FIELD TEST DELTA

Demonstration and Evaluation of Lighting Technologies and Applications

DAYLIGHT-HARVESTING SWITCH

Contents

The three elements of the DaySwitch (clockwise, from upper left): control module, remote commissioning device, and sensor module

Project Profile

The DaySwitch® is a simple daylight-harvesting switch designed to turn off electric lights when plentiful daylight is available. The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute developed the DaySwitch, collaborated with manufacturing partners to build prototypes, and demonstrated the device in a wide range of locations throughout the Rensselaer campus. This publication summarizes the product features and demonstration results.

Field Test Objectives

- Test the DaySwitch operation in diverse, real-world conditions (private offices, open-plan offices, and public spaces)
- Calculate energy savings
- Assess occupant acceptance
- Gather installation feedback from electricians

Overview of DaySwitch Features

The DaySwitch was designed to make setup and commissioning as simple as possible, which had been identified as a barrier to widespread implementation of daylighting controls technology.[1] The primary market for the DaySwitch is commercial retrofit, though it can be incorporated into new luminaires.

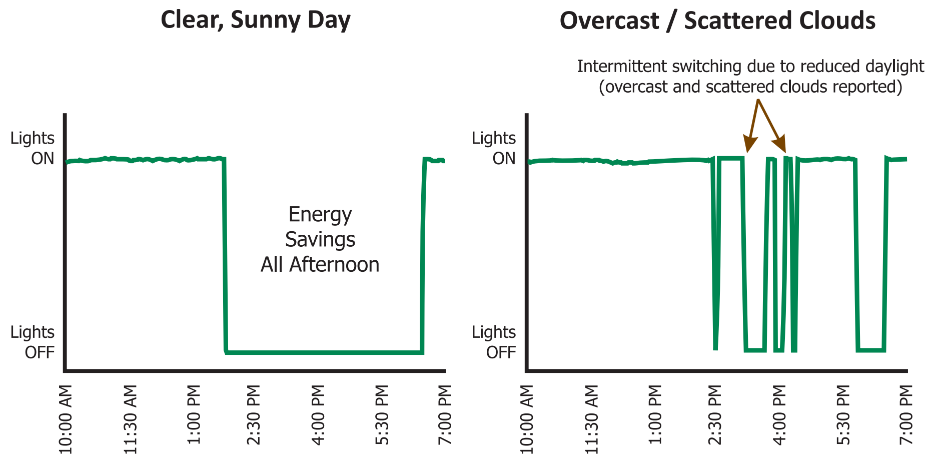
There are three main components to the DaySwitch: the sensor module, the control module, and a remote commissioning device. The sensor is connected to the control module with Cat5 RJ45 plenum-rated cable. (For these prototype demonstrations, the sensor was adhered to the ceiling with ultra-adhesive double-stick foam tape.) The DaySwitch control module is wired in-line with the luminaire or circuit that it controls. It is intended to be located in the wireway inside a luminaire.

When commissioning the DaySwitch, the commissioning device is placed under the sensor, and the commissioning button is pressed (see blue button in photo, above). There are no mechanical adjustments or switches on the control module that would require a ladder to access (a limitation of other systems); the commissioning device communicates wirelessly with the sensor to initiate setup and communicate setup options. The whole commissioning process takes less than 30 seconds. Commissioning can be performed any time daylight is present, without having to return at nighttime (a requirement of other systems). Embedded microcontrollers in the control module and the commissioning device automatically take measurements and calculate setpoints for light level and time delay.

1 Spectrum Associates Market Research, Inc. Daylight Dividends Focus Group Research Project: Final Report. Submitted to the Lighting Research Center, May 12, 2003. Available at: www.lrc.rpi.edu/programs/daylighting/pdf/LRCdaylightingFR.pdf

Field Test

DaySwitches were installed in 72 locations around the Rensselaer campus in 2008-2009. Sites included private offices (43%), open-plan offices (21%), and large public spaces (36%), all with access to daylight. All building orientations were included (north, south, east, west, and toplight). Most installations were retrofits of existing luminaires, as this is the primary market for the DaySwitch. Ten luminaires were provided for one location to test DaySwitch integration in new luminaires.



Typical DaySwitch operation with west-facing windows, sunny and overcast/scattered cloud conditions.

Monitoring Results

DELTA monitored 60 of the 72 sites hosting a DaySwitch. A pair of battery-powered light loggers were installed to record on-times for a DaySwitch-controlled luminaire, compared to on-times of another luminaire on the same circuit but not controlled by a DaySwitch. This allowed DELTA to measure the amount of time that the DaySwitch kept the lights off.

Monitoring showed that the DaySwitch did successfully turn off lights when sufficient daylight was present. As shown in the example, the DaySwitch typically keeps the lights off all afternoon in clear weather. When daylight decreases (likely due to weather change or time of day), the DaySwitch turns lights back on when necessary.

The Rensselaer sites demonstrated key site features that are necessary for the DaySwitch to be cost effective. The space must receive plentiful daylight, in an amount 2.5 to 3 times greater than the amount from electric light alone. Window blinds, tinting, and other obstructions were identified as preventing daylight from entering a space in sufficient quantity to enable the electric lighting to be switched off.

Some spaces had excessively high electric light levels. Because the DaySwitch bases its switch point on the electric lighting level (i.e., the amount of electric lighting measured in the space when no daylight is present), some spaces had insufficient daylight to meet that criterion.

The DaySwitch was designed with the assumption that it would control a substantial portion (>50%) of the electric illuminance directly underneath the sensor. The demonstration showed that if luminaires produce a diffuse distribution, many lamps should be controlled by one DaySwitch. A single lamp in a luminaire with a diffuse distribution (particularly uplight) may not make a substantial contribution to the illuminance directly underneath the DaySwitch sensor. As a result, the DaySwitch may keep the circuit turned off later into the evening.

The demonstration also revealed several reasons why private offices may not be the most promising locations for the DaySwitch. (See "Occupant Feedback" page 5.)

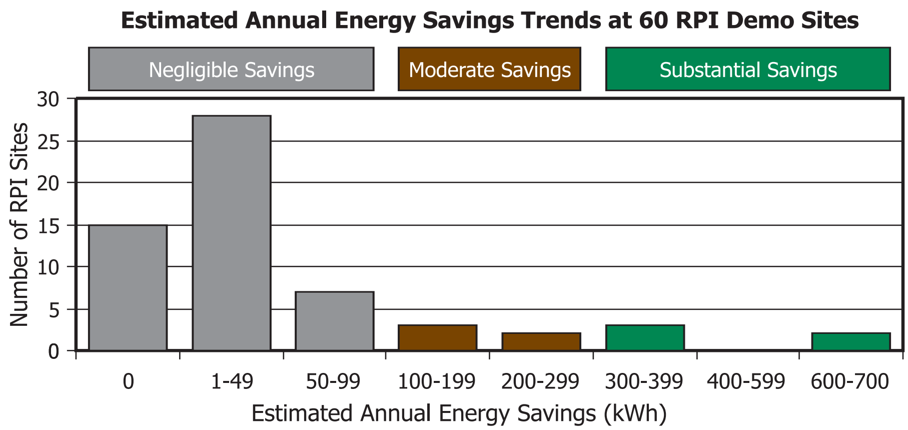
Energy Savings, Annual Cost Savings, Payback, and Pollution

Energy Savings

DELTA monitored each of the 60 sites for 1 to 2 weeks, primarily in winter.[2] The results of this monitoring are likely conservative estimates because daylighting potential is often greater in the summer. The results of those occupancy patterns were annualized by multiplying by the estimated numbers of days of the year that the building is open, per feedback from building managers.

The type of space, the amount of daylight available,

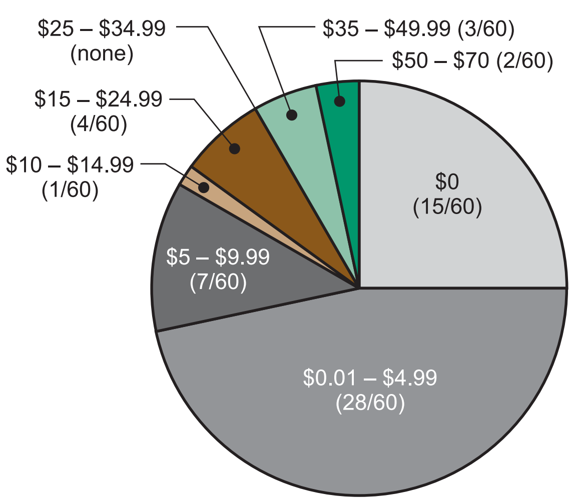
2 The DaySwitch installations took place over one year, so it was not desirable to delay the project monitoring further in order to collect equinox or summer activity data.



Estimated annual energy savings per site at 60 Rensselaer demonstration sites

and the occupancy pattern had significant impact on the amount of energy savings achieved with the DaySwitch. More than 80% of the monitored sites showed little or no energy savings during the monitoring period. A few sites did not save energy because of minimal occupancy during the daytime. At most of these sites, the amount of daylight simply did not exceed the electric light levels, so the DaySwitch, rightly, did not switch off the electric lighting. For many of these sites, this could have been predicted by simply measuring the amount of daylight available and comparing this to the installed electric light levels. (See "Recommended Field Evaluation Technique" page 7.)

Five out of 60 sites that were monitored were shown to be most promising for a DaySwitch retrofit. These sites exhibited substantial energy savings due to long hours of use, substantial daylight penetration, and a relatively large connected lighting load (many or high wattage lamps).



Estimated annual energy cost savings for 60 demonstration sites at Rensselaer ($0.098/kWh, no demand charge.[3])

Annual Cost Savings

Based on the actual electricity rates paid at the sites,[3] estimated annual savings are shown in the figure below.

Payback Period

Rensselaer pays very low rates for electricity (less than $0.10/kWh); therefore, the lower the rate charged by the electric utility, the longer the payback period.

Installation time took longer than in previous DaySwitch installations because of fit and luminaire access problems, thus lengthening the payback period. The DaySwitch did not fit in all of the existing luminaires at the sites chosen for demonstration, and electricians had to spend extra time providing alternate wiring and housings.

The LRC estimates that the five most promising site locations had a simple payback period of 2 to 7 years. If electricity rates were higher, or installation time were shorter, or if summer conditions were included, the payback period would have been shorter.

Pollution Calculations

Using the five most promising sites, it is possible to estimate annual pollution averted. The LRC consulted NYSERDA's rates for all of New York State to translate from kilowatt hours saved to pollution averted.[4]

Annual reduced power plant pollution due to DaySwitch energy savings.

	SO_2	NO_x	CO_2
Demonstration Site	lbs (kg)	lbs (kg)	lbs (kg)
Public Safety corridor	1.1 (0.5)	0.5 (0.2)	397 (180)
Student Union entry	1.1 (0.5)	0.6 (0.3)	409 (186)
Ansell Lounge	1.1 (0.5)	0.6 (0.3)	418 (190)
Dining Commons 1	1.9 (0.9)	1.0 (0.4)	700 (318)
Dining Commons 2	2.1 (1.0)	1.1 (0.5)	767 (349)

Sulfur dioxide (SO_2) is associated with visible pollution (haze) and acid rain. SO_2 is also a direct lung irritant. Nitrogen oxides (NO_x) are a primary cause of ozone production (a main component in smog) and acid rain. Carbon dioxide (CO_2) is a possible contributor to future climate changes, such as global warming.

3 Most sites paid $0.098/kWh, including delivery charges, and no demand charges. Electric rates for seven monitored sites at one building were $0.088/kWh and $1.89/monthly kW demand charge. DELTA assumed peak demand would be affected eight out of 12 months per year. Thus, the overall electricity cost at this building is slightly higher than on-campus buildings.

4 As provided by New York State Energy Research and Development Authority's Energy Analysis group.

Occupant Feedback

Occupants in public spaces did not observe much of the DaySwitch operation, so their comments were generally neutral. Occupants in office workspaces closely observed the DaySwitch operation. While most rated the device as neutral or positive, three out of 27 respondents indicated they were not satisfied with the device. Two were unhappy about frequent switching on overcast days, and one felt the device kept the lights off longer than appropriate in the evening. In addition to one of those with complaints, three other people requested that the device be disabled because they were dissatisfied with the switching. This occupant feedback suggests that the DaySwitch, as currently programmed, may not be ideal for use in private and open-plan office environments.

> *"It was a little disconcerting for the first few turn-offs; I thought it was a power outage."*
>
> *-Private Office Occupant*
>
> *"(It switches) a lot on cloudy days."*
>
> *-Private Office Occupant*

Installation Observations and Feedback

The installations at Rensselaer took electricians considerably longer than previous DaySwitch installations. Some spaces were difficult to access, particularly those with excessive height or immoveable ceilings. There were also many cases in which the DaySwitch control module did not fit in more slender or molded wireways, or the luminaire was already full of ballasts/wires; in those cases, the site was either eliminated or the control module was placed in a separate junction box located outside the luminaire. Electricians suggested that future DaySwitch housings connect outside a luminaire or junction box at a knockout.

At a few of the sites, electricians rewired luminaires so that only the lamps closest to the windows switched off. This approach increased installation time but also increased the potential time that some lights could be switched off.

While the wiring of the DaySwitch was understandable to the electricians, sensor location was a source of confusion at some sites. Electricians needed more guidance about location and mounting procedure.

The super-adhesive tape used to mount the sensor in this demonstration was insufficient in some cases. When the DaySwitch is commercialized, the sensor should be mounted with a mechanical fastener of some sort.

It should be noted that if occupants depart during daylight hours when the DaySwitch is keeping lights off, they may inadvertently leave their wall switch turned on overnight, thus undermining energy savings. While this was not demonstrated at the Rensselaer sites, it did occur in a previous prototype demonstration in one private office. If ALL of the following conditions exist, it is possible that luminaires controlled by a DaySwitch could be accidentally left on overnight:

- A wall switch controls the circuit;
- The DaySwitch controls ALL the same lights on the circuit;
- No occupancy sensor or automated sweep-off systems (time clock, building energy management systems, etc.) are in use.

DaySwitch Specification Decision Process

The DaySwitch is intended for use primarily as a low-cost retrofit product for spaces in which there is plentiful daylight and where manual switching of lights in response to daylight is not expected. Examples include large airport concourses, shopping malls, atriums, lobbies, glazed corridors, cafeterias, fitness centers, and lounges.

The installations at Rensselaer revealed several lessons that will assist a specifier in evaluating whether a space is likely to be suitable for retrofit with the DaySwitch. In addition to verifying the presence of daylight, specifiers must also consider many other features: building occupancy patterns and schedules, electrical circuiting patterns, luminaire and ceiling hardware, other lighting controls in use, and electric light levels.

A specifier should pose the following questions in order to identify inappropriate locations for the DaySwitch. This list assumes retrofit conditions, as well as side-lighting (not skylights).

Does the space have plentiful daylight? *(see evaluation technique, page 7)*

- If no, then the DaySwitch is unsuitable for the site.
- Are there special tasks that require closed window blinds? Example: LCD projector, computer display screens, etc. If so, occupants will take measures to block entering daylight, thus the DaySwitch would be unsuitable.

Is the space occupied (and therefore electrically illuminated) during the day?

- If the space is primarily vacant and not electrically illuminated during the day, savings will not be realized from the DaySwitch.

Does the electric lighting system provide too much light relative to the requirements of the task?

- If yes, consider permanently reducing electric light levels to save energy at all times (e.g., removing lamps, or using lower ballast factor ballasts). If space is over-lighted electrically, present DaySwitch programming will not turn off lights as frequently,[5] and thus energy savings will be minimized, particularly in the darkest winter months.

Is there a wall switch that is easily accessible to the occupant(s)?

- No switch: good opportunity for the DaySwitch.
- Switch available: benefits of the DaySwitch may be reduced, or eliminated because occupants may independently decide to turn off lights; therefore, device payback would be longer because energy savings due specifically to the DaySwitch would be reduced.

Is there another energy-saving lighting control device on the circuit?

- Occupancy sensors (which may be required by code) may already be providing energy savings during the daytime. Additional investment may not be warranted.
- Time clocks or other energy management systems are commonly used after dark, and thus would not likely undermine savings from the DaySwitch; furthermore, they may prevent accidental night lighting (see page 5).

What is the electrical distribution pattern?

- Circuiting runs perpendicular to windows. Each luminaire will require a separate DaySwitch. Alternatively, the electrician can re-wire the space so the lights closest to the windows are controlled by one device; this will increase installation cost.
- Circuiting runs parallel to windows. One DaySwitch can control an entire row of lights parallel to the windows; thus, the wattage impact increases without increasing installation cost. However, this plan would not allow individual adjustment in the event that one worker wants to close blinds and needs to turn on electric lights over just one desk.

How many watts will the DaySwitch control?

- There is a limit to the wattage that can be switched with the present design of the DaySwitch. The maximum load per device in this prototype design is 600 watts. The greater the watts able to be controlled by one DaySwitch, the greater the energy savings; thus, a shorter payback period.

What is the light distribution from the luminaire?

- For luminaires with a direct/downward distribution, the DaySwitch will function properly, even with a small quantity of controlled lamps.
- With a diffuse distribution (especially indirect), the DaySwitch will not function properly if controlling a small quantity of lamps. The DaySwitch should control enough lamps to make a substantial contribution to electric illuminance directly beneath the sensor.

Does the luminaire have sufficient space to contain the DaySwitch?

- Some luminaire wireways do not have sufficient room for additional electronic devices such as the DaySwitch in its current design. Thus, additional wiring and junction boxes may be needed, which increases installation cost, and may also have an unsightly appearance.
- At this installation, several sites had to be eliminated, or additional wiring and junction boxes were required, due to this issue. (Future DaySwitch housings may be redesigned to address this issue.)

What energy rates are applicable at the site?

- The higher the rate charged by the electric utility, the shorter the payback period. Peak demand charges should be considered as well.

For retrofit, actual usage patterns and building conditions should be evaluated on-site, and the DaySwitch recommended only on a case-by-case basis. The cost of site evaluation should be included in payback calculations, similar to other building-rating exercises (e.g., HVAC evaluations). For new construction when site visitation is not possible, follow the guidelines above to identify suitable sites.

5 A future version of the DaySwitch could incorporate adjustments for overlighting.

Promising Space Types for Use of the DaySwitch

Based on the experiences at the Rensselaer demonstration, the types of spaces most suitable for the DaySwitch, based on space type and typical occupant operating patterns, are listed below. These assume good daylight availability.

- **Best: Public spaces.** Typically, lights in these areas are left on all day with no clear responsibilities for (or ability to) perform manual switching. As a result, public spaces with plentiful daylight are the best opportunity for savings with the DaySwitch.
- **Sometimes: Open-plan offices.** When many people occupy a work space, lights may be left on unnecessarily during the day for long hours of use, thus providing a good opportunity for savings with the DaySwitch. However:
  - Occupants may object to automated control devices, or may have complicated preferences.
  - Occupants may use blinds to ensure visual comfort and task visibility, which reduce daylight availability.
- **Use with caution: Private offices**
  - The number of luminaires able to be switched is likely to be small, thus reducing the potential energy savings. It is important to consider potential wattage reductions before specifying the DaySwitch.
  - Hours of use may be shorter (compared to an open-plan office), thus reducing the potential energy savings. It is important to consider hours of use before specifying the DaySwitch.
  - The occupant may conscientiously turn off lights at the wall switch on sunny days; this reduces the opportunity for energy savings from the DaySwitch.
  - The occupant may use blinds to ensure visual comfort and task visibility, thus reducing daylight availability.
  - The occupant may object to automated control devices or may have complicated preferences.
  - Luminaires controlled by both a wall switch and a DaySwitch may encounter accidental night lighting.

Recommended Field-evaluation Technique

To determine if the DaySwitch is suitable for retrofit at an actual site, the following steps are recommended:

- Visit the site at a time of day in which one would expect to be able to turn off the lights.
- Position an illuminance meter horizontally at the workplane height, directly under the location where the sensor will be installed.
- Verify that daylight is present in quantities 2.5 to 3 times higher than electric light alone.
  - It is not necessary to return to the site at night; one can measure illuminance with the lights on, then turn off lights and measure daylight only. The difference is the illuminance from daylight.

There were several Rensselaer demonstration sites that would NOT have passed this test, and thus had no energy savings from the DaySwitch. In order to pass this test, a site would need both plentiful daylight and moderate (not over-lighted) electric light levels.

Findings

- The DaySwitch worked as intended: It automatically switched off lights when sufficient daylight was available.
- Commissioning worked as intended, requiring less than 30 seconds per site.
- The DaySwitch provided the most energy savings in large open spaces with plentiful daylight, little or no blind use, minimal window tinting, and no wall switch available.
- Private offices showed little or no energy savings because of minimal daylight availability (blinds, window tinting, obstructions), low wattages, short hours of occupancy, and manual operation of a wall switch. Some private offices at Rensselaer were over-lighted, thus reducing ability to turn off the lights (see below).
- The higher the electric light levels, the greater the amount of daylight required in order to switch off the lights. This impacts energy savings opportunities.
- Feedback from most occupants was generally neutral or positive. However, some private-office occupants objected to automatic switching of their lights.
- The DaySwitch housing could be made smaller or an elongated shape to fit into smaller spaces inside the luminaire. Alternatively, it could be built to connect outside a luminaire or junction box.
- Sensor location was a source of confusion for the electricians. Electricians needed more guidance about location and mounting procedure.
- Potential specifiers of the DaySwitch should verify that daylight will be present in quantities 2.5 to 3 times higher than that of the electric lighting alone.

Current product status

- Several manufacturers are in negotiation to commercialize the DaySwitch.

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Field Test DELTA evaluates new energy-efficient lighting products to independently verify field performance claims and to suggest improvements. A primary goal of the Field Test DELTA program is to facilitate rapid market acceptance of innovative energy-efficient technologies.

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