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School Lighting

High Performance Schools
August 24, 2004
Bridget Ford
GE Lighting
630-573-3877

Energy Savings
COLOR
Sustainable Design
Dark Schools

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Schools Facts

- Educational institutions in the US pay almost $9 billion per year for energy costs.
- Lighting accounts for $61/student and $0.41/sq ft.!
- **Energy and Utilities account for 30% of typical school budget---2nd only to Payroll at 53%.**
- Alliance to Save Energy Predicts Schools can save approx. 20% of these costs by being more energy efficient.
- Daylight Harvesting is one type energy saving measure that not only benefits the utility bills but also student test performance.
- School Safety is a serious and costly concern--Shatter Resistance Combined with Energy savings for security in cafeterias and common areas.
- **Dark Schools, Motion Detectors New Trends in After Hours Safety**

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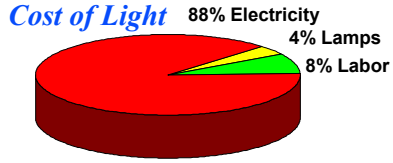

Trends for School Lighting:

- Aging Infrastructures
- Increased Government Regulations
- Operating Cost Pressures
- Environmental Regulations

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School Needs Overview

Safety & Security

- Student and Staff Protection.
- Regulatory Compliance.

Labor Savings

- Reduction in Maintenance Staff & Budgets
- Decrease Classroom Disruptions From Lighting Maintenance.

Environmental

- Decrease Cost of Disposal.
- Energy Efficiency Reduces Our Dependence on Fossil Fuels.
- Reduce Trespass Light

Energy Savings

- This Budgeted *Fixed* Cost Can Be Better Allocated to Books, Computers, Teachers.

Light Quality

- Provide for Better Attitudes and Test Scores.
- Light Levels at 20-30 Foot Candles Ideal for Classrooms.

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Light Quality

Why be concerned about the quality of your lighting?

Complex tasks made easier
Feeling of comfort
Clean appearance
Large Interest in "Daylight Colors effect on attention spans and improving overall ambiance

- High CRI lamps provide more vibrant environment…
  Student Test Scores & complex tasks
- The Ambient Lighting effect" can be cool or warm.
  Cool looks cleaner, warm is more home-like
- Educational facility changing image from "institutions"
  Lighting is key element of image change.

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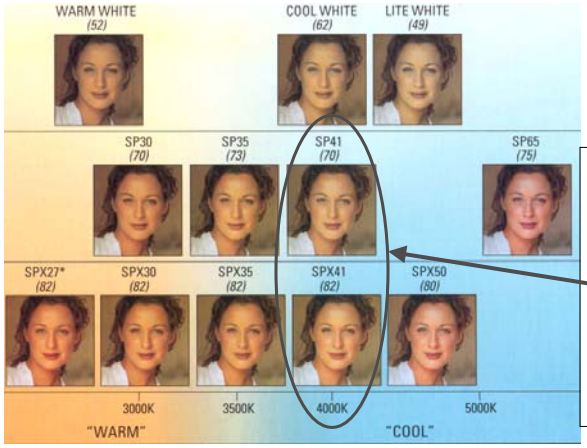
Light Color and Quality

Color Rendering Index (CRI) and Color Temperature...



- ***4100K - most common Color in the Classroom***
- ***Trend Towards 5000K***

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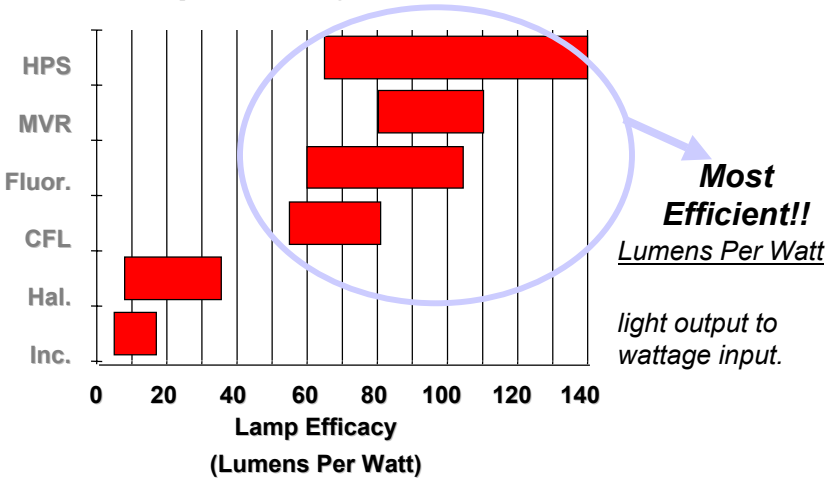
Energy Savings

Lamp Efficacy ...



Most Efficient!!

Lumens Per Watt

light output to wattage input.

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Products to use For High Performance

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High Performance Fluorescent

T8 <u>New Lamps & Ballasts-</u> Greater Efficacy!

More Lumens pre watt on New products

Save 44% on New 28 watt system compared to T12

T5- Most Effective Total High performance system

- Shatter protected lamps

-Expanded 5000K product line

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High Performance Compact Fluorescent

- Complete Energy Star® rated line

-7 to 42 watt Screw in lamps- can be used in incandescent socket

-5 to 70 watt in plug in lamps

-Dimable

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High Performance HID

New Shapes and sizes
Give an incandescent look
For a lot less money to operate

HID
CMH- Improved Color
Expanded dimming possibilities
Greater Efficacy

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Environmental

LAMP DISPOSAL REGULATIONS

- **Federal law Conditionally Exempts Small Quantity Generators (CESQG Status)**
  - Under Federal Law, facilities generating less than 100 kg of total hazardous waste per month are exempt from federal hazardous waste regulations, (360 4' T12 lamps = 100 kg)
- **Lamps which pass the TCLP test are considered non-hazardous waste in PA and can be disposed in solid waste landfills.**

■ **Adopted Universal Waste Rule for Lamps**

- **Can "recycle" hazardous waste lamps as non-hazardous waste under Universal Waste Rules**
  - **Significantly Reduces Transportation, Storage and Record Keeping Requirements**
- **List of Recyclers: www.lamprecycle.org**

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Safety

Shatter Containing Fluorescent lamps for Safety...

Multiple Products are available with shatter protection.

Shrink wrapped to end sleeves---won't flake or peel off

- **Least amount of light loss for any safety lamp available...**
- **Available in all the High Performance Lamp types, Long life, ECO,**
- **Easier to replace than acrylic shields**
- **FDA *MANDATED* product**
  Food Processing and Grocery
- **Meets OSHA standards--work site safety**
- **National Sanitation Foundation (NSF) app'd**

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Safety and Security

Is the school safer from vandals with the lights off?

Trends towards more and more parking lot lighting… does that light the way for Vandals?

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Labor Savings

Improve Maintenance Staff Productivity and Decrease Disruption... Retain Design integrity

- Approx. 1/3 of maintenance work hours
  Servicing lighting systems
- Average per lamp replacement costs rising
  Fluorescent and Incandescent:
  $10.00/lamp or $3.00/lamp (Group re-lamp)*
  HID- Can be significantly more expensive

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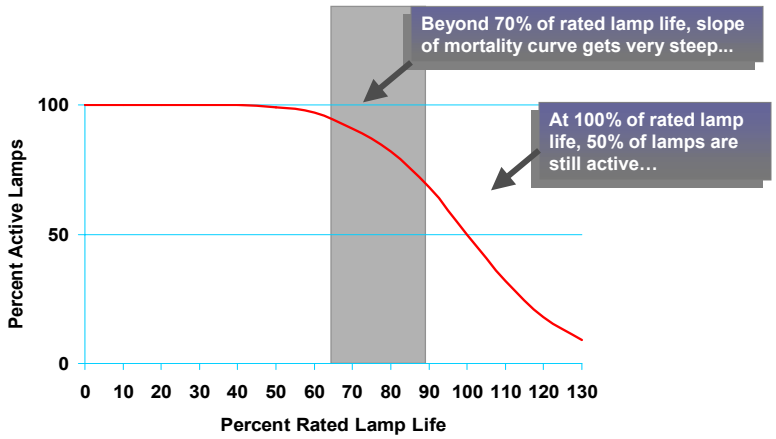
Labor Savings

Lamp Mortality & Planned Maintenance



Where on this curve is your lighting maintenance done now?

Labor Savings

Solution=
Long life lamps

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COLOR
Energy Savings
Sustainable Design
Dark Schools

"Sustainable Lighting Design meets the qualitative needs of the visual environment with the least impact on the physical environment." - IALD Sustainability Committee

- Collaborating with other design disciplines to further green building practices
- Maximizing the use of daylighting
- Minimizing the use of energy
- Avoiding skyward illumination
- Ensuring system durability and maintainability
- Encouraging environmentally responsible manufacturing processes
- Advocating the development and use of renewable energy and other sustainable building materials and technologies

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Sustainable Lighting Design

Collaboration with other design disciplines

- U.S. Green Building Council (USGBC)
  - leading organization for sustainable design industry
  - administers Leadership in Energy and Environmental Design (LEED) green building rating system
- AIA Committee on the Environment
- International Dark Sky Association (IDA)
- IESNA, LIRC, NCQLP, IALD

LEED
LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

Leadership in Energy & Environmental Design

A leading-edge system for designing, constructing, operating and certifying the world's greenest buildings

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Why Was LEED™ Created?

- Use as a design guideline
- Recognize leaders
- Stimulate green competition
- Establish market value with recognizable national "brand"
- Raise consumer awareness
- Transform the marketplace!

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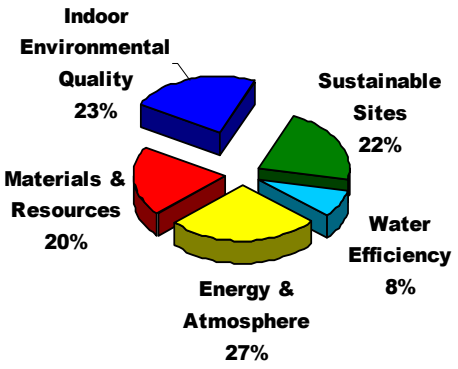
Technical Overview of LEED™

- Green building rating system for new construction and major renovation.
- Existing, proven technologies

70%
Directly related to lighting



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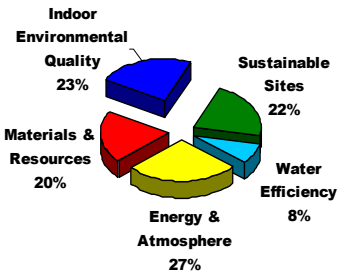
Technical Overview of LEED™

- Optimizes environmental and economic factors
- Emphasize Daylighting
- Four levels of certification
  - LEED Certified 26 - 32 points
  - Silver Level 33 - 38 points
  - Gold Level 39 - 51 points
  - Platinum Level 52+ points (69 possible)

Minimizing the use of energy

- Standards for "energy-effective" lighting
- Energy code requirements
- **Energy conservation & efficiency - largest category in LEED ratings**
- ASHRAE/IES Standard 90.1
- Quality of the Visual Environment
- Energy efficient systems including controls



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Meeting LEED$_{tm}$

•LEED requires that you meet or exceed ASHRAE 90.1-1999

"Provide a LEED Letter Template, signed by a licensed professional engineer or architect, stating that the building complies with ASHRAE/IESNA 90.1-1999 or local energy codes. If local energy codes were applied, demonstrate that the local code is equivalent to, or more stringent than, ASHRAE/IESNA 90.1-1999 (without amendments)."
(US Green Building Council)

•LEED will award 1 point for every 5% reduction in design energy cost beyond ASHRAE 90.1-1999.

Up to ten points can be earned here!

•LEED will award 1 point for regional material on project

"Use a minimum of 20% of building materials and products that are manufactured* regionally within a radius of 500 miles."
(US Green Buildings Council)

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The Impact of Energy Legislation

LIGHTING	ASHRAE/IES 90.1-1999

- Library - 1.5 W/ft^2
- Office - 1.3 W/ft^2
- School - 1.5 W/ft^2

For New Construction and Remodeling Projects

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ASHRAE/IES 90.1-1999

- ***4.1.2.2.5 Lighting Alterations***
  - Existing Buildings:
    - If alterations replace greater than 50% of the luminaires in a space, building space shall comply with the lighting power density requirements
    - Automatic Shut-off controls not required.
- ***9.2 Mandatory Provisions - Interior Controls***
  - If New Construction is greater than 5000 sq. ft.
  - Interior Lighting Controls - Automatic Lighting Shutoff
    - Programmable Lighting Whole Building Controller
    - Occupancy Sensors
    - Occupant Intervention
      - Signal from another control or alarm system indicating that the area is unoccupied

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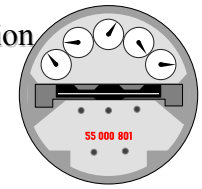
Lighting Control Strategies

- Occupancy responsive - turn lights on in response to movement or sound
- Timing - schedule lights on and off
- Manual Dimming - occupant adjusts light level
- Daylighting - dims lights in response to daylight level
- Lumen maintenance - reduces high initial light level when lamps are new, fixtures clean
- Tuning - adjusts light levels to meet the needs of users
- Adaptation compensation - dims/increases interior lights for dark/bright outdoor lighting conditions
- Load shedding - reduces lighting power consumption during peak electrical demand



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Public awareness of light pollution or "sky glow"
Powerful Advocate: International Dark Sky Association
Balance between lighting and dark sky objectives

Avoiding skyward illumination

Ensuring system durability and maintainability

- "Ensure that the design has a life beyond the initial installation."
- Longer life lighting systems
- Standardizing lamps, minimizing the quantity of different lamps

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Sustainable Lighting Design

Encouraging environmentally responsible manufacturing processes

- Fluorescent lamps use Mercury to start the lamp, look for TCLP compliant or "ECO" lamps
  - Major technology improvements in Fluorescent Lamps have given us 85% less Mercury than the 1970's counterparts
- Reduction of lead in base solders
- Ballast PCB's- No ballasts manufactured after 1978 contains PCB's
- Encourage Recycling

Sustainable Lighting Summary

- 70% of LEED principals pertain to lighting
- Min. of 26 pts for LEED certification 11 points can be obtained through effective lighting
- 1/3 of the schools utility bill is for Lighting
- Student productivity increases as lighting quality increases

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high performance lighting products

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Save 75%

Compared to Incandescent:

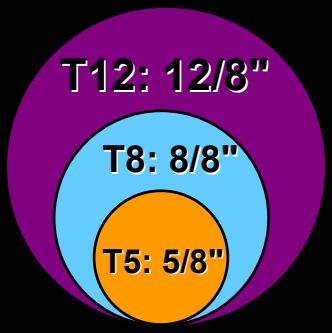
8-13X More life
Up to 13%
more light

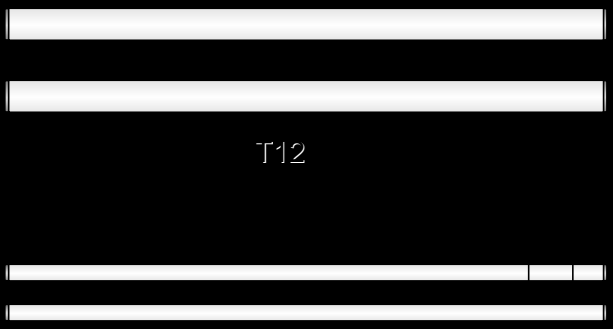
7-20X More life
Up to 35%
more light

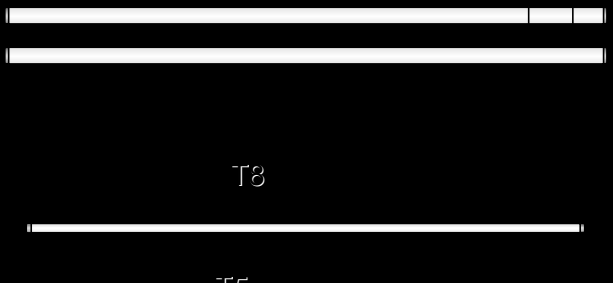
5-8X More life
Up to 150%
more light

3-13X More life
Up to 129%
more light

Linear Fluorescent Lamps







same lumens as two T8's

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4 Foot Lamps

	Light	Life	Watts	
T12 magnetic Ballast	100%	100%	144%	
Standard F32T8 on Standard Electronic	100%	100%	100%	
"Long lifeXL"	100%	+20-50%	100%	
F32T8 HL	109%	+25%	100%	
30 Watt T8	100%	+25%	-11%	11% when used on High efficiency Ballasts
28 watt T8	97%	100%*	-18%	when used On High efficiency Ballasts
25 watt	82%	100	-22%	

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Choosing wisely

Things to watch for with Fluorescent Lamps

- Dimming requires a special more expensive ballast
- Frequent switching reduces lamp life
- Temperature sensitivity
- Compact fluorescent + occupancy sensor can be slower warm up time

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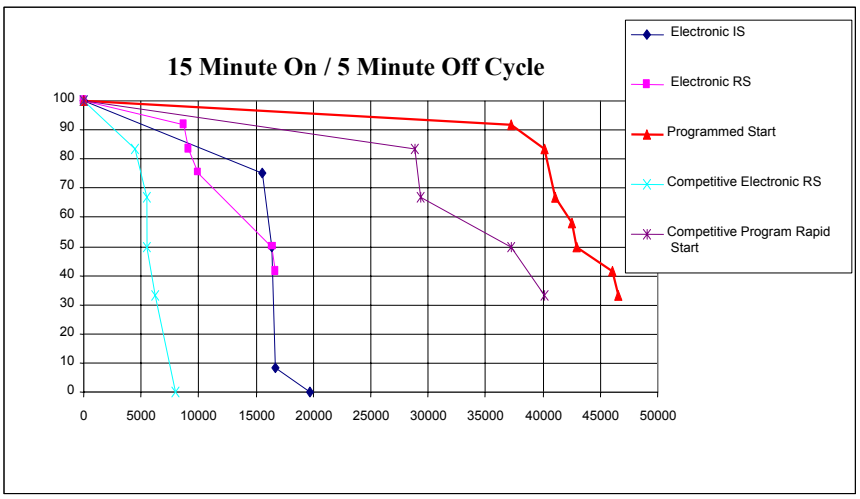
Programmed Start Electronic Ballast for Short Cycle Applications



Longer Life AND Lower Power Consumption

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About Ballasts

- Use electronic ballasts exclusively for fluorescent and compact fluorescent lamps.
  - For T8 Lamps: use the latest “High efficiency electronic” ballasts
  - For T-8 lamps, investigate “low light output” and “high light output” ballasts to fine tune fixture watts to the minimum needed for a space.
  - Dimming ballast prices are falling and allow full daylighting integration.
  - Low temperature ballasts permit compact fluorescent lamp starting and operation at <0º ºF.
  - Electronic Ballasts are cost competitive and in 2005 the most common Magnetic ballasts will no longer be manufactured

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Dimming

Is the Added cost worth it?

Do you need 100% to 5%

Higher installed cost: Power wires plus 2 control wires. Higher priced Compatible ballast & controls.

Limits lamp & ballast options

Higher energy savings

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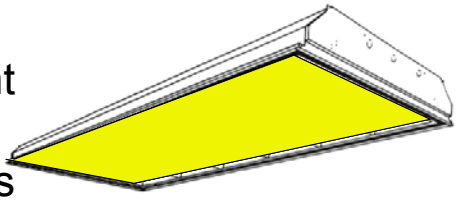
Inboard / Outboard



A high efficiency instant start ballast and High performance T8 lamp is very effective solution.

<u>Switch 1</u> controls 1-lamp ballast for 33% light.

<u>Switch 2</u> controls 2-lamp ballast for 67% light.

Both Switches on 100% light.

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Maximize

	Ballast High Efficient "N"		Ballast High Efficient "L"	
Light Output	Lumens	Watts	Lumens	Watts
100%	6750 all 3 lamps on	74	5970 all 3 lamps on	66
67%	4500 Outboard 2 lamps on	49	4000 Outboard 2 lamps on	44
33%	2225 Inboard 1 lamp on	25	1970 Inboard 1 lamp on	22

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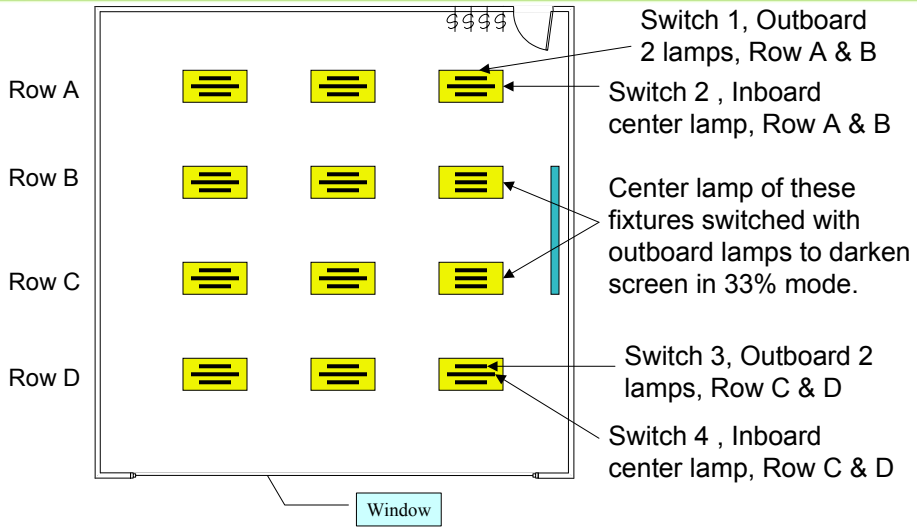
Inboard / Outboard Controls



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HID to T5HO Fluorescent

- **Existing system: 35 fixtures – 250watt Metal Halide – 25-30 footcandles - with 295 watts per fixture.**
- **New system: 21 fixtures – 2x4 6lamp T5HO – 50-60 footcandles – with 351 watts per fixture.**

Photos courtesy of Peter Brown

Before

After

High Bay & Fluorescent T8/T5HO

(3100 lumen T8 on 1.15BF)

	Lamp and Ballast *	
Lamp	**Maintained Light**	**Wattage**
4 - T8 Lamps	13,900 Lumens	152 watts
4 - T5/HO Lamps	19,000	242
1 - MVR250/Pulse	17,000	288
1 - MVR250/U	13,500	293
6 - T8 Lamps	20,850 Lumens	228 watts
6 - T5/HO Lamps	28,500	363
1 - MVR400/Pulse	33,000	456
1 - MVR400/U	23,500	458

* (Impact of Fixture Design and application on Performance NOT included)

AND: Instant on, dimmable, choice of colors, no color shift...

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LED

- Invented in 1962
- common to signal and sign lighting
- Beginning acceptance in general lighting

•Will entirely change lighting as we know it!

High Performance Lighting Design

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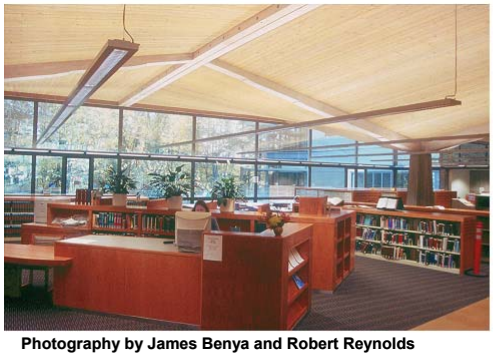
Paul L. Boley Library, Lewis & Clark Law School(Portland, OR)
-Lighting design by James R. Benya and Jon H. Wiener



Photography by James Benya and Robert Reynolds

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University of Oregon Football Weight Room (Eugene, OR)

-Lighting design by Mark S. Godfrey and Earl F. Levin

-Award for Sustainable Lighting Design

Photography by Earl F. Levin and Robert L. Smith

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University of Oregon Football Locker Room (Eugene, OR)

Photography by Earl F. Levin and Robert L. Smith

"Energy-effective" and sustainable lighting design:

- **Utilizes high efficiency lamp, ballast and fixture components**
- **Integrates daylighting and electric lighting systems**
- **Incorporates control strategies that allow light levels to be adjusted to meet the needs of the occupants while satisfying load management directives**
- **Responsibly lights our outdoor environments**
- **Promotes the use of environmentally friendly materials**
- **Provides easy maintenance by limiting the number of different systems, and specifying longer-life products**

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Warning:
Do not assume that "Daylight"
Or High Color Fluorescent will perform the same as Natural Daylight

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"Light can have a number of effects on humans in addition to its relationship to vision. We have known for some time that environmental lighting exerts profound biological effects on humans such as mood and biological rhythms. Within the context of children's environment research, lighting has been found to have important effects on attendance, growth and physical development.
In a typical study testing differences between full-spectrum lighting and cool white fluorescent lighting commonly used in institutional settings, it was found that physiological measures indicated that most subjects showed less fatigue after a study session in natural light than in a traditionally illuminated instructional environment."

Jeffery A. Lackney, Ph.D., A.I.A Twelve design principles based on brain based learning research

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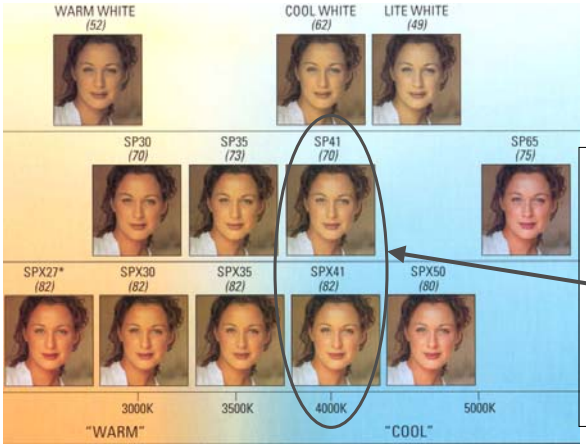
Light Color and Quality

Color Rendering Index (CRI) and Color Temperature...



- ***4100K - most common Color in the Classroom***
- ***Trend Towards 5000K***

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Trends In School Lighting

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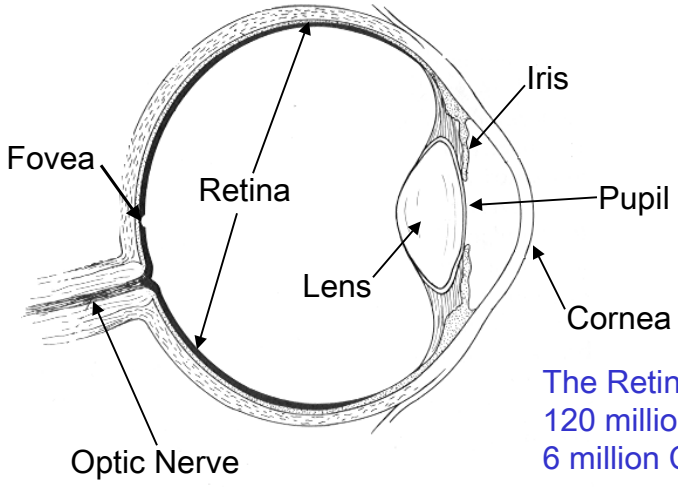
Current Status in the Lighting World:

Lots of Interest
Lots of Opinions
Lots of "Studies"
Tons of Disagreement!

…and, therefore, No Consensus!
No Formal Acceptance from IESNA

Some Background:



The Retina contains
120 million Rods and
6 million Cones

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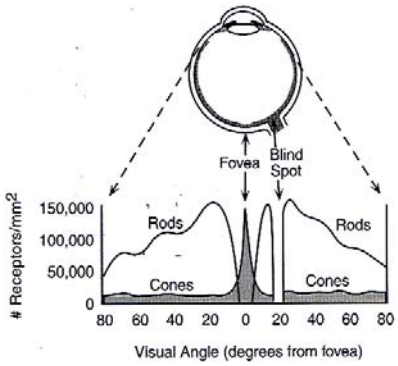
Distribution of Rods and Cones over Retina



Note: No Rods in Fovea

As many as 100 Rods Converge
On a single Optic Nerve Fiber

Peak Rod Density ~17 deg from
Fovea

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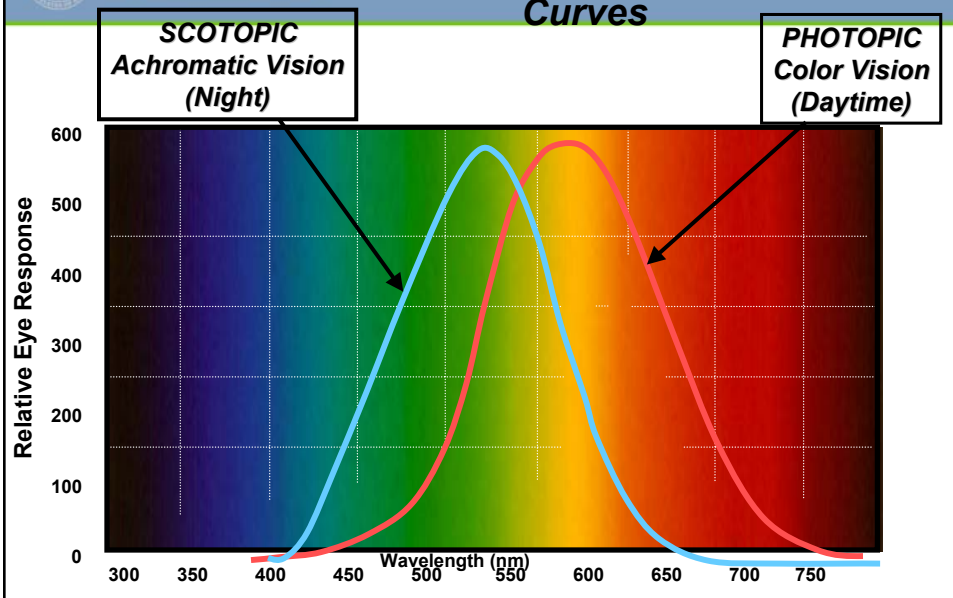
Eye Sensitivity Curves



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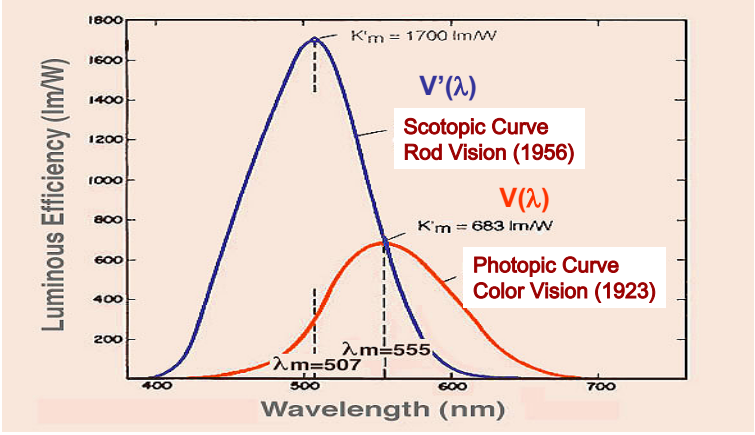
Some Background:

Scotopic and Photopic Functions



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Some Background:

The LUMEN, and the FOOTCANDLE, are
Based on the Photopic Sensitivity Curve

The LUMEN is the only SI Unit Based on Human Response

The Photopic Sensitivity Curve is Based on the Central
2 Degrees of our Vision, and only at Light Levels that
Activate our Cones!

Catalog Lumen Ratings are generated by Summing the
Product of Lamp Energy at Each Wavelength of the Lamp
Spectral Power Distribution (SPD) Curve times the
Photopic Curve Weighting Factor and then Multiplying
by a Constant.

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Some Background:

The SPD of the Lamp Determines the Lamp's
Color Temperature, CRI, and Lumen Rating

Scotopic Lumens are Based on ROD Sensitivity

Every Lamp will Usually have a Different Photopic
and Scotopic Lumen Rating

The S/P Ratio is the Scotopic Lumens Divided by
The Photopic Lumens for any Lamp

For Ease of Understanding – the Higher the S/P Ratio,
The More "Bluish" the Lamp Appears

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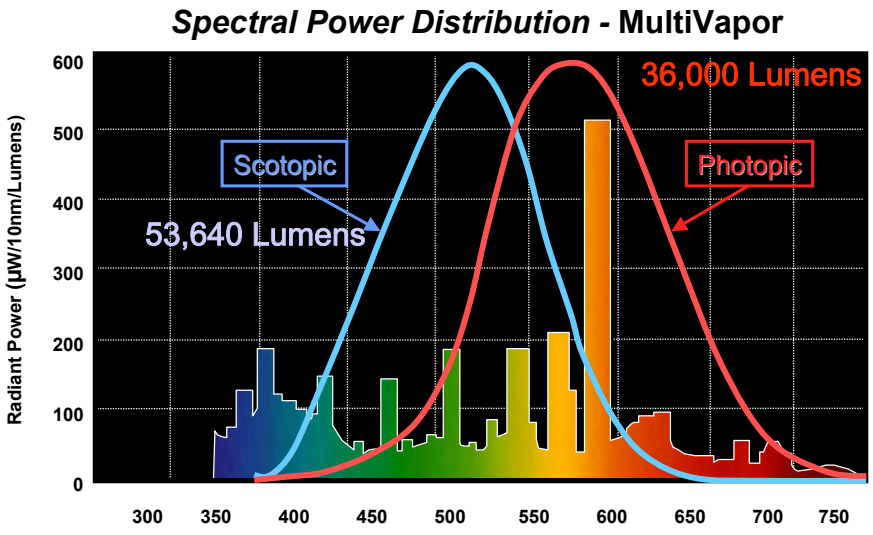
COLOR ISSUES



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Some Examples:

Lamp	Scotopic Lumens	Photopic Lumens	S/P Ratio
400 Watt Lucalox	31,620	51,000	0.62
400 Watt MultiVapor	53,640	36,000	1.49
F32T8/SP50	5,225	2,750	1.90

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Pupil Size is Largely Determined by
the Amount of Rod Stimulation

Rods are Stimulated by Scotopically Enriched Lamps

(i.e. Higher S/P Ratio Lamps)

Smaller Pupil Size Leads to Better Visual Acquity

- Easier to see Fine Detail
- Better Depth of Field

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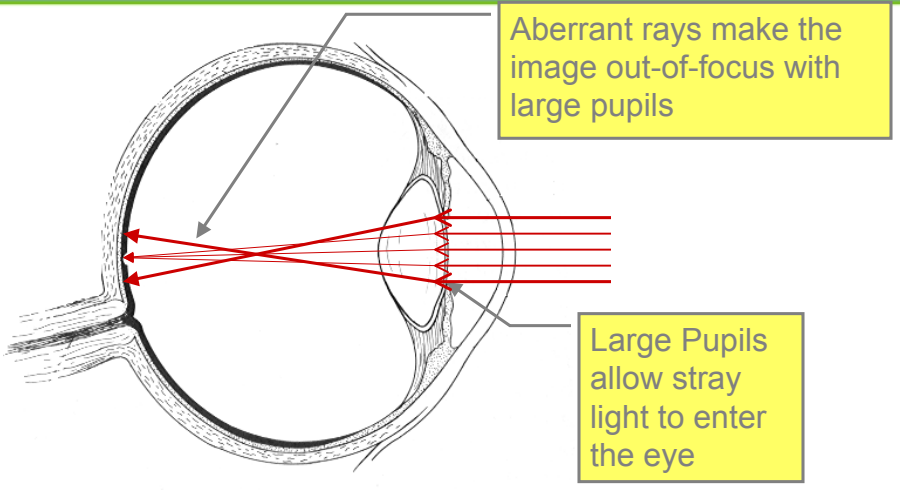
Aberrant Rays



Courtesy of Stan Walerczyk, Brian Liebel

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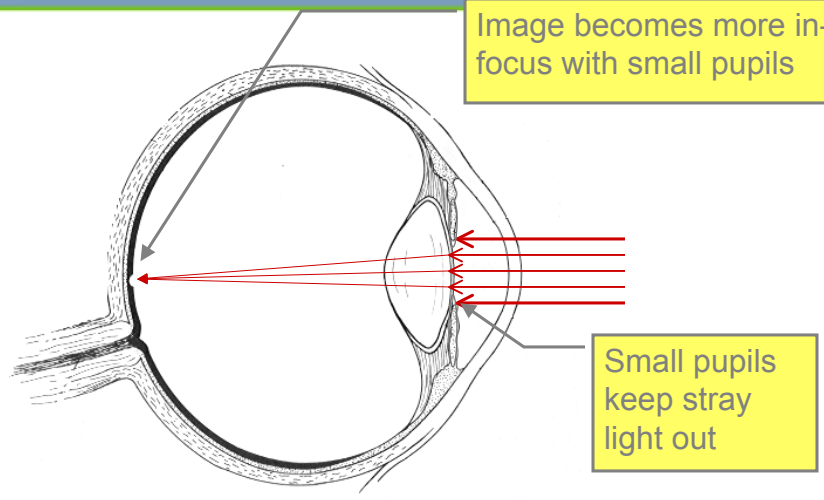
Aberrant Rays



Courtesy of Stan Walerczyk, Brian Liebel

What the "Experts" are saying:

INDOOR Lighting – Use High S/P Ratio Lamps and You Can Reduce Wattage and Get Better Vision, and Make Indoor Spaces Look Brighter and More "Cheerful"

OUTDOOR Lighting – Use High S/P Ratio Lamps and You Can Reduce Crime and Accidents, Make Areas More Attractive and Safer

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Lighting Efficiency S/P Ratio Method

(Credited to Dr. Sam Berman – LBL)

- Obtain Scotopic/Photopic Ratios from lamp manufacturers.
- These ratios can be used to determine more accurate visual efficiencies for these tasks:

Std. Lumens	Ratio	Brightness Perception	Reading Paper	Computer Tasks
P	(S/P)	$P \times (S/P)^{0.5}$	$P \times (S/P)^{0.78}$	P x (S/P)

- *This method is not yet recognized by IESNA*

Courtesy of Stan Walerczyk, Brian Liebel

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S/P Ratio Example

Compare 735 to 850 fluorescent lamps

Lamp	Efficacy (P)	S/P Ratio	Brightness $P(S/P)^{0.5}$	Paper $P(S/P)^{0.78}$	Computer Tasks $P(S/P)$
735	89	1.39	104.9	115.1	123.7
850	93	1.9	128.2	153.4	176.7
The Scotopic Benefit: *Increase in energy efficiency when considering full field visual effect*			+ 22%	+ 33%	+ 43%

This method is not yet recognized by IESNA

Courtesy of Stan Walerczyk, Brian Liebel

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Outdoor Luminance Levels

>3 Cd/M^2 - Clearly Photopic

<.001 Cd/M^2 - Clearly Scotopic

In Between those Values – Variable Levels of Mesopia!

Note - 10 Cd/M^2 - Comfortable Reading Level
3 Cd/M^2 - 1Fc on White Paper
.001 Cd/M^2 - White Paper in Moonlight

Outdoor Testing -

Reaction Time
Off Axis Identification
Contrast Threshold
Color Identification
Object Identification
Preference (Brightness)
Sense of Security

Results –

Mixed and Frustrating!

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Energy Savings
Sustainable Design

COLOR

Dark Schools

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Knowledge Check:

Q-What is the easiest way for a School to save energy?

A-Turn the lights off

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Reasons for Night time lighting

- Normal Occupancy winter time
- Maintenance
- special events
- Safety
- Security
- Enhance aesthetic of area

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Effective Night Lighting Strategies

- Vandals can't see without light
- No light, no vandalism
- Dark Schools can offer greater security
- This concept is catching on as an energy effective solution

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Dark Schools

- Testimonial in Nevada Schools Reduction of Vandalism
- Use of Dark schools with Occupancy Sensors alert community of trespass
- Integration of Security and lighting systems
- Don't be afraid of the dark!

Summary High Performance Design

Environmental benefits: reduce the impacts of natural resource consumption

Economic benefits

improve the bottom line

Health and safety benefits

enhance occupant

comfort and health

Community benefits minimize strain on local infrastructures and improve quality of life