DELTA

Portfolio

Demonstration and Evaluation of Lighting Technologies and Applications ▲ Lighting Case Studies

DAYLIGHTING IN WHOLE FOODS MARKET

Yonkers, New York

Volume 4 Issue 1

DAYLIGHTING IN WHOLE FOODS MARKET

Contents

Project Profile

Whole Foods Market® is a chain of over 300 grocery stores specializing in natural and organic foods. In 2012, DELTA evaluated a newly-built Whole Foods Market in Yonkers, New York, with skylights, clerestory windows, and a roof monitor that provide daylight. The store's daylighting allows the building management system to turn off half of the general lighting during the day.

Objectives

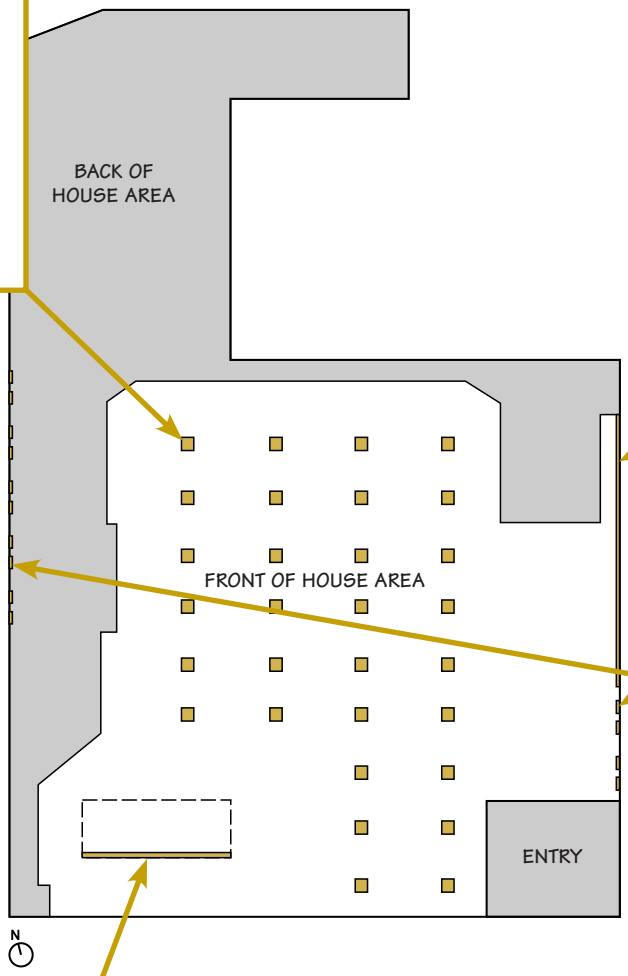
- Create a pleasant environment that incorporates daylighting to reinforce the image of the store
- Reduce electric lighting energy use by turning off half the general lighting when daylight is available
- Provide a low cost lighting control solution

Project Specifications

Daylight Design

Skylights. Located throughout the store. Translucent skylights, sized 4' x 4', spaced approximately 16' x 26'.
Visible transmittance (VT) = 0.52
Solar heat gain coefficient (SHGC) = 0.5

Café windows. East façade. Shading provided from horizontal exterior overhang and adjacent building.
VT = 0.65, SHGC = 0.6



Clerestory windows. Located in café (east façade) and stockroom (west façade), sized 4.5' x 4.5'. No external shading.
VT = 0.65, SHGC = 0.6

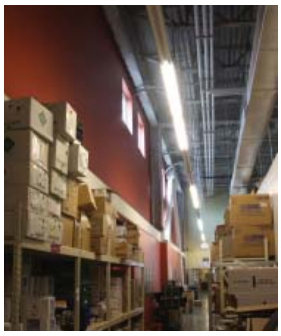
Roof monitor. Located above produce area. Tinted glass oriented vertically, facing south, sized 45' x 5'. No external shading. VT = 0.65, SHGC = 0.6

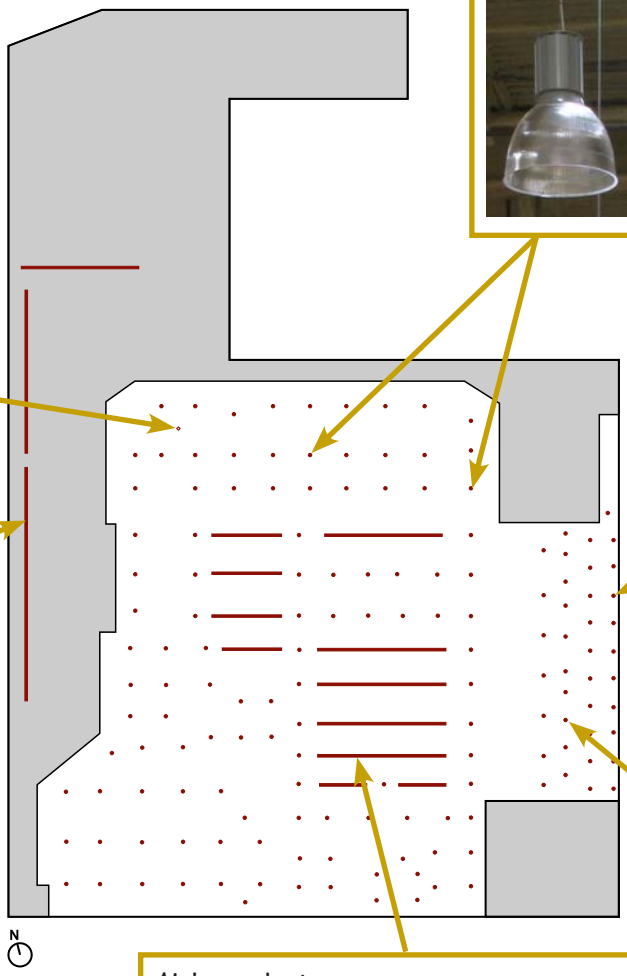
Electric Lighting Controlled in Response to Daylight

Several layers of light are switched off in response to daylight. The store uses additional lighting equipment (such as track heads and case lighting, not shown here) that is not controlled in response to daylight. One photosensor controls general lighting in the store, as well as the east-facing café and west-facing storage area.[1] The commissioning agent reported that the photosensor switches off lights when it measures greater than 55 footcandles (fc) at the skylight,[2] and switches lights back on when it measures less than 45 fc;[3] visual evaluation was used to establish these set points, rather than quantification of design illuminance on the workplane.

Photosensor. Mounted in one skylight well, facing upward. Open loop system, measuring only daylight (not electric light) feeds data to the building management system.

Stockroom pendants. Linear fluorescent strip lights, hung at 11'-7" above floor. Two 32 W, T8, 3500 K lamps in cross-section. Alternating 8' segments switch off in response to daylight.





Prismatic CFL pendants. Each with two 42 W, 3500 K CFLs, mounted 13'-1" above the floor. Alternating luminaires switch off in response to daylight.

Café window pendants. Glass pendant with one 18 W, 3500 K CFL, mounted at 7'-5" above floor. All café window lights switch off in response to daylight.

Café pendants. Each with one 42 W, 3500 K CFL mounted 9'-11" above floor. Alternating luminaires switch off in response to daylight.

Aisle pendants. Linear fluorescent pendants with white cross-baffles. Two 32 W, T8, 3500 K lamps in cross-section. Ballasts tandem-wired to switch off one lamp in cross-section in response to daylight.

[1] Use of a photosensor with a different daylight exposure (i.e., top-lighting) than the space being controlled (i.e., east/west side-lighting) was not intended; both photosensors installed for east/west side-lighting malfunctioned, thus the commissioning agent notified the client, and programmed the east/west circuits to be controlled by the skylight sensor.

[2] 1 footcandle = 10.76 lux

[3] DELTA believes set points were higher than these reported values, due to illuminance data (page 5) and luminaire switching behavior (page 9).

Photometric Results

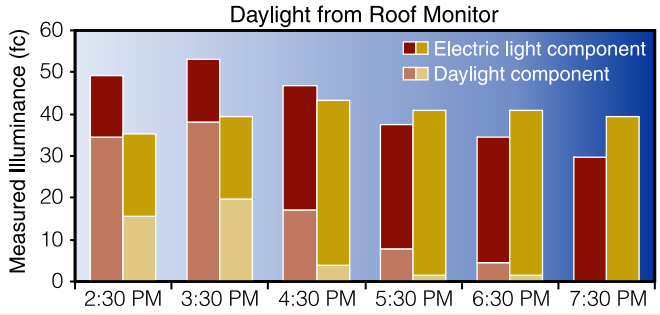
LRC measured illuminance in the four, publically-accessible areas of the store with photosensor-controlled general lighting. These areas included the produce area, an aisle, the prepared foods area, and the café dining area (see photos on page 6). LRC measured two points in each of these four areas. Measurements took place every hour on a sunny afternoon in May, as well as after sunset.

Because photometric measurements were a mixture of daylight and electric light, and because the electric lights eventually increased to full output, the measurements changed over the course of the afternoon.

As shown below, during the afternoon, horizontal measurements ranged from approximately 35 to 60 fc. In late evening, after sunset, horizontal measurements ranged from approximately 20 to 40 fc. Therefore, in these areas, even when electric lighting is switched to 50% output during the day, use of daylight provides higher light levels than after dark (when electric light is operated at 100% output).

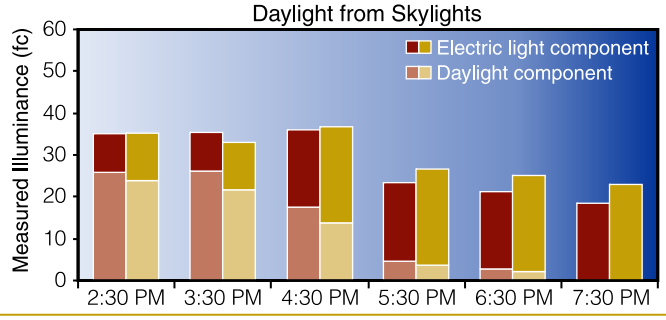
Vertical measurements in the aisle were 20 to 40 fc during the afternoon with electric light at half output. When the lights turned on to full output, vertical measurements increased to 35 to 50 fc in the aisle. In late evening, vertical illuminances in the aisle tapered off to 20 to 50 fc.

Produce Area



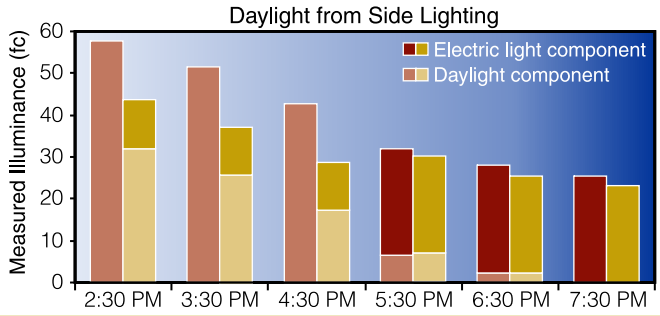
Point A
Point B

Prepared Foods Area



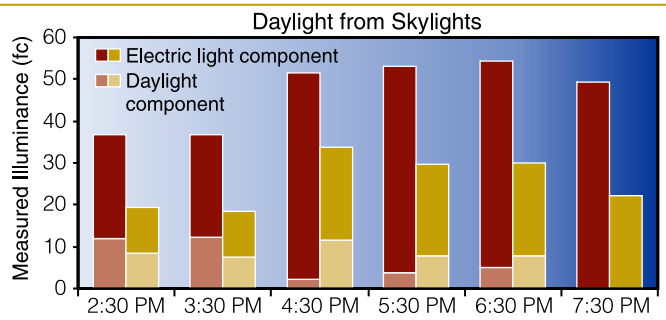
Point A
Point B

Café Dining Area



Window Table
Inner Table

Aisle (vertical)



Upper Shelf
Lower Shelf

Questionnaires: Customers and Employees

LRC researchers administered questionnaires to 88 customers and 18 employees in the four, publically accessible areas of the store with photosensor-controlled general lighting. Electric lighting was allowed to operate normally; thus, it was sometimes at half output and sometimes at full output. Most of the customers and employees answered the questionnaire during the daytime.

"Feels like outdoors in a market. I like the natural light."

– Customer

"Gives an outdoorsy feel."

– Customer

Café Dining Area

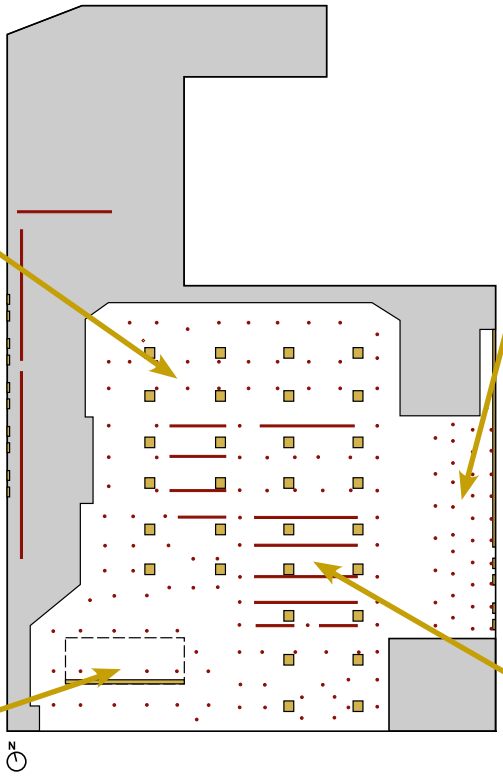
Prepared Foods Area

"Not as glaring as other stores. It's less lit than usual, but it's adequate."

– Customer

"We like that it's a little dark in here. It's nice and relaxing."

– Café customer



Produce Area

Aisle

Customer Results

Most customers (73-87%) agreed that the light in these four parts of the store is comfortable. Most agreed that the light makes each part of the store both easy to see (67-91%) and attractive (53-86%). Ratings for the prepared foods area were the least emphatically positive, perhaps because 40% of customers found it to be "too dim" or "slightly too dim." In terms of brightness, most customers (74-90%) found the three other areas neither too bright nor too dim.

"Can't see sugar and cream for my coffee."

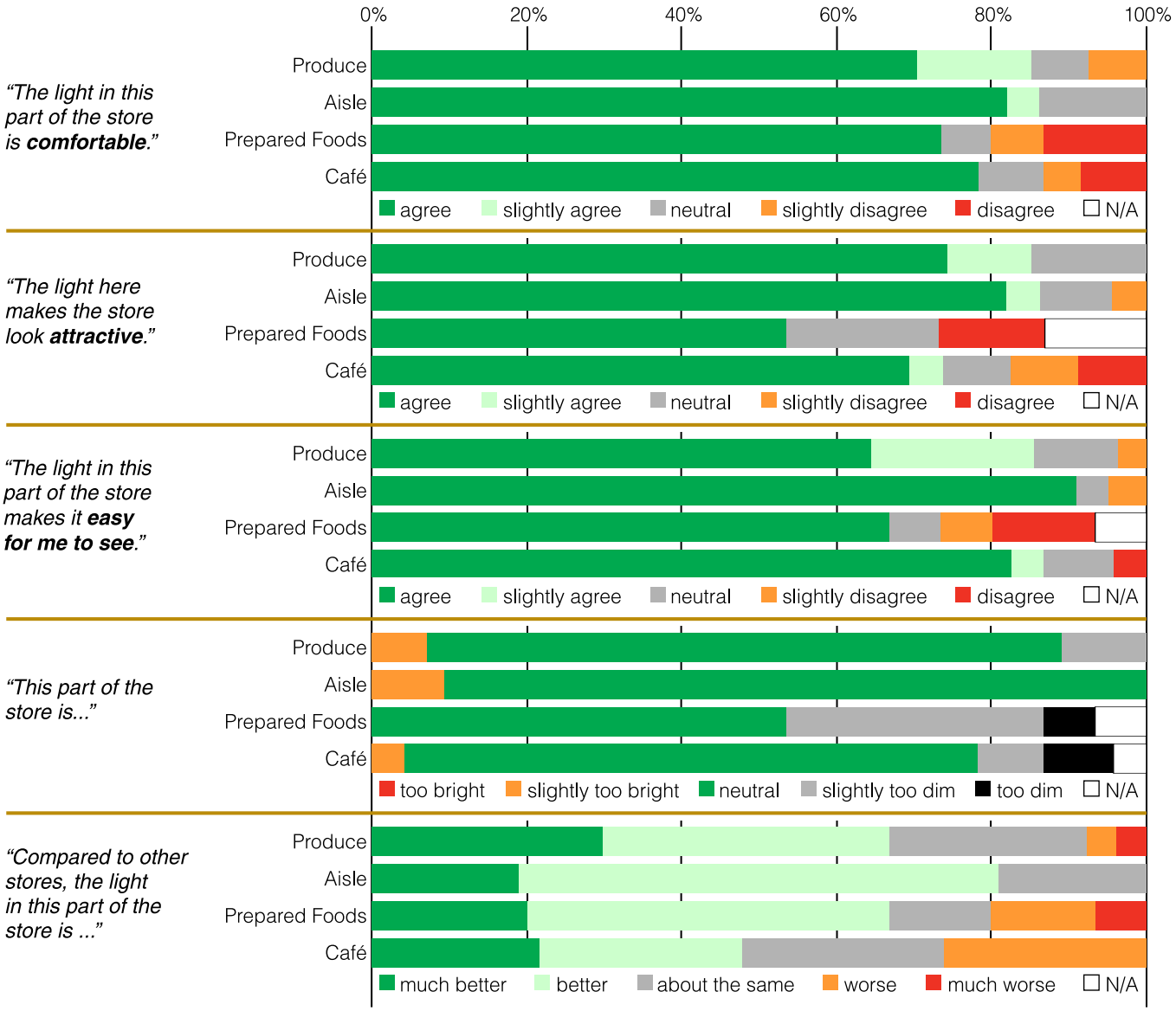
– Café customer

Overall, most customers (48-81%) thought the light was "better" or "much better" than other stores. These results show that the customers do not generally mind that some electric lights are turned off when there is daylight. This can be attributed to the fact that many of the display cases have separate, integral accent lighting that is not controlled by the photosensor.

"I sometimes think other stores are over lit. This is just right."

– Customer

The LRC administered the same questionnaire at another Whole Foods Market similar in size and lighting design, but without skylights. The customer ratings were not significantly different between these two stores.



Survey responses: n = 15-28

Employee Results

The majority of employees reported that all four spaces are comfortable, attractive, and easy to see. In the two areas where there is direct sun (café dining area and produce area), employees reported that the sun is good for displaying the products.

"It's a happy medium, because if it gets too dark, the lights automatically come on."

– Employee

Because employees observe the store at many times of day, the questionnaire asked employees how often they found the space too bright or too dim. In the aisles and café, they indicated that it was "rarely" or "never" too bright. Over half the respondents "sometimes" found the produce area to be too bright. A third of the respondents "sometimes" found the prepared foods area to be too bright. About a third of the respondents "sometimes" or "often" found these four areas of the store to be too dim.

"I like the fact they save energy with sensors so it keeps the lighting even."

– Employee

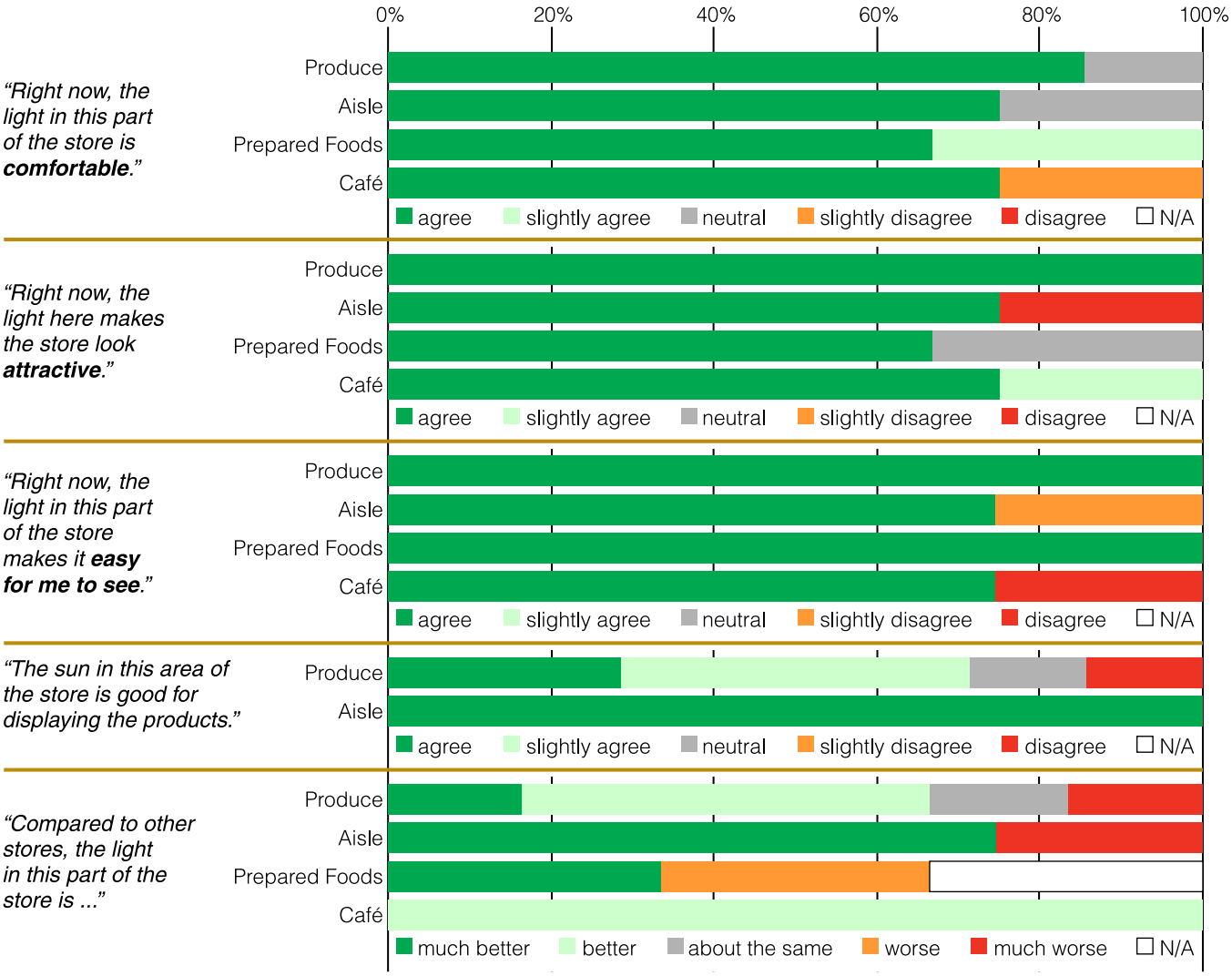
Compared to other grocery stores, the majority of the employees reported that the light was "better" or "much better" in three of the four spaces evaluated.

"No complaints from any customers."

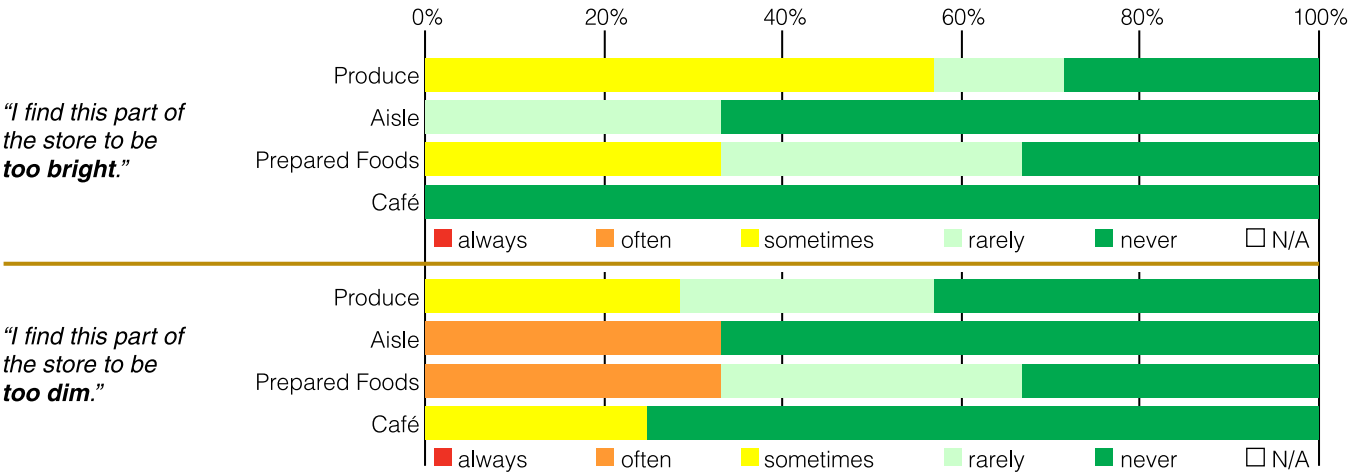
– Employee

"Natural light… I'm a big fan!"

– Employee



Survey responses: n = 3-7



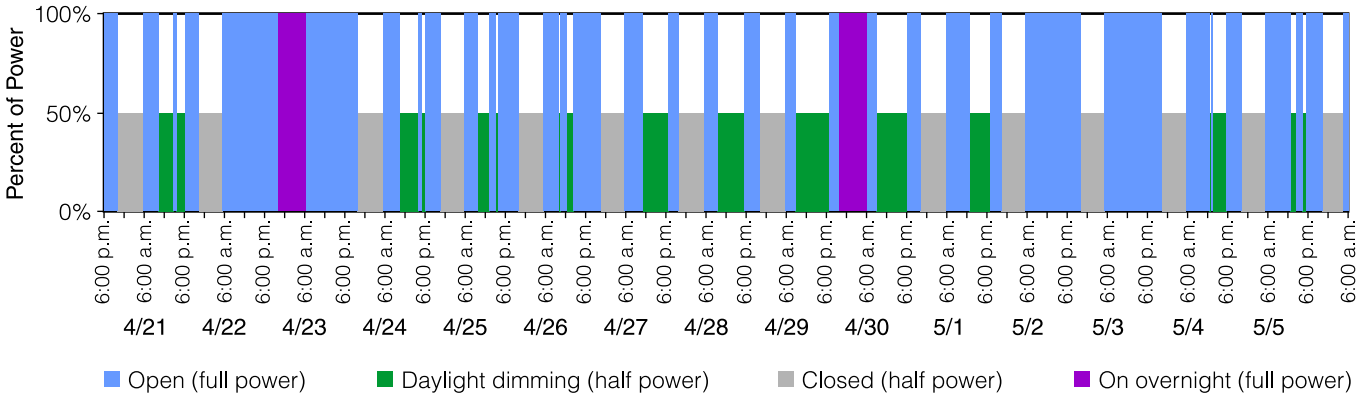
Survey responses: n = 3-7

The prepared foods area

Energy

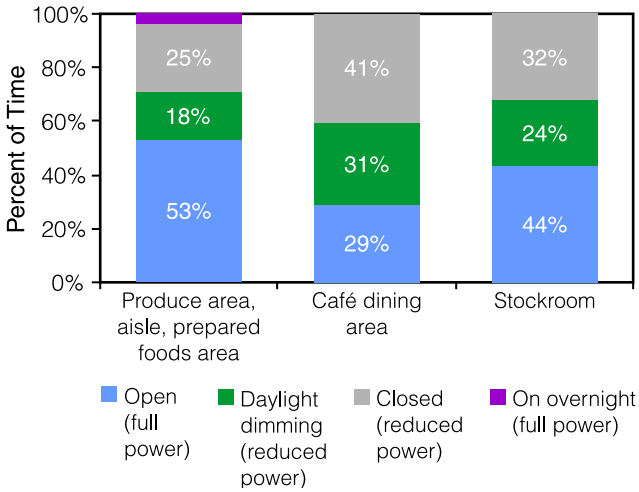
This Whole Foods Market is open 8 a.m. to 10 p.m., seven days a week. The energy management system is programmed to operate the lights automatically. According to the commissioning agent, when the photosensor measures greater than 55 fc,[4] half the luminaires turn off.[5] When illuminance at the sensor drops below 45 fc, lights turn back on.[6] The range between these values is referred to as "dead band." The dead band reported at this store is narrow, which could result in frequent switching of lights.

LRC monitored luminaire switching at the Whole Foods store. LRC installed monitoring devices in luminaires in the four areas of the store controlled by the photosensor for 16 days in spring 2012. An example of the resulting pattern of usage is shown below. Some days, the photosensor turned off lights all day long; on other days, lights were intermittently switched. For four days during the monitoring period, the lights were all on, all day long. There were two Sunday nights in which the override button was apparently used, keeping lights on all night; interviews with the current store manager indicated that use of the override is not typical (monitoring was done under a previous manager). Most nights, the energy management system switches the general lighting to half output (shown in grey). Frequent switching was not apparent in these data.



Lighting power use during monitoring period

These usage patterns were translated to percent of monitoring time (see figure below). The setpoint at which the lighting in aisles, produce, and prepared foods turns off is different (less aggressive) than in the café and stockroom. As a result, the percentage of time in the daylight-off state is greater for the café and stockroom.



Usage percentages: lighting circuits controlled by photosensors (16 days of monitoring, April-May 2012)

[4] Lighting power use data suggest that the actual illuminance in the skylight is substantially higher than the 45 fc and 55 fc set points reported by the commissioning agent; these set points would likely have kept the lights at reduced output from sunrise to sunset regardless of weather and season.

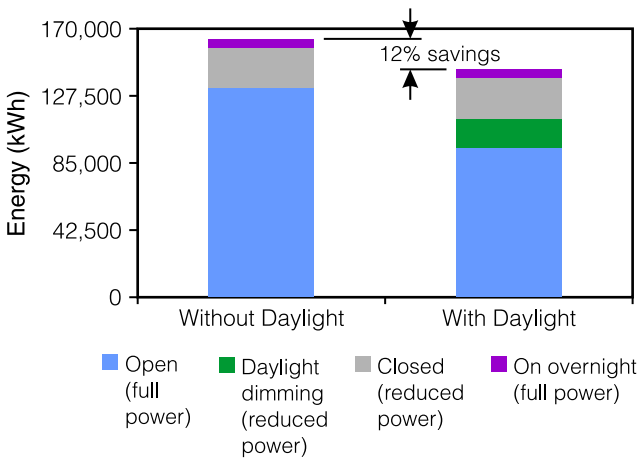
[5] In the café, the row closest to the window switches off entirely, rather than alternating luminaires.

[6] As shown in the *Lighting Power Use* figure, the café and stockroom areas spend more time at reduced output, thus they appear to have lower, more aggressive illuminance set points than the aisles/produce/prepared foods areas.

Assuming these usage percentages apply to an entire year,[7] these were multiplied by the total lighting power in each mode, and by annual hours of use.

These energy calculations were compared to what the usage would have been if there had been no daylight and photosensor (see figure below). This shows that the daylighting system at the Yonkers store saves approximately 19,000 kWh annually.

As shown below, this represents 12% reduction in annual energy use for the circuits controlled by the photosensor.



Annual lighting energy comparison: photosensor control of general lighting in produce area, aisles, prepared foods area and café dining area

Café dining area CFL pendant with monitoring device

[7] Photosensor hours of use are expected to be longer in summer and shorter in winter. As this monitoring took place in the spring (April 20 to May 6), these usage percentages were assumed to represent the year.

Pollution Avoided

These annual lighting energy savings can be translated to pollution avoided, as shown below.

Monthly pollution avoided due to photosensor energy savings

SO_2		NO_x		CO_2	
lbs	kg	lbs	kg	lbs	kg
1.9	0.9	5.3	2.4	11,604	5,264

Sulfur dioxide (SO_2) is associated with visible pollution (haze) and acid rain.
Nitrogen oxides (NO_x) are one of the main causes of ground level ozone (smog) and acid rain.
Carbon dioxide (CO_2) is a possible contributor to global warming.

Impact on Mechanical System Energy Use

The annual impact of the daylighting and switching of lights on heating and cooling energy was analyzed using DOE2.1 computer simulations. Compared to a store without skylights or roof monitors, the daylighted store's annual heating energy increased by about 1%, but cooling costs decreased by about 3%.

Economic Impact

The cost of skylights, roof monitors and windows would have a long payback time when considering these lighting energy savings. However, if a store were planning to install these elements anyway, as would be the case with a major remodel or construction of a new store, the incremental cost to implement this simple daylighting control system is minimal. Building codes in other areas (e.g., California's Title 24) require daylight and lighting controls for large spaces such as this store.

Lessons Learned

- Customers and employees enjoy the appearance of the store with daylighting.
- There were no customer or employee complaints about lights switching off automatically; light on much of the merchandise is provided by integral case lighting or accent lighting that is not controlled by photosensors.
- Simple switching of electric lights in response to daylight provided a modest energy savings (12%).
- Skylights do add to the cost of operating mechanical equipment.
- While the skylights and roof monitor are not paid for by energy savings from electric lighting, the store was planning to provide daylight anyway to create an ambiance consistent with the image of the store.
- Net energy savings would pay for photosensor controls in about two years.

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Daylight in Whole Foods Market

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