Design & Engineering Services

# Dynamic Window Shading Systems Technology Overview and Product Assessment

*ET 07.02 Report*

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*August 15, 2008*

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**Acknowledgements**

Southern California Edison's Design & Engineering Services (DES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technology program under internal project number ET 07.02. DES project manager Chris Buntine conducted this technology evaluation with overall guidance and management from the Heschong Mahone Group, Inc. Senior Project Manager Mudit Saxena managed the project at HMG with assistance from Research Associates Laura Krugh and Derrick Leung. Principal in charge at HMG was Lisa Heschong. For more information on this project, contact *Chris.Buntine*@sce.com.

**Disclaimer**

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# EXECUTIVE SUMMARY

Dynamic window shading systems can be adjusted in response to changing daylight and other climate conditions over time to achieve energy savings while optimizing occupant comfort. They can combine any of the following elements:

- Shades, which are usually interior, consist of semi-translucent or opaque fabric that can be raised or lowered
- Blinds, which can be interior or exterior, consist of slats that can be tilted as well as raised or lowered, such as Venetian blinds, or
- Louvers, which are usually exterior, consist of slats that can be tilted, but cannot be raised or lowered.
- A control mechanism that will adjust the window shading system, and
- An automated control strategy that determines the trigger for opening, closing, or adjusting angles of the shading system.

These products can offer whole building energy savings by optimizing daylight and solar heat gain from windows with varying sun angles or climatic conditions, while managing occupant comfort.

While manual shading for window shades such as Venetian blinds have been in use for a long time, energy savings from them have traditionally been hard to quantify for two main reasons:

1. It is very hard to predict the operation of manual controls with any amount of certainty. Observations of occupants using shading devices show that their choices vary considerably.
2. There are a lack of simulation tools that accurately simulate the energy performance of an optically complex shading system, like blinds.

New window shading products are now available in the market that offer automated motorized controls that can adjust blinds for optimum occupant comfort and maximum energy savings. At the same time, simulation technology has improved to a point where annual hourly simulation tools can be used to determine energy benefits with these dynamic products.

This report provides an overview of the current status of commercially available dynamic window shading products and estimated results of energy saving simulations, as input to the Emerging Technologies Program at Southern California Edison (SCE).

Our findings indicate that a wide variety of products are available in the market, ranging from interior shading (Nysan, Warema) to exterior shading (Nysan, C.S. Controls, ASCA) to integral blinds (VisionControl, CPI ControLite, Wausau, Pella). The types of controls range from simple up/down buttons (Somfy, Lutron) to sophisticated touch screens with programmable schedules and overrides (Mecho Shades, Warema). Most of these are premium products with low sales volumes resulting in higher costs, especially when compared to simple manual interior shades. Typically, the biggest part of the cost is that of automation.

From our interviews with manufacturers, we found a wide variation in the level of interest in dynamic shading technology. Manufacturers at one end of the spectrum were very interested in the energy savings potential and investing resources to test their products for energy performance, thermal and visible properties, etc. (VisionControl, Nysan, Warema, CPI ControLite). These manufacturers also had some of the most highly engineered products. In most cases, these manufacturers were based in Canada or Europe, where they have had more success in selling dynamic window shading products and have only a marginal presence in the U.S. market. At the other end of the spectrum were manufacturers with very little interest in the technology, and only interested in providing manual shading controls (*Traco, Levolor, Kirsch*). We also found some U.S. manufacturers who offer simple motorized controls with their products (*Wausau, Graham*), but had not yet taken the step towards developing a truly integrated dynamic shading solution optimized for energy savings.

Simulation software can be used to estimate annual whole building energy use with dynamic shading systems, albeit with many limitations. *DOE-2* and *Energy Plus* can both model automated shades and blinds, but are limited to simple, flat blind geometry. When the new release of *Windows 6* is incorporated, enabling the modeling of optically complex systems, the capability of these simulation tools will increase. *Radiance* can be used to model optically complex systems, but is very labor intensive, and does not produce whole building annual energy analysis. *DaySim* can be programmed to use the more sophisticated Radiance analysis to generate annual simulation results, but only considers lighting energy use, and not thermal impacts. Newer software such as *Daylight 1-2-3* can be used to estimate annual lighting and thermal energy impacts from daylighting using various fenestration shading schemes, but provides only very limited user inputs and building geometries.

Table 1 shows whole building energy savings estimates using two available "commercial-grade" software products, *Daylight 1-2-3* and *DOE-2*. Two interior shading strategies were simulated using a generic flat Venetian blind shading system: automated slats - where only the slat angles were adjusted automatically; and automated blinds - where the entire blinds were raised or lowered automatically. The automatic adjustment was triggered by direct sunlight on the window. The base case was assumed to be a condition where blinds are left at a fixed angle of 45° with manual lighting controls in the room.

**TABLE 1. ANNUAL ENERGY SAVINGS ESTIMATION FOR DYNAMIC INTERIOR BLINDS**

| 22FT X 22FT OPEN OFFICE PLAN, LOS ANGELES | | ANNUAL LOADS (KWH / SQUARE FOOT / YEAR) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *DAYLIGHT 1-2-3* | | | | *DOE-2* | | | |
| | DESCRIPTION | LIGHTING | HEATING | COOLING | **TOTAL** | LIGHTING | HEATING | COOLING | **TOTAL** |
| **Base Case** | Fixed blinds and manual lighting | 2.2 | 2.7 | 3.5 | **8.4** | 2.6 | 4.4 | 18.6 | **25.6** |
| **Measure Case 1** | Automated slats with lighting controls | | | | | 2.1 | 4.4 | 18.5 | **25.0** |
| | % Savings from Base Case | | | | | 19.2% | 0% | 0.5% | **2.3%** |
| **Measure Case 2** | Automated blinds with lighting controls | 1.7 | 2.7 | 3.2 | **7.6** | 1.4 | 4.4 | 17.8 | **23.6** |
| | % Savings from Base Case | 22.7% | 0% | 8.6% | **9.5%** | 46.2% | 0% | 4.3% | **7.8%** |

The differences in the assumptions and calculation methodologies between the two models cause the results to vary significantly but provide an initial indication of the

energy impacts. We find that the lighting energy savings are in the range of **19%** to **46%** for the two strategies considered using *DOE-2*, while *Daylight 1-2-3* predicts lighting energy savings to be **23%**. Accounting for heating and cooling energy savings due to avoided solar heat gain and less cooling demand due to dimmed lights, the total estimated whole building energy savings for the study space are in the range of **2%** to **10%**.

Another key benefit from dynamic window shading systems is the ability to mitigate glare and the ability to reopen the shades for view after the glare conditions have passed. Recent research[1] on productivity and daylighting has shown a significant link between health and productivity and view. The research shows that having a better "view" out of a window was most consistently associated with better worker performance. Also workers with better views were least likely to report negative health symptoms. Reports of increased fatigue were most strongly associated with a lack of view. The same research also showed that "glare" potential from windows was found to have a significant negative effect on performance. Combining the benefits on occupant health, increased productivity and employee retention due to reduced glare and increased view can potentially be the most significant benefit of dynamic window shading systems.

From the cost data collected from a few of the manufacturers reported in Table 2, it was found that the cost of automated controllers is very high, which was the main barrier for increased market penetration. The data demonstrated that specialty products like those highly engineered interior daylight blinds have a very high cost. The manufacturers cited cost of shipping the products, most manufactured in Europe, as one reason for their high cost.

**TABLE 2. COST DATA FROM VARIOUS DYNAMIC WINDOW SHADING SYSTEM MANUFACTURERS**

| MANUFACTURER TYPE | PRODUCT | QUANTITY / SIZE | PRICE | NOTES |
|---|---|---|---|---|
| Shades Manufacturer | Shades | ~ 5 shades (small order) | $5-$6/sq ft | Uninstalled |
| | | ~ 5 shades (small order) | $10-$12/sq ft | Installed |
| | Automated Controller | | Did not collect | Did not collect |
| Shades Manufacturer | Shades | 48" x 48" opening | $63/sq ft | Shades only |
| | Automated Controller | For 10 shades | $1200/10-shade-unit | Unit cost only, does not include commission |
| Integral Blinds and Shades Manufacturer | Between Glass Blinds | 29" x 47" opening | $99/sq ft | Uninstalled |
| | Between Glass Fabric Shade | 29" x 47" opening | $103/sq ft | Uninstalled |
| | Automated Controller | | Not Available | Not Available |
| Integral Blinds Manufacturer | Integral Blinds (includes Automated Controller) | Small Order (~500 sq ft) | $90/sq ft | Uninstalled - inc. automatic controller |
| | | Medium Order | $60/ sq ft | Uninstalled - inc. automatic controller |
| | | Large Order | $50/ sq ft | Uninstalled - inc. automatic controller |
| | | | $20/ sq ft - $30/ sq ft | Installation & Commissioning cost |
| Integral Blinds Manufacturer | Integral Blinds | Small Order (~ 5 windows) | $48/sq ft | Uninstalled |
| | | Small Order (~ 5 windows) | $94/ sq ft | Installed |
| | | Large Order | $40/ sq ft | Uninstalled |
| | | Large Order | $86/ sq ft | Installed |
| | Automated Controller | | Not Available | Not Available |
| Interior Daylight Blinds Manufacturer | Interior Blinds | 17 windows order | $144/sq ft | Installed with manual controls |
| | | | $288/sq ft | Installed with motorized controls |
| | Automated Controller | | $2000/blind-unit | Rough estimate from dealer |

# INTRODUCTION

This project reviewed and evaluated commercially available "Dynamic Window Shading Systems" that are suitable for the commercial retrofit and new construction markets in California.

The study had three main objectives:

- Review and evaluate commercially available dynamic window shading technologies most suitable for the commercial retrofit and new construction markets in Southern California.
- Report on available data on energy performance, availability, limitations in construction or design, and capabilities. Include an assessment of market potential for each technology.
- Review simulation software for their capabilities and limitations in simulating automated window shading systems. List possible solutions to overcome these limitations.

This report summarizes Southern California Edison's (SCEs) findings on the current status of available products and the capabilities of building energy-performance simulation software programs to model the performance of these products.

# DEFINITION OF PRODUCT TYPES

Dynamic window shading technology is defined as window shading products that can be adjusted in response to changing daylight and other climate conditions over time to achieve energy savings while optimizing occupant comfort. Dynamic window shading systems can combine any of the following elements:

- Shades that are usually interior and consist of semi-translucent or opaque fabric that can be raised or lowered
- Blinds that can be interior or exterior, consist of slats that can be tilted as well as raised or lowered, such as Venetian blinds, or
- Louvers that are usually exterior, consist of slats that can be tilted, but cannot be raised or lowered.
- A control mechanism that adjusts the window shading system, and
- An automated control strategy that determines the trigger for opening, closing, or adjusting angles of the shading system.

Most buildings either have no window shading at all, or have manually operated interior blinds or shades that are only rarely adjusted, resulting in lost savings. A dynamic system automatically adjusts the shading system to optimize both occupant comfort and energy savings. Dynamic window shading systems may consist of some or all of the following components:

- Shading device
- Motors
- Sensors for glare, illuminance and/or heat gain
- Shading device controllers
- Electric lighting photocontrols (or daylight harvesting controllers)
- Inputs or outputs from a daylight sensor to a building-system energy management system (EMS).

## PRODUCT CATEGORIES

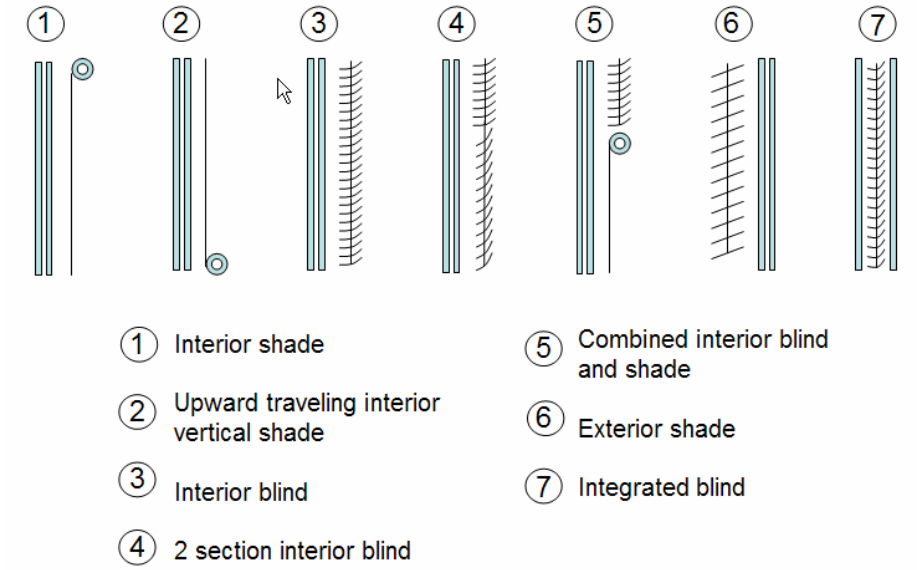



**FIGURE 1. TYPES OF DYNAMIC WINDOW SHADING SYSTEMS**

Initially we categorized the dynamic window shading systems into seven categories as described in Figure 1. However, as we collected information on products, we modified the seven categories into five as shown in Table 3. In the new categories, we removed “Combined Interior Blind and Shade” as we did not find enough products in this category, combined “Interior Shade” and “Upward Traveling Interior Vertical Shade” as simply “Interior Shade” and incorporated “Two Section Interior Blinds” within the “Interior Blinds” category. Also, we added a category called “Shade Controls” to include manufacturers of controls that are an essential part of the dynamic window shading systems.

Table 3 also lists all the manufacturers of products that we included in this report. Some manufacturers span across categories such as Nysan, which offers products in most of the listed categories.

In this list, three manufacturers offer products that are currently not available in the U.S. These European companies have sophisticated and well-developed dynamic shading systems, and are included in this report to provide a more complete listing of products that offer dynamic window shading systems. However, this list is by no means a comprehensive one, and is limited to the products for which information was obtained.

**TABLE 3. LIST OF PRODUCTS REVIEWED AND CATEGORIES**

| | MANUFACTURER | INTEGRATED BLINDS | EXTERIOR LOUVERS | INTERIOR SHADES | INTERIOR BLINDS | SHADE CONTROLS | AVAILABLE IN US |
|---|---|---|---|---|---|---|---|
| 1 | Vision Control | X | | | | X | X |
| 2 | CPI ControLite | X | | | | X | X |
| 3 | Graham Architectural Products | X | | | | | X |
| 4 | Traco | X | | | | | X |
| 5 | Pella | X | | | | | X |
| 6 | Wausau | X | | | | | X |
| 7 | Eckelt (Non-U.S.) | X | | | | | |
| 8 | Nysan | | X | X | X | X | X |
| 9 | ASCA | | X | | | X | X |
| 10 | C.S. Controls | | X | | | X | X |
| 11 | Bomin-Solar (Non-U.S.) | | X | | | | |
| 12 | Siteco (Non-U.S.) | | X | | | | |
| 13 | Colt (Non-U.S.) | | X | | | | |
| 14 | Warema | | X | | X | X | X |
| 15 | Mecho Shades | | | X | | X | X |
| 16 | Lutron | | | X | | X | X |
| 17 | Draper, Inc. | | | X | | X | X |
| 18 | Somfy | | | | | X | X |
| 19 | Siemens | | | | | X | X |

# METHODOLOGY

Information on products that offer dynamic window shading technology was collected during the fall of 2007 by interviewing practitioners, manufacturers and researchers in this field. A candidate list of window manufacturers, window blind manufacturers, and controls manufacturers, along with practitioners and researchers was created. Each was contacted via email, and then by telephone whenever possible. Performance data was collected from the manufacturer's literature that was either sent by mail or downloaded from the manufacturer's website. Cost information was obtained from sales representatives over the telephone.

A total of 25 manufacturers, six researchers and five practitioners were contacted for this study. Of the 25 manufacturers, eight informed us that they did not have dynamic window shading products, while two manufacturers were suppliers of parts such as actuators for motors or fabrics for shades. These were dropped from the list. The remaining 15 manufacturers were interviewed. In cases where an interviewee was not available, or could not be reached, the local sales representatives were contacted to get information on the product and we located the product's description on the company's website.

A list of 18 non-U.S. manufacturers of window shadings was obtained from Dr. Marilyne Andersen at Massachusetts Institute of Technology (MIT), who is working to catalogue window shading products (both static and dynamic). From this list, four manufacturers were found that had "dynamic" shading products. These were also included in our list of products reviewed.

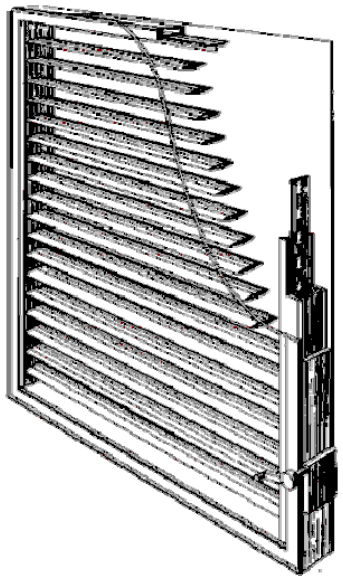
Researchers and practitioners working in the field of window shading, as well as developing software to simulate their performance were also interviewed. A list of software was developed and information about their simulation capabilities was collected through user guides and telephone interviews.

# PRODUCT DESCRIPTIONS

This section discusses the findings from research and interviews with product manufacturers, researchers and practitioners. Each product has a dedicated sub-section.

At the beginning of each sub-section, an overview is provided with key product features and a picture. Each product is then described in bullet points, followed by a small discussion of our assessment of the product in the context of this study and the level of information detail we were able to obtain for each product.

# VISIONCONTROL® BY UNICEL ARCHITECTURAL



| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **VisionControl®** |
| Shade Type | **Integral Blinds** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **No** |

**FIGURE 2. VISIONCONTROL PRODUCT INFORMATION**

Unicel Architectural's VisionControl® glazing panel consists of operable louvers sealed between insulated glasses.

- The gear housing is mechanically attached to the frame. The product uses no cords or magnets.
- There are four manual and electric control options for blinds operation. A programmable logic controller (PLC) computerized system can be used with timer/sun-sensor options that can rotate blinds up to one degree. Groups of VisionControl panels can have ganged controls.
- The PCL controller is provided by a third-party company who partners with Unicel to provide turnkey solutions. It uses Profibus, Modbus and Ethernet protocols for communication.

This is the only product found in our research that had motorized blinds located within insulated glass (IG), unlike, for example, the integral window blinds from Graham or Traco, where the blinds are located between the IG panel and a removable interior access glass panel.

The company, Unicel Architectural, is based in Montreal, Canada. Researchers from Concordia University have experimentally assessed the product's energy savings potential. Detailed thermal and visible performance data is available for this product.

Practitioners who have used the product say that it is "well engineered and mature".

# CPI CONTROLITE®


| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **CPI ControLite®** |
| Shade Type | **Integral Blinds** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **Yes** |

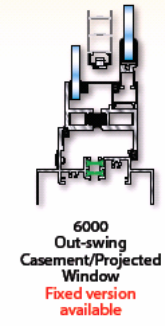
**FIGURE 3. CPI CONTROLITE® PRODUCT INFORMATION**

ControLite® panels consist of a 1.18" (30mm) translucent polycarbonate panel and translucent half-cylinder rota-blades with an opaque face, built into the polycarbonate panels.

- The angle of the rota-blades is adjustable.
- The panels are self-contained units that come with a motor, controls and rota-blades.
- Units can be up to 40 feet in length.
- Controls for the rota-blades are available in three options: manual, motorized and fully automatic, in which a user sets a desired level of light, and angle of lighting control is continuously adjusted to maintain this level.

The ControLite® is promoted as a self-contained package that has the ability to intelligently control the amount of daylight, as well as electric lighting, in a room with an added occupancy sensor. The product is typically used in monumental atria, like in malls, where its translucent properties are an advantage in creating light distribution.

# GRAHAM ARCHITECTURAL PRODUCTS


| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Casement/Projected: Guardian Series 6000, 6100, 6500, 6600, 6800, S6800, 6900 Fixed: Guardian Series 1500, S1500, 6500 Double Hung: Guardian Series 2500, S2500, 3400** |
| Shade Type | **Integral Blinds** |
| Motorized Controls | **Prototype Stage** |
| Control Software | **No** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **No** |

**FIGURE 4. GRAHAM WINDOWS PRODUCT INFORMATION**

Graham offers “Between-Glass Blinds” as an optional feature for many of its ‘Guardian Series’ commercial windows. These are promoted by Graham as windows that provide privacy protection, dynamic light transmission and solar heat gain control.

They are available with manual controls for blinds. Motorized controls have been developed, but only as a prototype.

There has been testing done for U-factor based on American Architectural Manufacturers Association (AAMA) and National Fenestration Rating Council (NFRC) test methods for all Graham windows, some with the blinds option. However, none of the test results that were sent to us gave a clear understanding of how U-factor differs with and without blinds. There has been no testing by Graham Windows for visible light transmittance (VLT) or solar heat gain coefficient (SHGC) of products with integral Venetian blinds.

Graham shares a positive outlook on the prospect of developing their product further with automated controls and enhanced daylighting features. They have held back on these developments due to lack of demand in the market.

# TRACO

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Traco Commercial Windows (various)** |
| Shade Type | **Integral** |
| Motorized Controls | **No** |
| Control Software | **No** |
| Development Stage | **Manual control product available, Motorized controls product not developed** |
| Ltg Ctrls Integration | **No** |

**FIGURE 5. TRACO WINDOW PRODUCT INFORMATION**

Traco provides integral mini-blinds as an option in 22 of its 54 commercial window products, as counted from the product listing on their website. These mini-blinds feature:

- A manual control for slat tilt angle
- Are usually sandwiched between the insulated glazing on the outside and a single-pane interior access panel that can be hinged open to access the blind for maintenance.
- Can be custom ordered to have the concave surface turned upward.

There has not been any testing for thermal, visible or solar properties of window products with integral blinds from Traco, so this data is not available

Traco has concentrated their research and development efforts on advanced framing and not dynamic window shading. Although Traco has integral mini-blinds as an option available for many of its commercial windows, they do not consider dynamic window shading as a potential energy saving measure, but rather a comfort and privacy tool. Their research efforts have focused on electro-chromic glass and advanced framing, on which they have worked with the U.S. Department of Energy (DOE) and Lawrence Berkeley National Laboratory (LBNL).

# PELLA

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Designer Series** |
| Shade Type | **Integral** |
| Motorized Controls | **No** |
| Control Software | **No** |
| Development Stage | **Manual controls product available, motorized controls product in R&D / experimental stage** |
| Ltg Ctrls Integration | **No** |

**FIGURE 6. PELLA WINDOWS DESIGNER SERIES PRODUCT INFORMATION**

With the Designer Series, Pella offers snap-in between-the-glass blinds, fabric shades, decorative panels and removable grilles. They are available in double- or triple-paned glass in any style of Pella Designer Series window or patio door.

- Snap-In Between-The-Glass blinds feature cordless operation.
- Snap-In Between-The-Glass fabric shades are available as bottom-up or top-down operation.

Pella has conducted tests based on National Fenestration Rating Council (NFRC) test methods for their double- and triple-pane windows with Slimshade™ between-the-glass blinds and cellular fabric shades. Importantly, Pella is the only manufacturer in our research that has tested their product both with and without integral blinds and shades options using NFRC test methods.

Pella acknowledged that they are currently working on prototypes of window products that will feature dynamic window shading technology. They, however, did not provide any other information about these future product(s). Pella currently offers integral blinds with manual controls only.

# WAUSAU

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **3250 Series, SEAL Series** |
| Shade Type | **Integral** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product available with motorized controls** |
| Ltg Ctrls Integration | **No** |

**FIGURE 7. WAUSAU PRODUCT INFORMATION**

Wausau offers an integral blinds option for its 3250 and SEAL-series commercial grade windows.

- They come with manual or one/two switch motorized controls.
- Supplier of their between-pane-blinds and controls is Windows Accessories Company, Inc. (WACI). They are also the suppliers for EFCO Corporation.
- They can be ordered to be concave side-up.

Wausau is aware of the energy savings potential for these windows, and have collaborated with researchers in the past with their integral blinds windows, but have not done extensive testing for energy rating of their integral blinds products.

Their market has been hospitals, for ease of cleaning, and schools, for resistance to vandalism and ease of maintenance.

Wausau has offered an integral blinds window for the last 35-40 years, and is one of the leading domestic window manufacturers for non-residential integral blinds windows. They are collaborating with LBNL's research program on advanced facades and in the future hope to develop a better understanding of their existing products and how they can be best optimized through tools such as Window6 and COMFEN.

# ECKELT (NON-U.S.)

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Ecklite SC** |
| Shade Type | **Integral blinds,** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product Available, Europe only** |
| Ltg Ctrls Integration | **No** |

**FIGURE 8. ECKELT PRODUCT INFORMATION**

ECKlite SC is an insulating glass, in which electronically driven blinds are integrated within the glazing to provide solar and glare control. The manufacturer is Eckelt.

- Operation of the blind is through a 24-Volt electric motor that can be powered by direct current, batteries, chargers or solar cells.
- Overall thickness of the glazing unit is given to be between 41mm - 44mm or 1.61in - 1.73in

The controls for the louvers are not provided by Eckelt. Eckelt notes on their website that they recommend using their nominated suppliers for the controls, but providing controls is the responsibility of the customer.

Information about the products performance is available for download from their website.

# NYSAN

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **External/Internal Venetian Blinds, External/Internal Roller Shades, Nysan Large Shades, Dual Shades, Bottom-up Shades, Specialty Systems** |
| Shade Type | **External/Internal Shades, External/Internal Blinds** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **Yes** |

**FIGURE 9. NYSAN PRODUCT INFORMATION**

Nysan offers various products that provide dynamic window shading. They have a "standard line of products" listed on their web site, from which we have described only those products that offer dynamic window shading technology. From a total of 19 standard products listed, we found nine provided dynamic shading solutions, and seven out of these were solutions for windows. Besides the standard line of products, Nysan also offers "specialty systems" or "custom systems" that are engineered and developed specifically for a project. Most of these specialized systems are automated using Nysan's basic/advanced/intelligent controls and fall under the category of dynamic window shading.

Nysan's products offer flexibility and can generate shading solutions for most situations requiring dynamic window shading systems. All Nysan systems offer full motorization and automation available for raising, lowering, and adjusting the shade, enabling an active shading solution for sun-facing elevations.

Of all manufacturers researched, Nysan has the largest selection of dynamic window shading systems available in the U.S. market. Since they provide both the shading systems and the controls, it is possible to automate most of their moveable shading solutions either through custom solutions or through one of the many available products listed here.

Nysan has conducted various energy studies to quantify the energy savings potential of their products.

# NYSAN PRODUCT DESCRIPTIONS

## EXTERNAL VENETIAN BLINDS AND LOUVERS

- Nysan external Venetian blinds with slats between 2” and 4” can be tilted to optimize shading at varying sun angles, managing thermal gain and glare, while also capturing daylight. External louvers of customizable widths are also available.
- Integration with intelligent controls makes it possible to create an active shading solution on sun-facing elevations.

## INTERNAL VENETIAN BLINDS

- Daylight-enhancing blinds with slats between 3” and 4” allows an upper portion of the blind to be positioned independently from the lower portion. This permits blinds to provide daylighting through an open top section and control glare through the lower section.
- Internal Venetian blinds also available for Nysan with motorized controls that can be automated using advanced controls.

## EXTERNAL ROLLER SHADES

- Gravity drop roller shades resemble standard interior shades, but have operating mechanisms.
- Markisolettes allow shades to extend away from a building in addition to raising and lowering.

## INTERNAL ROLLER SHADES

- Motorized solutions available with a variety of controls, from simple switches to intelligent sun-tracking systems that incorporate sun/wind sensors and integrate with building management systems.

## NYSAN LARGE SHADES

- Dimensionally stable fabrics ideal for large-scale use. They will not sag nor stretch, allowing shades to remain free of battens and seams to over 500" in height.

## DUAL SHADES

- The Nysan Dual Shade system combines two operating mechanisms and fabric shades onto a single bracket.

## NYSAN BOTTOM-UP SHADES

- For motorized bottom-up shades, a single motor drives the shade in both directions.

### NYSAN SPECIALTY PRODUCTS OR CUSTOM LOUVER AND SHADES SYSTEMS

- Nysan can provide custom exterior or interior blinds or shades systems.
- Custom external shades including motorized folding screens to sliding shutters.

## NYSAN CONTROLS DESCRIPTIONS

### BASIC CONTROL SYSTEMS

- Basic control systems use the Nysan MC2 controller to provide a control method for one or two motors.
- Systems respond to a range of controls, including switches and master switches, programmable timers, and radio and infrared remotes.
- All low-voltage switching options can operate in single, group, or zone control of multiple controller configurations.

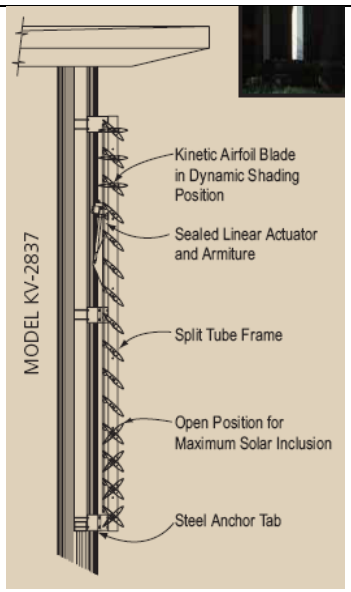
### ADVANCED CONTROL SYSTEMS

- Featuring the Nysan Matrix™ controller, the advanced control systems enable programmable, multi-positional stops and automatic alignment of up to four motors.
- Single and master switches give light-emitting diode (LED) status of systems, allowing up to 32 pre-programmed or user-defined stops per motor and up to 128 per matrix board.
- Systems support touch screen, audio visual, and lighting control, smart switches and user feedback options, and programmable response to sun and wind sensors.

### INTELLIGENT CONTROL SYSTEM

- This control system enables highly effective shading throughout the day and around the year, taking into account a building's geographic location and orientation to the sun.
- System features BUS LINE communication for individual shade motors;
- Remote software reconfiguration from any location in the world
- Full integration with building management systems (BMS) available.

# ASCA INC.




| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Kinetic System** |
| Shade Type | **External Louvers** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **No** |

**FIGURE 10. ASCA INC. PRODUCT INFORMATION**

ASCA Design, Inc. provides sun control solutions for buildings. Their catalogue lists eight products for daylight and solar control, two of which are dynamic window shading systems, described here.

## SUNSHIELD MONUMENTAL VENETIAN BLINDS

- The Sunshield line features a 3-foot deep internal or external Venetian blind, designed to be controlled either via an integrated electrical motor, or via manual crank operation.
- Multiple blinds can be grouped or controlled independently.
- The series of slats can be fully lowered from their continuous housing or recessed pocket at the head of the window. Once in place, the horizontal vanes may be adjusted according to desired light levels, or fully closed for privacy.
- The slats are curved with concave surface down.

## KINETIC SYSTEM

- The kinetic system features external lovers that can be controlled using a motor.
- The slats are tubes with convex surfaces on both sides.

# C/S GROUP SUN CONTROLS

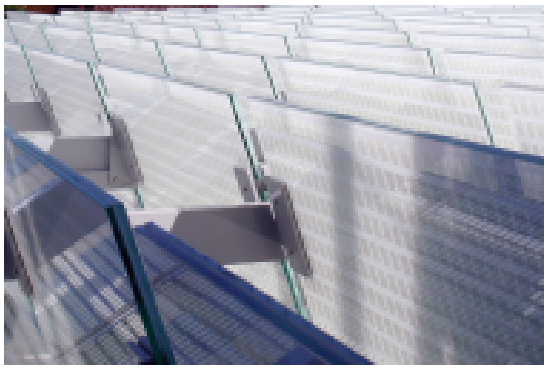

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **SunShades** |
| Shade Type | **Exterior Louvers** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **No** |

**FIGURE 11. C/S GROUP SUN CONTROLS PRODUCT INFORMATION**

C/S Group provides operating external sunshades that provide solar shading for elevations.

- C/S Sunshades pivot up to 110° to reduce solar glare and heat gain and are designed to control the amount of daylight coming into the building interior.
- Blades can close completely to provide energy savings, or for security purposes.

# BOMIN-SOLAR (NON-U.S.)



| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Prismalite, Bomin GL, Bomin AL, Helio SC** |
| Shade Type | **Exterior Louvers, and Control System** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available, Europe only** |
| Ltg Ctrls Integration | **Yes** |

**FIGURE 12. BOMIN-SOLAR PRODUCT INFORMATION**

## PRISMALITE

- PRISMALITE is an exterior prismatic system that provides daylight redirection using prisms built into a movable external louver. The prisms refract and reflect light such that the direct component of the incident run is reflected out and diffuse light enters. The angles of the prisms are changed using a motorized controller.

## BOMIN GL

- The BOMIN Glass Louver (GL) System is a daylight redirecting glass louver system that consists of GLs, controlled by Helio SC Control Unit. The controls ensure that the sun is always incident at right angles to the louver, which helps redirect it in the desired direction. The glass louvers can have prints or holographs to enhance its light redirection capabilities.

## BOMIN SOLAR'S HELIO SC

- Helio SC is the instrumentation and control system that calculates the position of the sun at any given time and controls heliostats, prisms, louvers and light reflection systems offered by Bomin Solar. It provides digital setting of parameters, system wind protection, storm and fire sensors, plug-in connections, and integration in building management systems.

# SITECO (NON-U.S.)

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Moveable Prism Systems** |
| Shade Type | **Exterior Louvers** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product Available, Europe only** |
| Ltg Ctrls Integration | **No** |

**FIGURE 13. SITECO PRODUCT INFORMATION**

Siteco's Moveable Prism System is a transparent sun protection system for façades and glass roofs. It is designed to prevent the ingress of the sun's heat into the interior of the building while letting through a maximum of diffused daylight.

- It consists of non-specular prismatic plates that reflect light entering from a direction vertical to the longitudinal axis.
- Diffuse daylight coming from the other directions is almost completely let through.
- The blocking solar rays are a result of the prism's 90° angle and the total reflection occurring within each prism. The principle of total reflection functions only within a very narrow range of angles, whereby a tracking of the louver blades in their longitudinal axis according to the sun's position is necessary.
- The prism blades can be laterally "parked" away on cloudy days, allowing unhindered vision through the glazing. On cloudy days, the prisms are moved into a horizontal position in order to allow a maximum of diffuse daylight to reach the building's interior.

# COLT (NON-U.S.)

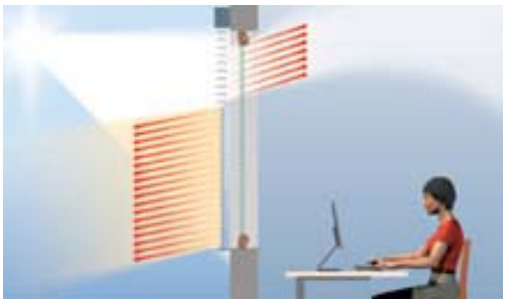
| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Solarfin, Shadoglass, Shadovoltaic** |
| Shade Type | **Exterior Louvers** |
| Motorized Controls | **Yes** |
| Control Software | **No** |
| Development Stage | **Product Available, Europe only** |
| Ltg Ctrls Integration | **No** |

**FIGURE 14. COLT PRODUCT INFORMATION**

Colt produces exterior solar shading systems that are made of either metal or glass fins and can be controlled with motors that are usually incorporated within the mullions of the glazing systems.

- Shadoglass controllable or fixed glass louver shading systems can reduce solar heat gain, lower air conditioning running costs, and lessen glare while maximizing the use of natural daylight.
- Shadovoltaic system consists of movable glass louvers and photovoltaic cells are integrated into the glass so as to generate electricity.
- Solarfin system comprises a series of extruded aluminum fins mounted into a support frame. The fins may be fixed at any angle and can rotate under motorized control.

# WAREMA



| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Daylight-Optimized Venetian Blinds, Lonworks-Bus controls, Light-guiding systems** |
| Shade Type | **Internal Blinds, External Blinds** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **Yes** |

**FIGURE 15. WAREMA PRODUCT INFORMATION**

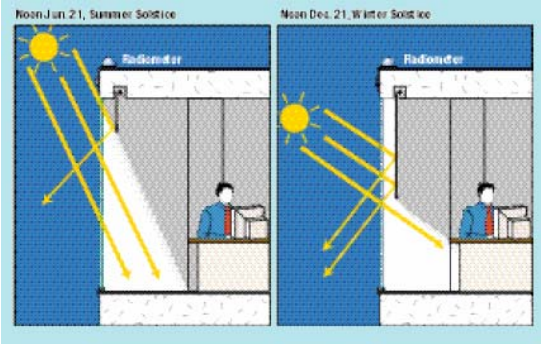
Warema creates one of the most advanced daylight optimized Venetian blinds systems.

- The 2-foot internal Venetian blinds are divided into two sections with different opening angles of the slats so as to provide a glare free environment near a workstation and yet have daylight through the upper section.
- The external Venetian blinds are made of an aluminum alloy and are corrosion-proof. The surface has a total reflection of up to 93%.
- The blinds are “highly engineered” with specially developed slat geometry and can be partially perforated to provide view even while they are in a “closed” position.
- The blinds can be lowered and raised and slat angle changed using advanced motorized controls

Their Lonworks-Bus controls feature a central intelligent control system, which can be programmed to adjust groups of blinds (internal/external) based on weather conditions, sun angles and even shading from surrounding buildings.

The product seems to be optimized for achieving energy savings through daylight harvesting, yet maintaining occupant comfort through glare control. The advanced and powerful plug-and-play capability of the Lonworks-Bus system paired with the daylight-engineered blinds makes this one of the most advanced dynamic window shading systems reviewed here.

# MECHO SHADES




| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **AAC SolarTrac™** |
| Shade Type | **Internal Shade** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **Yes** |

**FIGURE 16. MECHO SHADES PRODUCT INFORMATION**

Mecho Shades' AAC SolarTrac™ is an Advanced Daylighting Module that manages and controls the amount of daylight/brightness in a space using a software-based control system, designed to adjust automatically the position of the shades incrementally on the window. Shades are available in various weaves and colors with a range of visible light transmission ratings.

- The SolarTrac System uses the LON-WORKS backbone enabling a variety of products (motors, controllers etc) to be added. It consists of a daylight sensor placed on the roof looking skyward. Shades adjust automatically based on input from this sensor.
- The system consists of an AAC-Brightness Override Module, a Touch Screen Window Management System and a Shadow Override.

In our assessment, the product's open-architecture communication protocol makes it especially attractive as a means of developing dynamic control strategies for products that do not have a dynamic control feature built-in.

Mecho Shades has also shown that they are willing to support the development of systems with their open architecture controls, which indicates the company's commitment to further developing and enhancing this new technology.

The product seems to be optimized for achieving occupant comfort, a simple yet powerful user interface and plug-and-play expandability. The system can reduce sun penetration and glare but it also simultaneously reduces the amount of daylight. Energy savings are primarily from rejection of solar heat gain, while savings by turning off electric lights can be achieved only in the perimeter zone.

# LUTRON


| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Sivoia QED™, GRAFIK Eye QS** |
| Shade Type | **Internal Shade, Controls** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **Yes** |

**FIGURE 17. LUTRON PRODUCT INFORMATION**

Lutron creates the Sivoia QED™ (Quiet Electronic Drive) family of controllable shading products. The Sivoia QED family includes roller shades, Roman shades and drapery track systems. It also creates the GRAFIK Eye™ QS, a fully customizable preset light and shade control system.

- Uses low-voltage, quite drives
- Features integration with Lutron lighting control systems
- Features programming and operation through electronic keypads and remote controls

Lutron creates an advanced control system that is optimized for occupant comfort, and provides various options for programming preset conditions for lighting and window shade controls for the occupant. The system can be used with a variety of window shades including but not exclusive to shade fabrics from Lutron.

As is the case with any other controlled roller shade system, energy savings are primarily achieved from rejection of solar heat gain, while savings by turning off electric lights can be achieved only in the perimeter zone.

# DRAPER, INC.

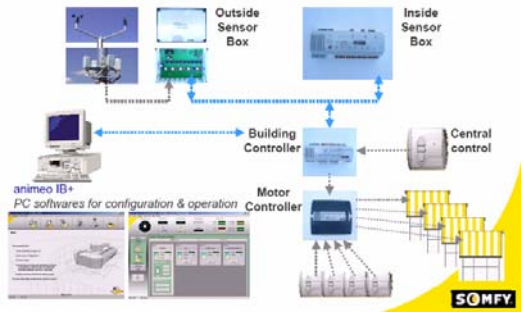

| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Solar Track System with Intelli Flex** |
| Shade Type | **Internal Shade, Controls** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **No** |

**FIGURE 18. DRAPER PRODUCT INFORMATION**

The Draper Inc. Solar Track System combines Somfy's Animeo controls with fabric shades to provide a complete solution for enhanced energy savings and comfort through dynamic window shading controls.

- Draper's Solar Track system is an assembly of various components that are purchased by them through other manufacturers such as Somfy for controls.
- Draper has conducted simulation studies of cooling energy savings using their product for various climates in the U.S. Energy savings are only for heating, ventilating, and air conditioning (HVAC) cooling energy, not lighting.

# SOMFY




| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Animeo IB+** |
| Shade Type | **Controls** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **No** |

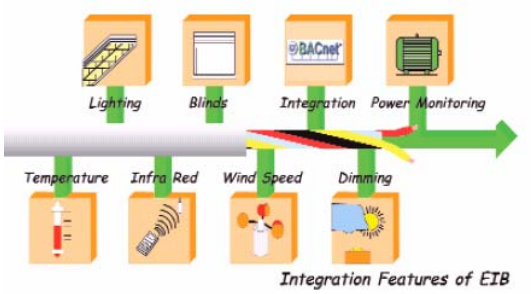
**FIGURE 19. SOMFY PRODUCT INFORMATION**

Somfy creates the Animeo IB+ control system, which consists of external and internal sensors, motor controllers and a PC to run the control software.

- The system uses an open architecture protocol (R485) to communicate.
- The system can control any kind of a roller shade-type product.
- Can be integrated with motion/infrared sensors.
- User interface is through wall switches or remote controls. Control interface has been developed to be simple and intuitive.

The system has been optimized for simplicity of use and installation. The Animeo IB+ controls do not integrate with lighting controls, hence do not offer an in-built solution for daylight harvesting along with dynamic window shading control. Instead, they seem to be optimized for solar heat gain rejection and HVAC energy savings.

# SIEMENS




| PRODUCT PROPERTIES | |
|---|---|
| Product Name(s): | **Siemens Instabus EIB** |
| Shade Type | **Controls** |
| Motorized Controls | **Yes** |
| Control Software | **Yes** |
| Development Stage | **Product Available** |
| Ltg Ctrls Integration | **Yes** |

**FIGURE 20. SIEMENS PRODUCT INFORMATION**

Siemens offers an integrated Instabus EIB (European Installation Bus) solution for all building automation needs which is optimized for easy installation, ease of addition in future and centralized control.

- With Instabus EIB all operating functions and procedures, such as blinds, controls, HVAC, lighting, appliances, windows, security systems can be controlled, monitored and signaled via a single common cable and a centralized location
- Blinds and windows can be controlled using solar sensors through the Instabus EIB.
- The system can potentially control both roller shade and blinds or louver type products.
- Since blinds and windows can be connected to the same bus system as the lighting, an integrated solution for daylight harvesting is possible. Siemens claims that this can be achieved using around 30% less cabling and avoiding complex integration to third party systems when Instabus EIB is used.

# COST DATA

Manufacturer cost data was collected as reported in Table 4.

**TABLE 4. COST DATA FROM VARIOUS DYNAMIC WINDOW SHADING SYSTEM MANUFACTURERS**

| MANUFACTURER TYPE | PRODUCT | QUANTITY / SIZE | PRICE | NOTES |
|---|---|---|---|---|
| Shades Manufacturer | Shades | ~ 5 shades (small order) | $5-$6/sq ft | Uninstalled |
| | | ~ 5 shades (small order) | $10-$12/sq ft | Installed |
| | Automated Controller | | Did not collect | Did not collect |
| Shades Manufacturer | Shades | 48" x 48" opening | $63/sq ft | Shades only |
| | Automated Controller | For 10 shades | $1200/10-shade-unit | Unit cost only, does not include commission |
| Integral Blinds and Shades Manufacturer | Between Glass Blinds | 29" x 47" opening | $99/sq ft | Uninstalled |
| | Between Glass Fabric Shade | 29" x 47" opening | $103/sq ft | Uninstalled |
| | Automated Controller | | Not Available | Not Available |
| Integral Blinds Manufacturer | Integral Blinds (includes Automated Controller) | Small Order (~500 sq ft) | $90/sq ft | Uninstalled - inc. automatic controller |
| | | Medium Order | $60/ sq ft | Uninstalled - inc. automatic controller |
| | | Large Order | $50/ sq ft | Uninstalled - inc. automatic controller |
| | | | $20/ sq ft - $30/ sq ft | Installation & Commissioning cost |
| Integral Blinds Manufacturer | Integral Blinds | Small Order (~ 5 windows) | $48/sq ft | Uninstalled |
| | | Small Order (~ 5 windows) | $94/ sq ft | Installed |
| | | Large Order | $40/ sq ft | Uninstalled |

| | | | | |
|---|---|---|---|---|
| | | Large Order | $86/ sq ft | Installed |
| | Automated Controller | | Not Available | Not Available |
| Interior Daylight Blinds Manufacturer | Interior Blinds | 17 windows order | $144/sq ft | Installed with manual controls |
| | | | $288/sq ft | Installed with motorized controls |
| | Automated Controller | | $2000/blind-unit | Rough estimate from dealer |

Based on our data collection the cost of automated controllers is very high, which was the main barrier for increased market penetration. We also found that specialty products such as highly engineered interior daylight blinds have a very high cost. The manufacturers cited cost of shipping the products manufactured in Europe as one reason for their high cost.

# SIMULATION SOFTWARE

In this section, each software program is discussed in its own sub-section, which includes its simulation capabilities and limitations.

Dynamic shading systems such as daylighting blinds are optically complex and require significant computational effort and complex simulation techniques. While it is theoretically possible to simulate their complex geometry, this requires an almost prohibitive investment of time and effort on the part of the researcher to get accurate results. This has been one of the reasons why dynamic window blinds have not been modeled in the past. However, ongoing work at the LBNL on tools such as Comfen and Window6 is expected to bridge this gap by providing more capable tools, that are expected to be easy to use and capable of modeling complex blind geometries.

Existing annual energy simulation software such as DOE-2 have had the capability to model blinds operation with automatic controls, but this part of the software has not received much attention or development in the past, which makes it difficult to work with. Newer software, such as Daylight 1-2-3, makes it easier to model dynamic blinds by using pre-determined blind configurations and correction factors for simulating complex geometries. For greater accuracy in modeling daylighting through blinds, software such as DaySim can be employed, which require greater expertise, time and effort from the researcher. Future releases of software programs such as Window6 and Comfen are expected to address these issues, and provide an easier path for researchers and architects to model dynamic window shades more accurately.

Assumptions for automatic controls for window shading can be specified using a trigger, such as a trigger that closes or lowers the blinds when direct sunlight hits the window surface (*DOE-2*), or when there is glare to an occupant (*Daylight 1-2-3*). Other control scenarios could also theoretically be programmed.

Algorithms for automated controls of blinds can be programmed using a variety of assumptions, such as a trigger that closes or lowers the blinds when direct sunlight hits the window surface (*DOE-2*), or when there is glare to an occupant (*Daylight 1-2-3*). Other control scenarios could also theoretically be programmed. However, the comparison to a base case of manual controls of blinds is not well understood due to a lack of field studies of real occupants' behavior. These either are currently based on gross assumptions, (*DOE-2*), or in some cases monitored occupancy behavior from few field studies such as the Lightswitch model (*Daylight 1-2-3*).

## DOE-2 /EQUEST

Window shadings such as simple, flat blinds or pull-down shades can be modeled in DOE-2 though the "WINDOW-LAYER" input method. Both the latest version of DOE-2, i.e. DOE-2.2, and legacy version currently in use in California's Title-24 code compliance software and CA utility programs, i.e. DOE-2.1e, use the same WINDOW-LAYER method, and are practically identical in their treatment of window shadings systems. Using this method, a layer of "Blinds" or "Pull-down shades" can be specified either as an external, internal or between-the-panes shading layer. Furthermore, this shading layer can be automated for slat adjustment or for blind-coverage adjustment based

on a trigger. In DOE-2, this trigger can be solar radiation incident of the window surface or a specified room temperature. The user has the ability to specify this trigger as an annual schedule. Savings calculated with this method from preliminary runs are presented in a separate section in this report.

While this feature is available in DOE-2 and can be programmed directly in BDL language using keywords, eQuest, simulation software that uses the DOE-2.2 engine, provides an easy to use graphic user interface where users can specify each of these keywords.

## SIMULATION METHOD

A series of keywords can be used to describe properties such as SLAT-ANGLE-MIN, SLAT-ANGLE-MAX to set the minimum and maximum angle that the slats can be rotated, SLAT-ORIENTATION to specify if the slats are horizontal or vertical, SLAT-WIDTH, SLAT-SEPARATION to set the specifics of the slat construction, etc. The coverage of the shading can also be specified using keywords such as BLIND-COVER-MIN and BLIND-COVER-MAX.

The blinds can be automated for slat adjustment or for blind-coverage adjustment based on a trigger. The keyword BLIND-ADJ-TYPE has to be set to either SOLAR-INTENSITY or ROOM-TEMP to determine if the blinds are adjusted automatically using solar radiation or room temperature as the trigger. The keywords BLIND-TRIGG-SCH or SLAT-TRIGG-SCH can be used to specify the trigger schedule.

## LIMITATIONS

The basis of algorithms in DOE-2's window model is an older version of LBNL's program for calculating total window thermal performance, Window version 4. It hence shares the same limitations that Window 4 has, as compared to newer versions of the software, the most significant limitation being the inability to model multi-spectral light. This impacts the simulation of spectrally selective and low-e coatings. DOE-2 can accept files output from the Window program and DOE-2.2 (eQUEST) recognizes files up to Window version 5.2.

Another limitation is that a maximum of 60 windows can be specified in a given DOE-2 model. For large or multistoried buildings, this limitation can be a problem as the "LIKE" keyword, used in DOE-2 for saving the time to model and simulate similar elements cannot be used to overcome this limitation.

Importantly, for internal room reflections the daylighting calculation in both DOE-2 and Energy Plus rely on the split-flux method. This method does not model multiple bounces within a room. It therefore underestimates indirect daylight that relies on the reflection of light off multiple surfaces in a room, usually under-predicting the amount of daylight that reaches to the interior of the room, away from the window.

With products like daylight blinds that bounce light upwards towards the ceiling for deeper daylight penetration, the whole benefit of effectively increasing the daylight zone in a space is lost when using the split flux method.

# ENERGY PLUS

Energy Plus uses a window model similar to DOE-2 to model dynamic window shading systems. The same schedules and triggers available in DOE-2 are also available in Energy Plus to model automated blinds. In terms of functionality of modeling dynamic window shading systems, the two programs are virtually identical. There are, however, some key differences in the calculation methods employed by these two programs.

## SIMULATION METHOD

Since DOE-2 and Energy Pro share a similar model for window shading simulation, the simulation methods for both are identical.

### LIMITATIONS OF SPLIT FLUX METHOD

For internal room reflections, the daylighting calculation in both DOE-2 and Energy Plus rely on the split-flux method. This method does not model multiple reflections within a room. For this reason, it underestimates indirect daylight that relies on the reflection of light off multiple surfaces in a room, usually under-predicting the amount of daylight that reaches the interior of a room, away from the window.

With products like daylight blinds that bounce light upward towards the ceiling for deeper daylight penetration, the whole benefit of effectively increasing the daylight zone in a space is lost when using the split flux method.

### DIFFERENCE BETWEEN DOE-2 AND ENERGY PLUS WINDOW MODELS

The optical model for windows in both programs is essentially identical, while there are some key differences on the thermal side.

- The thermal model in Energy Plus is fundamentally different from that in DOE-2. Energy Plus uses the heat balance method, a numerically intensive method of calculating surface and air temperatures for each time step, while DOE-2 uses the weighting factor method; a method where weighting factors are first determined using heat balance methods and then used to determine response factors and weighting factors for the thermal response of the building.
- Another difference is that in Energy Plus, boundary conditions of the fenestration are calculated simultaneously with other thermal calculations for each time step. DOE-2 uses a prescribed boundary condition, which is not calculated at every time step.
- There is also a difference in the way that calculations of thermal interactions between glazing and blind layers are done in the two programs. Energy Plus's model is based on ISO-15099, which specifies detailed calculation procedures for determining the thermal and optical transmission properties of windows.

- Energy Plus current version's (2.1.0) window model shares the same algorithms as LBNL's WINDOW 5 software

# WINDOW 5 / WINDOW 6

WINDOW is a software program developed by LBNL to determine the thermal and optical properties of glazing and window systems. WINDOW 5 is the latest full release, while WINDOW 6 has been released as a Research Only version. WINDOW 6 has the added capability of modeling complex glazing systems, such as windows with shading systems, in particular, Venetian blinds.

## SIMULATION METHOD

Windows modeled through the WINDOW program can be exported to annual hourly simulation programs, such as DOE-2 (5.2 version) or Energy Plus (5.2 Version). In the near future, Energy Plus will have the capability to accept outputs from WINDOW 6. Rob Hitchcock, at LBNL mentioned that they expect to develop Energy Plus to accept WINDOW 6's output by September 2008.

Results from WINDOW 6 are output in two forms –

1. Results calculated at normal incidence: These are the results displayed in the Glazing System Library results section.
2. Results calculated for many incoming and outgoing angles: These results are calculated as bi-directional transmittance/reflectance distribution functions (BTDF/BRDF).

These are the results displayed in the matrix reader. The matrix reader provides some very useful information about the optical and thermal performance of the window product such as total solar transmission as it changes with the profile angle of a ray of light relative to the glazing system. It also provides a contour plot of directional and hemispherical visible transmittance as it changes over altitude and azimuth. The matrix reader also generates a contour plot of an average hourly hemispherical visible light transmittance for each month of the year.

## LIMITATIONS

The results are produced for the specified properties of a window, which includes a given slat tilt angle. Modeling dynamic window shading means that the slat tilt angle changes over time. To visualize this, a similar matrix is required that shows solar and visible transmittance as it changes for different slat tilt angles. At present WINDOW 6 does not have the ability to calculate all this information and present it in a format similar to the matrix reader. To get this information, multiple parametric runs have to be conducted changing the angle of the slat each time.

Christian Kohler, of the LBNL Window and Daylighting Group, mentioned that they are working with the Energy Plus Group to develop an interface with Energy Plus for the Window 6 output. Energy Plus at present has a Venetian blinds model based on WINDOW 5.

# DAYLIGHT 1-2-3

Daylight 1-2-3 is an analysis tool from the National Research Council, Canada that predicts the annual daylighting and energy performance of sidelit and/or toplit private offices, open plan offices and classrooms. The tool can be used to quantify annual energy savings (both lighting and heating/cooling loads) for different façade design and lighting, and shading control strategies. The program uses annual daylight simulations using a validated, RADIANCE-based daylight coefficient approach and integrated thermal/lighting simulations based on a customized version of ESP-r. Manual lighting control model is based on the Lightswitch model, which is based on monitored occupancy behavior from several field studies, and window blinds models are based on SkyVision correction factors, a simplified method of simulating the blinds light transmission and redirection properties using a reference radiance run.

## SIMULATION METHOD

All user inputs are limited to set values built into the program. There are three generic options for window shading type: interior shades, inter-pane shades and no shades; and two options for shading controls: Manual (active user or passive user) and Automated. Along with this, there are up to six options for electric lighting controls ranging from manual to auto dimming + occupancy sensor. Combining these and other input options, energy savings from various types of automated window shading systems can be determined.

The program outputs annual lighting energy use as well as heating and cooling loads by month. Another output is advanced daylight performance metrics including daylight autonomy and useful daylight index.

With Radiance as its engine for daylight simulation, Daylight 1-2-3 can provide more accurate daylight simulation than the split-flux method used in DOE-2 or Energy Plus.

## LIMITATIONS

The basic limitation of this program is that all user inputs are limited to set values built into the program. Also, the user has limited choice of space geometry, size and end use. Hence, it is not an ideal tool to evaluate daylighting in specifically designed spaces, but its strength is as a pre-design tool to workout various scenarios and determine the most energy-efficient approach.

Future work on the program will include exterior shadings and light shelves, adding new facade systems, and translucent glazing. As SkyVision correction factors form the basis of the blinds models. Christoph Rehinhart, the primary author of the program, told us that things like concave-side-up blinds are possible and can be easily incorporated in future releases of the software. He also mentioned that slat angle control by users, which is currently not available as an option in the software, can be incorporated in future releases.

# DAYSIM (RADIANCE)

Daysim is daylighting analysis software that calculates the annual daylight availability as well as the lighting energy use of automated lighting controls (occupancy sensors, photocells) compared to standard on/off switches. Daysim combines the backward raytracing software Radiance, developed by Lawrence Berkeley National Laboratory, with a daylight coefficients approach along with an underlying Lightswitch manual lighting control model, which is based on monitored occupancy behavior from several field studies.

Among the dynamic daylight performance metrics calculated by Daysim are daylight autonomy and useful daylight index.

## SIMULATION METHOD

Daysim is now linked to the Ecotect building design software. Ecotect models can be directly exported to Daysim for further analysis. Vice versa, Daysim results can be imported back into Ecotect for presentation. This feature gives the user the ability to model complex geometries within Ecotect for use analysis in Daysim. Unlike Daylight 1-2-3, Daysim can be used to evaluate daylighting in specifically designed spaces and has the ability to provide very accurate results.

## LIMITATIONS

A limitation of using Daysim is that it only has a daylighting model, and does not have a thermal loads model. For this reason, it can be used to determine daylighting, but not to determine the interactive effects of heat gain/loss and reduction in cooling loads due to electric lighting controls.

# SENSOR PLACEMENT + OPTIMIZATION TOOL (SPOT)

The Sensor Placement + Optimization Tool (SPOT) is intended to assist a designer in quantifying the existing or intended electric lighting and annual daylighting characteristics of a given space and to help establish the optimal photosensor placement for the space relative to annual performance and annual energy savings.

## SIMULATION METHOD

The user has the ability to specify “blinds”, “shades” or “translucency” for any window defined within SPOT. “Blind rotation” can be set to determine the extent to which the slats can be rotated, along with “reflectance” and “shade transmittance” of the blinds.

Shade controls can also be specified. Each zone can be assigned either an "auto" or "fixed" shade control. An automatic control ties the shades to a defined photosensor location and setpoint that determines when the shades will be drawn or retracted. Auto generating the shade position will place the photosensor on the exterior of the wall or roof that contains the shades for the given zone. Auto generating the shade sensor setpoint will set the setpoint just above the brightest cloudy day, ensuring that the shades will be retracted under overcast conditions but drawn during most instances of direct sunlight. To simulate passive manual control of the shade zone, the "fixed" option can be used. This will keep the shades drawn at all times, representing the typical 'passive' user behavior when manual control of shades is given.

SPOT generates a detailed report of annual daylight illuminance at the work plane, and also calculates the annual electric, heating and cooling savings.

## LIMITATIONS

At this time, a “timer” and “manual” option for shade controls is not available, and slated to be incorporated in a future release.

# ENERGY SAVINGS ESTIMATE

Rough energy savings from a generic dynamic window shading system were estimated using the Daylight 1-2-3 and DOE-2 programs. The shading system selected for this study is an internal blind with adjustable slat angles and adjustable window coverage. In other words, the blinds can be lowered or raised and the slats can be adjusted for their angle.

It should be noted that the savings estimates generated are rough ballpark estimates. Both software programs have various limitations as described earlier that influence the accuracy of the results. The controls for blinds and electric lighting in the base case model are based on either monitored occupancy behavior from several field studies (such as the Lightswitch model used in Daylight 1-2-3 for manual control of electric lighting) or on gross assumptions (such as the model for manual blinds controls in DOE-2 and Daylight 1-2-3). However, until more research is available on actual field behavior with manual controls for window shades and electric lighting, these limitations will be the norm.

## BASE CASE

The base case model is an open plan, 22 ft x 22 ft office with 9 cubicles in Los Angeles, California. Windows are on the south façade, with a 33% window-to-wall ratio.

In both simulation programs, Daylight1-2-3 and DOE-2, we specified the window to be double-glazed, clear with interior Venetian blinds. As a base case, to represent a typical scenario, a fixed slat angle of 45°, and manual lighting controls were specified. In Daylight 1-2-3, which uses the Lightswitch model, this meant that lights get turned on for the first time when daylight levels fall below set point and remain on for the rest of the day. In DOE-2, they were specified as always on for the period of occupancy.

### DAYLIGHT 1-2-3

For the dynamic window shading system case in Daylight 1-2-3, “automated” controls were specified, to lower fully the blinds to avoid glare as soon as direct sunlight above 50 $W/m^2$ hits the work surface. The blinds are re-opened when this glare criterion is no longer met. The lighting controls are specified as “dimmed + occupancy sensor”, where a photosensor-controlled dimming system is switched on and off by an occupancy sensor. Daylight setpoint is kept at 500 lux.

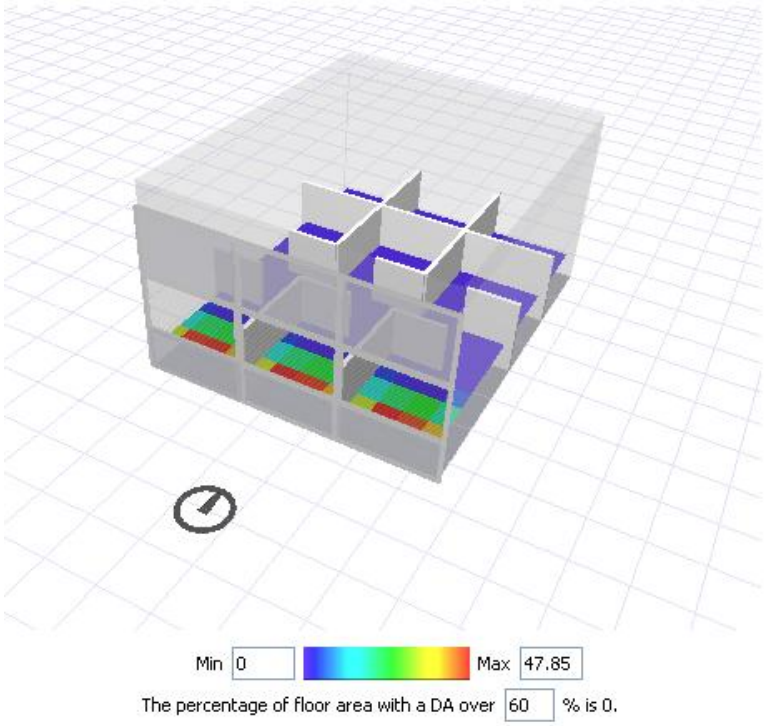



**FIGURE 21. SCREENSHOT OF OFFICE MODEL IN DAYLIGHT 1-2-3**

## DOE-2

For the dynamic window shading system case in DOE-2 two cases were run based on a) dynamic slat angels, and b) dynamic window coverage. When a specified amount of solar radiation, i.e., 50 Btu/hr-sf hits the window surface, this triggers the blinds to either change slat angles, or raise/lower to avoid glare. Fifty Btu/hr-sf (~150 W/m$^2$) was chosen to be equivalent to having 50 W/m$^2$ (used in the Daylight 1-2-3 case) at the work surface. This number was based on using an approximation that 1/3 of the radiation hitting the window surface will get to the work surface.

The blinds then change slat angles or window coverage to admit maximum daylight into the space when the glare condition is no longer met. The lighting controls were specified to be dimming with a setpoint of 46 fc (~500 lux) to match the Daylight 1-2-3 case.

### RESULTS

Table 5 summarizes the results of the simulations. There are other assumptions built into models in both simulation cases and given these assumptions the heating and cooling energy usage numbers are quite different in the base cases. However, lighting energy use has a fairly close match. Findings demonstrate that the lighting energy savings are in the range of 19% to 46% for the two strategies considered using DOE-2, while Daylight 1-2-3 predicts lighting energy savings to be 23%. Accounting for heating and cooling energy savings due to avoided solar heat gain and less cooling demand due to dimmed lights, the total estimated whole building energy savings for the study space are in the range of 2% to 10%.

**TABLE 5. ANNUAL ENERGY SAVINGS ESTIMATION FOR DYNAMIC BLINDS - AUTOMATED SLATS AND AUTOMATED BLINDS SHADING USING DAYLIGHT 1-2-3 AND DOE-2.2**

| 22FT X 22FT OPEN OFFICE PLAN, LOS ANGELES | | ANNUAL LOADS (KWH / SQUARE FOOT / YEAR) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *DAYLIGHT 1-2-3* | | | | *DOE-2* | | | |
| | DESCRIPTION | LIGHTING | HEATING | COOLING | **TOTAL** | LIGHTING | HEATING | COOLING | **TOTAL** |
| Base Case | Fixed blinds and manual lighting | 2.2 | 2.7 | 3.5 | **8.4** | 2.6 | 4.4 | 18.6 | **25.6** |
| Measure Case 1 | Automated slats with lighting controls | | | | | 2.1 | 4.4 | 18.5 | **25.0** |
| | % Savings from Base Case | | | | | 19.2% | 0% | 0.5% | **2.3%** |
| Measure Case 2 | Automated blinds with lighting controls | 1.7 | 2.7 | 3.2 | **7.6** | 1.4 | 4.4 | 17.8 | **23.6** |
| | % Savings from Base Case | 22.7% | 0% | 8.6% | **9.5%** | 46.2% | 0% | 4.3% | **7.8%** |

Lighting savings due to daylighting are expected to be maximal during mid day which coincides with the utility peak. Demand savings due to the lighting energy savings are expected to be significant, but were not calculated in this analysis.

# PERFORMANCE TESTING

Performance testing was conducted for U-value, visual light transmittance (VLT), solar heat gain coefficient (SHGC). Overall, we found that basic information required to estimate energy performance is available for most of the products. However, the level of rigor of these tests and simulations vary.

As of September 2006, National Fenestration Research Council (NFRC) added a label for dynamic glazing (DG) products, with the opportunity to show the range of performance from open to closed, or on to off.


**FIGURE 22. NFRC LABEL FOR DYNAMIC WINDOW GLAZING.**

NFRC offers this recommendation for dynamic window glazing:

> "To ensure maximum comparability to existing NFRC certified fenestration products, no fundamental change in testing procedure is being proposed. Dynamic glazing (DG) should be subjected to the same tests, standards, and hurdles as all other NFRC certified products. The only modification needed for DG is to allow for rating the multiple states of performance that dynamic glazing offers."

Only thermal performance characteristics are currently required for NFRC rating. Visible light transmission (VLT) is optional. Products that redirect daylight, such as inverted blinds or daylight optimized blinds, should also be able to describe their effects on daylight distribution, in addition to the NFRC VLT rating. However, there is no NFRC-prescribed format for this information.

Some manufacturers have undertaken extensive thermal performance testing of their product (*VisionControl, CPI ContoLite, Mecho Shade, Nysan, Pella, Warema*) using test-bed facilities and experimental evaluation. Daylight enhancing products (*from Warema, Nysan and VisionControl*) have also been tested or simulated for daylight performance. The test methods used were found to be either based on NFRC test methods or developed by researchers at universities, showing evidence of comparable scientific rigor. Other manufacturers (*Lutron and Draper*) also reported solar and visible properties for their shade products in their product literature, but the test methods could not be determined.

# STATUS OF OCCUPANT ACCEPTANCE TESTING AND EVALUATION

Of all the manufacturers we interviewed, none had conducted formal occupant acceptance testing. Only two products (*CPI ControLite and Mecho Shades*) had other researchers conduct occupant acceptance testing and evaluations in spaces with their products installed.

For *CPI ControLite*, Professor G.Z.(Charlie) Brown at the University of Oregon has conducted occupant surveys for an installation at the Mount Angel Abbey Prototype School in Mt. Angel, Oregon.

LBNL is studying the *Mecho Shades* installation at the New York Times. A workplace productivity study was conducted at the Herman Miller Headquarters building which has installed Mecho Shades.

In general, it was found that occupant acceptance testing was not something the manufacturers were beginning to consider. When asked about occupant assessment, their general response was that, they have not had complaints from their customers or that they have anecdotal evidence that people like their products and are happy using them. There are, however, no published results or reports on occupant assessment.

We found only a few research studies on behavioral models that represent a realistic base case condition for manual or automated blinds operation with manual overrides. The key study we found was the “Lightswitch 2002” [2] study done by NRC-IRC, Canada. This study is also the basis for the assumptions in the Daylight 1-2-3 software. Another study “Adding advanced behavioral models in whole building energy simulation” [3] from NRC-IRC, Canada, deals with the behavioral models for manual and automated lighting controls.

These studies provide a good beginning to understanding behavioral aspects of manual and automatic blind controls, but more research is needed, specifically to define the California marketplace (or the U.S.) with an emphasis on actual on-field data collection. This information is critical to further advance this technology into utility programs. Unless data is available upon which to base assumptions for manual and automated blinds operation that can become input to the simulation programs, incentives cannot be calculated. Further progress in the field of simulating dynamic window shading will be limited unless occupant acceptance and behavior is assessed.

# DISCUSSION ON PRODUCT OPTIMIZATION

Almost all products researched have been optimized for solar shading through the use of dynamic controls. Solar heat rejection is the primary design goal of *CPI ControLite*, *VisionControl*, *ASCA*, *C.S. Controls*, and some products from *Nysan*. Other products also provide solar heat rejection, but vary considerably on other aspects of performance.

*VisionControl* with its blinds placed inside the insulated glass and *CPI ControLite* with its use of translucent polycarbonate panels and translucent half-cylinder rota-blades seems to optimize for U-value enhancement.

Products by *Nysan* and *Warema* seem to optimize for daylight distribution. They seem primarily engineered for optimum reflection of daylight and its distribution into the room.

*Mecho Shades*, *Warema* and *Somfy Controls* were found to be optimized for automated control, and simplified user interface. *Mecho Shades* offers a touch-screen control that replaces the need for multiple buttons. *Warema* and *Somfy Controls* provide simplification as well as functionality through their user interface. *Lutron's* Sivoia QED™ (Quiet Electronic Drive) system seems to optimize for quiet operation of its motors.

*Mecho Shades* and *Nysan* seemed to optimize for maximum flexibility in terms of deploying controls with plug-and-play expandability. *Mecho Shades* has chosen to use an open architecture protocol to provide flexibility of use with components other than those from *Mecho*, and to allow for expandability of the system.

Integral blinds products from *Traco* and *Graham* seem to optimize for privacy. With only manual controls available for the integral blinds, using these products for solar shading or as daylight windows is not the design intent for the products.

# MARKET OPPORTUNITY

This section presents a discussion of findings from the data collection and research on dynamic window shading systems for this project.

## MARKET CHARACTERIZATION

Dynamic window shading technology is available in the U.S. market with a variety of commercially available products. The potential market identified by most manufacturers was owner-occupied buildings, such as schools, hospitals, museums, libraries etc., where there is a willingness to invest for comfort and automated performance. Currently, the market is limited to high end or early-adopters/ experimental buildings.

Manufacturers differ significantly in their perception of the level of market demand for dynamic window shading systems. In some cases they cited high demand (either current or anticipated future demand) (*Nysan, VisionControl, CPI ControLite, Pella, Mecho Shades, Lutron, Draper*), while in other cases their experience or perception was completely the opposite (*Traco, Graham*).

Manufacturers who envision a large potential market and a strong demand, usually have a dynamic, market-ready automated shading product (*except Pella, that has a dynamic window shading product in the works*) and have either internal testing of their product's solar, thermal and visible properties, or some experimental or theoretical evaluation of its energy savings potential. Lutron was the only exception; they had not conducted an evaluation of energy savings. These manufacturers have also had some success in selling their dynamic shading product to early adopters, and have received positive feedback from customers. They are also promoting their products as energy saving measures.

Manufacturers who do not see a strong demand for dynamic window shading systems (*Traco and Graham*) as means of saving energy, cited other non-energy benefits as the selling feature of their products. These manufacturers also have dynamic shading products (integral blind windows), but there are a few key differences in their products and in their company philosophy from those who see a strong demand. The most important difference is in company philosophy. These manufacturers are not promoting their products as energy saving measures, but rather as a means of controlling privacy and occupant comfort. They do see a market and demand for their product in market sectors that require strong privacy and comfort controls, namely hospitals and schools. The key difference in products is that their products do not have motorized/automated controls. Manual controls make it hard to estimate annual energy savings of the product with any level of certainty and as a result these companies have not invested in researching or documenting the energy performance of their product.

The chief reasons cited for the lack of demand are the high cost of dynamic controls (*Graham*) or the energy saving value of dynamic window shading being too low (*Traco*). These manufacturers have also not invested in product testing for their dynamic shading products (*Traco and to a lesser extent*

*Graham - which has product testing for thermal resistance on a few integral blind products*).

Companies with market-ready products are largely based outside the U.S., in Canada or Europe, where they have already had success in selling their dynamic window shading products. They either have a small presence in the U.S., (*Warema*), or are poised to have a greater presence in the U.S. through collaboration with companies in the U.S. (i.e., *Nysan in collaboration with Hunter Douglas*).

On the other hand, large U.S. based window manufacturers (*Traco, Graham*) as well as some of the largest blinds manufacturers in the country (*Levolor, Kirsch*) were not interesting in pursuing dynamic window shading technology with their products, which currently only have manual shading controls.

# COMMERCIAL AVAILABILITY

Most (*8 out of 12*) manufacturers interviewed had distributors in California and the products researched were commercially available, with the following few exceptions:

- *Pella* is developing new products that are in the prototype or R&D stage.
- *Draper* has the Animeo controls shades product just being released into the market in October, with no installations yet.
- *Graham* has a commercially available integral blinds window product with manual controls, while a motorized version is in prototype stage.
- *Traco* also has a similar integral blinds window in the market, but does not plan to create a motorized/automated version.

Among those products that are commercially available, those with manual controls have been in the market for many decades, with various installations in California. Automated products range from new – about 5 yrs, to well established – with about 10 years of presence or more in the U.S. market.

On the issue of installation and commissioning, some manufacturers provided detailed training, and certification for dealers and installers (*Mecho, Nysan, Lutron*), while others did the installation and commissioning themselves or through a small network of dealers that are familiar with their product (*CIP Controlite*). Others state that the general contractor does installation and the manufacturer commissions the installed automated blind products (*VisionControl*). Manufacturers that did not have automated controls integrated into a commercial product yet (*Traco, Graham*) said that installation was done by the general contractor.

## MARKET BARRIERS

The biggest barriers to greater commercialization most commonly mentioned by manufacturers are cost and education. From their point of view, albeit somewhat circular, with a small market, the costs of production are high, and not enough customers appreciate the value of their products.

Another barrier identified is that the players see the process as being “too multi-disciplinary,” involving coordination between electrical engineers, architects, interior designers, and facility managers. Manufacturers said that

"unless there is a mandate from the owner, energy efficiency features that require such multi-disciplinary approaches always seem to get dropped off." Manufacturers described a need to make the process simpler for the architect to implement.

Manufacturers interviewed said repeatedly that it was not too hard to convince the architect of the benefits of an automated shading system, but the owner and facility managers were the hardest to convince on issues of "reliability" of the moving parts and "persistence" of savings.

A specific market barrier identified by one manufacturer of an integral blind window was that in California, there are stringent fire codes that ask for a fire rated assembly. The manufacturer told us that they have to go through a rigorous approval process, which takes time and money. As an alternative, fire rated glass can be specified in the assembly by the architect, but sometimes that was not sufficient to convince the authorities.

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