Daylight Dividends
CASE STUDY

TomoTherapy Incorporated
Madison, Wis.

Daylight Dividends Case Study

Location ..... TomoTherapy Incorporated
1240 Deming Way
Madison, Wisconsin 53717

Completed 2003

Architect, Consulting Engineer,
and General Contractor ..... PLANNING Design Build, Inc.

Building Owner ..... The Gialamas Company, Inc.

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 and reporting those results so that others considering daylighting can see what works and what does not.

Daylight Dividends sponsors and the Lighting Research Center express their sincere thanks to the employees and officers of TomoTherapy and PLANNING Design Build as well as the staff of The Gialamas Company for their assistance in developing this case study.

This case study is unique in that it involves a tenant-occupied building that the designers and building owner agreed to design to take advantage of daylighting. PLANNING Design Build was the primary force behind the promotion of daylighting for the TomoTherapy building as a means of improving energy efficiency and helping to ensure occupant comfort.

The building's owner, The Gialamas Company, has a long history of producing high-quality buildings and is willing to take a long-term financial approach to building improvements. About 75% of Gialamas buildings employ some type of daylighting strategy.

Of the 70,000 square feet of floor space in this building, 12,000 square feet employ photosensor-controlled dimming. Within this daylit area, 22% of the lighting energy is saved due to the dimming system.

The absolute savings for the TomoTherapy facility averages 20 kilowatt hours per day because of the low lighting power density of one watt per square foot built into the design.

Background

TomoTherapy Incorporated has developed an innovative medical system to deliver conformal radiation therapy to cancer patients, designed to target radiation treatment to the patient's tumor while helping to limit damage to the surrounding tissues. This technologically advanced company, founded in 1997, has doubled in employment each year to a total of approximately 100 employees today. To house this growing company, TomoTherapy sought a developer and building designer that focused on quality and leading-edge technology. The result is a new facility that makes extensive use of windows to bring the outside into the workspace. The facility consists of office space on one and one-half floors and an assembly area on half the ground floor. As the evaluation of the TomoTherapy building was underway, Tomo-

The TomoTherapy Hi·Art System®

Therapy was expanding to occupy the third floor of their building.

The Gialamas Company has developed approximately 1 million square feet of Class A rental space in the Madison, Wisconsin area. Their development philosophy is to only construct buildings that they intend to own that are of high quality, efficiency, and maintainability. They have a sense of stewardship and sustainability that permeates the organization. A comment from their director of facilities sums up the Gialamas philosophy, "The sun is free, so let's use it." Building occupancy is high (over 95%) and tenant turnover is minimal, demonstrating that tenants value quality and are willing to pay the higher lease prices Gialamas buildings garner in the competitive Wisconsin office rental market.

> ***"The sun is free, so let's use it."***
>
> *–Gialamas facilities director*

Gialamas desire for quality, coupled with PLANNING Design Build's drive to improve building energy efficiency, produces buildings that incorporate daylighting, high-efficiency window treatments, and heating, ventilating and air conditioning systems that go beyond the norm. Add to this formula a tenant, TomoTherapy, who has a highly motivated workforce, and the TomoTherapy building was born.

Besides incorporating the daylighting design, the building employs a high-efficiency, direct-expansion cooling system with evaporative condensing. The building exhausts are tied together and sent through a heat wheel to recover heating and cooling energy that is used to temper the fresh air stream.

Design Strategy

The building orientation is predominantly along a north/south axis to fit onto the available land/site configuration. This causes the majority of the windows to face east or west. Some private offices on the first and second floors face either north or south. East- and west-facing windows present the greatest challenges to designers of daylit buildings because of the potential for glare problems in early morning and late afternoon.

Heavily tinted, low-e windows allow occupants to feel connected to the outside environment while reducing solar transmittance.

The window glass is all low-emissivity (low-e) insulating glass. The bottom majority of the windows or view windows are heavily tinted to reduce solar transmittance and glare. The heavy tinting reduces summer air-conditioning needs. This tinting also reduces visible transmittance. Solar transmittance is 14%; visible transmittance is 32% for south-, east-, and west-facing windows and 36% for north-facing windows.

The top sections of the windows are fitted with slightly clearer glass to allow daylight to illuminate the office and assembly spaces. Solar transmittance is 24% and visible transmittance is 60%. The *u*-value for all windows is 0.30 BTU/hr/ft²/°F.

Even with heavy tinting, glare on work surfaces, especially computer screens, is an issue in early morning and late afternoon on sunny days.

Blinds limit glare on work surfaces in early mornings and late afternoons.

Manual window blinds are employed to reduce glare. These blinds are drawn by the employees and reopened after the sun has passed by. Observations during the evaluation indicate employees do reopen the blinds in the office areas as soon as the sun no longer creates glare problems. However, some of the blinds in the assembly area remain closed throughout the day.

Lighting Strategy

The open office areas on the first and second floors employ direct/indirect Peerless lighting fixtures with a single T5, high-output (HO), 54-watt, 4100 K lamp. The ceiling height of ten feet allows for the use of these direct/indirect fixtures and provides good glare-free, even light levels for general illumination. The dominant activity in the open offices is computer work, with up to 80% of an employee's time spent on the computer.

General illumination levels logged over time and instantaneous readings indicate highs of approximately 120 footcandles near windows on sunny days to 17 footcandles in interior spaces or near the windows on cloudy days. Because of the lower illuminance levels and the desire by some employees not to use the overhead lighting system, task lighting is used by approximately 30% of the employees. Employees bring in their own task lights, which are all incandescent. Because of the higher-than-normal ceiling height and the use of T5 HO lamps, the number of lighting fixtures necessary for general illumination is reduced from more prevalent office lighting designs.

The rows of direct/indirect fixtures near the east- and west-facing windows are equipped with Lutron dimming ballasts controlled with a Lutron Microwatt control system and wall switches. The ballasts dim the lamps in response to the amount of daylight entering the space. A photosensor located near the east or west windows controls the row of lights near those windows. All remaining rows of light fixtures in the open offices are controlled with wall switches.

Open office areas use direct/indirect fixtures, each with a single, high-output T5 lamp providing workers with glare-free, even light levels.

Most private and semi-private offices have two recessed, 2' x 4' parabolic light fixtures with three T8, 4100 K lamps and electronic instant-start ballasts. These lights are controlled through a motion sensor with manual-on and automatic-off functions. The light level of each office can be set by controlling the number of lamps that are on. The office occupant can have zero, one, two or three lamps on. Corner private offices utilize the Peerless direct/indirect lighting fixture with a

The hallways use 26-watt CFL downlights which are usually off until evening hours.

single T5 HO, 4100 K, 54-watt lamp. These are controlled with the same wall switch, motion sensor and light level switch as the other private offices.

Hallways are lit with two-lamp, quad tube compact fluorescent downlight fixtures. Each compact fluorescent lamp is rated 26 watts. These lights are controlled via wall switches. Observations during the evaluation and data logged on lighting energy usage indicate these lights remain off until the evening hours.

The lighting in the first floor assembly area is industrial fluorescent fixtures with three T8, 4100 K lamps and an instant start, electronic ballast per fixture. These light fixtures are only controlled by wall switches. The lighting design produces a lighting power density of 1.0 watt per square foot, far below allowable energy codes.

Survey Response

More than 70% of TomoTherapy employees and officers participated in a lighting survey or interviews conducted by the Lighting Research Center. Interviews were also conducted with employees and officers of PLANNING Design Build, the building's architects, consulting engineers and general contractor, and with the director of facilities for the building's owner, The Gialamas Company.

According to TomoTherapy's president, the company is employee focused, and employee satisfaction is very important. The use of daylighting and the large window areas for people to be connected to the outside are important ingredients of employee morale. The facility manager at TomoTherapy expressed that the building is very comfortable (well lit, well air-conditioned, lots of windows) and the use of daylighting is "great," with building occupants using the electric lights sparingly.

Employees interviewed and surveyed all want to be seated near a window. Employees sitting near east- and west-facing windows are, however, concerned with glare from direct sunlight entering the building. The use of window blinds helps to control glare. The blinds are closed or partially closed when direct sunlight is present and reopened when the sun no longer shines directly into the window. The location of computer screens is critical to minimize glare on the screens from light entering the windows. Most people in the open offices use their computers in excess of 70% of the time.

Employees enjoy the outdoor views and ample lighting brought by the daylighting scheme.

One employee interviewed believes the view through the windows actually increases positive thinking. She believes the view to be as important as the daylighting.

Software engineers and computer programmers located in interior semi-private offices found the overhead lighting from the parabolic recessed

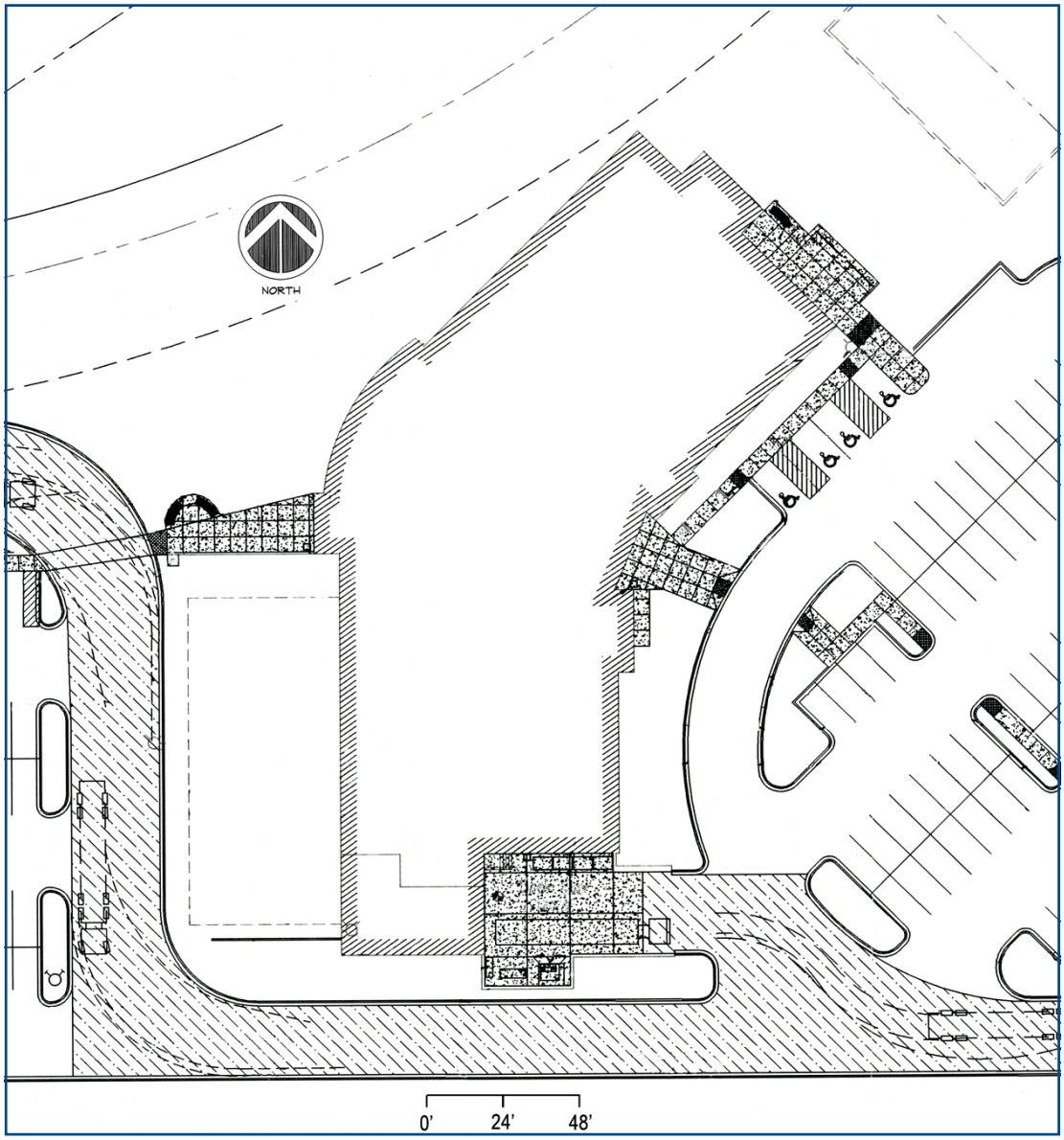
fixtures to produce glare. These employees usually keep the overhead lights off and use task lighting. Employees seated in the interior of the open offices accept the light levels.

In general, the employees believe the lighting within the TomoTherapy building is better than other places they have worked. Comments from survey participants include:

"In general, it is an excellent working environment."

"I like working with lots of windows for light."

"I 'love' the fact we can bring the outside into the workplace…it creates a healthy atmosphere."



Adapted from original image by PLANNING Design Build, Inc.

Building site plan

Light switches with built-in occupancy sensors enable 1-, 2-, or 3-lamp luminaire operation.

Ceiling-mounted photosensors monitor light levels within the office areas.

Maintenance Issues

Initial setup of the lighting control system did not present any problems. All maintenance within the building is conducted by Gialamas, the building's owner. Tenant satisfaction is important to Gialamas and good maintenance practices help to improve satisfaction. There was a high (75%) failure rate of the initial motion sensors. According to representatives of Gialamas, there appears to be a higher incidence of premature failure of the T5 HO lamps. Motion sensors and lamps that failed were replaced under warranty.

Data Logging

To understand the daylighting design effects on lighting energy use at TomoTherapy, the LRC installed data loggers to collect typical open office lighting levels and lighting energy use. Data was collected and recorded from May 18, 2004 to June 15, 2004.

A light logger was placed on an employee's desk approximately ten feet from the east-facing window. A second light logger was placed ten feet from the west-facing window. Illuminance levels include both daylight and electric light contributions. Light levels were recorded at two-minute intervals. To collect lighting energy levels, a recording ammeter was placed on the electrical circuit that fed the lights in the second floor, south end of the building, open office area and some of the hallways. This lighting was the only electrical load on this circuit. The recording intervals were six minutes apart, with the recording ammeter averaging the usage every minute between recordings.

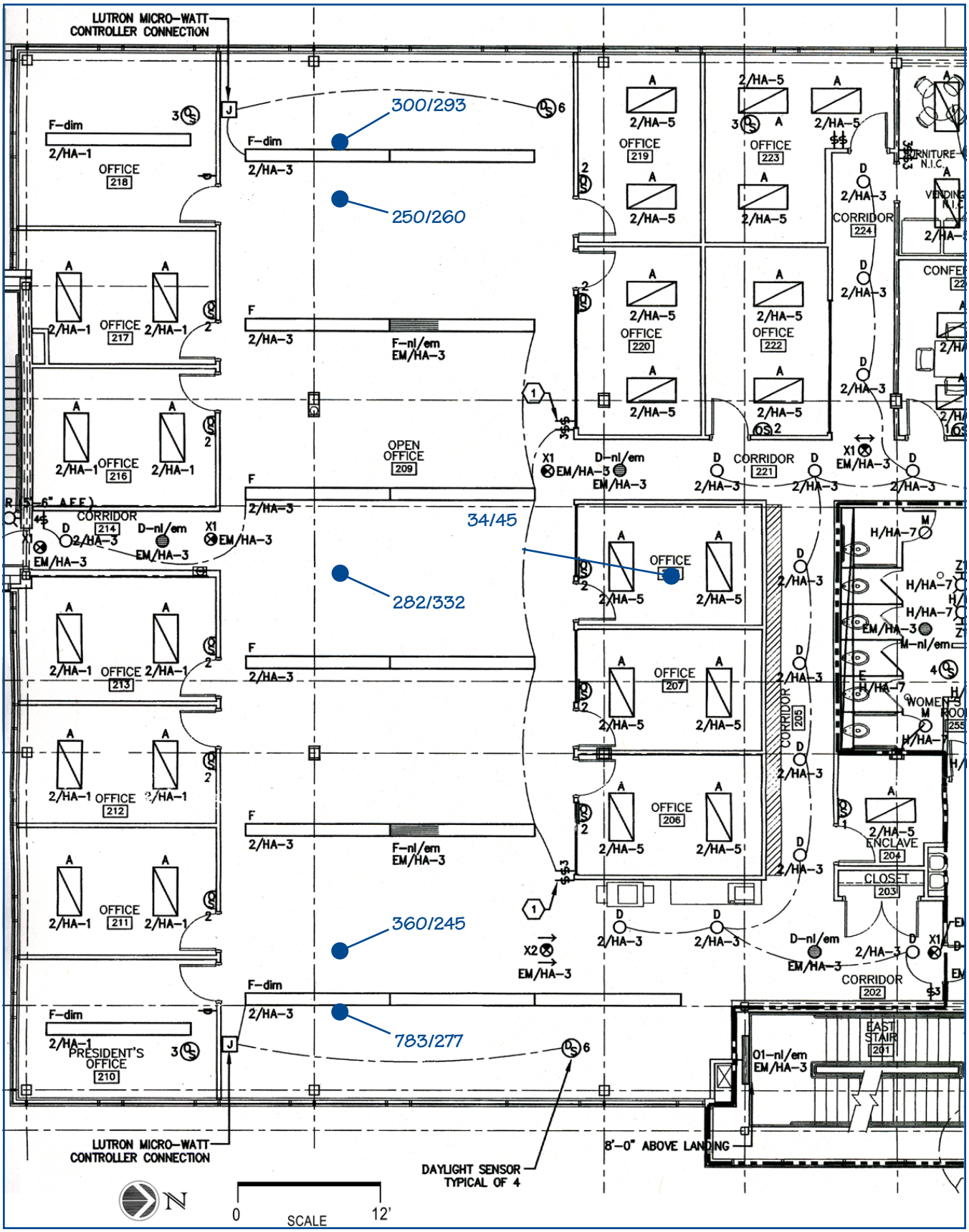
A weather station was also erected on the building's roof to collect temperature and solar intensity data. Researchers placed the station in a location where nothing would block or shade the radiometer from sunlight at any time during the day. Solar intensity and temperatures were recorded in two-minute intervals.

Table 1 shows an average sampling of the recorded results. Three days of sunny and partly cloudy conditions, selected randomly, and two days of cloudy conditions indicate the lighting energy saved due to the daylighting strategy employed.

Table 1. Lighting Data for Open Office Area—Second Floor, South Side

Weather	Average Daily Lighting Energy with Daylighting (overhead lights only) *kWh*	Average Daily Lighting Energy without Daylighting (overhead lights only) *kWh**	Average Daytime Room Lighting Levels Near East Window *lux***	Average Daytime Room Lighting Levels Near West Window *lux*	Average Hourly Daytime Solar Intensity *μ mol/m²/sec*
Sunny	21.1	26.8	347	275	1072.7
Partly cloudy	23.4	29.0	300	227	682.0
Cloudy	24.6	30.1	220	191	251.5

** Energy use based on connected lighting load.* *** 1 foot-candle = 10.76 lux*



Adapted from original image by PLANNING Design Build, Inc.

Illuminance measurements in an open office area and a private office, locations shown as ●. Two readings, taken on May 17, are shown in lux; the first reading was taken at 10:30 a.m. with partly cloudy skies/the second reading was taken at 1:45 p.m. with cloudy skies.

Summary of Lessons Learned

- Offices designed to low lighting power densities, like the TomoTherapy building, will not financially support a dimming system responsive to daylight levels. A less costly strategy would be to utilize an automatic on/off control scheme for the row of lighting fixtures along the windows. This control would respond to daylight levels, turning off the lights when the daylight level was sufficiently high. The lights would remain off until some predetermined, minimum lighting level was reached.
- Window tinting, even dark/heavy tinting, still allows some glare in the absence of internal shading. This is especially true with east- and west-facing glass in the early morning and late afternoons. Office building designers must make arrangements to eliminate/reduce glare. At a minimum, interior, manually operated shades or blinds must be provided so building occupants can control for any glare issues.
- Controlling the quality of daylight is difficult with large expanses of east- and/or west-facing windows. The potential for glare is great. If at all possible, building orientations should allow for north- and south-facing glass while minimizing east- and west-facing glass.
- Given a desire to be connected to the outside environment, employees will reopen manually operated blinds after the sun no longer produces glare through the windows. However, to ensure blinds are reopened, management must be diligent in reminding employees to open the blinds to take full advantage of the daylighting scheme.

- Within TomoTherapy, there is a strong desire of most employees to sit near a window. This is true even though employees realize there could be glare problems with their computer screens.
- The location of computer screens with respect to windows is critical in reducing glare. Computer screens should be at right angles to the windows. Some of the computer screens within TomoTherapy faced the windows. These screens had to be relocated on the employees' desks to avoid glare issues.
- Private and semi-private offices, where employees utilize computers for much of their workday, should employ direct/indirect or indirect lighting similar to the open office lighting plan. These would be preferred even over parabolic troffers, according to office occupants.
- Employees provide their own task lights. All of the task lights observed utilize inefficient incandescent lamps. If task lighting is needed, it would be better to have the employer provide these lights with compact fluorescent technologies.
- High-quality buildings can attract higher rental fees and maintain a high occupancy factor. Daylighting is considered part of the design of high-quality and highly desirable buildings by both TomoTherapy's building owner and the building's designer.

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

The following organizations sponsor Daylight Dividends:
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