Integrated Lighting for Fire Stations: Daylighting and Electric Lighting Strategies

Technical Brief

City of Seattle Department of Planning & Development

What is Integrated Lighting

The fundamental arc of an integrated lighting strategy demands an architectural daylighting response to site, climate, and patterns of use- with integrated electric lighting designed to respond to daylight and provide the highest-quality, visually appropriate, and energy efficient indoor environment in order to support the critical functions of a fire station.

Image courtesy Samaha Associates

Lighting is integral to high performance design. A deeply integrated relationship between Architect, Lighting Practitioner and engineering team is crucial to achieving the highest-quality visual environment with substantial energy savings.

Daylighting is the strategy of providing access to the light of the sky for the purpose of functionally illuminating the interior spaces of a building during daylight hours. At its core, it is a process of balancing the available light of the sky to provide appropriate levels of diffuse light in a space while blocking the direct rays of the sun which can cause glare and overheating.

The Illuminating Engineering Society of North America (IESNA) and the International Association of Lighting Designers (IALD) define sustainable lighting design as "meeting the qualitative needs of the visual environment with the least impact on the natural environment." Visually effective and appealing, high quality lighting

"The natural daylighting, improved indoor air quality and radiant heat from passive solar gain will create a better environment for the firefighters who use the station 24 hours a day."
Tom Lee, Samaha Associates.

provides the greatest environmental and economic value for all project types.

The basic goals of sustainable lighting design include:

- Using daylight as the primary source of illumination
- Minimizing the use of energy through an integrated design that includes effective controls
- Avoiding skyward illumination to reduce light pollution
- Specifying environmentally-preferable materials and equipment and managing their disposal to reduce their end-of-life environmental impact.
- Ensuring system flexibility, maintainability, durability and controllability.
- Providing for proper monitoring and commissioning

The integrated design process is changing the traditional roles and relationship of the Architect, Lighting Designer, Electrical Engineer, and Manufacturer. Including lighting design considerations at the beginning of a project allows for sustainable design goals to be more thoroughly addressed and successfully achieved.

Benefits of High Performance Lighting

The visual needs of building occupants are complex and involve emotions, actions, perception and health, all influenced by lighting. From visually locating objects to the speed and accuracy of doing tasks, lighting is central to how people function within a space. In addition to the functional aspects of lighting, the emotional and perceptual aspects are equally important. The way we perceive the mood and atmosphere, visual comfort, and judge the aesthetics of a space, determines how we feel about working and living in this space. Lighting based upon human needs is central to making a fire station function as a place of precise, efficient and accurate visual work, while also being a welcome visual respite from the enormous stresses placed upon firefighters.

Health Benefits

The health benefits of daylighting can produce positive effects for the health and wellbeing of all building occupants. Recent studies indicate that day lit environments lead to higher worker satisfaction, reduced health problems, and lower absenteeism as well as a richer daily experience for workers.

Circadian Rhythms

"Circadian rhythms are regular changes in mental and physical characteristics that occur in the course of a day (circadian is Latin for "around a day"). Most circadian rhythms are controlled by the body's biological "clock." - Healthlink, Medical College of Wisconsin.

A well day lit space can help maintain normal circadian rhythms. In the fire station environment where a normal sleep schedule is regularly interrupted, circadian rhythms can fall out of synch, which may cause problems with concentration, alertness, and overall wellness. Providing quality daylight balanced with appropriate darkness at night can help regulate the circadian system leading to improved mental health and increased readiness. Daylight and views can decrease stress and have a calming effect on occupants of a building.

Well designed electric lighting can help support the wakefulness of occupants by creating lighting that does not disturb the hormonal melatonin response of the circadian system. This can be done by creating light at night that is emitted at certain non-intrusive wave lengths (typically toward amber light) and by creating quality darkness for restful sleep.

All these benefits are vital to the firefighters who must be alert at a moments notice. Additionally, improved health of fire station occupants means a reduced cost in insurance premiums to the City and fewer accidents so that the fire station performs better.

Visibility

Good visibility is critical for the functions of an effective fire station. An understanding of contrast, luminance, time and size are critical variables to good visibility. Age changes these variables; for the older occupant, the task must be larger and brighter and its contrast higher in order to achieve visibility levels equivalent to younger occupants. In general, higher contrast and improved lighting can help offset visibility losses due to age or other vision factors. Using diffused daylight and mitigating contrast from glare and shadows can provide higher levels of visual acuity. This causes less eye strain and allows for more accurate performance of visual tasks. Both are important to a team of firefighters preparing their equipment for the next emergency.

Task Performance

Lighting must enable occupants to perform their work quickly with few or no errors. The range of tasks includes: cleaning and inspecting equipment, writing office reports in the office, preparing meals and relaxing. Each of these tasks requires different illumination requirements.

Mood and Atmosphere

The need for a distinct change in visual atmosphere from the functional Apparatus Bay to the relaxed feel of the Dayroom is critical for creating a space that functions both as a home and as a work environment.

Carefully planned lighting and interior design can facilitate adaptation in these different spaces with varying in mood and atmosphere.

Emergency Operations

Using light to make the environment safe for quick exits and to allow occupants to move about the space during a power outage is vital in a fire station.

In an emergency situation when power is unavailable, daylight can provide a safe operating environment for the firefighters during daylight hours, saving emergency generator power for other crucial operating tasks. A space that is well day lit will aid the firefighters in their effort to rapidly respond to emergency situations.

This fire station in Houten, Netherlands was designed by Samyn and Partners practice. The glazing on the south side encloses the apparatus bay. It is also integrated with a photovoltaic panel system to provide the station with additional power and allow some of its functions to remain operational in case of emergencies.

Lighting Strategies by Space and Function

Functional Areas

Apparatus Bay

Lighting Design Criteria:

Very Important	Important	Somewhat Important
diffuse daylight	wide distribution with overlapping sources	occupancy controls
uniform horizontal illumination	high color temperature (4100 kelvin for electric lighting)	integral emergency lighting
diffused light sources	hierarchy of surfaces: rigs, walls, floors, ceilings	
energy efficient sources	low maintenance	
daylight controls	Photo-controlled dimming or step switching	

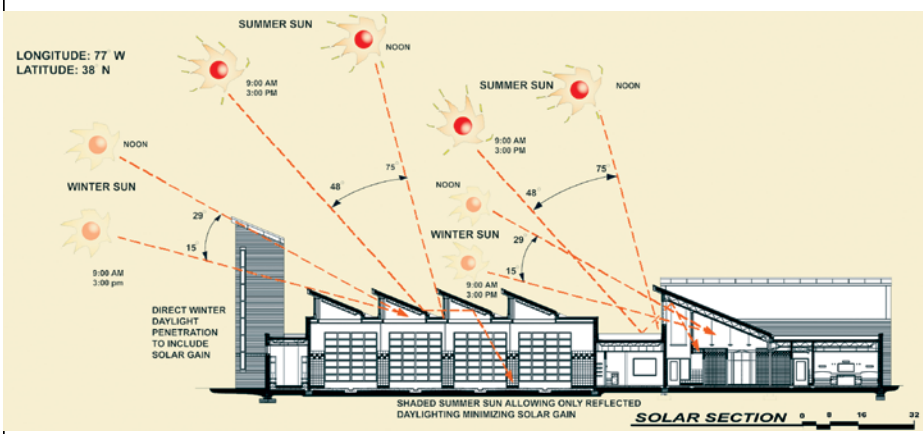


Image courtesy of Samaha Associates

Crosspointe Fire Station. Daylighting drove the design of the buildings' site orientation and envelope. The building is oriented so that light monitors face south. Apparatus bays are stepped to best fit the site and to extend the length of the southern façade. Monitors are designed with overhangs to block direct high summer sun angles and allow low winter sun angles directly when solar gain is desired. Summer daylighting is captured by light reflecting off of the adjacent flat roofs and the ceiling of the interior spaces to eliminate solar gain.

With careful planning, daylight can be the primary source of illumination at the apparatus bay. An appropriate target daylight factor (DF- see definitions) for the apparatus bay is a daylight factor of 3. Any areas below a daylight factor of 2 cannot be considered day lit, and areas above a daylight factor of 6 would likely benefit from a reduction in glazing area. It is crucial to eliminate all direct sun penetration at visual task areas within the apparatus bay.

The Apparatus bay is the "low hanging fruit" when daylighting a fire station. As a high-bay space (with a ceiling height above 15'-0"), the potential for top-lighting is significant. A well designed top-lighting system will take advantage of the dome of the overcast sky while maintaining complete direct sun control. During overcast times, the zenith of the sky dome (directly overhead) is 3 times brighter then the horizon. This means that on the darkest overcast day, horizontal skylights will deliver three times as much light as vertical glazing. Translucent or light diffusing glazing material will be critical to ensure diffuse daylight during both overcast and clear sky days. In an overcast sky climate like Seattle, a good rule of thumb is to provide translucent and/or prismatic skylights (visible light transmission of 50% (tvis = 0.50) or greater) at about 5-7% of the floor area. Light colored interior surface finishes, especially in the upper third of the interior volume, can significantly increase daylight performance by increasing daylight inter-reflections within the interior space and enhancing the perception of brightness.

The apparatus bay, if illuminated from above with translucent horizontal unit skylights, can be oriented in almost any direction due to that direct sun will be controlled via light diffusing skylight glazing. Translucent or prismatic skylights will provide the most even distribution of daylight across a space with the smallest amount of glazing area. Daylighting options such as roof monitors, clerestories, and "saw-tooth" monitors can also be very successful, but are optically complex and require sophisticated design and simulation to ensure effective daylight performance and visual comfort.

It is critical to determine locations of critical tasks and interior objects, such as the fire trucks when locating daylight apertures. It is also important to illuminate the vertical surfaces of the interior- this will increase the perception of brightness in the space and contribute to reducing contrast within the primary visual field.

The electric lighting should be positioned to light in-between the rigs to provide a uniform light using High-bay lighting for general light and fluorescent task lights at workbenches. High mounting heights raises the luminaires out of the normal field of view. Using the IESNA Handbook under "Factors of Industrial Lighting" as a guide, the Apparatus bay should have a minimum of 50fc average on the floor for general illumination from electric light only. Supplimental task lighting may be as high as 100fc for workbenches and should be locally controlled. Emergency lighting should be integral to the general lighting fixtures.

Lighting controls strategies that are most effective in spaces identified as industrial service include: daylight sensors to reduce electric lighting when useful daylight is available, and wall or ceiling mounted occupancy sensors.

Image courtesy Samaha Associates.

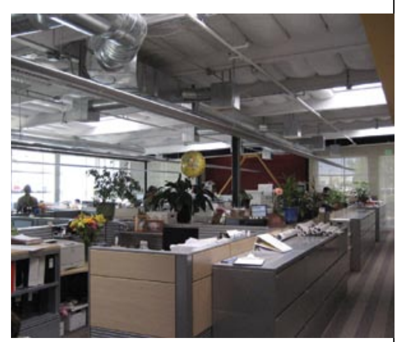
Crosspointe Fire Station, Fairfax County, Virginia. The driving concept of daylighting was coupled with passive solar heating, mechanical controls, and reflective surfaces to reduce electric and cooling costs.

Offices/Reception Area

Lighting Design Criteria:

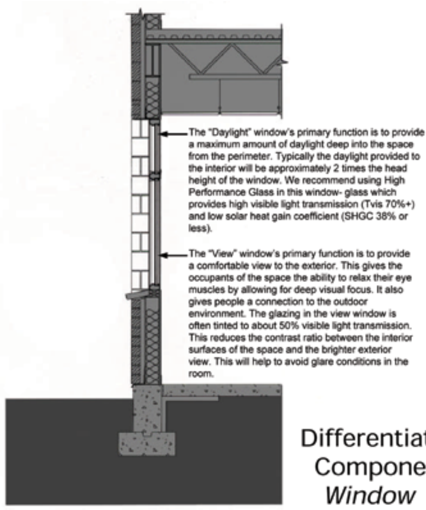
Very Important	Important	Somewhat Important
diffuse daylight and views	occupancy controls	integral emergency lighting
no direct glare	diffused light sources	
energy efficient sources	daylight controls	local task light control
hierarchy of lit surfaces: desks, ceilings, walls, floors	low maintenance	
high color rendering (CRI)	Photo-controlled continuous dimming	

Daylight should provide the first "layer" of light in any office environment. An appropriate target daylight factor (DF) for an office environment is a daylight factor of 2-4. Any areas below a daylight factor of 2 cannot be considered day lit. Areas above a daylight factor of 5 would likely benefit from a reduction in glazing area. It is crucial to eliminate all direct sun penetration all visual task areas and fixed workstations.

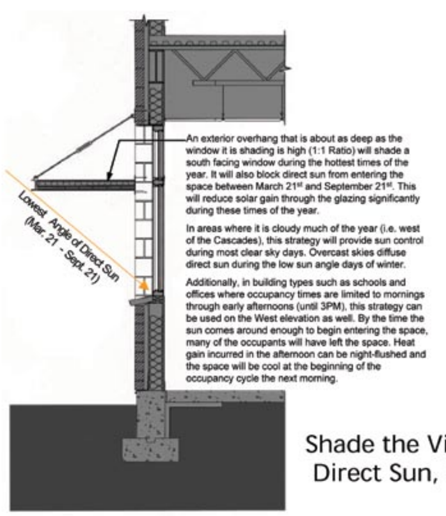


Daylit Office: A combination of translucent skylights and perimeter windows allow this office to be illuminated with daylight alone during much of the time that it is occupied. Note that the electric lights have been dimmed and shut off via photo-sensors.

Simulation is the key to ensuring successful daylight performance. Here is a successful comparison of an actual space to a model in the Integrated Design Lab's overcast sky simulator. The photo on the left shows the space as it was built. The photo of the model on the right shows simulated daylight distribution and approximate intensity on September 21st at noon.



Differentiate the Window into its Component Parts: The *Daylight Window* and the *View Window*



Shade the View Window to Block Direct Sun, Eliminate Glare, and Reduce Solar Gain.

Providing a carefully designed exterior shading and well thought-out user friendly blind system is critical for office daylighting. This requires orienting the spaces so they respond to the path of the sun and providing sufficient diffuse sky illumination. Achieving this requires simulation of daylight performance. In side-lit offices a good rule of thumb is that the sectional depth of the office should not exceed twice the head height of the window. This will ensure that the entire office area is within the daylight zone.

Office areas are ideally oriented either north or south where direct sun can be controlled to avoid direct sun penetration and maximize daylight performance. This will require careful design of the window aperture to deliver adequate daylight while blocking direct sun and providing comfortable views. The first step is to optimize the window into its two component functions: daylight and view window (see diagrams). One way this is achieved is by using an exterior shading device and an interior light shelf. The daylight glazing occupies the upper portion of the window to maximize daylight distribution into the space (approximately two times the head height of the window). Adding an interior light shelf may increase the amount of light along the ceiling- and help to control direct sun at this aperture. Using high reflectance material on the ceiling will increase the visual comfort of the space by brightening the upper portion of the room. The exterior overhang should be designed to protect the view portion of the window from direct sun (complete shading from March 21st through September 21st), while providing a visual connection to the outdoors.

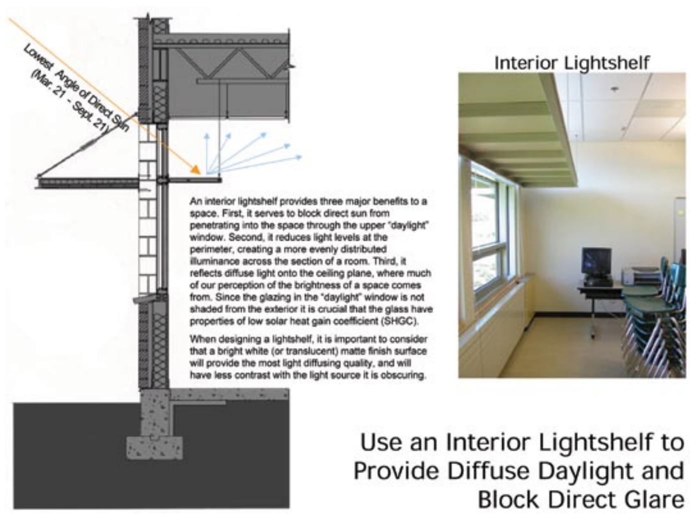
Fixed architectural shading devices (both interior and exterior) on the south side of a building should provide roughly a 45 degree cut off angle (1:1 ratio). Fixed shading must be supplemented with interior blinds and/or fabric roll-down shades (see diagrams). This will allow occupants to control glare during periods of low-angle sun. Other options include automated exterior or interior Venetian blinds, fabric awnings, and daylight optimized blind systems.

Electric lighting should provide general ambient light as well as task illumination, typically 30fc to 50fc average with electric lighting only while using only 0.79 w/sf. A direct/indirect lighting system allows for direct task lighting while providing light in the space for comfort and well being. Lighting that addresses the visual comfort or visual ergonomics of the occupants can help relief eye strain and visual stress within a facility. Accent lights also help add visual interest to the space. This could be in the lighting of a wall of pictures of past Fire Chiefs, or the accent lighting of an old battered Fire hat of deep reverence.

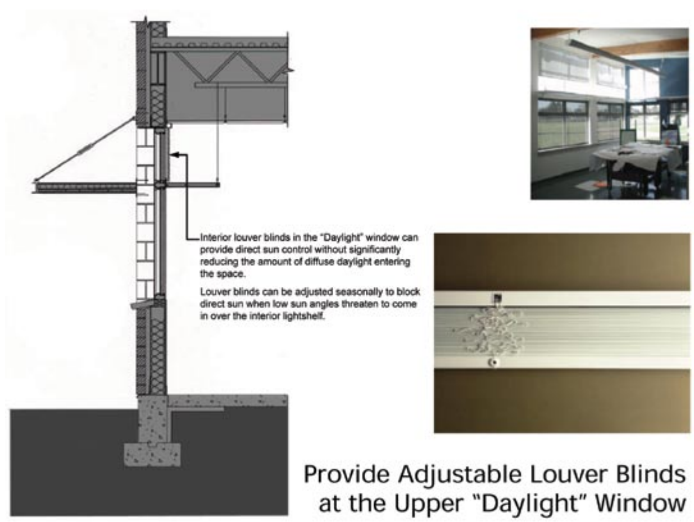
Lighting controls strategies that are most effective in small office spaces include: occupancy sensors, personal controls through dimming, and daylight sensors to reduce electric lighting when useful daylight is available.

Active Storage

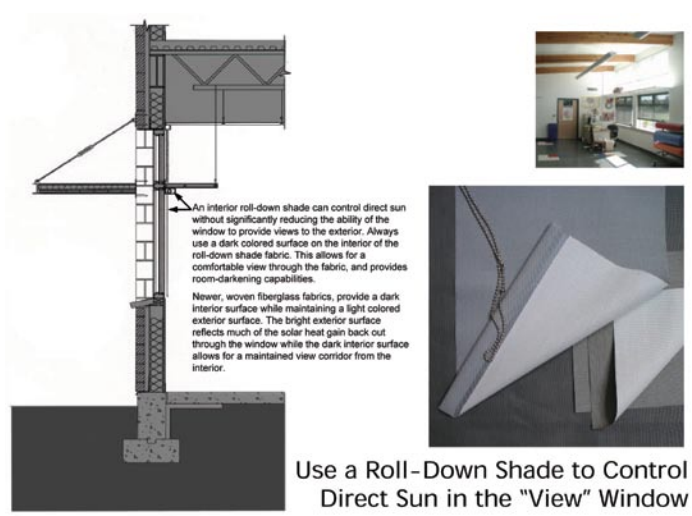
What is required here is basic functional efficient overhead lighting, being mindful that some of the equipment may be UV sensitive and require special shielding. Controls should be a manual switch on and a "vacancy sensor" turning lights off when activity is no longer present.



Use an Interior Lightshelf to Provide Diffuse Daylight and Block Direct Glare



Provide Adjustable Louver Blinds at the Upper "Daylight" Window



Use a Roll-Down Shade to Control Direct Sun in the "View" Window

Images courtesy of Samaha Associates.

Crosspointe Fire Station Office, Lavatory and Beanery. Living areas are flooded with daylight through the monitor, low walls and interior clerestory glazing.

Living Areas

Lighting Design Criteria:		
Very Important	**Important**	**Somewhat Important**
uniform task light	ambient illumination 10fc to 20fc avg.	decorative elements (sparkle)
horizontal illumination at task surfaces -50fc to 100fc	ambient and task lighting strategies	
warm color temperature	energy efficient sources	
high color rendering (CRI)	no direct glare	

Living/Cooking/Beanery (Kitchen and Dining Area)

The living/cooking areas are less demanding from a daylighting perspective. Because visual tasks tend to be less complex at these locations, the designer has more flexibility with the amount and character of daylight employed. However, it is always crucial to provide an easy to use and effective interior glare control system such as blinds, curtains, or roll-down fabric shades. Care should be taken to provide comfortable views and control of solar heat gain during times when thermal comfort requires cooling.

Electric lighting is more critical on task areas such as dining tables and counter tops. General lighting should make the space feel more residential than institutional. An effective way to provide ambient lighting is to light vertical surfaces such as cabinets or walls. Manual controls, including dimming would be appropriate here.

Bunk Area (Private Sleeping Rooms)

Reading lamps and/or desk lamps along with a simple general light (using manual switches) would work best for these private bunk areas. Studies have shown that creating a quality darkness is critical for people to sleep and achieve a healthy rejuvenation as well as to support re-synching the circadian rhythms of the occupant. This would involve reducing the unwanted stray light entering the room by using shades, and if necessary, only using amber colored light sources for safety/step lights. Local dimmer controls or manual on/off switches would be recommended for private sleeping quarters.

Bathrooms and Showers

During the day, daylight should be the primary source supplemented with electric lighting at task areas such as sinks and vanities; however, at night, the general lighting should be functional in order to support a clean, maintainable space. Controls should be an "occupancy sensor" with a manual on switch to turn lights on upon entering and off when activity is no longer present.

Dayroom (Multi-Purpose Space)

This room is a misnomer in that its primarily use is to escape from the day into a multi-functional den with flat screen TV's, video games, pool tables and other distractions from the stresses of work. Thus this space is usually dark and is considered a cave of refuge. Windows in this area would be used solely for views to the exterior. Electric lighting can be more focused on task surfaces, dramatically lit wall art and localized floor and table lamps. Controls should be manual and include zoning and dimming functions.

Workout Room

When possible, daylight should be the primary source supplemented with electric lighting at task areas such as sinks and vanities; however, at night the general lighting should be functional to support a clean, maintainable space. Controls should be an "occupancy sensor" wth a manual on switch to turn lights on upon entering and off when activity is no longer present.

Work Bench Room

What is required here is basic functional efficient overhead lighting and task lighting at work benches. Controls should be an "occupancy sensor" with a manual on switch to turn lights on upon entering and off when activity is no longer present.

Site Lighting

Fire stations must blend in with the surrounding neighborhoods and yet be a presence representing safety and permanence. Exterior lighting is an important visual presence for the fire station, providing safety and security for the occupants. Listed below are several steps to consider in designing exterior lighting that meet sustainable guidelines:

- Light only where it is needed using carefully evaluated functional, safety and comfort criteria.
- Ask the question: what needs to be lighted? Justify your answers. If you cannot justify lighting an area, you probably don't need to light it.
- Light only when needed using carefully-evaluated functional, safety and comfort criteria:
- Specify photocell and photocell/time clock controls so lighting will be on only when needed.
- Use self-setting or astronomic time clocks to ensure proper operation in the event of power failures.
- Consider occupancy-sensing controls for incandescent or fluorescent systems, especially on security lighting.
- Do not over-light.

Consider using IESNA criteria as maximums, not minimums. Note that improving lighting quality (such as reducing glare or improving uniformity of illumination) may be a better solution than adding more light.

Wherever possible, eliminate light from luminaires that is projected above the horizontal plane toward the horizon. Use techniques such as:

- Aiming/mounting limits
- Full cut-off (fully shielded) "flat bottom" luminaires

When you must use "period" or decorative fixtures that emit light above horizontal, use fixtures with optical systems that have very little uplight; two percent maximum of total fixture output above horizontal is a good target limit.

Minimize the use of broad-beam floodlights for area lighting. Specify shields, especially visor type shields for floodlights.

Eliminate and control glare

Do not specify luminaires with unshielded lamps. Using the ASHRAE 90.1-2004 Exterior Lighting requirements, match lamp power with the lighting requirements. Better quality exterior lighting results from lower glare and better uniformity, when lower wattage lamps are used and mounted so that most of the light is aimed downward rather than outward from the mounting location. Check lamp lumen maintenance data to avoid over lighting.

Match lamp wattage with mounting height. One of the most common mistakes in outdoor lighting is to install too many watts on too short of a pole.

Control Light Trespass

Locate poles and luminaires so light stays within property lines as much as possible.

Shield light sources and luminaires so that sources are not visible from off of the property.

Model illumination levels at property lines. Calculate both horizontal and vertical illumination values since both may be needed to meet design or legal requirements.

Base design decisions on IESNA Recommended Practices and other current criteria, conform to the appropriate Lighting Environmental Zones (LZ) as classified by the IESNA and the International Commission on Illumination (CIE) (see table below). As of the date of this guide, California is the first state to adopt the zone concept defining zones based upon population density. (CA Reference) (Table of Zone).

Lighting Energy Performance

Daylighting can have a significant impact on the energy use of a building. With proper design and the integration of electric lighting, a well day lit building can "harvest" up to a 60% reduction in lighting power use during daylight hours. This means that by using the light from the sky and reducing electric light output during the day, daylighting can produce significant savings both in dollars and consumption of resources. The most successful integrated lighting control strategy for most interior spaces (such as the offices and the apparatus bay) is photo-controlled continuous dimming. This strategy can provide substantial lighting power savings, with the least obtrusive adjustment of electric light in response to daylight. In some cases, such as transitional spaces, multi-level switching may be appropriate, however, sudden adjustments in light levels can be perceived as obtrusive or worse by some occupants.

Cost Benefits of Daylighting

The following tables show potential lighting power savings using photo responsive lighting controls. The first table shows the input factors dictated by the design; a daylight factor of 3 is optimal for spaces such as the apparatus bay. The next table shows the predicted energy savings over the year based on turning lights off during daylight hours. Next is the amount of light expected from the overcast sky in Seattle which dictates the percentage of energy saved. This is then translated into a savings per year in the final table.

These savings do not include the benefits of load reduction at other building systems including reduced cooling loads, higher performance building envelope, or passive solar heating.

ILLUMINANCE PREDICTION SPREADSHEET FOR HORIZONTAL GLAZING - OVERCAST

12/19/07 (please fill in the required text and numerical values in the provided cells)

BUILDING MODELLED:	Firestation- Apparatus Bay	
CONSULTATION FOR:	Architect/Engineer	
OPERATOR:	IDL Seattle	
SOURCE OF ILLUM. DATA:	Digital or Physical Model	
MEASUREMENT LOCATION:	Photocell Location	
HEIGHT OF WORK SURFACE:	2'-6"	feet
POINT ILLUMINATION:	n/a	footcandles
OUTSIDE ILLUMINATION:	1421	footcandles
DAYLIGHT FACTOR:	0.03	(entered or calculated as a decimal value)
CONTROL ILLUMINATION:	35	footcandles
CONTROLLED WATTS/SQ. FT.:	1.00	watts/sq.ft.
NUMBER OF DAYS IN WORKWEEK:	5	(enter 5 as a default value)
GLAZING TRANSMITTANCE :	1.00	(enter 1 if transmittance was previously modelled)
GLASS MAINTENANCE FACTOR:	1.00	(enter 0.8 as a default value)
MULLION FACTOR:	1.00	(enter 0.9 as a default value unless mullions were previously modelled)
LIGHTING CONTROL SYSTEM:	2	FLUOR. DIMMING, LUT. ECO-10 (100-10%) (see manual)

CORRECTED DAYLIGHT FACTOR : - 0.030 (measured daylight factor*glazing transmittance*maintenance factor*mullion factor)

OPTION INPUT SPREADSHEET

OPTIONS FOR SYSTEM SAVINGS CALCULATION:

1 CONTINUOUS DIMMING (IDEAL)
2 FLUOR. DIMMING, LUT. ECO-10 (100-10%)
3 FLUOR. DIMMING, LUT. HI-LUME (100-0.5%)
4 ONE-STEP SWITCHING (ON/OFF)
5 TWO-STEP SWITCHING (50/100%)
6 THREE-STEP SWITCHING (33/66/100%)
7 H.I.D. DIMMING (1000 WATTS)
8 H.I.D. DIMMING (400 WATTS)
9 H.I.D. HIGH/LOW SWITCHING (400 WATTS)

CALCULATED OVERCAST ILLUMINANCES AT REFERENCE POINT (SEATTLE)

(hours of day - - - - - - - ->)

	5AM	6	7	8	9	10	11	12	1PM	2	3	4	5	6	7	8
JANUARY				7.0	14.0	17.6	20.2	21.1	20.2	17.6	14.0	7.0				
FEBRUARY			3.9	13.8	18.8	23.7	27.6	29.1	27.6	23.7	18.8	13.8	3.9			
MARCH			13.0	19.0	25.9	33.4	38.7	40.6	38.7	33.4	25.9	19.0	13.0			
APRIL		11.9	18.4	26.1	35.9	44.6	50.2	52.2	50.2	44.6	35.9	26.1	18.4	11.9		
MAY	8.5	15.9	22.6	32.3	42.8	51.4	57.7	60.6	57.7	51.4	42.8	32.3	22.6	15.9	8.5	
JUNE	11.0	17.3	24.5	34.7	45.3	53.8	61.2	65.1	61.2	53.8	45.3	34.7	24.5	17.3	11.0	
JULY	8.8	16.1	22.8	32.6	43.1	51.7	58.1	61.1	58.1	51.7	43.1	32.6	22.8	16.1	8.8	
AUGUST		12.1	18.5	26.4	36.2	44.9	50.5	52.5	50.5	44.9	36.2	26.4	18.5	12.1		
SEPTEMBER		0.6	13.2	19.2	26.3	33.8	39.2	41.1	39.2	33.8	26.3	19.2	13.2	0.6		
OCTOBER			3.5	13.6	18.6	23.4	27.3	28.8	27.3	23.4	18.6	13.6	3.5			
NOVEMBER				6.7	13.9	17.5	20.0	21.0	20.0	17.5	13.9	6.7				
DECEMBER				2.1	11.7	15.6	17.8	18.6	17.8	15.6	11.7	2.1				

AVERAGE ANNUAL ILLUMINATION (Daylight Hours.) = 29.4 footcandles

Firestation- Apparatus Bay — Photocell Location

ENERGY SAVINGS - PERCENT: FLUOR. DIMMING, LUT. ECO-10 (100-10%)

(hours of day -------->)

	5AM	6	7	8	9	10	11	12	1PM	2	3	4	5	6	7	8
JANUARY				0.16	0.32	0.40	0.46	0.48	0.46	0.40	0.32	0.16				
FEBRUARY			0.09	0.32	0.43	0.54	0.63	0.67	0.63	0.54	0.43	0.32	0.09			
MARCH			0.30	0.43	0.59	0.76	0.80	0.80	0.80	0.76	0.59	0.43	0.30			
APRIL		0.27	0.42	0.60	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.42	0.27		
MAY	0.19	0.36	0.52	0.74	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.74	0.52	0.36	0.19	
JUNE	0.25	0.40	0.56	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.56	0.40	0.25	
JULY	0.20	0.37	0.52	0.74	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.74	0.52	0.37	0.20	
AUGUST		0.28	0.42	0.60	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.42	0.28		
SEPTEMBER		0.01	0.30	0.44	0.60	0.77	0.80	0.80	0.80	0.77	0.60	0.44	0.30	0.01		
OCTOBER			0.08	0.31	0.42	0.53	0.62	0.66	0.62	0.53	0.42	0.31	0.08			
NOVEMBER				0.15	0.32	0.40	0.46	0.48	0.46	0.40	0.32	0.15				
DECEMBER				0.05	0.27	0.36	0.41	0.42	0.41	0.36	0.27	0.05				

AVERAGE ENERGY SAVINGS:

DURING DAYLIGHT HOURS (7AM-7PM).

= 61 percent.

Firestation- Apparatus Bay — Photocell Location

ENERGY SAVINGS - WATTS/SQUARE FOOT: FLUOR. DIMMING, LUT. ECO-10 (100-10%)

(hours of day -------->)

	5AM	6	7	8	9	10	11	12	1PM	2	3	4	5	6	7	8
JANUARY				0.16	0.32	0.40	0.46	0.48	0.46	0.40	0.32	0.16				
FEBRUARY			0.09	0.32	0.43	0.54	0.63	0.67	0.63	0.54	0.43	0.32	0.09			
MARCH			0.30	0.43	0.59	0.76	0.80	0.80	0.80	0.76	0.59	0.43	0.30			
APRIL		0.27	0.42	0.60	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.42	0.27		
MAY	0.19	0.36	0.52	0.74	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.74	0.52	0.36	0.19	
JUNE	0.25	0.40	0.56	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.79	0.56	0.40	0.25	
JULY	0.20	0.37	0.52	0.74	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.74	0.52	0.37	0.20	
AUGUST		0.28	0.42	0.60	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.42	0.28		
SEPTEMBER		0.01	0.30	0.44	0.60	0.77	0.80	0.80	0.80	0.77	0.60	0.44	0.30	0.01		
OCTOBER			0.08	0.31	0.42	0.53	0.62	0.66	0.62	0.53	0.42	0.31	0.08			
NOVEMBER				0.15	0.32	0.40	0.46	0.48	0.46	0.40	0.32	0.15				
DECEMBER				0.05	0.27	0.36	0.41	0.42	0.41	0.36	0.27	0.05				

ENERGY SAVINGS PER MONTH : (in watthours per square foot.)

DURING DAYLIGHT HOURS (7AM-7PM)

JANUARY	68.86
FEBRUARY	99.70
MARCH	136.37
APRIL	156.75
MAY	164.97
JUNE	168.34
JULY	165.36
AUGUST	157.07
SEPTEMBER	137.37
OCTOBER	98.29
NOVEMBER	68.15
DECEMBER	56.04

ENERGY SAVINGS PER SEASON :

(in kilowatthours per square foot)

(Dec. - Feb.) **Winter =**	0.225
(Mar. - May) **Spring =**	0.458
(Jun. - Aug.) **Summer =**	0.491
(Sep. - Nov.) **Fall =**	0.304

TOTAL ENERGY SAVINGS PER YEAR :

= 1.48 kilowatthours per square foot.

Firestation- Apparatus Bay — Photocell Location

LIGHTING ENERGY - WATTS/SQUARE FOOT: FLUOR. DIMMING, LUT. ECO-10 (100-10%)

(hours of day -------->)

	5AM	6	7	8	9	10	11	12	1PM	2	3	4	5	6	7	8
JANUARY			1.00	0.84	0.68	0.60	0.54	0.52	0.54	0.60	0.68	0.84	1.00	1.00		
FEBRUARY			0.91	0.68	0.57	0.46	0.37	0.33	0.37	0.46	0.57	0.68	0.91	1.00		
MARCH			0.70	0.57	0.41	0.24	0.20	0.20	0.20	0.24	0.41	0.57	0.70	1.00		
APRIL			0.58	0.40	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.40	0.58	0.73		
MAY			0.48	0.26	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.26	0.48	0.64		
JUNE			0.44	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.44	0.60		
JULY			0.48	0.26	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.26	0.48	0.63		
AUGUST			0.58	0.40	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.40	0.58	0.72		
SEPTEMBER			0.70	0.56	0.40	0.23	0.20	0.20	0.20	0.23	0.40	0.56	0.70	0.99		
OCTOBER			0.92	0.69	0.58	0.47	0.38	0.34	0.38	0.47	0.58	0.69	0.92	1.00		
NOVEMBER			1.00	0.85	0.68	0.60	0.54	0.52	0.54	0.60	0.68	0.85	1.00	1.00		
DECEMBER			1.00	0.95	0.73	0.64	0.59	0.58	0.59	0.64	0.73	0.95	1.00	1.00		

Interior Lighting Energy Goals

Once the lighting needs of the fire station have been established, we are then able to establish lighting efficiency goals. Below is a chart based on ASHRAE 90.1 2004. A whole building approach considers the total building energy use through modeling. Connected load or Lighting Power Density (LPD) is one measure of the efficiency of a lighting design system, but the true test is in its annual usage measured in Kwh. By trading the lighting energy in some areas with others, a sustainable design should be able to exceed ASHRAE 90.1 2004 LPD by about 30% through a combination of effective daylighting design and electric lighting controls.

Space Type	2004 LPD	30% less
Corridor/Transition	0.46	0.32
Electrical/Mechanical	1.45	1.02
Beanery/Kitchen Area	1.24	0.87
Restrooms	0.86	0.60
Lobby	1.32	0.92
Dayroom/Multi-Purpose	1.25	0.88
Meeting Room/Multi Purpose	1.25	0.88
Office/Administration Room	1.13	0.79
Workroom	1.91	1.34
Active Storage	0.76	0.53
Apparatus Bay	0.75	0.53
Laundry	0.60	0.42
Exercise Room	0.91	0.64
Total Building LPD	1.07	0.75

Exterior Lighting Energy Goals

Based on ASHRAE 90.1-2004, Table 9.4.5 Lighting Power Densities for Building Exteriors

Tradable Surfaces	
Uncovered Parking Areas--Parking Lots and drives	0.15 W/ft_
Building Grounds--Walkways less than 10 feet wide	1.0 W/linear foot
Building Grounds--Stairway	1.0 W/ft_
Building Entrances and Exits--Main entries	30 W/linear foot of door width
Building Entrances and Exits--Other doors	20 W/linear foot of door width
Canopies and Overhangs--free standing and attached	1.25 W/ft_
Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.	

Non-Tradable Surfaces	
Building Facades	0.2 W/ft_ for each illumiated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
Entrances and gatehouse inspection stations at guarded facilities	1.25 W/ft_ of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft_ of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
Lighting power density calculations for these applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. These allowances are in addition to any allowance otherwise permitted in the "tradable Surfaces" section of this table.	

Appendix

Glazing Selection Chart

It is crucial to specify the right glazing for any daylight apertures. This includes selecting glazing with appropriate visible light transmission (Tvis or VLT), solar heat gain coefficient (SHGC) and thermal conductance (U-Value). Spectrally selective glazing can provide high visible light transmission with a low solar heat gain coefficient. Glazing of this type will have a light to solar heat gain (LSG) coefficient of 2 or greater. Additionally, because of the need to protect the equipment in the apparatus bay, it may be critical to select glazing or skylights that provide UV filtering. There are manufactures that make skylights that block over 98% of UV radiation.

LEED

Sustainable lighting design strategies and specifications can play an important supporting role for projects seeking LEED certification. Several points in the LEED system pertain directly to lighting design, including goals for minimizing outdoor light pollution, reducing energy use, and optimizing daylighting.

LEED Sustainable Site – Credit 8: Light Pollution Reduction.

The intent of this credit is to minimize light trespass and light pollution from the building and site. To achieve this credit special attention must be paid the following:

- glare reduction
- energy reduction
- reduced fixture mounting heights
- precise fixture aiming

LEED 2.2 offers two credits explicitly dealing with daylight performance in the Indoor Environmental Quality (IEQ) section of the rating system. The first is Credit 8.1 (daylight) which requires 75% of all regularly occupied spaces to be day lit. The second, Credit 8.2 (views), requires a direct line of sight to vision glazing to the exterior from 90% of regularly occupied spaces.

A properly designed daylighting system will accrue other LEED credits as well. These will include Energy and Atmosphere (EA) Credit 3 (Enhanced Commissioning- to ensure that the electric lighting controls for daylight are properly installed and calibrated), EA Credit

6.1 (Controllability of Systems- Lighting), higher levels of energy performance (through reduced electric lighting use, better thermal performance due to exterior shading, and climate responsive building massing). Additionally, exceptionally day lit spaces (95% or greater) may qualify for Innovation and Design (ID) Credits.

Energy performance offers the most credits of any LEED category. Since lighting accounts for about 40% of the electric energy use of a typical commercial facility, energy-effective lighting can contribute directly to LEED certification. Facility Managers are well aware of the energy benefits of using high-efficiency fluorescent and compact fluorescent lamps, LED, electronic ballasts, and occupancy sensors. A lighting design strategy that integrates daylighting to minimize the dependence on electric lighting can produce tremendous savings over typically uniform lighting layouts. New technologies such as High-Efficiency T8, T5 and T5HO fluorescents lamps, ceramic metal halide lamps, LED, efficient dimming ballasts, and daylight control systems can provide even more savings.

Under the category of indoor environmental quality, LEED provides credits for daylighting and views. Good daylighting is a result of careful architectural design to optimize diffuse daylight while shielding glare and maintaining thermal control. High performance insulated windows, effective shading and window treatments, daylight-oriented interior designs, and highly reflective finishes can add up to well-lighted facilities that need minimal electric lighting during the day. Neutral tinted, low-emissivity windows provide both natural-colored lighting transmission and solar heat rejection. Combined with the bonus of views to the outside, daylighting helps create more desirable and productive facilities. See the daylighting section of this guide for specific information on daylighting design and material specification for fire stations.

Resources:

Lighting Design Lab- www.lightingdesignlab.com

Integrated Design Lab- www.integrateddesignlab.org

The U.S. Department of Energy (DOE)- http://www.doe.gov

DOE Energy Efficiency and Renewable Energy- http://www.eere.energy.gov

DOE: Building Energy Software Tools directory- http://www.energytoolsdirectory.gov

DOE: Energy Plus Simulation Software- http://www.energyplus.gov

DOE: High Performance Buildings- http://www.eere.energy.gov/buildings/highperformance

NBI Advanced Buildings- http://www.advancedbuildings.net

CALARCH Benchmark 2.1- http://poet.lbl.gov/cal-arch/

Windows for High Performance Buildings- http://www.commercialwindows.umn.edu

Books:

Advanced Energy Design Guide - Small Office

IESNA Lighting Handbook, 9th Edition

Sun Wind and Light

Daylighting in Sustainable Design

Daylight Design of Buildings

A large majority of this guide was based upon material from the IES Sustainable Lighting Design and Application Guide.

Definitions

Daylight Simulations

Computer simulations can be another effective way to test daylight performance. These can be used for spaces that are difficult to model and also as an additional level of understanding for space tested on the heliodon and in the overcast sky simulation. Computer simulation tools range from sophisticated programs such as Radiance, which provides photo realistic renderings and illumination data, to simple SketchUp shadow simulations.

Heliodon

A device for adjusting the angle between a flat surface and a beam of light to match the angle between a horizontal plane at a specific latitude and the solar beam at a specific time.

Overcast Sky Box

Simulates a typical overcast day in order to measure effective daylight during overcast conditions. Using photo sensors and photography both a quantitative and a qualitative analysis can be achieved.

Overcast Sky Dome

Overcast conditions create a dome of light where the illumination directly overhead is 3 times as bright at the zenith then at the horizon.

Horizon

The circular line bounding an observer's view of the surface of the earth where the sky and earth seem to meet.

Glare

Excessive contrast or light intensity that creates discomfort. An example might be the reflection of the direct sun off specular surfaces in the interior of a space. This is most troublesome when the disc of the sun is visible to the human eye.

Skylight

Horizontal glazing set in the roof of a building.

Monitor

High vertical glazing usually projecting above the roof of a building.

Daylight Window

Vertical glazing used for bringing daylight into a space. Usually the top third of window utilizing a light shelf to carry daylight farther into the space and reflected light onto the ceiling.

View Window

Window used primary to see from the interior to the exterior. Not the primary source of daylight.

Light Shelf

Interior shading device used in conjunction with a daylight window to cast a reflection onto the ceiling and project light farther into a space.

Exterior Shade

Shade mounted on the exterior of a building to cast a shadow on the window and prevent direct sun light from reaching the glazing.

Daylight Factor

The percentage of available daylight that reaches a room. A daylight factor of 2 is the minimum for a space to be considered day lit.

Circadian Rhythms

The human body's response to the earths night and day cycle, especially as it concerns the body's production or suppression of the hormone melatonin.

Contacts

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www.seattle.gov/dpd/greenbuilding

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