

# Daylight Dividends **CASE STUDY**

Reference and Information

**Harmony Library  
Fort Collins, Colorado**

## **Daylight Dividends Case Study**

Location ..... Harmony Library  
Front Range Community College  
4616 South Shields Street  
Fort Collins, Colorado 80524

Completed ..... April 1998

Architect ..... Davis Partnership P.C., Architects

Electrical/Mechanical Designer ..... Cator-Ruma Associates

Daylighting Design ..... Steve Ternoey, LightForms

Utility Contact ..... Gary Schroeder, Fort Collins Utilities

Library Contact ..... Ken Draves, Branch Manager

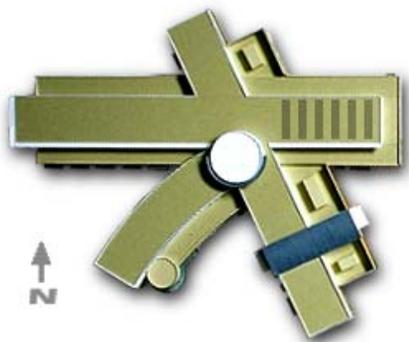
*Daylight Dividends promotes the effective use of daylighting strategies in nonresidential buildings. Part of this effort focuses on impartially evaluating the use of daylight in different building types, reporting those results so that others considering daylighting can see what works and what does not.*

*The Lighting Research Center (LRC) and Daylight Dividends sponsors wish to thank the following individuals for their assistance in the evaluation of Harmony Library: Gary Schroeder and Phil Swartz, Fort Collins Utilities; Ken Draves, branch manager, and his staff; Leonard Kiel, Dennis DeRemer, Duane Risse, Teri Asmussen, and Thomas Gonzales, Front Range Community College; and Judie Porter, Architectural Energy Corporation.*



*“I’ve always enjoyed coming to the (Harmony) library because it is bright. I live in a townhouse that doesn’t have windows on the connecting walls, so I love the sun shining through. To me, it is cheery.”*

*—Library patron*



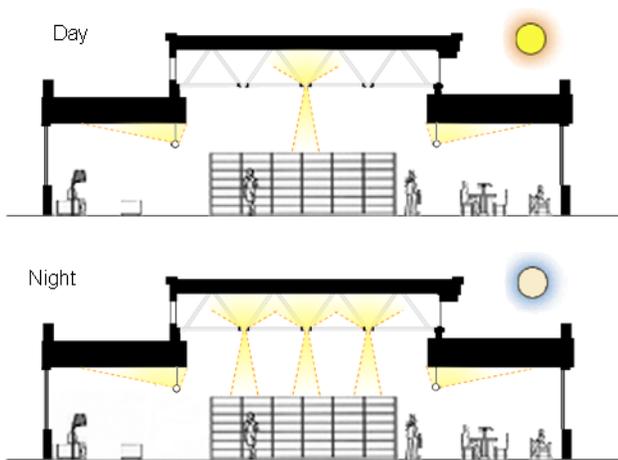
Plan view

In 1998, Harmony Library opened its doors to the citizens of Fort Collins, Colorado, and to the students of Front Range Community College. This case study documents how thoughtful integration of architectural elements and electric lighting can result in good daylighting design.

### **Site Background**

Fort Collins is a city with a high level of awareness about energy efficiency and daylighting. The town is the home of Colorado State University and is known for having a predominantly sunny climate. Fort Collins Utilities acts as a catalyst for daylighting implementation by providing design assistance for significant new construction or major remodel projects. This design assistance program provides energy expertise and helps pay extra costs for daylighting specialists or HVAC consultants.

Harmony Library, located on the corner of two main streets, serves the citizens of Fort Collins and students enrolled at Front Range Community College. In addition to the traditional library functions, students can be seen studying, working collaboratively on projects and using laptop computers.



By day, the outer luminaires are switched off in response to daylighting levels. As evening approaches and daylighting diminishes, outer luminaires switch back on.

## Design Strategy

This evaluation focuses on the main public areas in the library that use daylighting, including the main bookstacks, public study areas, periodicals, and children’s bookstacks.

The daylighting design was part of an integrated, whole-building approach intended to provide a high-quality library environment with low operation and maintenance costs. Daylight integration started with the choice of building orientation and shape. The long, narrow spine of the main room takes advantage of daylight. Most windows face north and south, which facilitates shading of direct sun. Daylight penetrates deep into the central part of bookstacks from upper clerestory windows.

Although the clerestory design was intended for north-south orientation, it was also used to a limited extent in other exposures. This created some complaints of sunlight penetration at certain times of year (see “Survey Results” section).

Clerestory glazing is shaded by overhanging roof eaves and neutrally-tinted glass (22% visible transmittance). Spaces along the perimeter of the main spine receive daylight from windows. Window shading is provided

*“The amount and type of light in here makes the library a very comfortable, inviting place. There is always plenty of natural light and never any harsh blue/white light.”*

*—Library patron*

by perforated overhangs, manually-operated perforated roller shades, and neutrally-tinted glass (17% visible transmittance). The perforated overhangs were originally intended to form a continuous line above windows, but were ultimately shortened (see photo, page 10). Although these segmented overhangs do allow shafts of sun to enter the library, there were no major complaints from patrons. (See “Survey Results”)

Bookstacks are oriented perpendicular to the windows, so that both sides are free from shadows. Several of the lower shelves are angled for better visibility and access. Reflective, off-white painted walls and ceilings promote light interreflections.

The result of these integrated efforts is that daylight is uniform and pleasant, and free from uncomfortable glare. Patrons commented that the space feels open and cheerful.

Harmony Library was constructed to incorporate the advantages of daylighting at a price comparable to standard library facilities (\$97/ft<sup>2</sup>).



Daylight in the bookstacks is diffuse and free from shadows.



Daytime



Evening



Adjustable indirect luminaires provide general lighting along the periphery.

## Electric Lighting Strategy

Electric lighting at Harmony Library is closely integrated with spatial and temporal patterns of daylight; luminaires are aligned with clerestory windows and are switched off in response to daylight.

General lighting is provided by direct-indirect luminaires custom-built on site. The typical luminaire housing spans the 16-foot (4.9 m) distance between structural trusses. Within the housing are linear fluorescent strip lights, two lamps in cross-section. Paracube louvers prevent glare by blocking view of the lamps from below.

To provide for future controls flexibility, general lighting in the “Children’s Place” is equipped with dimming ballasts. This area is currently operated in on/off mode like the general lighting in the rest of Harmony Library.

Other general lighting is provided by adjustable, indirect lighting in the lower ceiling areas, adjacent to view windows. This luminaire type is not turned off in response to daylight.

General lighting at Harmony Library is intended to provide a low ambient illuminance, and is augmented as needed by task lighting. Table lamps and floor lamps use a 13-watt, pin-based, compact fluorescent lamp, a glare protection shield, and an innovative timer to auto-

automatically turn off the lamp two hours after being turned on. This allows librarians to focus on the task of managing the resource collection rather than turning off lights. These task lights are operated independently of the daylighting control system. Other task lighting is integral to the study carrels. Two-foot long T8 fluorescent lamps are switched locally by occupants. These lamps do not have automatic control switches.



## Control System

The development of the lighting controls scheme for Harmony Library was a complicated process. The initial control scheme did not meet the design intent and was very complex for users. After a year of occupancy, the initial system was upgraded. The city utility provided an energy services staff person to champion the development of the new control system. This person became a familiar sight at the library, acting as an intermediary between controls manufacturers and building occupants.

*“I study in here all the time and I’ve never had trouble with the light levels. Please don’t change anything!”*

*–Library patron*



*Pushbuttons are programmed to operate lighting scenes for Opening, Public, Pre-Shutdown, Custodian, and Night.*

The new lighting control system has two main components: a relay-based automatic switching system (PLC Multipoint) and a lighting scene module (Triatek). The lighting scene module has “if-then” logic that integrates information from the pushbuttons and from the PLC Multipoint’s photosensor, timeclock, and sweep-off functions.

Lighting scene functions are accessed through pre-programmed buttons. Lighting scenes are manually turned on, and relate to typical uses of the library at various times of day (Opening, Public, Pre-Shutdown, Custodian, and Night). Scenes are automatically switched off according to the programmed schedule.

The “Custodian” button is an important refinement of the lighting controls system. This device allows lights to be turned on after hours, but only for a limited amount of time. Lights in the library late at night would be very conspicuous to passing citizens of Fort Collins; it is important that the lighting reinforce an energy-efficient image by being off at night. A key switch is provided to turn on all lights for maintenance checks or emergencies.

The lighting control system can be reprogrammed to change which luminaires are turned off in response to daylight. For instance, in the Children’s Place, a higher daytime light level was desired, so the system was reprogrammed to leave outer luminaires on while the inner luminaires are switched off.

Most of the photosensor-controlled general lighting operates from non-dimming ballasts, thus minimizing the cost of hardware.

The photosensor is located on the roof facing north. The system operates in an “open loop” configuration, receiving input only from daylight.

After persistent fine-tuning of the lighting controls system, the building staff are now satisfied with the functioning of the system.

LRC researchers asked for feedback about ease of commissioning of the lighting controls system from the main person responsible for the system, Gary Schroeder, energy services engineer for Fort Collins Utilities. He explained that he would install this type of system in future projects and would consider incorporating simplifications for some of the buttons. At this type of facility, the energy savings for

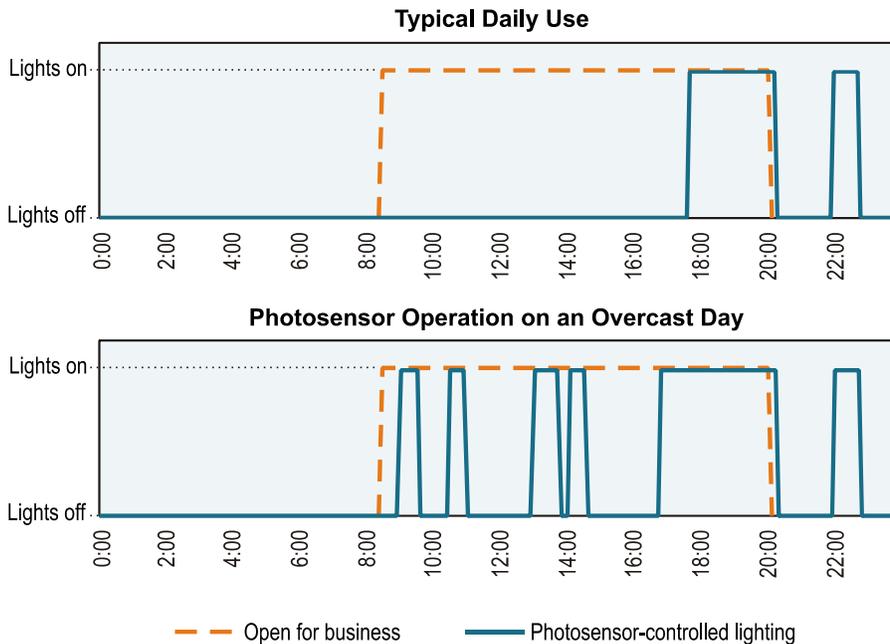


*The roof-mounted photosensor faces north.*

having five types of buttons may not justify the increased commissioning complexity. But it is certainly valuable to the people at this facility to have pre-programmed buttons for the typical daily patterns of use.

## Photosensor Operation

LRC researchers monitored the typical operation of photosensor-controlled lighting circuits during the month of April 2004 (see “Energy Savings” section). On most days the photosensor kept the lights off



all day, until between 5 p.m. and 7 p.m. Most days during the week, the library is open from 8:30 a.m. to 8 p.m. On weekends, the library is operated on a reduced schedule, during which time there is typically enough daylight for the photosensor to keep lights off for the entire day.

Researchers noted that some overcast days showed intermittent on/off cycling, but this only happened for 5 of 31 days of monitoring during one of the more cloudy times of the year (April). There were few complaints about lights frequently turning on or off.

## Survey Results

The LRC visited the facility in April 2004. Patrons were approached to give their opinions of the lighting in a survey. Nearly 40 patrons agreed to complete the survey. Questions on the survey concerned impressions of brightness and darkness, visual comfort of the windows, and comparison to other libraries.

Nearly all respondents (95%) thought there was “never” too much light. This shows that glare from direct sun and electric luminaires is usually well controlled (see “Staff Interviews” for exceptions).

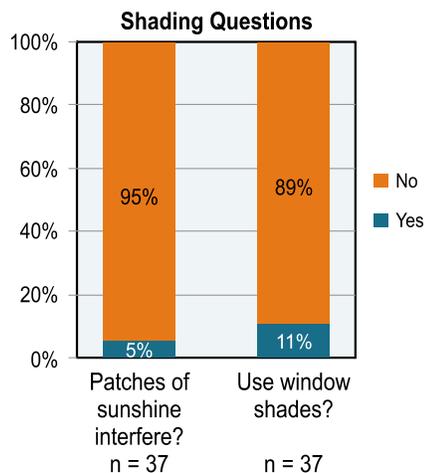
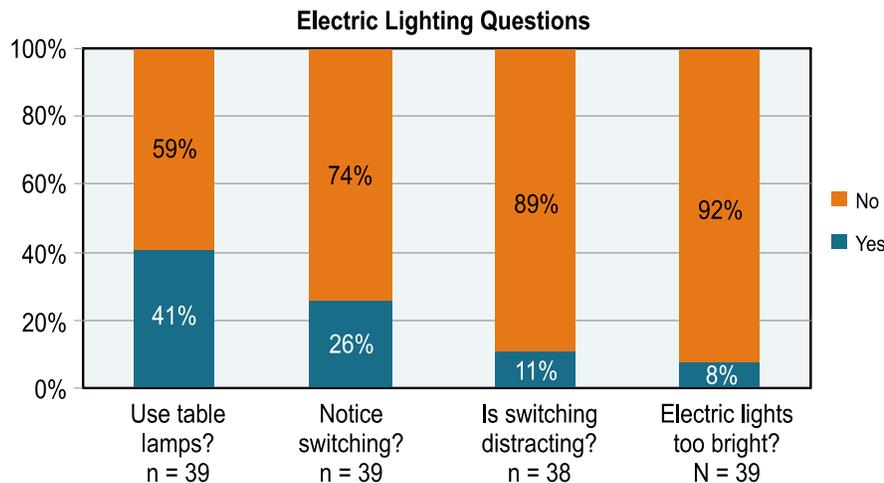
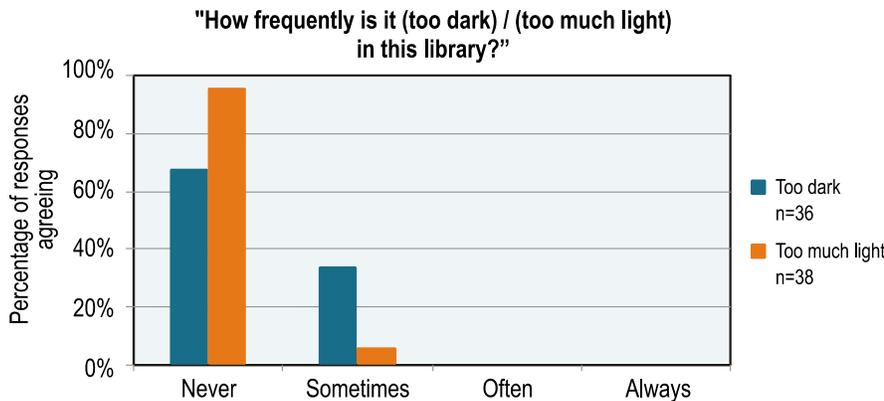
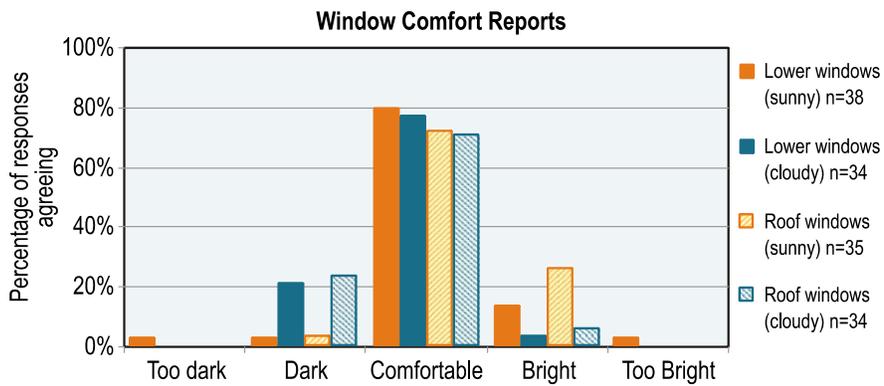
Over half of the respondents thought the library was “never” too dark, but about a third thought it was “sometimes” too dark, commenting “later in the day (it is sometimes dark),” “nighttime it’s a little too dark,” and “center areas are not well lit.”

Illuminances on some vertical surfaces at Harmony Library were less than the 300 lux (30 fc) recommended by the Illuminating Engineering Society of North America (IESNA) (see “Photometric Measurements” section for more information).

Low-transmissivity windows were widely considered comfortable to look at, both on lower and upper clerestory windows, and in both cloudy and sunny conditions. (Subjects were asked to leave the answer blank if

*“(The lighting at Harmony Library) is better than the library at Colorado State University...it’s like a dungeon in there... This lighting is, like, the greatest!”*

*—Library patron*



they had not experienced more than one weather condition.)

A few people thought the windows were “dark” on cloudy days, or “bright” on sunny days; as shown in the window comfort graphic, there was a slight shift in opinion with weather changes. One patron noted, “Sometimes when the sun is not out it can be [too dark], but mostly there is good light in here.” Another responded, “When cloudy it is dark; makes you want to take a nap.”

Most patrons did not complain that patches of sunshine interfered with library use. Few found the need to adjust the window shades.

Almost half of the patrons surveyed said they use the table lamps. One library patron commented, “The table lamps are a nice, functional touch. I don’t know of another library that has these.” Another patron added, “When I am here late, especially at the side desks [it can be too dark], but the lamps work well.”

Although a quarter of respondents said they notice when the lights automatically switch on or off, less than half of those people find this switching distracting.

Very few people considered the electric lights too bright.

Overall, the lighting of Harmony Library was well liked by patrons; compared to other libraries, about half of the patrons thought the lighting was “about the same,” and the other half thought the lighting was “better.”

## Staff Interviews

LRC researchers interviewed five library staff members to further understand acceptance of the daylighting at Harmony Library.

Librarians heard comments from patrons that the space appears welcoming, open, and “not oppressive.” The staff found that the daylight and electric lighting system provides adequate illumination in most areas.

One librarian commented that some parts of the audiovisual media shelves are too dark at night. This area is illuminated by indirect adjustable luminaires that are not designed to direct light down to the lowest surface. To compensate, librarians turn on nearby floor lamps.



*On the northwest side of the Children's Place there is insufficient shading for some times of day. One clerestory window allows a shaft of sun to penetrate deep into the space where librarians are stationed.*

Two librarians interviewed by LRC are stationed in the west-facing "Children's Zone." They both pointed out that a shaft of sun enters the space during late afternoons in the spring and fall.

The branch manager librarian had a philosophical outlook about the occasional western shafts of sun: "I (actually) like it because it reminds me that we are here on earth. It's ok to be uncomfortable for a few minutes."

Two other librarians commented that some patrons have complained about occasional afternoon shafts of sun that interfere with the view of laptop computer screens. Patrons have been seen changing their posture or seating location to improve viewing conditions. LRC observed a shaft of light entering the

main bookstack area from the western side, as the sun set.

A few librarians commented about the automatic switching of lights in response to daylight. One said that some weather conditions caused the system to switch on and off repeatedly. Researchers noted occasional on/off switching while monitoring energy use (see "Photosensor Operation" section). One staff member thought that the on and off set points do not always seem logical, but switching was not a major concern of the staff.

One librarian pointed out that switching is noticeable when the sky suddenly becomes dark. Another pointed out that patrons feel confused when the lights turn off, and sometimes they ask staff whether the library is closing.

Other comments from library patrons included:

- "If I'm working on my laptop near the windows in the afternoon, it is hard to see."
- "Sometimes it's gloomy, but not dark enough to trigger the lights on."
- "(The switching) is noticeable, but people are not put off by it."
- "People don't complain, but are aware."

*"In [the Children's Place] sometimes the sun sneaks through and hits librarians in the eyes."*

*-Librarian*

Window blinds are not critically important to the use of Harmony Library. Librarians have seen some patrons using the perforated roller shades. The blinds are so well integrated with south-facing windows that one librarian didn't realize the blinds were available. These comments demonstrate that the architectural features successfully provide the majority of shading.



*The west-facing clerestory allows shafts of sun to enter.*



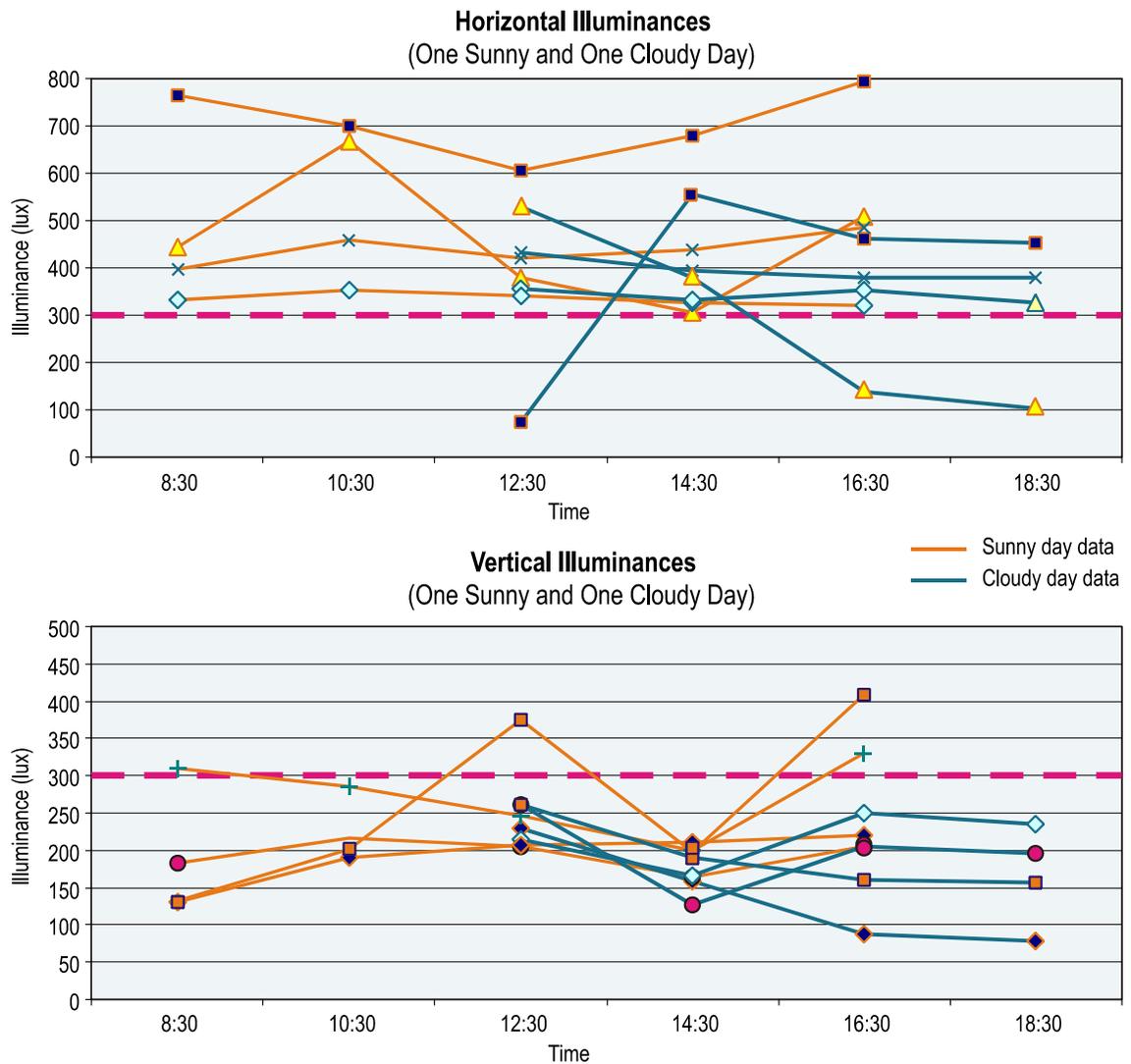
*South-facing windows are shaded by perforated roller shades and perforated overhangs.*

## Photometric Measurements

To determine the degree to which the electric lighting and daylighting are integrated, LRC measured illuminances over the course of a sunny day and a cloudy day.

As shown in the graphs below, illuminances in most areas are well controlled over the course of the day. One exception is on the western-most edges of the building, when a shaft of sun penetrates deep in the stacks. This condition only lasts a few minutes, so although it may not make ideal archival storage conditions, it does not represent a failure of the controls system.

In general, horizontal illuminances at Harmony Library exceed the IESNA recommendation of 300 lux (shown as red dashed line below). Vertical illuminances typically were below these IESNA recommendations. This may explain why in some locations (e.g., media storage area) some librarians felt that the space was too dark.



*Illuminances (electric + daylight); each data line represents readings taken at various locations within the building. The dashed red line indicates the IESNA-recommended illuminance of 300 lux horizontal and vertical.*

## Energy Savings

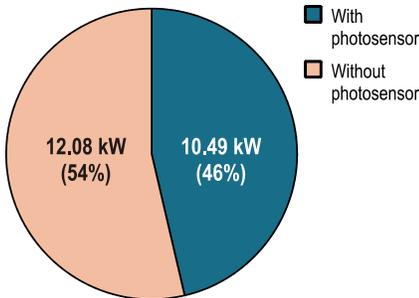
Nearly half of the lighting watts in the main areas of the library are turned off by a photosensor on the roof. With the help of the city utility, LRC technicians installed a panel-based metering device to monitor lighting energy use at Harmony Library. The metering device was installed on a photosensor-controlled circuit for five weeks from early April through early May 2004.

With the help of maintenance staff at Front Range Community College, LRC researchers collected a list of lamp types, lamp quantities, and ballast system wattages. The subsequent kW totals were multiplied by hourly totals from the panel metering device.

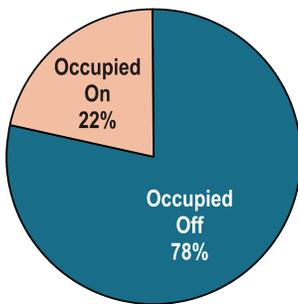
Photosensor-controlled lighting was turned on for only 22% of the operating hours. During the remaining 78% of operating hours, the photosensor-controlled lighting was turned off, allowing substantial energy savings (36%).

Fort Collins Utilities has noted that the lighting was designed to have a low connected load compared to typical lighting designs.<sup>1</sup> Therefore even when all lighting is turned on, lighting operation costs remain relatively low.

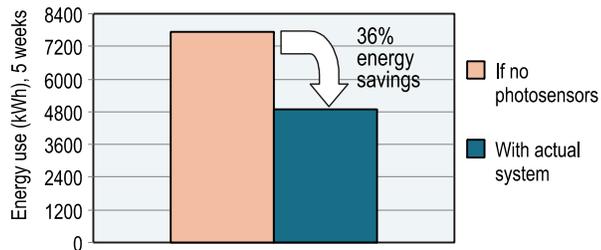
Photosensor-controlled Lighting Loads



Percentage of Operating Hours that Photosensor-controlled Lights Are Switched ON or OFF



Energy Savings - 5 Weeks of Monitoring



<sup>1</sup> Lighting power density in the evaluation area is estimated to be 1.19 W/ft<sup>2</sup>. Power density would increase to 1.26 W/ft<sup>2</sup> with all of the plug-load task lighting in operation. This compares favorably to the energy code under which the building was designed (ASHRAE 90.1-1989), which allowed 1.50 W/ft<sup>2</sup> for stack areas and 1.90 W/ft<sup>2</sup> for reading areas, not including plug loads. The actual power density also meets the stricter requirements of ASHRAE 90.1-2004, which limits lighting power density to 1.30 W/ft<sup>2</sup> and does include plug-load task lighting. The primary direct/indirect luminaires contribute 0.85 W/ft<sup>2</sup>, which drops to 0.37 W/ft<sup>2</sup> when photosensor control is in use.

## **Summary of Lessons Learned**

- The lighting and building design of Harmony Library provides a comfortable environment for staff and visitors.
- When a building is designed well, occupants do not need to rely on blinds to provide shading of direct sun.
- Task lighting is appreciated when the general lighting is designed to provide low ambient illumination.
- Even if only half the lighting load is controlled by photosensors, significant energy savings can be achieved without causing occupant discomfort.
- A shading design intended for north-south orientation should not be applied to other orientations without modification. West-facing clerestory windows may allow shafts of sun to penetrate deep into the space, causing glare and discomfort for patrons.
- Library patrons do not find dark window glass objectionable when the weather is predominantly sunny.
- Switching (as opposed to continuous dimming) is noticeable and sometimes confusing to new visitors (such as library patrons), but not offensive. In an environment not serving the public, switching may be even more acceptable.
- Switching (as opposed to continuous dimming) avoids the initial cost of dimming ballasts, but still can save substantial energy.
- A large public facility needs simple, pre-programmed buttons that allow lights to be turned on in scenes, but also automatically switched off according to a programmed time schedule. Developing a control system that will do both without integrating different manufacturers' controls products would help to simplify commissioning.

The following sources were used in this study:

- City of Fort Collins website: <http://www.fcgov.com/electric/harmonylib/index1.htm>
- Fort Collins Utilities and Burns Marketing Communications (some images adapted from originals)
- IESNA Handbook, 9th edition. Mark S. Rea, ed. 2000. Illuminating Engineering Society of North America, New York, N.Y.
- Weather information from Western Regional Climate Center and Colorado Climate Center

## About the program...

Daylighting, employed properly, reduces the need for electric light by introducing natural light into a building. **Daylight Dividends** was established to build market demand for daylighting as a means of improving indoor environmental quality; to overcome technological barriers to effectively reap the energy savings of daylight; and to inform and assist state and regional market transformation and resource acquisition program implementation efforts. More information can be found at:

[www.daylightdividends.org](http://www.daylightdividends.org)

The following organizations sponsor Daylight Dividends:

California Energy Commission  
Connecticut Light and Power Company  
Iowa Energy Center  
Lighting Research Center  
New York State Energy Research and Development Authority  
North Carolina Daylighting Consortium  
Northwest Energy Efficiency Alliance  
U. S. Department of Energy

Daylight Dividends is administered by:

Lighting Research Center  
Rensselaer Polytechnic Institute  
21 Union Street  
Troy, NY 12180  
(518) 687-7100  
[www.lrc.rpi.edu](http://www.lrc.rpi.edu)

Principal Investigator ..... Jennifer Brons  
Project Assistance ..... Sandra Vasconez, Peter Morante,  
Vasudha Ramamurthy, Howard Ohlhous  
Editor ..... Judy Thorpe  
Graphic Design and Layout ..... Dennis Guyon  
Illustrations ..... Vasudha Ramamurthy  
Photography ..... Jennifer Brons