Daylight Dividends

CAPTURING THE DAYLIGHT DIVIDEND
Shade Controller with DaySwitch Demonstration Project

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SUMMARY

The shade controller was developed partially with a seed research grant from the Capturing the Daylight Dividend program. A group from the University of Oregon's School of Architecture, Energy Studies in Buildings Laboratory led by Professor G. Z. Brown is responsible for the shade controller's existence.

This report describes the results obtained through demonstrating the shade controller in conjunction with the DaySwitch at two small demonstration sites at the Lighting Research Center (LRC). The purpose of the demonstration and evaluation was to determine energy savings with the use of the shade controller in conjunction with the DaySwitch as compared with the DaySwitch only. It was also designed to measure easy of installation and user acceptance of the shade controller.

In reviewing this report, the reader must be cognizant that only a small sampling (two shade controllers) was possible. It must also be noted the shade controller is only in its alpha prototype version.

The shade controllers and the shades they were attached to were assembled by the University of Oregon. Two were shipped to the LRC for installation. The remaining two were installed by facilities management at the University of Oregon. In all cases, installation was straightforward and no significant issues were encountered. A minor issue arose with one of the LRC shade controllers. The allen screws on the coupler that attaches the shade controller to the shade tilting rod came loose in shipment and had to be tightened.

Significant energy savings were achieved with the use of the shade controllers and DaySwitch as compared to the DaySwitch only. At LRC sites, the savings increased by an average of 30% for test site Howard and nearly doubled for test site John. Both increases are attributable to the shades being opened sooner than they were with just the site occupants manually operating the shades.

Operational issues are present in the alpha prototype that need to be corrected before the shade controller can be considered for commercialization. When the shades opened automatically, it was with a loud "snap" that startled occupants. The mechanical latching mechanism required multiple yanks on the wand to engage the latch and keep the shades closed. The lack of the ability to manually adjust the angle of the shade's slats and not being able to manually open the shades until the shade controller timer opened the shades are undesirable features.

OPERATING CHARACTERISTICS OF THE SHADE CONTROLLER

Recognizing the shade controller is still undergoing patenting filings, this description of the operating characteristics of the controller is purposely vague.

The shade controller is a mechanical device that automatically opens a shade after a set time period from when the shade was closed. The occupant pulls on the wand normally used to tilt the shade's slats. This closes the shade and starts the timer for when the shade will reopen. The shade, in its current configuration, cannot be opened manually. It can only open when the timer has expired. There is only one angle position for the shade's slats and that is fully closed.

The goal of the shade controller is to open the shades after the sun has passed by a given façade and will no longer create glare within the space. By opening the shades sooner than would normally be achieved under manual operation, the amount of daylight that enters the space will increase. If the lighting is controlled by a sensor related to the amount of daylight present, additional energy savings should be possible from the savings achieved with manual blind operation.

TEST CONDITIONS

Two different locations were chosen for installations of the shade controller at the Lighting Research Center (LRC). They are designated by the person who occupies the space.

Test Site Howard, LRC

This site is an open office setting with five foot high partitions separating individuals. The size of this cubicle is six feet wide along the outer east wall and eight feet deep extending from the outer wall. Ceiling height is twelve feet and light fixtures are mounted ten feet above the light colored wood floor. All walls are painted a light cream color.

There is a large window within this space facing east. The window is 48 inches wide and 80 inches high. It utilizes single pane glass with no tinting or exterior shading. The visible transmittance is approximately 0.85. A horizontal shade with the shade controller provides glare control. There are south facing windows approximately 15 feet from this cubicle.

The shade controller was placed on a horizontal shade by the University of Oregon researchers and shipped to the LRC for installation at its two sites. The entire horizontal shade unit replaced similar horizontal shades. It was installed on February 14, 2006.

The light fixture is of the pendent variety with direct/indirect lighting provided by two four feet T8 lamps linearly placed. Total wattage is 60 watts. The total length of the fixture is eight feet. To control light energy based on the amount of daylight present, a

DaySwitch was installed between the power leads entering the fixture and the ballast. The photosensor is located horizontally at the end of the fixture facing downward, approximately five feet from the window.

This DaySwitch is programmed to turn the lights off at 2.7 times the illuminance level of the electric lights only as long as this illuminance level or higher is maintained for ten minutes. The DaySwitch calculates the lighting only illuminance level as part of its calibration process by subtracting the illuminance level it measures with the lights off (daylight only) from the illuminance level with the lights on (daylight and electric lights). The lights will be turned back on at the electric lighting illuminance level.

The individual occupying the space is male, between 35 and 44 years old, wears glasses and considers himself to be sensitive to light. He works in this space approximately two to fours hours per day, Monday through Friday usually doing work on the computer. He has a fluorescent 20 watt task light that he uses approximately one hour per day.

See photos below of Test Site Howard.

Test Site John, LRC

This site is a private office. The size of this office is eight feet wide along the outer west wall and ten feet deep extending from the outer wall. Ceiling height is twelve feet. However, HVAC duct work is suspended for the ceiling essentially reducing ceiling height to ten feet. Two direct/indirect light fixtures are mounted along the north and south walls and a third light fixture is mounted in front of the HVAC duct work parallel to the window. All walls and duct work are painted a light cream color.

There is a large window within this space facing west. The window is 48 inches wide and 80 inches high. It utilizes single pane glass with no tinting or exterior shading. The visible transmittance is approximately 0.85. A horizontal shade provides glare control. This horizontal shade was replaced with another horizontal shade with the shade controller built in on February 14, 2006.

The two wall mounted light fixtures are direct/indirect with one four foot T8 lamp per fixture. The light fixture parallel to the window is located about eight feet from the window and is pendent mounted. It too is a direct/indirect fixture with two four foot T8 lamps. All light fixtures were controlled from an electronic manual dimmer with an on/off function. This dimmer control was replaced with a simple on/off switch because of operation interference between the dimmer and the DaySwitch. The DaySwitch was installed between the incoming power lead and the power leads to each individual light fixture.

This DaySwitch is programmed to turn the lights off at 2.2 times the illuminance level of the electric lights only as long as this illuminance level or higher is maintained for five minutes. The lights will be turned back on at the electric lighting illuminance level. The DaySwitch was initially installed on November 9, 2005. Installation issues were overcome on December 14, 2005 and the DaySwitch has operated properly since.

See photos below of Test Site John.

DATA COLLECTION

Data collection was achieved using Hobo recording instruments. Information regarding window shade positioning prior to installation of the shade controller was collected via periodic visual observations. A Hobo recorder was used to collect shade information through a contact that was closed when the shades were open and open when the shades were closed. However, due to malfunctions of the contact built into the shade control device, data on the opening and closing of the shades was accomplished through examining illuminance levels at the work stations. A major change in illuminance levels at certain times of the day indicated an opening or closing of the shade. A recording ammeter was placed on the power lead from the DaySwitch to the light fixture's ballast at both sites. This apparatus measured whether the light fixtures were on or off and the time they switched states. Data was collected and recorded in five minute intervals. The ammeter readings were not used to determine power consumption because of their inaccuracy at the low power end of their capacity. The error rate was too high.

A recording illuminance meter was place on work surfaces at each site. For site Howard, the meter was approximately six feet from the window and two feet away from being directly under the light fixture. For site John, the meter was approximately two feet from the window and directly under one of the wall mounted fixtures. These meters collected and recorded data every one minute.

A weather station with recording capabilities was placed on the roof of the LRC to determine solar intensity. It measured solar radiation and outdoor temperature. Data was collected and recorded every one minute.

Surveys were conducted with space occupants to determine their acceptance of window shades and lighting conditions before and after the installation of the shade controller and DaySwitch. The survey instruments are included in Appendix A of this report.

INSTALLATION ISSUES

The shades with the shade controller required only a replacement of the mounting hardware for proper installation. The shades were easily installed once the new hardware was in place. Only one issue was encountered. The allen screws on the coupler that attaches the shade controller to the shade tilting rod came loose in shipment and had to be tightened.

The shade controller at test site John, after operating correctly for 20 days, failed to keep the shades closed for more than 10 minutes. In investigating the issue and after receiving disassembly instructions from the University of Oregon, personnel from the LRC were able to determine the timing mechanism that controls the closed time had come loose. The shade controller was put back in service after adjusting the timing mechanism. It has worked properly since.

DATA ANALYSIS

Test Site Howard, LRC

Shade positions, open or closed, were determined by large changes in illuminance levels, as measured by a recording illuminance meter, without the lights being turned on or off. Nine days were analyzed representing three sunny, three partly cloudy and three cloudy days. The following table illustrates when the shades were closed and when they automatically reopened at test site Howard and the changes in illuminance levels just before the shade opened or closed and immediately following the shade's action. Test site Howard has an east facing window.

Date	Sky Condition	Shade Manually Closed at	Work Surface Illuminance Level Before & After	Shade Automatically Reopened at	Work Surface Illuminance Level Before & After
Feb. 23	Cloudy	9:20 AM	25.3 fc / 16.5 fc	11:55 AM	29.7 fc / 53.8 fc
Mar. 1	Sunny	9:30 AM	80.9 fc / 78.0 fc	12:00 PM	41.4 fc / 57.5 fc
Mar. 2	Cloudy	No shade closings			
Mar. 6	Sunny	8:35 AM	585.6 fc / 89.0 fc	1:10 PM	56.8 fc / 73.6 fc
Mar. 9	Cloudy	No shade closings			
Mar. 10	Sunny	8:05 AM	97.8 fc / 28.2 fc	2:50 PM	28.9 fc / 43.6 fc
Mar. 13	Partly Cloudy	10:10 AM	40.6 fc / 26.7 fc	12:00 PM	28.9 fc / 42.1 fc
Mar. 14	Partly Cloudy	10:15 AM	225.2 fc / 97.9 fc	12:30 PM	17.9 fc / 33.3 fc
Mar. 15	Partly Cloudy	9:25 AM	45.0 fc / 26.0 fc	11:45 AM	47.2 fc / 62.8 fc

Energy savings with and without the shade controller were developed from energy data collected prior to the shade controller installation and after the installation. In both cases, the DaySwitch was controlling the light fixture. It was assumed, based on recorded data that the lights would be on during normal work days from 7:30 AM to 6:00 PM or 10.5 hours. The lights are either on or off when controlled by the DaySwitch. The total wattage controlled is 60 watts. To determine the energy savings, the hours the lights are off are multiplied by the controlled wattage. This methodology was used for both the standard shade controlled by the occupant and the shade controlled by the shade controller. The results of energy savings are presented in the following table.

Sky Condition	Avg. Energy Savings w/o Shade Controller	Avg. Energy Savings w/ Shade Controller	Avg. Percent Savings w/o Shade Controller	Avg. Percent Savings w/ Shade Controller
Cloudy	0.45 kWh	0.44 kWh	71.4%	70.3%
Partly Cloudy	0.44 kWh	0.53 kWh	68.8%	84.4%
Sunny	0.38 kWh	0.54 kWh	60.3%	86.2%

Shade observations prior to the installation of the shade controller indicated the occupant at test site Howard would keep his shades closed well beyond direct sun entering the east facing window. Some times the shades would be closed for two to three consecutive days without ever opening. With the manual shade controller in place, the occupant would shut the shade in the morning after direct sunlight was coming through the east window and the shade controller would automatically open the shade after a preset time. If the occupant wanted the shades to remain closed, he could close the shades again.

Based on the data collected, it appears the shade controller was set to automatically open the shades approximately 2.5 hours after they were closed.

Additional energy savings were achieved under sunny and partly cloudy sky conditions with the shade controller in place compared to occupant operation of the shades. For partly cloudy sky conditions, the energy savings increased with the use of the shade controller by 0.09 kWh per day or 20.5%. The increase was even higher for sunny sky conditions and the use of the shade controller, 0.16 kWh or 42%. As might be expected, under cloudy conditions energy savings remained about the same. The shades were infrequently closed under these sky conditions for both cases.

Surveys were completed before and after the shade controller device was installed to assess occupant satisfaction with shade operation and ability to reduce light and glare at the workstation. At test site Howard, the occupant was satisfied with the ability of the initial shade to block unwanted glare and the ease of operation of the shade. The occupant of this space rated the operation of the shade with the shade controller as unacceptable. When the shades opened automatically, it was with a loud “snap” that startled the occupant. The mechanical latching mechanism required multiple yanks on the wand to engage the latch and keep the shades closed. The lack of the ability to manually adjust the angle of the shade’s slats and not being able to manually open the shades until the shade controller timer opened the shades were listed as undesirable features.

Test Site John

Shade positions, open or closed, were determined by large changes in illuminance levels, as measured by a recording illuminance meter, without the lights being turned on or off. Nine days were analyzed representing three sunny, three partly cloudy and three cloudy days. The following table illustrates when the shades were closed and when they automatically reopened at test site John and the changes in illuminance levels just before the shade opened or closed and immediately following the shade's action. Test site John has a west facing window.

Date	Sky Condition	Shade Manually Closed at	Work Surface Illuminance Level Before & After	Shade Automatically Reopened at	Work Surface Illuminance Level Before & After
Feb. 23	Cloudy	1:30 PM	87.5 fc / 42.1 fc	4:00 PM	83.9 fc / 140.3 fc
Mar. 1	Sunny	3:00 PM	168.8 fc / 124.9 fc	Opened after sunset	
Mar. 2	Cloudy	No shade closings			
Mar. 6	Sunny	12:05 PM	70.7 fc / 27.5 fc	4:20 PM	130.7 fc / 120.7 fc
Mar. 9	Cloudy	No shade closings			
Mar. 10	Sunny	11:40 AM	68.5 fc / 54.6 fc	Opened after sunset	
Mar. 13	Partly Cloudy	2:30 PM	102.9 fc / 86.1 fc	Opened after sunset	
Mar. 14	Partly Cloudy	12:25 PM	64.8 fc / 20.9 fc	3:00 PM	75.8 fc / 167.4 fc
Mar. 15	Partly Cloudy	2:45 PM	59.7 fc / 16.5 fc	5:10 PM	61.2 fc / 113.9 fc

Energy savings with and without the shade controller were developed from energy data collected prior to the shade controller installation and after the installation. In both cases, the DaySwitch was controlling the light fixtures. It was assumed, based on recorded data that the lights would be on during normal work days or 9.0 hours. The lights are either on or off when controlled by the DaySwitch. The total wattage controlled is 130 watts. To determine the energy savings, the hours the lights are off are multiplied by the controlled wattage. This methodology was used for both the standard shade controlled by the occupant and the shade controlled by the shade controller. The results of energy savings are presented in the following table.

Sky Condition	Avg. Energy Savings w/o Shade Controller	Avg. Energy Savings w/ Shade Controller	Avg. Percent Savings w/o Shade Controller	Avg. Percent Savings w/ Shade Controller
Cloudy	0.00 kWh	0.26 kWh	0%	22.2%
Partly Cloudy	0.09 kWh	0.22 kWh	8.8%	18.9%
Sunny	0.22 kWh	0.41 kWh	18.9%	34.9%

Shade observations prior to the installation of the shade controller indicated the occupant at test site John would keep his shades closed for two to three consecutive days without ever opening them. With the shade controller in place, the occupant would shut the shade in the early afternoon after direct sunlight was coming through the west window and the shade controller would automatically open the shade after a preset time. Sometimes the shades would not open until the occupant left for the day. If the occupant wanted the shades to remain closed, he could close the shades again and often did so.

Based on the data collected, it appears the shade controller was set to automatically open the shades approximately 3.5 – 4.0 hours after they were closed.

Additional energy savings were achieved under all sky conditions with the shade controller in place compared to occupant operation of the shades. For cloudy sky conditions, the energy savings increased with the use of the shade controller by 0.26 kWh or 100%. For partly cloudy sky conditions, the energy savings increased with the use of the shade controller by 0.11 kWh per day or 122.2%. The increase was even higher for sunny sky conditions and the use of the shade controller, 0.19 kWh or 86.4%. The additional energy savings are attributable to the shades being opened automatically toward the end of each workday. Under occupant operation of the blinds, the occupant would start many days with the blinds in the closed position. This did not happen with the shade controller in place.

Surveys were completed before and after the shade controller device was installed to assess occupant satisfaction with shade operation and ability to reduce light and glare at the workstation. At test site John, the occupant was satisfied with the ability of the initial shade to block unwanted glare and the ease of operation of the shade. The occupant of this space rated the operation of the shade with the shade controller as very unacceptable. When the shades opened automatically, it was with a loud noise that the occupant characterized as “scary”. The lack of the ability to manually adjust the angle of the shade’s slats and not being able to manually open the shades until the shade controller timer opened the shades were listed as undesirable features.

CONCLUSIONS

- The report is based on only four shade controller installations. This is a limitation on the amount of data collected. Results of this demonstration must be viewed with this limitation.

- Substantial additional energy savings were achieved with the use of the shade controller. The additional savings are attributable to opening the shades quicker than what the occupants would have done on their own with only manual shade controls.

- There are many operational issues of the shade controller that need to be overcome prior to the shade controller being offered as a commercial package. The snapping open of the shades will startle most people. The lack of the ability to manually open the shades prior to the shade controller timing out is not acceptable and the inability to adjust the angle of the shades blades needs to be addressed.

- The shades with the shade controller were easy to install and the instructions accompanying the shade controller were easy to understand.

- The needle valve that controls the timing of the shades opening came loose in one of the shade controllers requiring a disassembly of the mechanism to make the repair.

RECOMMENDATIONS

Recommendations for the shade controller involve improvements to the operation of the shade controller. While only a limited sample was used, potential increases in energy savings with the use of a shade controller device that automatically opens shades is encouraging.

- Some type of damping effect needs to be added to the opening operation of the shade controller to limit the harsh noise it currently produces.

- A means of manually opening the shade prior to the shade controller automatically opening the shade needs to be added to the shade controller operation.

- A means of manually adjusting the angle of the shade's slats needs to be added to the shade controller operation.

- Some method of adjusting the timing mechanism by the occupant rather than being set at the factory needs to be found. This will allow for some interaction between the occupant and the device. Also, some way of "locking" the needle valve in place needs to be added so that it cannot change settings if it should become loose.

- A larger demonstration is suggested after some of the operational issues have been solved to verify energy savings and occupant acceptance. This should occur prior to commercial launch of the product.

Appendix A: Occupant Survey

General Lighting and Window Blind Survey

August 22, 2005

The University of Oregon's Energy Studies in Buildings Laboratory and Rensselaer Polytechnic Institute's Lighting Research Center are conducting an experiment that examines automatic lighting and window shade controls. So we may obtain a baseline on the current lighting and window shade systems, we need you to complete the following survey questions.

Please consider the lighting and window shades of your office and your work area and answer the following questions by circling the appropriate answer or filling in the blank. Then, please return this questionnaire to Ms. Terry Blomqiust at the University of Oregon or Peter Morante at the LRC. Your responses will be kept in the strictest confidence.

Background:

1. How old are you?
   18-24   25-34   35-44   45-54   over 54

2. Do you wear glasses or contact lenses?   Yes   No

3. How long have you worked at your current work location?   ________ years

4. How many months during the year do you work at this location?   _______ months

5. What days of the week do you work at this work location?   _________________

6. How sensitive to light would you say you are?   Very sensitive   sensitive
   average   not sensitive

7. How far is your work space from the closest window?   (__________ feet)

8. Which way does the window face?
   North   South   East   West

9. In a day, how many hours do you usually spend at your work area?
   less than 2,   2-4,   4-6,   6-8, or   more than 8

10. While you are at your work area, how do you spend most of your time?
    paper work,   computer work,   telephone,   other (   )

11. Please describe your job briefly, e.g., engineer, clerical, accounting, management, etc.
(   )

12. Do you have task lights in your work area? Task lights are “extra” lights (desk lamp, under shelf lighting, etc.) beyond the lighting provided by the ceiling lights.
yes, no

If yes,

- How many task lights do you have? ( )
- How many lamps do you use for each task light? ( )
- What types of lamps are they? Fluorescent lamps, incandescent lamps, halogen lamps, or other ( )
- What are the wattages of the lamps? ( )
- How many hours do you usually use the task lights per day? ( )

General Questions On Lighting:

1. Can you turn the overhead lights in your work area on and off with a switch?
   Yes No

   If yes:
   - When do you normally turn the lights on? ___________________
   - When do you normally turn the lights off? ____________________
   - Do you normally turn the lights off and on manually during the day if there is plenty of natural light from the window? Yes No Once in awhile

   If there is no light switch in your area to turn the lights on/off, how are they turned on and off?

   Master switch controls all lights in the area.

   A time clock turns the lights on in the morning and off at night.

   I've never seen the lights off.

   I don't know

   Other (explain) ____

2. How do you like the lighting in this office?
   dislike very much, dislike, neutral, like, like very much
3. How comfortable is the lighting in this office?
   very uncomfortable, uncomfortable, neutral, comfortable, very comfortable
4. How well can you see to do your work at your work area?
   very poorly, poorly, neutral, well, very well
5. How bright does the office look?
   very gloomy, gloomy, neutral, bright, very bright
6. Do the light fixtures in the ceiling appear:
   too dark, dark, neutral, bright, too bright
7. How bright is the lighting at your work area for the tasks you perform?
   too dim, dim, about right, bright, too bright
8. How does the lighting in your office compare with other offices?
   much worse, worse, about the same, better, much better

General Question on Window Shades:

1. What types of window blinds do you currently have at your work area?
   Vertical Blinds Horizontal Blinds No Blinds

2. Do you close and open the blinds during the day to meet your needs?
   Yes No
3. If you close and open the blinds during the day:

   Why do you close the blinds? ______________________________________

   What time of the day do you normally close the blinds? ________________

   When do you normally reopen the blinds?
   After the sun has passed by When I remember to do so The next day

   I forget to reopen them and the blinds remain closed for extended periods of time

   Other (explain) ____

4. How easy are the blinds to close/open?
   Very difficult Difficult Neutral Easy Very Easy

5. How well do the current blinds reduce glare from the windows at your work area?
   Very poorly Poorly Neutral Well Very well

6. What are you more inclined to do to provide good lighting through the window?
   Raise or lower the shade tilt the shade's louvers do both

Lighting and Window Shade Survey Under Experiment Conditions

The University of Oregon’s Energy Studies in Buildings Laboratory and Rensselaer Polytechnic Institute’s Lighting Research Center are conducting an experiment that examines automatic lighting and window shade controls that respond to natural light coming through the window. The purpose of the survey is to examine your reactions to these systems.

Please consider the lighting and window shades of your office and your work area and answer the following questions by circling the appropriate answer or filling in the blank. Then, please return this questionnaire to Ms. Terry Blomqiust at the University of Oregon or Peter Morante at the LRC. Your responses will be kept in the strictest confidence.

Date survey completed: ____________________

1. Were the instructions you were given for the operation of the lights and the window shades sufficient to allow you to properly operate these devices? Yes No

   What additional instructions would you have liked? _________________________

____

2. Did you notice the lights in your work area turning off or on in response to the amount of light coming through the window? Yes No

3. If yes:
   In your opinion, did the lights turn on or off excessively during the course of a day?
   Yes No

   Was the amount of light at your work area sufficient for you to conduct your work when the electric lights were turned off?
   Too Dark Dark Neutral Bright Very Bright

   How acceptable to you was turning the lights on/off automatically at your work area?
   Very unacceptable Unacceptable Neutral Acceptable Very acceptable

4. Did you notice the window blinds being opened automatically? Yes No

5. If yes, was the way the blinds reopened acceptable to you?
   Very unacceptable Unacceptable Neutral Acceptable Very acceptable

6. Were there any times the window blinds opened automatically and you had to shut them again? Yes No

   Why did you have to shut them again? _____________________________________

7. How well were you able to manually operate the blinds?
   Very poorly Poorly Neutral Well Very well

8. After you manually shut the blinds, did you have to manually open the blinds before they were opened automatically? Yes No

   If yes, why did you have to open the blinds manually?
   ____
   ____

9. Did you find the fixed angle of the blind's slats either in their closed or open position to be troublesome to you?
   Very troublesome somewhat troublesome neutral
   No trouble at all