPA Multiplier (lbs/CO ₂)	Natural Gas	EPA Multiplier (lbs/CO ₂ /Therms)
Atlanta	55%	2.095	11%	1.321	6%	1.969	30%	0	100%	11.0
Boston	15%	2.095	34%	1.321	10%	1.969	41%	0	100%	11.0
Chicago	71%	2.095	4%	1.321	1%	1.969	25%	0	100%	11.0
Denver	67%	2.095	14%	1.321	1%	1.969	18%	0	100%	11.0
Houston	40%	2.095	45%	1.321	1%	1.969	14%	0	100%	11.0
Los Angeles	5%	2.095	31%	1.321	1%	1.969	73%	0	100%	11.0
Mexico City	40%	2.095	45%	1.321	1%	1.969	14%	0	100%	11.0
Ottawa	37%	2.095	12%	1.321	6%	1.969	45%	0	100%	11.0
Philadelphia	37%	2.095	12%	1.321	6%	1.969	45%	0	100%	11.0
Phoenix	67%	2.095	14%	1.321	1%	1.969	18%	0	100%	11.0
St. Louis	78%	2.095	2%	1.321	1%	1.969	19%	0	100%	11.0
Seattle	5%	2.095	31%	1.321	1%	1.969	73%	0	100%	11.0

Formula for CO₂ Emissions Calculations:

kWh x local fuel source for electrical power generation (coal % + natural gas % + oil %) x EPA lbs/CO₂ multiplier (coal + natural gas + oil) + therms x EPA lbs/CO₂/therms multiplier
 2,000 (tons) = CO₂ Tons.

Sample Calculation

City: *Atlanta*
 Building Type: *Eight Story Office Building, Window Wall*
 Glazing Type: *Dual Pane Tinted Glass*
 kWh Used: *4,736,231*
 Natural Gas: *72,094 therms*

Annual Electrical Generation

(Kwh: 4,736,231 x Local Fuel Mix for Electrical Power Generation)
 Coal: 4,736,231 x 55% = 2,510,202 Kwh x 2.095 = 5,258,873 lbs/CO₂
 Gas: 4,736,231 x 11% = 520,985 Kwh x 1.321 = 688,102 lbs/CO₂
 Oil: 4,736,231 x 06% = 284,174 Kwh x 1.969 = 559,539 lbs/CO₂
 Other: 4,736,231 x 30% = 1,420,869 Kwh x 0.000 = 0 lbs/CO₂

Annual Natural Gas Consumption (Heat)

Therms: 72,094 x 11.0 = 782,034 lbs/CO₂

TOTAL CO₂ Emissions 7,288,541 lbs/CO₂
 ÷ 2,000 lbs (1 ton)
3,644 tons/CO₂



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