Dynamic Glass

Energy benefits of View Dynamic Glass in workplaces

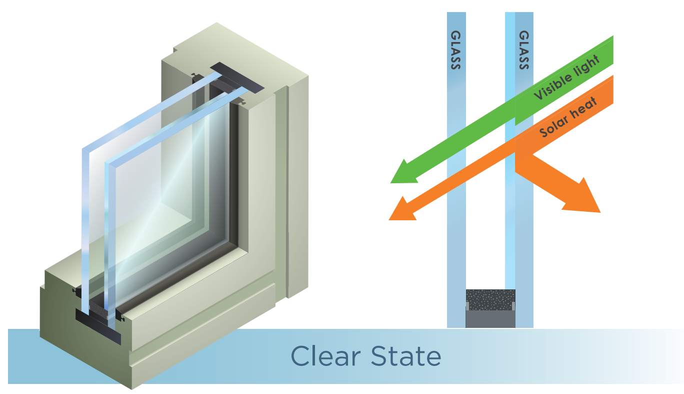
Energy consumption by buildings

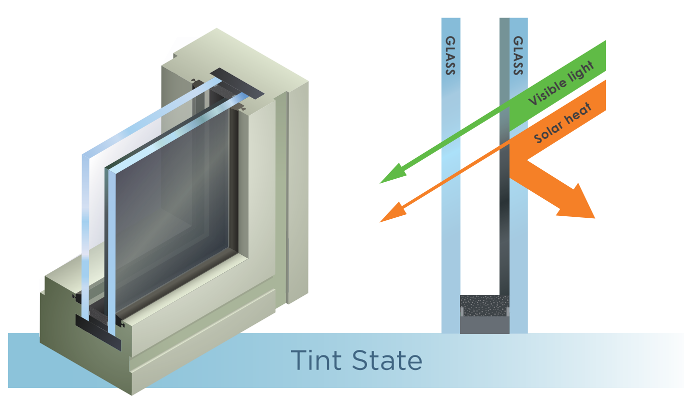
The building sector in the U.S. and much of Europe accounts for approximately 40 percent of energy consumption and more than 70 percent of electricity use[1], about half of that coming from commercial buildings. For rapidly developing areas of the world, their impact is currently less severe, but increasing. In India, commercial buildings currently account for 8 percent of total energy consumption, and their use is growing about 12 percent annually[2]. China's buildings already consume more than 30 percent of the country's energy and with China accounting for 50 percent of new buildings globally through 2020, energy consumption will increase dramatically[3].

Windows are commonly regarded as one of the least energy efficient building components, responsible for up to 40 percent of the total heating, cooling and lighting consumption. View Dynamic Glass improves the performance of the building by making windows energy efficient.

Smart Windows and View Dynamic Glass

Smart Windows are a category of next generation windows that have the ability to change traditionally static performance characteristics such as visible light transmittance and solar heat gain coefficient. Examples of technologies that enable Smart Windows are electrochromic (EC), thermochromic, photochromic, liquid crystal (LC) and suspended particle devices (SPD). Thermochromic and photochromic technologies change their properties based on ambient temperature and light respectively. EC, LC and SPD technologies have the advantage of electronic control of glass performance, enabling truly intelligent controls that can be integrated with occupant schedules, lighting levels, or algorithms to increase building energy efficiency. Unfortunately, both LC and SPD require continuous high voltage AC to operate and their failure mode is dark. EC technology has the advantage of using low voltage, low energy consumption and a failure mode being clear. In addition EC is the only technology that has passed the rigorous ASTM standard for accelerated environmental durability[4] which is equivalent to >50yr lifetime[5] . The application of EC technology to windows can substantially reduce the energy consumption of buildings by reducing cooling and heating loads as well as the demand for electric lighting.





[1] U.S. Department of Energy, "Energy Efficiency Trends in Residential and Commercial Buildings," 2008.
[2] S. Bhattacharya, M. Cropper, Rff DP 10–20, "Options for Energy Efficiency in India and Barriers to Their Adoption," 2010.
[3] Renewable Energy and Energy Efficient Partnership, "Worldwatch Report 182,"2010.

[4] ASTM Test Standard E2141-06 "standard Test Method for Assessing Durabiltiy of Absorptive Electrochromic Coatings on Sealed Insulating Glass Units". Testing conditions: 1 Sun (1000W/m2) at 85C; >50,000 cycles.
[5] Assuming swithing three times a day between highest and lowest transmission states.

View Dynamic Glass uses EC technology to change solar transmission properties (in the ultra-violet, visible and infrared spectrum) in response to a small applied voltage (< 5 volts). This enables control of the amount of light and radiative heat passing through a window that results in a window that ranging from a tinted transparent state to a clear transparent state. In addition, the coating has low emissivity properties, adding to the thermal performance when combined into a dual pane insulting glass unit (IGU). View Dynamic Glass is beneficial to all types of buildings as a method of controlling solar heat gain and light levels.

Energy benefits of View Dynamic Glass

1. Peak cooling load reduction:

   View Dynamic Glass can tint during peak cooling demand periods, thereby blocking more than 90 percent of solar radiation and resulting in tremendous savings in peak load cooling energy use. This results in reduced HVAC equipment sizing as well as system simplicity when compared to traditional glazing solutions.

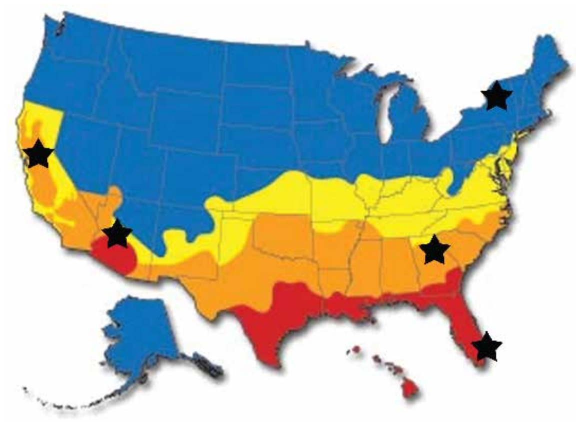
2. Annual energy savings:

   Due to its dynamic nature, View Dynamic Glass reduces overall HVAC energy consumption and costs by limiting unwanted heat gain in summer but allowing beneficial passive heat gain in winter. Intermediate states convey additional benefits by saving lighting energy, thus allowing for optimal daylighting.

Impact of View Dynamic Glass on building energy consumption

To gain a better understanding of the energy efficiency benefits available from applications of its glass, View performed whole-building energy simulations to characterize the energy use between current Low-E glazing and View high-performance Dynamic Glass.

The analysis was done across five U.S. cities in different ASHRAE climate zones (Please see below Climate Zone Map.) Comparing View Dynamic Glass to a location-specific ASHRAE baseline model illuminates potential performance improvements. In real-life building construction however, the type of glass defined by the baseline performance parameters is rarely used. Most designers and developers will opt for better performing and more aesthetically appealing glass solutions, such as a PPG Solarban 60, a Viracon VE1-2M or similar. Accordingly, high performance Low-E is used in this report as a typical performance comparison to dynamic glass.

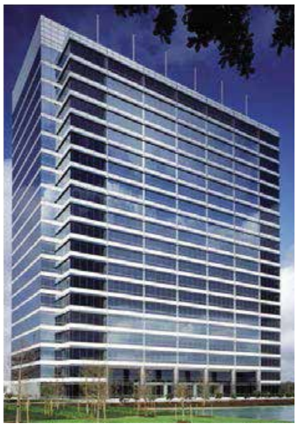


ASHRAE Climate Zone Map

Summary of findings

View Dynamic Glass can change its state from clear to tinted on demand thereby providing unprecedented control over the amount of light and heat that enter a building. This dynamic control results in up to 20 percent reduction in HVAC energy consumption and up to 23 percent reduction in peak load compared to standard Low-E glass.

The significant savings in peak load also reduces the cooling capacity requirements of HVAC systems. Details of each case study can be seen in the relevant case study sections below.



A typical 20-story high-rise office building with high performance Low-E glass was modeled against a building with View Dynamic Glass. The window to wall ratio modeled was 50% which is typical for high rise buildings. With all other aspects constant, the difference in energy performance was a direct result of the performance of the glass. Input parameters are summarized in Appendix B.

Annual energy consumption

On average, use of View Dynamic Glass reduces lighting and HVAC electricity (space cooling, ventilation fans, pumps) consumption by 20 percent. The savings in lighting energy is attributed to the intermediate state features of dynamic glass and dimmable lighting. The relative use of building electrical energy across five climates is illustrated in Table 1.

Average of 5 Cities			% Savings
	Low-E	Dynamic	Dynamic vs. Low-E
End-Use	(MBtu)	(MBtu)	%
Space Cool	2,476	2,012	19%
Heat Rej	179	143	20%
Vent. Fans	1,262	979	22%
Pumps & Aux.	609	514	16%
Area Lights	2,441	1,957	20%
Total Electricity Energy	11,575	10,423	20%

Table 1: Electricity energy end use comparison

View Dynamic Glass can save an average 10 percent total building energy as seen in Chart 1.

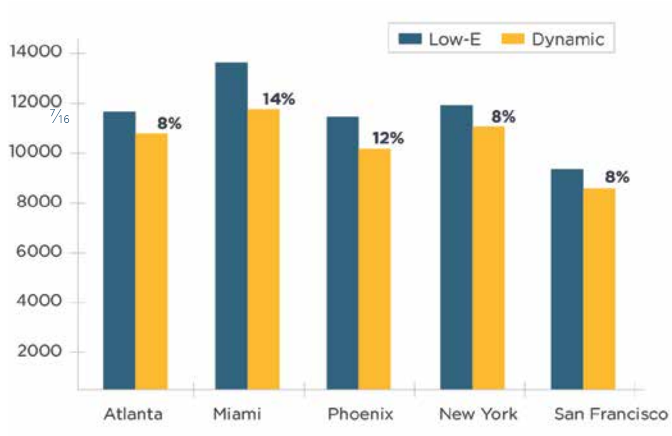


Chart 1: Annual energy use

Peak Load

Compared to high performance Low-E glazing, View Dynamic Glass reduces the building's cooling peak load by 23 percent.

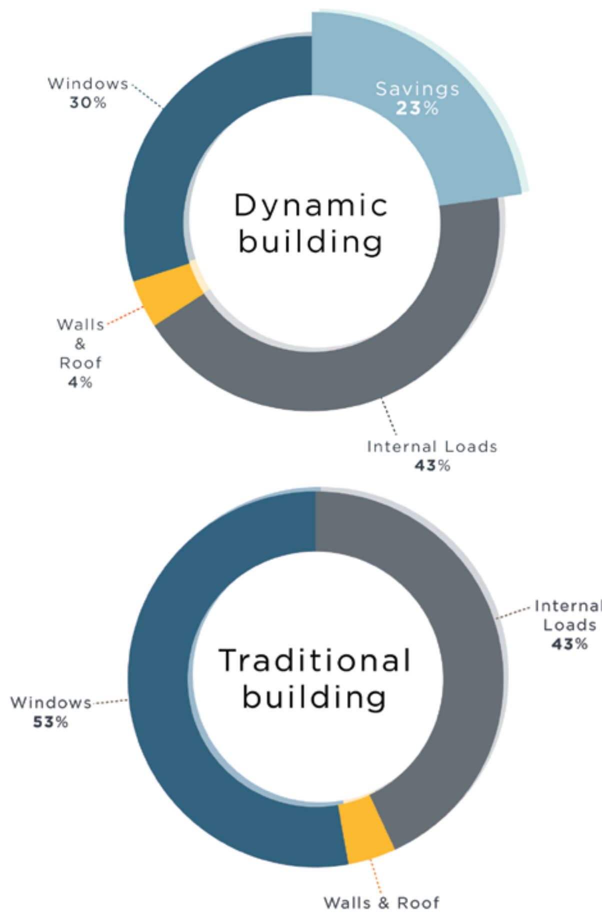


Chart 2: Peak Load Comparison

Reducing peak loads has two significant impacts on the design and operation of the building:

a. Peak load reduction can reduce HVAC system size (reduced cooling tons, fan, shaft & duct size, chiller, terminal units, diffusers, pumps and water circulation) required to meet loads in the building. Beyond the opportunity of straightforward equipment cost reductions, the reduced peak cooling loads offer a chance to use alternate cooling systems. Options such as radiant chilled ceilings and displacement ventilation can further reduce capital costs, lower maintenance or add greater design flexibility. As seen in Tables 2 & 3, View Dynamic Glass lowers required cooling tons and airflow cfm.

	Low-E	Dynamic	Delta	
	(tons)	(tons)	(tons)	%
Miami	1,472	1,090	372	25%
Atlanta	1,447	1,075	372	26%
New York	1,539	1,214	325	21%
Phoenix	1,578	1,055	523	33%
San Francisco	1,408	976	432	31%

Table 2: Cooling capacity tons comparison

	Low-E	Dynamic	Delta	
	(CFM)	(CFM)	(CFM)	%
Miami	471,376	311,612	159,764	34%
Atlanta	514,460	345,539	168,921	33%
New York	481,437	373,515	107,922	22%
Phoenix	513,582	348,202	165,380	32%
San Francisco	468,747	323,468	145,279	31%

Table 3: Supply airflow (CFM) comparison

b. Peak load reduction can reduce and possibly eliminate peak demand utility charges. Most utility companies, particularly electric, charge the consumer higher penalty rates if their building exceeds its pre-negotiated peak demand usage. Reducing peak loads for the building allows for the negotiation of a lower peak demand structure and passes significant operating cost savings to the owners of such facilities.

Similar to Case Study 1, a typical 4-story low-rise office building with high performance Low-E glass was modeled against a building with View Dynamic Glass. In the base case, the building using high performance Low-E glass contained a shading overhang on the southern façade. The window to wall ratio modeled was 40 percent which is typical for low rise buildings. In the View Dynamic Glass cases the shading overhang was eliminated. Input parameters are summarized in Appendix B.

Annual energy consumption

On average, use of View Dynamic Glass reduces lighting and HVAC electricity (space cooling, ventilation fans, pumps) consumption by 14 percent. Due to the availability of intermediate states, View Dynamic Glass can save up to 23 percent in lighting energy alone compared to Low-E glazing with internal shades. The relative use of building electrical energy across five climates is illustrated in Table 4.

Average of 5 Cities			% Savings
	Low-E	Dynamic	Dynamic vs. Low-E
End-Use	(MBtu)	(MBtu)	%
Space Cool	575	494	14%
Vent. Fans	98	78	21%
Pumps & Aux.	15	14	10%
Area Lights	670	518	23%
Total Electricity Energy	2,024	1,769	14%

Table 4: Electricity energy end use comparison

View Dynamic Glass can save on average 10 percent total building energy.

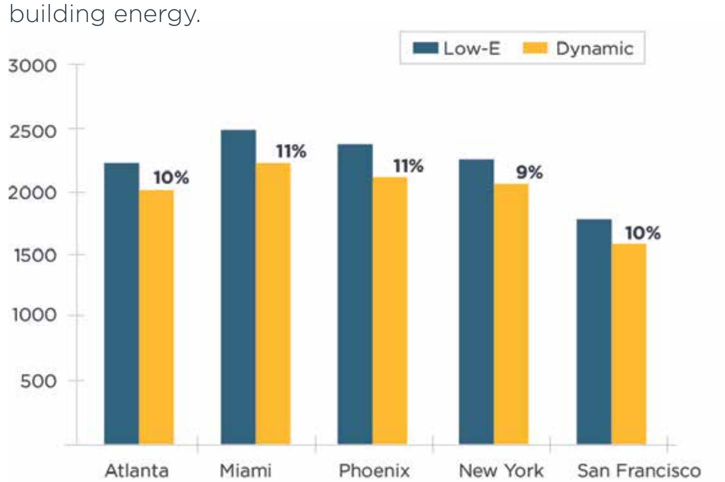


Chart 3: Annual energy use

Peak Load

View Dynamic Glass reduces cooling peak load by 8 percent compared to a baseline building with a fixed overhang on the south facade.

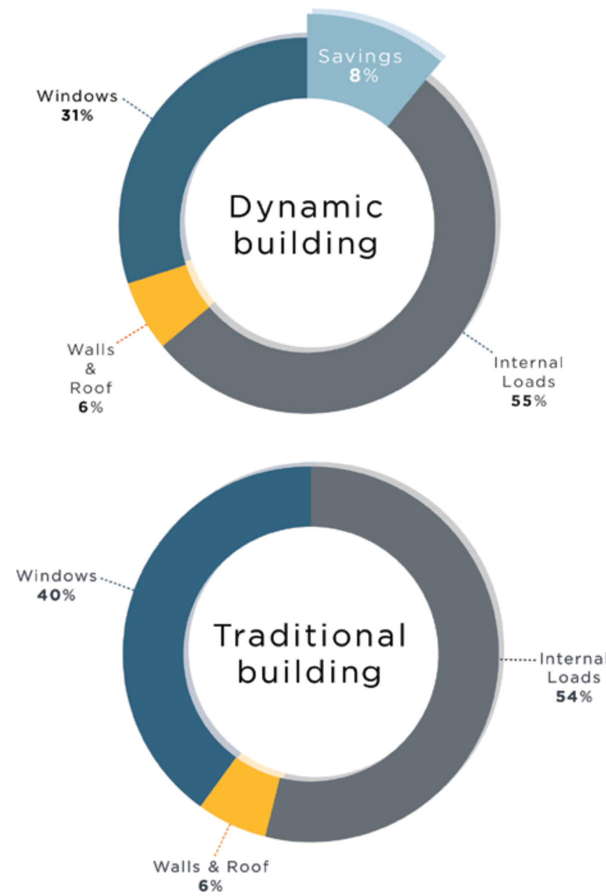


Chart 4: Electricity energy end use comparison

This reduction in peak cooling load results in lower cooling tons and airflow cfm required as seen in Tables 5 & 6. As explained in Case Study 1, this results in significant savings in HVAC system size reduction.

	Low–E	Dynamic	Delta	
	(tons)	(tons)	(tons)	%
Miami	187	177	10	6%
Atlanta	161	145	16	10%
New York	164	150	14	8%
Phoenix	203	187	16	8%
San Francisco	105	96	9	9%

Table 5: Cooling capacity tons comparison

	Low–E	Dynamic	Delta	
	(CFM)	(CFM)	(CFM)	%
Miami	76,156	64,736	11,420	15%
Atlanta	78,358	66,076	12,282	16%
New York	74,304	59,963	14,341	19%
Phoenix	85,610	73,868	11,742	14%
San Francisco	75,848	64,031	11,817	16%

Table 6: Supply airflow (CFM) comparison

Additionally, peak load reduction in a low-rise building acts in the same way as in a high-rise building. It leads to the reduction and possibly elimination of peak demand utility charges.

Other key benefits of View Dynamic Glass:

The value of View Dynamic Glass extends beyond energy efficiency:

1. Greater architectural design freedom: Higher efficiency View Dynamic Glass enables designers to use more glass while still meeting the performance objectives of building energy codes and standards.

2. Increased occupant comfort and productivity: In addition to improved daylighting and thermal comfort, View Dynamic Glass allows occupants unobstructed views even in the tinted state. This benefit is enhanced by user control abilities. Studies[6] have shown productivity increasing by 0.5-5 percent annually with improvements of indoor air quality, increased daylight and better control of office temperatures.

3. Reduction or elimination of internal blinds: Typical office buildings have some type of interior solar controls devices such as mini-blinds or roller shades, the management of which is often left to the user. While considered solar control devices, these devices are primarily used for glare mitigation and privacy. Research[7] has shown that in many cases once the blinds are dropped they remain closed for extended periods of time, limiting the potential to tie the performance of the lighting system to outside conditions. This results in excessive interior lighting usage as well as loss of passive solar heat in the winter. View Dynamic Glass can be automatically controlled based on external or internal conditions and optimized for energy performance and/or light levels while still maintaining the views outdoors.

4. Reduction or elimination of external shading structures: External shading devices are used in many glazed buildings to reduce the impact of direct solar gains, thus minimizing cooling loads. Devices like external blinds and louvers also block direct views. View Dynamic Glass can be deployed in its fully tinted state, taking advantage of its low shading coefficient when there is a high cooling demand, minimizing solar gains and thus reducing, if not eliminating, the need for external shades. This not only reduces the purchase cost of the shading devices but also reduces the added maintenance costs.

5. Significant contribution to achieving green building certifications: View Dynamic Glass can assist in achieving multiple credits for green building certifications like LEED due to benefits such as reduced energy consumption, user controllability and improved thermal comfort and daylighting.

6. Fading Reduction: Daylight brings in UV radiation which causes fading. View Dynamic Glass blocks greater than 99 percent of UV rays when tinted. Thus increasing the lifetime of office equipment, furnishings and fixtures.

Conclusion

View Dynamic Glass has tremendous potential in the emerging world of high performance green buildings. It not only provides the best energy performance for the building during operation, but also reduces capital cost and material waste in construction while improving occupant comfort and productivity. Use of View Dynamic Glass can:

- Allow greater design freedom to the architectural community
- Positively affect worker productivity through improved thermal and visual comfort as well as connection to the outdoors
- Reduce materials such as external and internal shading devices used in the construction or retrofit of buildings
- Downsize HVAC equipment and systems
- Reduce overall HVAC energy consumption and costs by limiting the heat gain in summer and allowing it in winter

[6] www.iaqscience.lbl.gov/performance-summary.html
[7] Newsham,G.R. 1994. Manual control of windows blinds and electric lighting: implications for comfort and energy consumption, indoor Environment, Vol.3, pp.135-144

Appendix A: Definitions, acronyms and terms

U-value is defined as a measure of the rate of non-solar heat loss or gain through a material or assembly. The lower the U-value, the greater the resistance to heat flow and therefore, better insulating properties.

SHGC or Solar Heat Gain Coefficient is defined as a measure of how well a window blocks heat from sunlight. It is expressed as a fraction of heat from the sun that enters the window. Lower SHGC indicates lower heat transmission.

SC or Shading Coefficient is defined as the ability of a window to transmit solar heat, relative to that same ability for 3mm clear, double-strength, single glass. Lower shading coefficients indicate a darker glass and therefore, greater shading ability.

Tvis or Visible Light Transmittance is defined as the ratio of total visible light passing through a glazing surface divided by the amount of light striking the surface of the glazing. The lower the Tvis, the less light enters the space.

ASHRAE is the American Society of Heating, Refrigeration and Air Conditioning Engineers

Building Load (or space load if the focus is on a zone, rather than the whole building) is an effect imposed on a piece of equipment, as in a heating or cooling load, or imposed on the electrical system, as in a direct electrical load. Heating and cooling loads usually result, indirectly, in electrical loads through fans, pumps and compressors and therefore result in energy use. A load in context of these discussions is defined as a net heat loss or gain resulting from a set of conditions.

TOT-SOL-HOR: Intensity of total (direct plus diffuse) solar radiation incident on an unobstructed Horizontal plane (legal keywords in DOE-2.2 to control dynamic glazing)

Appendix B: Input parameter summary

Baseline Building Definition

ASHRAE Standard 90.1-2004, Addendum G, Performance Rating Method. The model inputs are based on a prototypical 400,200 sf, 20-story high rise office building. The only parameter that changed was the glazing and glazing control strategies. Low-E glazing was assumed for the baseline, and View's dynamic glass was modeled using total horizontal solar tinting control strategies

Simulation Software

A combination of EQUEST (v3.63) and DOE-2.2 (v47g) computer simulation programs were used.

Weather Data

Five locations were simulated: Atlanta, Miami, New York City, San Francisco and Phoenix. The climate zones are 3A, 1, 4A, 3C and 2B, respectively, per ASHRAE Standard 90.1-2004. Typical Meteorological Year (TMY2) data sets were used with the building energy model. This data represents an average data for every hour collected over a period of 30 years. The TMY2 data are derived from the 1961-1990 National Solar Radiation Data Base (NSRDB).

Geometry

Case study 1: The assumed prototype building is a 400,200 sf 20-story high-rise office building. The floor plate is 174 ft on the East-West axis and 115 ft on the North-South axis.

The Window-to-Wall Ratio (floor-to-floor) = 50%

Case study 2: The assumed prototype building is a 80,000 sf 4-story low-rise office building. The floor plate is 200 ft on the East-West axis and 100 ft on the North-South axis.

The Window-to-Wall Ratio (floor-to-floor) = 40%

Internal Loads

	Lighting Power Density (LPD) W/ft^2	Equipment Power Density (EPD) W /ft^2
Case Study 1	0.8	0.75
Case Study 2	1.0	0.75

Glazing

Listed below are the glazing characteristics used in the model. The Low-E case was simulated with no blinds or drapes. View Dynamic Glass controls were simulated with different On/Off schedules depending on location.

	View Dynamic Glass	High Performance Low-E†
Daylight Dimming Controls	Yes	Yes
Internal Blinds, Drapes	No	Yes
External overhang	No	Case 1: No Case 2: Fixed Overhang (3ft on South windows)
Window Frames	Aluminum w/ Thermal Break	Aluminum w/ Thermal Break
U-value (center of glass)	0.29 Btu/ft^2 • °F • hr	0.29 Btu/ft^2 • °F • hr
Solar Heat Gain Coefficient	0.48 (bleached) 0.09 (tinted)	0.38
Visible Transmission	0.64 (bleached) 0.035 (tinted)	0.70
Energy Consumption	0.1 W/ft^2 (hold) 0.28 W/ft^2 (switch)	NA
Dynamic Control	All Year = Internal Photosensor 40fc	NA

Low-E specs are for PPG Solarban - 60 Low-E coated glass

Mechanical Systems

	Case Study 1	Case Study 2
System Type	Standard VAV, HW Reheat	Packaged VAV w/ Reheat
Ventilation Air	0.06 cfm/ft^2 plus 5 cfm/Person	0.1 cfm/ft^2 plus 20 cfm/Person
Cooling	2 Centrifugal Chillers	DX Coil
Nominal Cooling Efficiency	Design COP = 6.2	Design COP = 6.2
Heating	2 Forced Draft Boilers	Hot Water Loop
Nominal Heating Efficiency	80%	80%
Water Side Economizer	No	Per ASHRAE Requirements
Air Side Economizer	Yes	Per ASHRAE Requirements
Cooling Set Point Temperature	73°F	73°F
Cooling Setback Temperature	82°F	82°F
Heating Set Point Temperature	70°F	70°F
Heating Setback Temperature	64°F	64°F
HVAC and Occupancy Schedule	8am-5pm Excluding Weekends and Holidays	8am-5pm Excluding Weekends and Holidays

Utility Data

Shown below are utility rates for Atlanta, Miami, New York City, Phoenix and San Francisco.

Atlanta Electricity	
Monthly Charges ($/mo)	$17.00
Consumption Charges ($/kWh)	$0.10195 (first 3,000 kWh) $0.0943 (next 7,000 kWh) $0.0805 (next 190,000 kWh) $0.0624 (remaining)
Demand Charges ($/kW)	$7.46
Atlanta Natural Gas	
Monthly Charges ($/mo)	$6.95
Consumption Charges ($/therm)	$1.43
Miami Electricity General Service Larger Demand (2000 kW+)	
Monthly Charges ($/mo)	$179.19
Consumption Charges ($/kWh)	$0.0847
Demand Charges ($/kW)	$7.60
Miami Natural Gas	
Monthly Charges ($/mo)	$6.95
Consumption Charges ($/therm)	$1.43
New York Electricity	
Monthly Charges ($/mo)	$28.83
Consumption Charges ($/kWh)	$0.0903
Demand Charges ($/kW)	$21.47 (first 100 kW) $20.43 (next 800 kW) $19.41 (next 1100 kW) $16.03 (remaining)
New York Natural Gas	
Monthly Charges ($/mo)	$39.93
Consumption Charges ($/therm)	$1.226
Phoenix Electricity	
Monthly Charges ($/mo)	$17.83
Consumption Charges ($/kWh)	$0.091 (first 200 kWh) $0.053 (remaining)
Demand Charges ($/kW)	$8.472 (first 100 kW) $4.509 (remaining)
Phoenix Natural Gas	
Monthly Charges ($/mo)	$43.50
Consumption Charges ($/therm)	$1.298
San Francisco Electricity	
Monthly Charges ($/mo)	$120
Consumption Charges ($/kWh)	$0.10142 winter $0.13007 summer
Demand Charges ($/kW)	$6.49 winter $10.39 summer
San Francisco Natural Gas	
Monthly Charges ($/mo)	$150.00
Consumption Charges ($/therm)	$0.93 (first 4000 therm) $0.71 (remaining)

Appendix C: Results Summary

Case 1

	Atlanta		Miami		Phoenix		New York		San Francisco		Average	
	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic
End Use	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)
Space Cool	2,260	1,837	4,523	3,759	3,266	2,644	1,470	1,184	858	635	2,476	2,012
Heat Rej	169	137	378	308	204	161	104	83	39	26	179	143
Vent. Fans	1,172	907	1,432	1,082	1,556	1,210	1,092	962	1,055	733	1,262	979
Pumps & Aux	564	483	953	781	794	648	426	389	310	270	609	514
Misc Equip	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361	3,361
Area Lights	2,660	2,124	2,621	2,103	1,628	1,320	2,656	2,123	2,643	2,116	2,441	1,957
Space Heat	978	1,414	4	7	225	369	2,294	2,378	412	792	782	992
Hot Water	484	485	389	390	409	410	526	527	514	515	465	465
Total	11,648	10,748	13,661	11,791	11,442	10,214	11,929	11,007	9,192	8,447	11,575	10,423

Case 2

	Atlanta		Miami		Phoenix		New York		San Francisco		Average	
	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic	Low-E	Dynamic
End Use	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)	(MBtu)
Space Cool	546	440	975	878	807	703	374	315	173	134	575	494
Vent. Fans	92	72	116	99	125	102	79	63	79	52	98	78
Pumps & Aux	16	14	14	12	17	14	15	15	15	14	15	14
Misc Equip	666	666	666	666	666	666	666	666	666	666	666	666
Area Lights	676	520	666	514	664	516	673	520	671	518	670	518
Space Heat	164	218	1	4	40	60	383	409	77	125	133	163
Hot Water	93	93	75	75	79	79	101	101	99	99	89	90
Total	2,252	2,023	2,513	2,248	2,398	2,140	2,291	2,089	1,779	1,606	2,246	2,021