James R Benya PE FIES FIALD LC
BENYA LIGHTING DESIGN

The Design of Sustainable Lighting

Basic Lighting Design with Today's Design Issues

Some of the following slides were developed for the AIA Class about Classroom Lighting for Finelite by James Benya. Most of the following material is also part of the Energy Center of Wisconsin program in Efficient and Sustainable Lighting. Go to www.ecw.org for more information.

Design Criteria

"Lighting is not just about foot-candles."

Understanding the Visual Environment

20th Century Teaching and Work Environments

Understanding the Visual Environment

21st Century Teaching and Work Environments

Video: The Force of Change

Streaming video now playing in classrooms

Area districts, if they have the high-speed capacity, are switching to the versatile digital technology

By LUCIANA LOPEZ
THE OREGONIAN

The video of a hydrogen bomb safety drill, generated from an aging film, played fuzzily on Jeanette Ryan's computer at the Tualatin High School library.

With a few mouse clicks, the school librarian returned to a computerized archive containing similar footage, along with films about the Cold War, checking for other options.

In the past, Ryan would have had to switch tapes or DVDs or even filmstrips to show the images. These days, Tualatin High and many schools throughout the metro area are tapping into a new resource: streaming video, a sequence of images sent over the Internet that can be displayed on a user's computer as they arrive.

School districts are increasingly using digital video files in the classroom, because teachers can download them to show classes, and students can watch and use the files on their own.

Streaming video files, accessed through subscriptions that local education service districts buy, are more versatile than tapes or DVDs, although school officials acknowledge that the high-speed Internet connections streaming video requires

Please see **STREAMING**, Page 4

THURSDAY • APRIL 7, 2005

- PowerPoint Presentations
- Streaming Video Clips
- Internet Sites
- Still Images
- Animations
- Document Camera Projections
- Distance Learning
- Videoconferencing

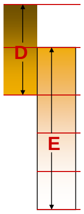
Lighting Levels (Average Illumination)

From the IESNA Ninth Edition Handbook (2000)

A	Circulation Orientation	2 fc
B	Public Areas	5 fc
C	Simple Tasks	10 fc
D	Large Tasks Good Contrast	30 fc
E	Small Tasks Good Contrast	50 fc
F	Small Tasks Poor Contrast	100 fc
G	Specially demanding tasks	300 fc +

A Design Strategy: D-E

- Most tasks are “D”, high contrast and large size. IESNA recommends 30 fc average (roughly 20-40 fc throughout the space.
- Some tasks will still be “E”, low contrast/large size or high contrast/ small size. IESNA recommends 50 fc average (roughly 30-70 fc throughout the space).
- A <u>MINIMUM</u> criterion of 30 fc on any desk, is in the mid-range of “D” and just within the “E” range
- Why not set the criteria at 70 FC? (The top of “E”) This is a case where “more” is not better.



Recommended Illumination Criteria

<u>Daylight Mode</u>

Desks
- Minimum 30 fc at any desk (meets D-E)
- Maximum 150-200 fc

Whiteboard
- Minimum 30 fc vertical average (meets D)

Walls
- Minimum 10 fc vertical average (meets C)

Recommended Illumination Criteria

<u>General Mode</u>

Desks
- Minimum 30 fc at any desk (meets D-E) up to 70 fc

Whiteboard
- Minimum 30 fc vertical (meets D)

Walls
- At least 10 fc average all walls (meets C)

Recommended Illumination Criteria

<u>A/V Mode</u>

Desks
- Minimum 10 fc at any desk (meets C)

Whiteboard
- Not applicable

Screen
- No more than 8 vertical footcandles anywhere on screen surface (allows 8:1 video image with a projector <3000 lumens)

Lighting Quality

All of these are quality considerations of the IESNA Lighting Handbook Design Guide

- Appearance of space and luminaires
- Color appearance
- Daylighting integration and control
- Direct Glare
- Flicker and Strobe
- Light distribution on surfaces
- Light distribution on task place (uniformity)
- Luminance of Room Surfaces

- Modeling of faces or objects
- Points of interest
- Reflected glare
- Shadows
- Source/task/eye geometry
- Sparkle/Desirable reflected highlights
- Surface characteristics
- System control and flexibility

Lighting Quality

Recessed troffer lighting and "old school" fluorescent lighting are no longer acceptable except under extreme circumstances due to:

- Negative appearance of space
- Negative appearance of luminaires
- More direct glare than other options
- Dark ceilings and upper walls
- Inability to provide two scene lighting

Recommended Lighting Quality Criteria

- *Aesthetically pleasing/ attractive lighting*
- *Reduce or eliminate direct glare*
- *Provide ceiling and upper wall surface luminance*
- *Flexibility of scenes and easy to use controls*

Setting Cost Budgets

Too often budgets are set according to outdated standards submitted by a contractor. DON'T FORGET INFLATION!!!!

Be certain to set the lighting budget carefully and avoid simple low-ball numbers. Otherwise, you will never recover.

Schools are 20-50 year investments. A bad lighting system today will persist and affect the operating costs and quality of the classroom environment for a quarter of a century.

Life Cycle Cost – "Winners"

Design choices that usually result in net life cycle cost benefits

- Lighting systems that anticipate and meet future needs – flexibility is key
- Premium, high lumen lamps
- Efficient electronic ballasts
- Motion sensing controls
- Daylight zone switching controls

Life Cycle Cost – "Questionables"

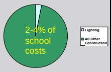
Design choices that MIGHT result in net life cycle cost benefits depending on site conditions

- Automatic daylighting stepped switching or continuous dimming controls

Life Cycle Cost – "Losers"

- Lighting systems that will require future modifications to accommodate changes in the teaching environment
- Lighting systems that save first cost by using less energy efficient components.

Setting the Lighting Budget

	*Good*	*Better*	*Best*
General Lighting System	High performance modern lighting system (optimum layout)	High performance modern lighting system (minimum layout)	High performance modern lighting system (optimum layout)
Teaching Board Lighting System	None (use the light from general lighting system)	Teaching board light	Teaching board light
Costs *With minimum code complying controls*	$3,180 ($3.31/sf)	$3,420 ($3.56/sf)	$4,140 ($4.31/sf)
With full daylighting dimming controls	$4,560 ($4.75/sf)	$4,800 ($5.00/sf)	$5,520 ($5.75/sf)

Setting Energy Budgets

Applicable Energy Codes for Schools		
	Code Requirement	Goal -20%
Ashrae/IESNA90.1-2004	1.4 w/sf	1.12 w/sf
IECC – 2004	1.4 w/sf	1.12 w/sf
California Title 24	1.2 w/sf	0.96 w/sf
Current Best Practices		**<.90 w/sf**

Criteria: Summary

Daylighting

- Optimize daylight and maximize its use

Energy

- Design electric lighting at least 20% less power density than current energy codes
- Employ lighting controls that harvest all possible energy savings.

Lighting quantity and quality

- Meet current IESNA recommendations
- Provide flexibility to meet varying activities and needs
- Address the complete visual environment

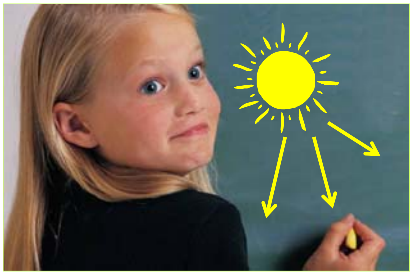
Controls

- Employ lighting controls that are flexible and accommodate daylighting and future teaching technologies

Cost

- Provide these capabilities for modest costs that contribute to overall life cycle cost reductions.

Daylighting



What To Expect from Daylighting

From conventional windows

- Useable light under most conditions for the side of the classroom nearest the windows
- Frequent need to use at least ½ of the electric lighting

From more advanced daylighting designs

- Decreased dependence on electric lights dependent on the daylighting design, solar orientation, climate, etc.

Conventional Daylighting

Typical windows will illuminate about ½ of the room to required levels on most days. Electric lighting will be needed for the area away from the windows and on dark days, for most of the room.

Clerestory windows provide light deeper into the room – on many days all lights can be off, but on darker days it still may be necessary to turn on lights for the side of the room away from the windows.

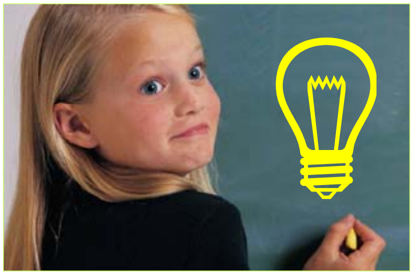
Advanced Daylighting

Advanced Daylighting

Integrating Daylight

1. Design electric lighting rows PARALLEL to the daylight source.
    - Provide separate switches so that rows of lights nearest the window can be extinguished.
2. Provide separate switches for daylighted and non daylighted zones.
    - Required by Energy Code
3. If desired, provide automatic daylight switching or dimming
    - Be certain to provide override controls when video shading systems are being used

Electric Lighting



Recommended Lamp & Ballast System

- Use high performance, high lumen T-8 lamps.
  Go the Consortium for Energy Efficiency (CEE) website for a listing of lamps and ballasts
- For long operating hours, efficient electronic instant start ballasts are probably the better choice.
- For spaces with frequent switching use program start ballasts
- Consider high ballast factor (1.15), normal ballast factor (0.88), or low ballast factor (0.71-0.80) as key options in the design.
- Consider high efficiency dimming ballasts

Control Technology

A room can have any or all of the following:

- Predictable Scheduling
    - *By calendar, clock, and/or solar time*
- Unpredictable Scheduling
    - *By motion sensing and/or manual switching*
- Daylighting
    - *Automatic switching or dimming*
- Use (scenes)
    - *Manual dimming or multi-level control*

Choosing Luminaires

How to Select a Luminaire

1. Efficiency
2. Quality
3. Appearance
4. Flexibility
   a) *For general lighting*
   b) *For daylighting integration*
   c) *For video low light level mode*
5. Cost

Choices

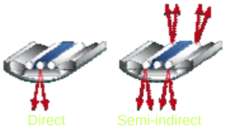
Surface and Recessed Lighting

- Wraps
- Lens troffers
  - Standard T8
  - High performance T5
- Parabolic troffers
- Basket troffers

Choices

Suspended fluorescent lighting

- Indirect
- Direct/indirect
- Two-scene



Choices

- ◉ Excellent
- ◓ Very Good
- ○ Good
- ◒ Fair
- ● Poor

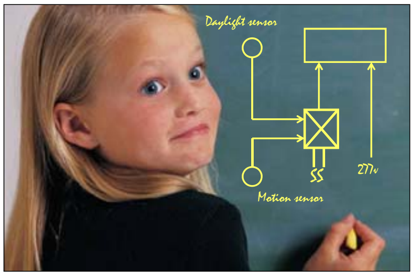
Lighting System	*Efficiency*	*Quality*	*Appearance*	*Flexibility*	*Cost*
Surface Wraps	○	●	●	●	$
Lens Troffers	◓	◒	●	◒	$-$$
Parabolic Troffers	○	◒ → ●	◒ → ○	◒	$$
Basket Troffers	◒	◒ → ○	◓	◒	$$-$$$
Pendant Uplights	○	◓	◓	◒	$$
Pendant direct-indirect	◓	◓	◓	○	$$-$$$
Pendant two-scene	◓	◓	◓	◉	$$-$$$

Vertical Surface Lighting

Practical modern lighting systems actually provide 30-40 footcandles vertical illumination with 2:1 or better uniformity (IESNA Category "D") permitting viewing of details from back of room

- Provide separate switching and locate luminaires to prevent specular reflections from the board

System Integration Ensures Success



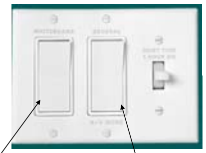
System Integration

- Light level (scene) controls
  - Manual switching
  - Dimming Options
- Daylighting
  - Control zones
  - Types of Control
  - Sensors
- Motion Sensing
  - Sensors
  - Switching
  - Override

Basic Light Level Control

Scenes

- General mode (uplights on)
- A/V mode (downlights on)
- General mode with board
- A/V mode with board



Basic control center at board

Switch turns board light on or off

Switch selects uplights or downlights NEVER BOTH

Daylight Integration

Daylighting Controls

- Daylight zone 1 (nearest windows)
- Daylight zone 2 (away from windows)

Manual entry station switch

Daylight zone switch

Non-daylight zone switch

Integrated Control Components

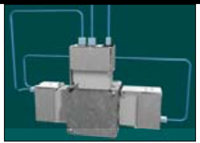
- Motion sensor ceiling mounted center of room
- Entry switches separate rows
- Ccontrol station selects uplights, downlights and board lights.

Integrated Control Options

- Switching photocell (window row only)
- Dimming photocell (preferably 2-zone)
- Manual dimmer for downlights

Smart Design: Less Copper, Less Labor

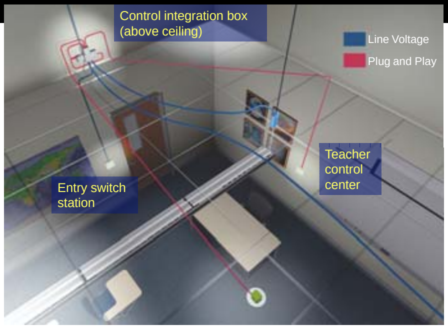
- Prewired luminaires – simple electrical terminations
- Prewired, plug and play control components
- Low voltage, plenum rated class II control wiring does not require conduit
- Significantly reduced first costs due to plug and play integration



Control integration box -1 per room

All wall stations are low voltage

Plug and Play Wiring



Field Activities

Commissioning and Start Up

- Plug and play eliminates wiring errors
- Commissioning includes
  - Calibrate and set motion sensors
  - Calibrate and set daylight sensors

Acceptance Testing

- Demonstrating full operation

User Education

- Teaching the user how to use the lighting systems and what they can (and can't) do

PIER Classroom System Performance

Parameter	***Criterion***	***PIER Performance – 2 Row "Good" System – 6 luminaires per row***	***PIER Performance – 2 Row "Better" System with Whiteboard luminaire – 5 luminaires per row***
Illumination throughout student seating area in general mode	30 fc Min (maintained)	59 fc Avg (31 fc Min in corner)	46.5 fc Avg (27 fc Min in Corner)
Board illumination in general mode.	10 fc min 4:1 or better	25.5 fc Avg 1.4 : 1	34 fc Avg 2 :1
Daylighting integration without dimming	at least 50% power reduction	Separate row switching minimum	Separate row switching minimum
A/V Mode illumination throughout student seating area	10 fc Avg (maintained)	22 fc Avg	18 fc Avg
Vertical illumination on screen in A/V Mode	8 fc max	8 fc Max	6 fc Max
Lighting Power Density (high efficiency lamps and ballasts)	0.96 w/sf or better	0.88 w/sf in General Mode 0.36 w/sf in A/V Mode	0.86 w/sf in General Mode 0.30 w/sf in A/V Mode
Meets Energy Codes	All	All	All

Design Today's Buildings

Defining Efficiency through "Net Zero"

Responsible Options

- Net Zero Electricity
- Net Zero Conventional Energy Use
- Net Zero Total Energy Use
- Net Zero Carbon Footprint
- Net Zero Electric TOU

Net Zero Options

	Measured Grid Energy Use	Measured Gas/fossil fuels Use	Net Energy of Building Materials and Construction	CO^2 generated by operations
Electricity	✓			
Energy Use	✓	✓		
Total Energy	✓	✓	✓	
Carbon Footprint	✓	✓	✓	✓
Electric TOU	✓*			

Arguments

Net Zero Electricity

- Very relevant
- Easy to measure
- Practical to accomplish
- Not fair when using other sources
- Could be a long way from “net zero”

Arguments

Net Zero Energy Use

- Very relevant
- Easy to measure
- Harder to accomplish
- Fair representation of energy use impact
- Not exactly “net zero”

Arguments

Net Zero Total Energy

- Extremely relevant
- Very hard to measure
- Very hard to accomplish
- Fair representation of energy impact
- Not exactly “net zero”

Arguments

Net Zero Carbon Footprint

- Profoundly relevant
- Nearly impossible to measure
- Probably impossible to accomplish
- Most honest representation of impact
- The real “net zero”

Arguments

Net Zero Electric TOU

** Accounts for time of use*

- Short term significant relevance
- On peak excess energy counts more than off peak
- Easily measured
- Practical to accomplish
- Encourages off peak use
- A practical measure of current needs
- A net zero that makes a lot of sense

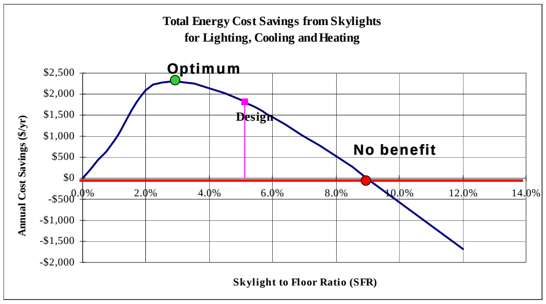
Concept Behind NZ Electric TOU

- Building energy demand profile does not match non-depletable source profile
- Excess thermal energy can be stored but excess electric energy is better off returned to the grid as a “bank”
- Bank “account” is depleted periodically
- Peak users pay a premium
- Peak generators are rewarded

Guiding Principles

1. Negawatts cost less than megawatts
2. Passive beats active any time
3. Start with the low hanging fruit on all trees

Step 1: Employ Daylighting



Savings from Good Daylighting

- Up to 100% of lighting demand
- The cooling associated with lighting demand
- Excessive cooling due to sub-optimal daylighting
- Cooling energy coincident with other peaks

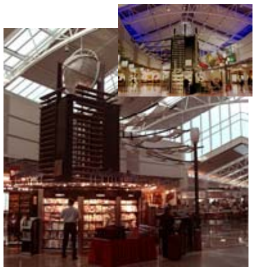
Critical to Good Daylighting

- Proper massing
- Proper orientation
- Proper shading
- Take advantage of topography, landscape and other natural elements

Step 2: Efficient Electric Lighting

- High efficiency lighting equipment
- Smart Lights – ability to control through digital lighting infrastructure
- Natural ambient design technique – in daylighted spaces, avoid trying to produce daytime light levels with electric light
- Low ambient design
- Integrated control that assures daylight harvesting

Technique: Natural Ambient



- Takes advantage of the day-night cycle
- High light levels by day (but not too high)
- Low light levels by night (but not too low)
- Lights OFF by day – let the levels follow nature

Technique: Natural Ambient

Top Technologies

Sources

- Super T8
- T5
- Compact fluorescent
- LED

Controls

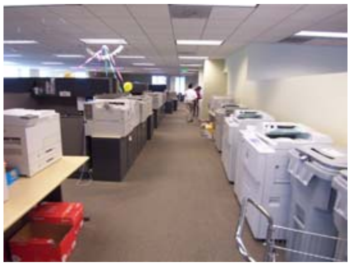
- Electronic dimming ballasts
- Digital lighting control infrastructure

Step 3: I.T. Power

2007 oPod Survey of California Offices

Lighting	1.1 w/sf
Computers	0.7 w/sf
Monitors	0.4 w/sf
Printers and misc	> 0.2 w/sf
TOTAL I.T.	1.3+ w/sf

I. T. Power can be as high as 3-4 w/sf in regular spaces



Simple I.T. Changes

- Use laptops or thin clients
  - Standard office computer 60-120 watts
  - Laptop 15-50 watts
  - Thin client 10-20 watts
- Use LCD screens
- Minimize wall-warts
- Employ IT energy management software

Step 4: Control Other Plug Loads

oPod Survey Plug Loads Discovered

Portable space heaters (10%)	1500w
Hot/cold water dispenser	500 w
Personal refrigerator (2%)	120 w
Personal fan (5%)	25 w

Step 5: Mechanical and Envelope Solutions

Passive Systems such as
- Passive solar techniques
- White roof
- Better insulation
- Natural ventilation

Active Systems such as
- Hot water collectors
- Heat pumps (ground or water source)
- Dark sky systems
- Storage systems

Step 6: Load Shedding Controls

A system to shed loads to force a better demand profile or simply prevent use at bad times

A system to shed load in response to grid demand and/or time of use costs

Step 7: Add non-depletable source

Ordinary Efficient Building

Lights	1.1 w/sf
Computers	1.1 w/sf
HVAC (cooling)	1.0 w/sf
Plug load other	.5 w/sf
Non-process	.5 w/sf
DEMAND	4.2 w/sf

Super Efficient Building

Lights	0.2 w/sf
Computers	0.5 w/sf
HVAC (cooling)	.5 w/sf
Plug load other	.25 w/sf
Non-process	.25 w/sf
DEMAND	1.7 w/sf

A Net Zero Building will have..

Envelope
- North facing triple glazed façade
- Central north facing clerestory skylight
- South facing windows with light shelf
- Skylights throughout

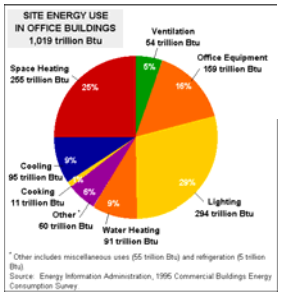
Mechanical
- Water source or ground source heat pump
- Natural ventilation
- Green roof with PV array
- Good insulation

A Net Zero Building will have..

Lighting
- General lighting 0.3 w/sf
- Task lighting 0.45 w/sf
- Digital dimming and controls for all systems
- Daylighting designed for >90% effectiveness

Plug Loads
- Demand response and management controls
- Workstation sensors
- >95% conversion to laptops without desktop monitor
- All LCD monitors on other computers

Example: Office Building Energy Use



* Other includes miscellaneous uses (55 trillion Btu) and refrigeration (5 trillion Btu)

Source: Energy Information Administration, 1995 Commercial Buildings Energy Consumption Survey

Prime Targets for Net Zero Electricity or Electric TOU
- Lighting
- Lighting related cooling
- Cooling due to bad daylighting
- Office Equipment

Opportunity
- 50% less energy
- 70% less demand

Net Zero Electricity

The Chartwell School, Seaside CA

EHDD Architects, San Francisco

- LEED Platinum
- Practical Costs

Net Zero Electricity

Other Keys to Success

- Totally integrated design team
- Daylighting is part of schematic design
- Owner, architect, engineers and consultants are all part of schematic design
- Early definition of goals
- Early identification of incentives and rules
- Use LEED later not now

Offices

Design Criteria

- Paperwork Category D or E
- Computer Screens
- Daylight integration
- LPD < 0.9 w/sf
- Controls needed

Choices

General Lighting System

- Recessed
- Suspended

Technique

- Normal
- Low ambient
- Natural ambient

Schools

Design Criteria

- Classrooms Category D or E
- Gyms 40-50 fc
- Computer Screens
- Daylight integration
- LPD < 0.9 w/sf
- Controls needed

Choices

Classroom Lighting System
- Recessed
- Suspended
- Board

Gym
- General Lighting
- Flexible Lighting

Technique
- Normal
- Low ambient
- Natural ambient

Stores

Design Criteria
- General Lighting
- Display Lighting
- Daylight integration
- LPD < 3 w/sf
- Controls?

Choices

General Lighting System
- Recessed
- Suspended

Accent Technique
- General lighting
- Low ambient/high contrast
- High ambient low contrast
- Natural ambient variable contrast

Big Boxes

Design Criteria
- Displays, merchandise
- Daylight integration
- LPD < 1.2 w/sf
- Controls ?

Choices

General Lighting System
- HID
- T5HO

Technique
- Normal
- Low ambient
- Natural ambient

Hospitality

Design Criteria
- Tasks B-D
- Decoration Needed
- Minimal daylight and integration
- LPD < 1.5 w/sf
- Dimminig needed

Choices

General Lighting System
- Recessed
- Suspended

Technique
- Normal
- Low ambient
- Natural ambient

Offices

Design Criteria
- Paperwork Category D or E
- Computer Screens
- Daylight integration
- LPD < 0.9 w/sf
- Controls needed

Choices

General Lighting System
- Recessed
- Suspended

Technique
- Normal
- Low ambient
- Natural ambient

Download all programs at www.benyalighting.com and at the Energy Center of Wisconsin website

Thank You