CREATING AN ENERGY-EFFICIENT BUILDING ENVELOPE USING SOLAR-CONTROL WINDOW FILMS

Steve DeBusk, CEM, CMVP
CPFilms Inc.
steve.debusk@cpfilms.com
Phone: (276) 627-3234
Fax: (276) 627-3091

Keywords:
Building envelope, DOE-2, energy-simulation, solar-control, solar films, window films, windows, window systems

SUMMARY

Solar-control films are used worldwide as an effective means of lowering building energy costs by reducing excessive solar heat gain through windows. Determining energy savings from actual installations is difficult due to the common practice of implementing several energy conservation measures simultaneously and due to annual variations in the many factors that can affect a building's energy usage.

To isolate and quantify the energy-saving benefits of solar films, an energy analysis study on a conventional office building was undertaken using the U.S. Department of Energy's sophisticated DOE-2 energy-simulation software. The study included several types of solar films applied to various glazing systems. Various cities were included in the study to illustrate the energy savings in different climates and to show the effect of differing electricity costs.

Based on the most typical types of installations and on customary installation costs for medium-sized commercial projects, the average return on investment (payback) from solar film application was an impressive 2.65 years. These savings were the result of reducing annual electricity kilowatt-hour (kwhr) usage by an average of 6.6% and reducing peak summer month KW demand on average by 6.4%.

INTRODUCTION

Solar-control window films are considered in the building industry to be "retrofit" products. That is, products that are applied to existing buildings after construction as opposed to use in new construction.

Solar Film Construction

Solar-control window films typically consist of a thin (0.025 mm, 0.001 inch) polyester film substrate that has a micro-thin, transparent metal coating applied to one side. This metal coating is applied using vacuum-based technologies such as vapor deposition or sputtering. The metal coating may be a single metal, an alloy, a metal-oxide, or a combination of these coatings. A second layer of polyester film is laminated over the metal coating to protect the metal. Onto one side of this laminated composite, an acrylic scratch resistant (SR) coating is applied to the surface that will face the building interior. This SR coating protects the film during normal window cleaning. On the opposite side of this film laminate a clear adhesive is applied, that will eventually bond the film to the window glass. This adhesive layer is protected by a removable release liner until just before field application. The film is protected from UV degradation by UV absorbers that are added to the polyester film layers, the adhesive layer, or to both.

Solar Film Appearance and Properties

The appearance of the film (color, the level of visible light transmission, and degree of reflectivity) depends on the metal coating(s) used. Typical all-metal solar films can be silver-reflective, gray, silver-gray, bronze, or light green in color. Visible light transmissions can vary from very dark (10%) to very light (70%), and visible reflectance can vary from the same reflectance as clear glass (8%) to highly reflective (60%). The ability of a glazing system to reduce solar heat gain is measured by its solar heat gain coefficient (SHGC). As expected from the variety of films available, the SHGC for solar films can vary significantly, from 0.14 to 0.69, as measured on 6 mm (1/4 inch) clear glass.

Solar Film Benefits

This combination of film properties produces a product that provides several important benefits:

- ✓ Reduced cooling energy costs by reducing excessive solar heat gain
- ✓ Enhanced reduction in cooling and heating energy costs when low-e type films are used
- ✓ Enhanced tenant comfort from improved temperature distribution (less hot and cold spots) and reduced glare
- ✓ Uniform building appearance from the exterior — improving tenant retention in leased buildings
- ✓ Reduced fading of carpets, drapes, and furnishings due to the UV blocking ability of films
- ✓ Privacy for building occupants when using reflective or dark films

Solar Film Installation Process

The first step in installation of solar film involves rigorous cleaning of the window glass surface. Next, an application solution is sprayed onto the glass, the release liner is removed from the film, and the adhesive-side of the film is carefully placed onto the glass surface. The application solution allows for moving the film on the glass for precise film placement and prevents air from becoming trapped between the film and glass. The film is then carefully trimmed around the perimeter of the window leaving a 1 to 3 mm (1/32 to 1/8 inch) gap between the film and frame. Water is sprayed onto the film surface and a rubber squeegee is used to remove the application solution and bond the film to the glass surface.

Motivation for Solar-control Film Energy Analysis Study

Solar-control films have been used since the early 1960's as an effective means for reducing building energy costs. Unfortunately, it is difficult to precisely determine the cost savings from applying film to a building due to variations in the many factors that affect a building's energy consumption from year to year (weather changes such as the amount of sunshine and temperature/wind differences, changes in occupancy, upgrades or other changes in building energy using equipment, changes in maintenance for key equipment, addition of energy consuming equipment such as computers, etc). This situation is usually complicated by the fact that building owners usually perform energy-conservation upgrades, such as solar-control film application, in conjunction with other upgrades making it impossible to determine the savings from film application alone. Therefore, a means of accurately estimating the energy savings from solar film application was needed.

One of the most accurate and reliable energy simulation software packages available is the U.S. Department of Energy's (DOE) DOE-2 energy analysis program. DOE-2, which uses an hourly calculation method, has been validated many times by comparing its results with thermal and energy use measurements on actual buildings (see http://gundog.lbl.gov). DOE-2 is used worldwide by energy engineers, architects, government organizations, and utilities as a means for estimating the affect of various measures on a building's energy consumption and for developing building energy codes. As a result, it was determined that a reasonable course of action was to use DOE-2 modeling to estimate the energy savings from application of solar-control window film.

Scope of Energy Analysis Study

The DOE-2 energy study was performed on a conventional (1990's) 10-story office building with a total floorspace of 16,257 square meters (175,000 square feet). To gauge the affect of different films, four films were chosen and categorized as "Maximum-Performance", "Maximum-

Performance Low-E", "High-Performance", and "High-Performance Low-E", based on the film's SHGC on single-pane, 6 mm (1/4 inch), clear glass.

The study was performed on single-pane clear, dual-pane clear, single-pane gray-tinted, and dual-pane gray-tinted window systems. Each film type was analyzed on each of these glazing systems. All windows consisted of 6 mm (1/4 inch) thick panes and for the dual-pane units the panes were separated by a 12 mm (1/2 inch) air space.

The Solar Heat Gain Coefficient (SHGC) and Winter Night-Time U-values for all glazing systems contained in the study are shown below. The SHGC shown is at normal solar incidence angle and the Winter Night-Time U-value is based on ASHRAE standard Winter conditions, using a -17.8°C (0°F) outdoor air temperature, an indoor air temperature of 21°C (70°F), a 24.1 km/hr (15 mph) wind speed outdoors, a 0 km/hr (0 mph) wind speed indoors, and 0 W/m^2 (0 BTU/hr/ft^2) solar intensity. In the analyses, the SHGC was calculated (by DOE-2) for the precise sun angle at each hour of the day and the window U-value was calculated at each hour based on indoor and outdoor temperatures, outdoor air speed, and solar intensity.

	No Film	Maximum Performance Film	Maximum Performance Low-E Film	High Performance Film	High Performance Low-E Film
SHGC					
Single Clear	0.81	0.23	0.17	0.36	0.28
Dual Clear	0.70	0.31	0.27	0.42	0.35
Single Gray	0.57	0.27	0.21	0.33	0.26
Dual Gray	0.45	0.24	0.21	0.30	0.25
U-values (W/m^2•°C)					
Single Clear	6.18	5.81	4.78	5.87	4.69
Dual Clear	2.74	2.65	2.35	2.66	2.32
Single Gray	6.19	5.81	4.78	5.87	4.69
Dual Gray	2.74	2.65	2.35	2.66	2.32
U-values (BTU/hr/ft^2/°F)					
Single Clear	1.09	1.02	0.84	1.03	0.83
Dual Clear	0.48	0.47	0.41	0.47	0.41
Single Gray	1.09	1.02	0.84	1.03	0.83
Dual Gray	0.48	0.47	0.41	0.47	0.41

Table 1 - Solar and Thermal Performance Factors for Windows and Films in Study

The model building was a square building with equal glass area facing North, South, East, and West. The glass area on each of the four building exposures was 557.4 m^2 (6,000 ft^2). Models with film applied used film on the East, South and West exposures only.

Other model parameters, typical of modern office buildings, used in the study included:

- Indoor lighting 10.76 W/m^2 (1.0 W/ft^2)
- Office equipment 11.95 W/m^2 (1.1 W/ft^2)
- Heating setpoint 21.1°C (70°F)
- Heating setback 18.3°C (65°F)
- Cooling setpoint 23.9°C (75°F)
- Cooling setback 26.7°C (80°F)
- Medium-colored blinds used 25% of the time. SHGC of blinds 0.69.
- Windows recessed from building face 15 cm (6 inch) providing partial shading of all windows.
- Variable-air-volume (VAV) air-distribution system and air-side economizer.
- Heating plant using gas boilers with an efficiency of 80%.
- Chillers with full-load efficiency of 0.69 KW per ton (COP of 5.1)

The parameters used (such as the use of blinds, recessed windows, VAV air distribution system, air-side economizer and high-efficiency chiller system) effectively reduces the savings from solar film application. This was desired to provide reasonable and conservative estimates of energy savings from solar film installation and not to create a "best-case" scenario.

Electricity costs for each location were determined from the commercial rate schedules published on the web site of electric utilities in each city. Rate schedules that applied to buildings with peak KW demands of approximately 1000 KW were used. Both kwhr and KW demand charges were used. The rate schedules used typically vary the kwhr and KW charges by time of year and time of day and are too complex to provide here, however, to provide the reader with a general idea of the costs used, below are the average costs for each city based on the total annual kwhr used and the total annual electricity costs for the four building models without film for each location.

City	Avg Cost per kwhr	Electric Utility and Rate Schedule
Boston	$0.1220	Boston Edison, Rate G-3
Chicago	$0.0892	Commonwealth Edison, Rate 6L
Dallas	$0.0907	Texas-New Mexico Power, Large General Service
Jacksonville	$0.0697	Florida Power & Light, GSLD-1
Los Angeles	$0.1336	So. California Edison, TOU-8, Large Gen. Service
Memphis	$0.0604	Memphis Light, Gas & Water, General Service GSA
Phoenix	$0.0595	Arizona Public Service Co., General Service
Toronto (Canada)	$0.0553	Toronto Hydro-Electric, Business Rates
Washington, D.C.	$0.0706	Baltimore Gas & Electric, Schedule GL (option 2)
Overall Avg	$0.0834	

Table 2 - Average Electricity Costs by Location

Natural gas was used as the heating fuel and for domestic hot water production at a cost of $0.70 per therm for all locations.

Results of Study

Tables 3, 4, and 5 show the payback, reduction in annual kwhr usage, and reduction in summer month peak demand for each location and for each film and window combination. Also shown are the averages for each window type and each location. The overall average for all locations, window types and films is also given.

Some general observations concerning the results of the study:

1. **For all window and film types and all locations, the overall average payback for solar film installation was 2.65 years (see Table 3) -** the average payback by window type: Single Clear 1.21 years, Dual Clear 2.09 years, Single Gray 2.58 years, and Dual Gray 4.72 years (in almost 50% of the cases involving Dual Gray windows the payback was less than 4 years).

2. **As seen in Table 3, it appears the payback period is affected more by the cost of electricity than from climate effects -** for example, the average payback in Boston (2.1 years) is less than the average payback in Jacksonville, Florida (2.8 years), due mainly to the higher average cost for electricity in Boston compared to Jacksonville (12.2 cents per kwhr average versus 6.97 cents). Also, the average payback for Memphis (3.6 years) was more than Washington D.C. (2.8 years) even though the climate in Memphis is somewhat warmer, due solely to the lower cost of electricity in Memphis.

3**. The data also shows that solar-control film is NOT a "warm-climate" only product -** the average payback for cities not considered to be in the "Sun Belt" was still less than 3 years on average (Boston 2.1 years, Chicago 2.8 years, Washington 2.8 years). The average payback for Toronto (the coolest climate of all cities considered) was still a very respectable 3.6 years, despite the fact that Toronto has the lowest overall electricity prices of cities in the study.

4**. Solar-control film has a considerable positive affect on reducing annual kwhr and summer peak demand, on average reducing annual kwhr usage by 6.6% and summer month peak demand by 6.4% (see tables 4 and 5).**

	Boston	Chicago	Dallas	Jacksonville	Los Angeles	Memphis	Phoenix	Toronto	Washington	**Average**
1. Single Clear										
Max-Perf Film	0.89	1.11	0.87	1.18	0.69	1.42	1.10	1.73	1.28	**1.14**
Max-Perf Low-E Film	0.81	1.00	0.85	1.15	0.69	1.33	1.07	1.43	1.16	**1.06**
High-Perf Film	1.12	1.37	1.10	1.53	0.87	1.82	1.38	2.19	1.66	**1.45**
High-Perf Low-E Film	0.91	1.10	0.95	1.31	0.79	1.48	1.20	1.55	1.30	**1.18**
						Single Clear - All Film Types Average:				***1.21***
2. Dual Clear										
Max-Perf Film	1.46	1.79	1.42	2.03	1.12	2.57	1.77	2.64	2.12	**1.88**
Max-Perf Low-E Film	1.34	1.65	1.34	1.90	1.08	2.29	1.70	2.29	1.93	**1.72**
High-Perf Film	2.01	2.50	2.00	3.02	1.57	3.69	2.47	3.94	3.14	**2.70**
High-Perf Low-E Film	1.55	1.91	1.60	2.31	1.25	2.68	2.01	2.69	2.30	**2.03**
						Dual Clear - All Film Types Average:				***2.09***
3. Single Gray										
Max-Perf Film	2.09	3.14	2.18	2.81	1.78	3.81	2.39	4.16	2.90	**2.81**
Max-Perf Low-E Film	1.42	1.94	1.59	2.09	1.36	2.49	1.90	2.34	1.96	**1.90**
High-Perf Film	2.62	3.95	2.81	3.70	2.26	4.96	2.99	5.31	3.84	**3.61**
High-Perf Low-E Film	1.49	1.98	1.73	2.28	1.49	2.61	2.03	2.39	2.08	**2.01**
						Single Gray - All Film Types Average:				***2.58***
4. Dual Gray										
Max-Perf Film	3.92	5.57	3.71	4.63	2.99	6.90	3.86	6.53	4.96	**4.79**
Max-Perf Low-E Film	2.90	3.56	2.81	3.57	2.32	4.65	3.18	4.26	3.57	**3.42**
High-Perf Film	5.60	8.02	5.49	6.82	4.34	10.26	5.20	9.19	7.04	**6.88**
High-Perf Low-E Film	3.12	3.86	3.19	4.04	2.62	5.11	3.58	4.53	3.99	**3.78**
						Dual Gray - All Film Types Average:				***4.72***
Location Average	**2.08**	**2.78**	**2.10**	**2.77**	**1.70**	**3.63**	**2.36**	**3.57**	**2.83**	

All Locations, All Window Types, All Film Types ***2.65***

Table 3 - Simple Payback by Location, Window and Film Type

	Boston	Chicago	Dallas	Jacksonville	Los Angeles	Memphis	Phoenix	Toronto	Washington	**Average**
1. Single Clear										
Max-Perf Film	9.5%	9.6%	12.1%	11.4%	11.7%	11.0%	13.6%	9.2%	10.3%	**10.9%**
Max-Perf Low-E Film	10.9%	10.9%	13.5%	12.7%	12.9%	12.3%	15.3%	10.5%	11.7%	**12.3%**
High-Perf Film	7.5%	7.8%	9.6%	8.9%	9.3%	8.7%	10.7%	7.2%	8.1%	**8.6%**
High-Perf Low-E Film	9.4%	9.6%	11.8%	11.0%	11.1%	10.8%	13.4%	9.1%	10.2%	**10.7%**
						Single Clear - All Film Types Average:				***10.6%***
2. Dual Clear										
Max-Perf Film	6.2%	6.4%	7.9%	7.1%	7.6%	6.8%	9.1%	6.2%	6.7%	**7.1%**
Max-Perf Low-E Film	7.3%	7.4%	9.2%	8.4%	8.8%	8.0%	10.5%	7.3%	7.9%	**8.3%**
High-Perf Film	4.5%	4.6%	5.7%	4.9%	5.5%	4.8%	6.6%	4.3%	4.7%	**5.1%**
High-Perf Low-E Film	6.1%	6.2%	7.6%	6.9%	7.4%	6.7%	8.8%	6.0%	6.5%	**6.9%**
						Dual Clear - All Film Types Average:				***6.8%***
3. Single Gray										
Max-Perf Film	4.2%	3.8%	5.3%	5.2%	5.0%	4.6%	6.7%	4.0%	4.7%	**4.8%**
Max-Perf Low-E Film	5.9%	5.4%	7.3%	7.1%	6.8%	6.5%	9.0%	5.7%	6.5%	**6.7%**
High-Perf Film	3.4%	3.0%	4.2%	3.9%	4.0%	3.6%	5.4%	3.1%	3.6%	**3.8%**
High-Perf Low-E Film	5.4%	5.0%	6.6%	6.3%	6.1%	5.9%	8.2%	5.1%	5.8%	**6.1%**
						Single Gray - All Film Types Average:				***5.3%***
4. Dual Gray										
Max-Perf Film	2.6%	2.5%	3.5%	3.4%	3.3%	3.0%	4.6%	2.8%	3.1%	**3.2%**
Max-Perf Low-E Film	3.5%	3.5%	4.7%	4.6%	4.4%	4.1%	6.0%	3.8%	4.2%	**4.3%**
High-Perf Film	1.8%	1.8%	2.4%	2.4%	2.3%	2.1%	3.5%	2.0%	2.2%	**2.3%**
High-Perf Low-E Film	3.1%	3.1%	4.0%	3.9%	3.8%	3.6%	5.2%	3.3%	3.7%	**3.8%**
						Dual Gray - All Film Types Average:				***3.4%***
Location Average	**5.7%**	**5.7%**	**7.2%**	**6.8%**	**6.9%**	**6.4%**	**8.5%**	**5.6%**	**6.2%**	

All Locations, All Window Types, All Film Types ***6.6%***

Table 4 - Reduction in Annual Kwhr Usage

	Boston	Chicago	Dallas	Jacksonville	Los Angeles	Memphis	Phoenix	Toronto	Washington	**Average**
1. Single Clear										
Max-Perf Film	11.4%	10.6%	11.2%	10.0%	9.7%	10.1%	11.3%	11.4%	10.4%	**10.7%**
Max-Perf Low-E Film	13.0%	12.2%	12.9%	11.5%	11.2%	11.8%	13.6%	13.0%	12.3%	**12.4%**
High-Perf Film	8.7%	8.2%	8.5%	7.4%	7.4%	7.6%	8.9%	8.7%	7.7%	**8.1%**
High-Perf Low-E Film	10.9%	10.4%	11.1%	9.9%	9.1%	10.0%	11.7%	11.1%	10.3%	**10.5%**
						Single Clear - All Film Types Average:				***10.4%***
2. Dual Clear										
Max-Perf Film	6.5%	6.8%	6.9%	5.7%	5.7%	5.8%	7.4%	7.6%	6.3%	**6.5%**
Max-Perf Low-E Film	7.8%	8.1%	8.4%	7.1%	6.5%	7.0%	8.9%	9.0%	7.6%	**7.8%**
High-Perf Film	4.7%	4.9%	4.8%	3.6%	4.0%	3.7%	5.2%	5.2%	4.1%	**4.5%**
High-Perf Low-E Film	6.6%	6.6%	6.9%	5.5%	5.8%	5.8%	7.4%	7.3%	6.1%	**6.4%**
						Dual Clear - All Film Types Average:				***6.3%***
3. Single Gray										
Max-Perf Film	5.3%	4.4%	4.9%	4.7%	4.6%	4.4%	5.7%	5.3%	5.4%	**5.0%**
Max-Perf Low-E Film	7.4%	6.3%	7.3%	7.0%	6.5%	6.7%	8.3%	7.4%	7.5%	**7.2%**
High-Perf Film	4.2%	3.4%	3.8%	3.6%	3.4%	3.3%	4.6%	4.0%	4.2%	**3.8%**
High-Perf Low-E Film	6.8%	5.9%	6.6%	6.3%	5.4%	6.1%	7.7%	6.6%	6.9%	**6.5%**
						Single Gray - All Film Types Average:				***5.6%***
4. Dual Gray										
Max-Perf Film	2.9%	2.8%	2.9%	3.0%	2.3%	2.6%	3.3%	3.8%	3.2%	**3.0%**
Max-Perf Low-E Film	3.7%	4.0%	4.3%	4.2%	3.2%	3.8%	4.7%	5.2%	4.4%	**4.2%**
High-Perf Film	2.0%	1.7%	1.9%	1.9%	1.6%	1.7%	2.4%	2.7%	2.4%	**2.0%**
High-Perf Low-E Film	3.5%	3.4%	3.6%	3.7%	3.0%	3.4%	4.2%	4.5%	3.7%	**3.7%**
						Dual Gray - All Film Types Average:				***3.2%***
Location Average	**6.6%**	**6.2%**	**6.6%**	**5.9%**	**5.6%**	**5.9%**	**7.2%**	**7.1%**	**6.4%**	

All Locations, All Window Types, All Film Types ***6.4%***

Table 5 - Reduction in Summer Peak KW Demand

Conclusions

This study clearly indicates that solar-control window film can play a useful and viable role in improving the energy-efficiency of many buildings and that window films can be effective at reducing energy costs and energy consumption for buildings in many locations. Excellent energy savings can be provided by this technology - typically 5-10% reductions in peak demand and annual cooling costs, with such savings provided within a reasonable payback period (averaging less than 3 years). Although the focus of this paper was locations in the United States, it has been the author's experience and it should be apparent that solar-control window films are applicable to a wide range of locations, climates, and countries.

It is important to note that while providing these important energy savings benefits, window films are also able to provide many other benefits that directly hit the mark of key scoring components for "green building" specification programs such as the Leadership in Energy and Environmental Design (LEED). As such, solar-control window films are able to meet the needs of many different design professionals, from property owner/manager, architect, energy engineer, to green-building professional.

References

International Window Film Association. “Advanced Solar Control Guide”. 2003.

International Window Film Association. “Window Film Information Center”. 2006. <http://www.iwfa.com/>

James J. Hirsch and Associates. “Welcome to DOE-2.com”. 2006. <http://www.doe2.com/>

U.S. Green Building Council. “LEED for Existing Buildings Project Checklist”. 2006. <https://www.usgbc.org/FileHandling/show_general_file.asp?DocumentID=679>

U.S. Green Building Council. “LEED: Leadership in Energy and Environmental Design”. 2006. <http://www.usgbc.org/DisplayPage.aspx?CategoryID=19>

ITEM Systems

Innovative Technologies for Energy Management

To: CPFilms, Inc.
From: Stephen Byrne

Review of CPFilms' DOE-2 Solar-Control Window Film Energy Study

ITEM Systems has completed our review of the DOE-2 simulation results from your Solar-Control Window Film Energy Study. The buildings in the CPFilms study were appropriately simulated with DOE-2.1E, using Demand Analyzer to create the input files and analyze the results. The buildings that are modeled in the study are based upon the Post-1992 Large Office prototype building used in Demand Analyzer. This prototype represents typical medium to large office buildings that were built during that time period with regard to building characteristics and construction that would affect energy consumption (wall and roof construction and insulation, glass and floor area, amount of interior lighting and equipment, type of heating and cooling systems, etc.). The buildings in this study were modeled using long-term average weather data for Boston, Chicago, Dallas, Jacksonville, Los Angeles, Memphis, Phoenix, Toronto, and Washington, D.C., representing a wide variety of climate zones in North America.

The results of the building simulations are summarized in the attached CPFilms study. ITEM Systems has verified that the results shown in the study are the same as the simulation results obtained using Demand Analyzer, Window 4.1 and DOE-2 with the building parameters described below. ***It is ITEM Systems' expert opinion that the results stated by CPFilms in their study accurately reflect the energy savings expected from retrofit of a building's glazing system with solar-control window films, based on the types of films and glazing systems modeled in the study. As shown in the study, applying window film to medium and large office buildings in each of these cities should result in a significant reduction of energy consumption and peak demand, with substantial economic savings for many film and glass combinations.*** DOE-2 has been validated several times by national laboratories and universities, who have compared the DOE-2 simulation results to thermal and energy use measurements from actual buildings. These validations should give readers of the CPFilms study confidence in the results presented.

The CPFilms study modeled the Demand Analyzer Post-1992 prototype with the following modifications:

Thermostat cooling setpoint of 75 F with an 80 F setback
Interior window shading (Solar Heat Gain Coefficient of 0.69) with 25% usage
Window glass type changed as indicated below
Additional insulation added to the domestic hot water tank and pipes
Domestic hot water circulation pump timeclock added
Additional insulation added to the air distribution ducts
Cooling tower fans changed to variable speed (from single speed)
Chiller efficiency increased to a COP of 5.1
Natural gas price increased to 0.70 $/therm
Electricity price varies by city (see study for actual rate schedule used for each city)

Other than the changes indicated above, the buildings that were modeled in this study are the same as the default Post-1992 Large Office prototype in Demand Analyzer, which is based upon survey data and represents a typical large office built during that time period.

The prices for natural gas and electricity were determined by CPFilms to represent typical prices for energy used in large office buildings in each of the cities in the study. The solar and thermal properties of the base case windows and the windows with applied film were calculated by CPFilms using the Window 4.1 fenestration analysis program with glass performance data provided by glass manufacturers in the Window 4.1 data library. The base case windows are single pane clear, dual pane clear, single pane gray, and dual pane gray glass. The window film is applied to the windows on the East, South and West sides of the buildings. The four types of applied window film presented in the study, available from CPFilms are: (1) Maximum-Performance (Vista V-14, LLumar R-20, LLumar N-1020 Bronze), (2) Maximum-Performance Low-E (LLumar E-1220), (3) High-Performance (Vista V-28, Vista V-33 Bronze, LLumar N-1020 Neutral, LLumar R-35, LLumar N-1035 Bronze), and (4) High-Performance Low-E (Vista VE-35).

Software used in this study:

Window 4.1 (see http://windows.lbl.gov/software/window/window.html) is a fenestration analysis program that calculates the thermal and solar properties of glazing systems. Window 4.1 was developed by the Windows & Daylighting Research group at Lawrence Berkeley National Laboratory for the U.S. Department of Energy.

DOE-2 (see http://simulationresearch.lbl.gov/dirsoft/d2whatis.html) is a whole-building analysis program that calculates energy use and operating cost. DOE-2 was developed by the Simulation Research group at Lawrence Berkeley National Laboratory for the U.S. Department of Energy. As detailed in the above link, DOE-2 has undergone validation by Los Alamos National Laboratory, LBNL and several universities to show that the program accurately predicts energy use in actual buildings. DOE-2 has been used by national laboratories, universities, and industry for numerous studies of products and strategies for energy efficiency. Because it is scientifically rigorous and open to inspection, DOE-2 has been chosen to develop state, national and international building energy efficiency standards, including the ASHRAE-90.1 standard for commercial buildings. DOE-2 is one of the most highly regarded programs for building energy analysis in the U.S. and the world.

Demand Analyzer was developed by ITEM Systems as a front end to the DOE-2.1E program. Using the built-in 17 building prototypes with 3 vintages of each prototype, Demand Analyzer allows a user to very quickly describe a building in the detail required by DOE-2, then simulate the building with DOE-2, and analyze the results of the simulations using a variety of publication-quality graphs and reports.

ITEM Systems

ITEM Systems is a consulting and software development company specializing in energy and economic analysis of buildings and utility markets. We have over 25 years of experience working with clients and customers throughout the world.

ITEM Systems has a unique combination of in-depth experience in:
statistical analysis of survey databases of building characteristics;
engineering analysis of monitored and simulated performance of buildings and energy conservation measures;
development of prototypical building designs suitable for energy demand simulation in research and market characterization studies;
simulation of end-use demand in residential and commercial buildings;
development of software to manage large databases of energy demand profiles; and
development of software for building energy design and analysis.

ITEM Systems has undertaken numerous evaluations of energy use in buildings, through use of computer simulation programs and monitored data. Staff members have conducted such studies for the purpose of developing building energy standards, characterizing market demand for specific end-use equipment, supplying data for demand forecasting models, and analyzing potential savings of a wide variety of energy conservation measures. Past clients for this work include the U.S. Department of Energy, the U.S. Agency for International Development, the U.S. Department of Housing and Urban Development, the American Society of Heating, Refrigeration and Air Conditioning Engineers, the Gas Research Institute, the California Energy Commission, the California Conservation Inventory Group, numerous electric and gas utilities, and several state and national governments.

The ITEM Systems team has in-depth knowledge of several survey databases that characterize building construction, vintage, and equipment types. The statistical expertise of the team members provides the ability to analyze these databases to derive significant data for developing prototypical buildings that accurately reflect the intended market.

The engineering expertise of ITEM Systems is especially valuable when analyzing the monitored performance and design characteristics of energy conservation measures that are applied to HVAC systems and central plant equipment in large commercial buildings.

ITEM Systems staff have over 25 years of experience with several building energy simulation programs, and have used these programs to model actual as well as prototypical buildings. Team members have developed large databases of over 10,000 simulations in order to characterize both commercial and residential building types in several climate zones.

The ITEM Systems team also has extensive experience in managing the large databases that result from such a comprehensive set of simulations. Software development and statistical techniques for reducing energy use data to simplified relationships are both important aspects of this work that ITEM Systems has successfully completed in several past projects.

ITEM Systems specializes in development of software design tools for architects, engineers, and utility analysts. Commercially available products developed by ITEM Systems include Demand Analyzer, a simplified interface for DOE-2 based on prototypical buildings; DOE-Plus, an interactive pre- and post-processor for DOE-2; and Prep, a batch preprocessor used for conducting multiple parametric simulations with DOE-2, BLAST and other programs. ITEM Systems also develops custom software for clients that require specialized applications.