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· August 15-18, 2010 · Dallas, Texas ·
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Spectrally Enhanced Lighting

SPECTRALLY ENHANCED LIGHTING

WHAT WE ARE TALKING ABOUT:

- Interior Lighting Applications
- Tasks where visual acuity is important
- Typically, IES Categories D through G:
  - 30-1500 Footcandles
  - Typical Task: Reading, Paper-based Tasks

WHAT WE ARE NOT TALKING ABOUT:

- Outdoor Lighting (Mesopic)

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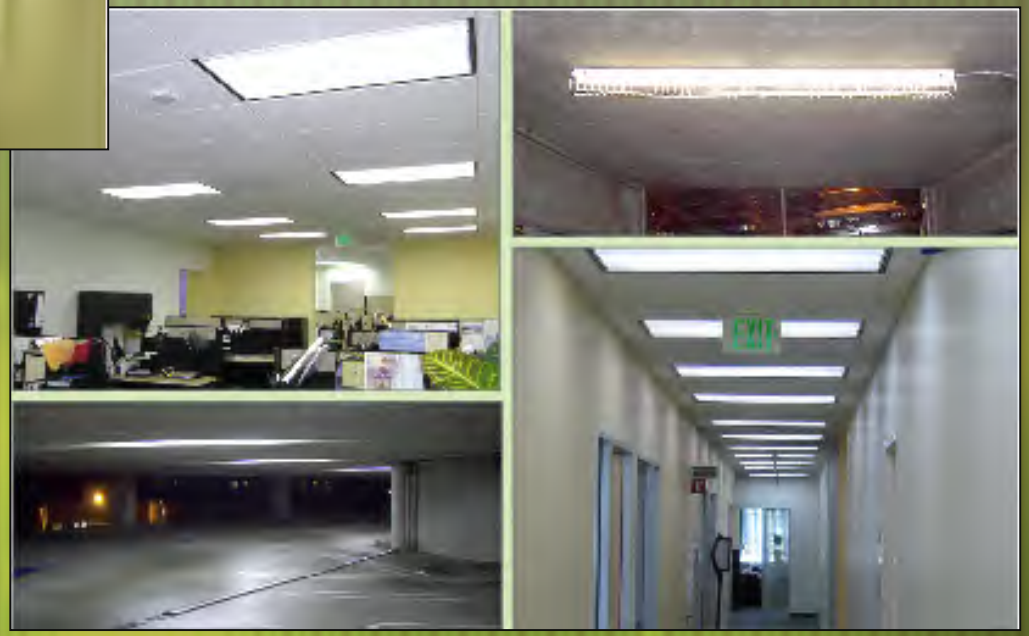
APPLICATIONS - LIGHTING RETROFIT

Office Space

Before



After

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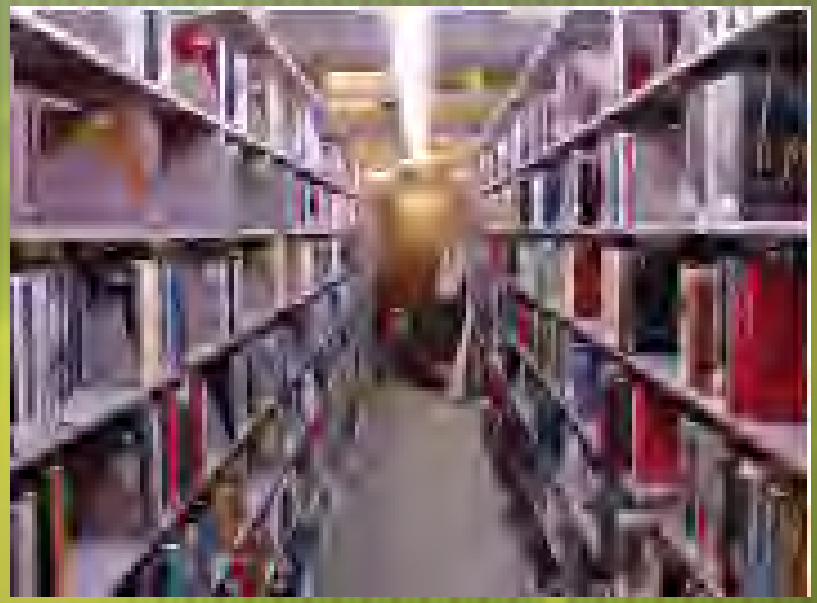
APPLICATIONS - LIGHTING RETROFIT

Library

Before



After

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APPLICATIONS - LIGHTING RETROFIT

Washington DC

Navy Office Building

Before

After

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APPLICATIONS - NEW CONSTRUCTION

Orinda City Hall: LEED Gold

New Construction:

- Integrates with Daylight
- Reduces Lighting Power Density
- Immediate Payback

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NATURAL ADVANTAGE OF DAYLIGHT SPECTRUM

The color of light has inherent qualities that have not been completely understood. Recent discoveries in vision science tells us that there's more to light than what we measure.

Using higher CCT lamps with spectra more like daylight:

- Makes the Eye's pupil smaller
- Improves Visual Acuity
- Increases Brightness Perception
- Affects Circadian Rhythm

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SPECTRALLY ENHANCED LIGHTING

Spectrally Enhanced Lighting is a Design Method:

- By changing to higher CCT lamps, we can reduce light levels while maintaining visual acuity - This saves energy!
- SEL can be used with ANY lighting design.
- Simple to implement, requires no special equipment or controls.

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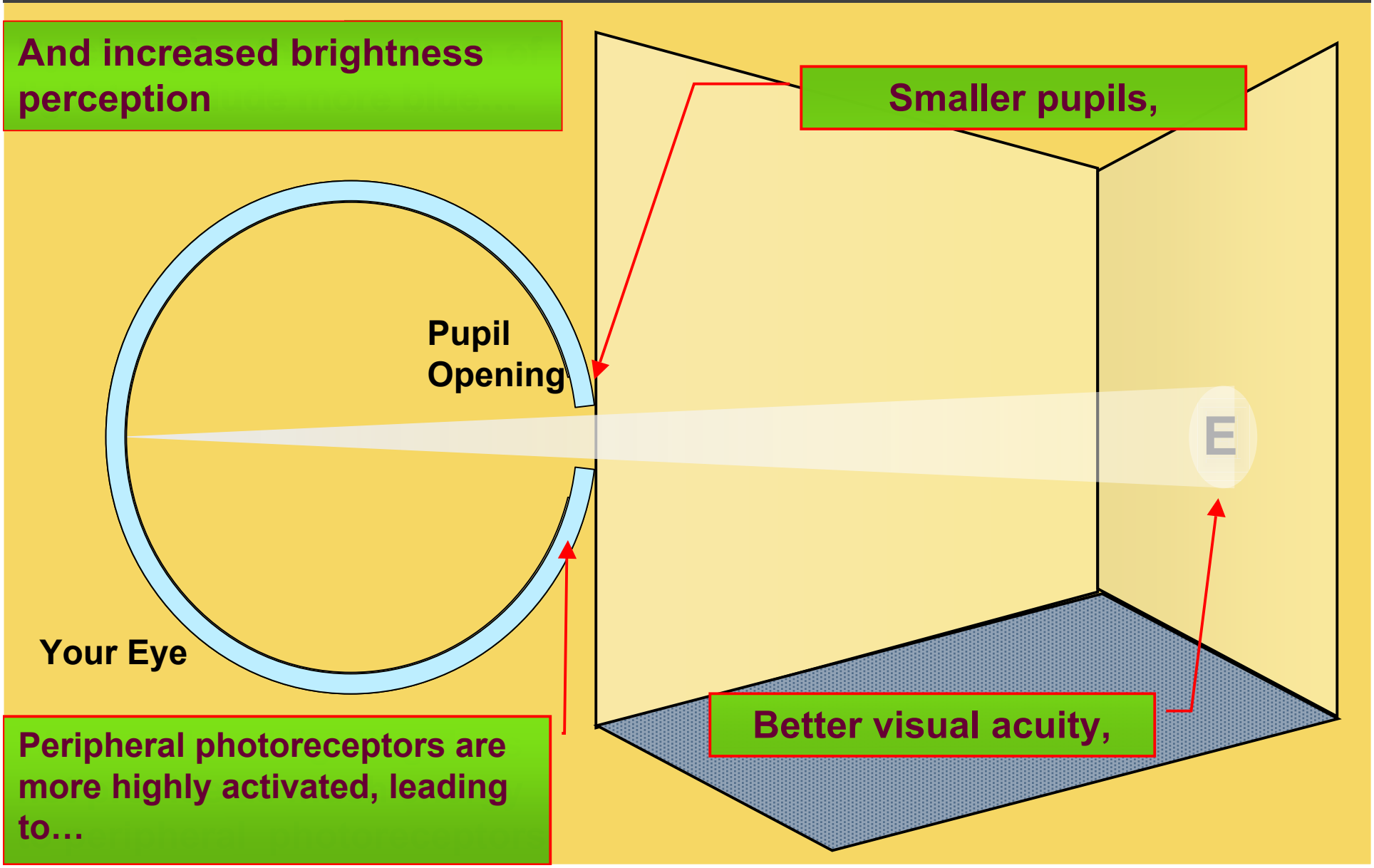
SPECTRALLY ENHANCED LIGHTING



CAN WE USE SPECTRUM IN LIGHTING?

Here's a Practical Question:

What happens when we increase light levels?

- *Pupils get smaller, spaces seem brighter, and* ***we see more clearly…***

What happens when we increase the color temperature (but don't increase the light level)?

- *Pupils get smaller, spaces seem brighter,* ***and we see more clearly…***

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WE CAN USE SPECTRUM IN LIGHTING!

Is increasing the color temperature of a light source like increasing the light level?

YES

Using spectrum to optimize visual effect is called
"Spectrally Enhanced Lighting"
(S.E.L.)

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Light Source

Shift Spectrum - Use Higher CCT

Enhances Visual Response

Smaller Pupils

Increased Visual Acuity

Increased Brightness Perception

Reduce Light Level → **Save Energy**

Equal Visual Acuity

Equal Brightness Perception

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INTERIOR LIGHT LEVELS - BASED ON VISUAL ACUITY

IESNA Illuminance Levels:

Category F: 1000 lx

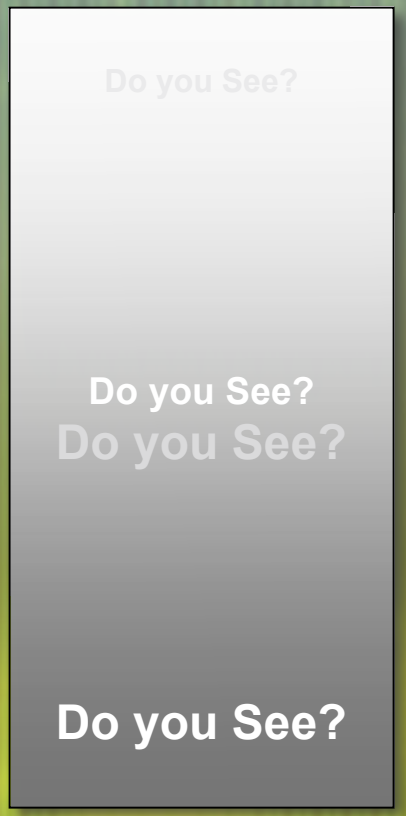
- low contrast, small size

Category E: 500 lx

- high contrast, small size
- low contrast, large size

Category D: 300 lx

- high contrast, large size



Light Levels for "Common Tasks" increase to improve visual acuity for tasks

IES Recommendations are "Photopic" and do not consider spectrum.

What does this mean to lighting design?

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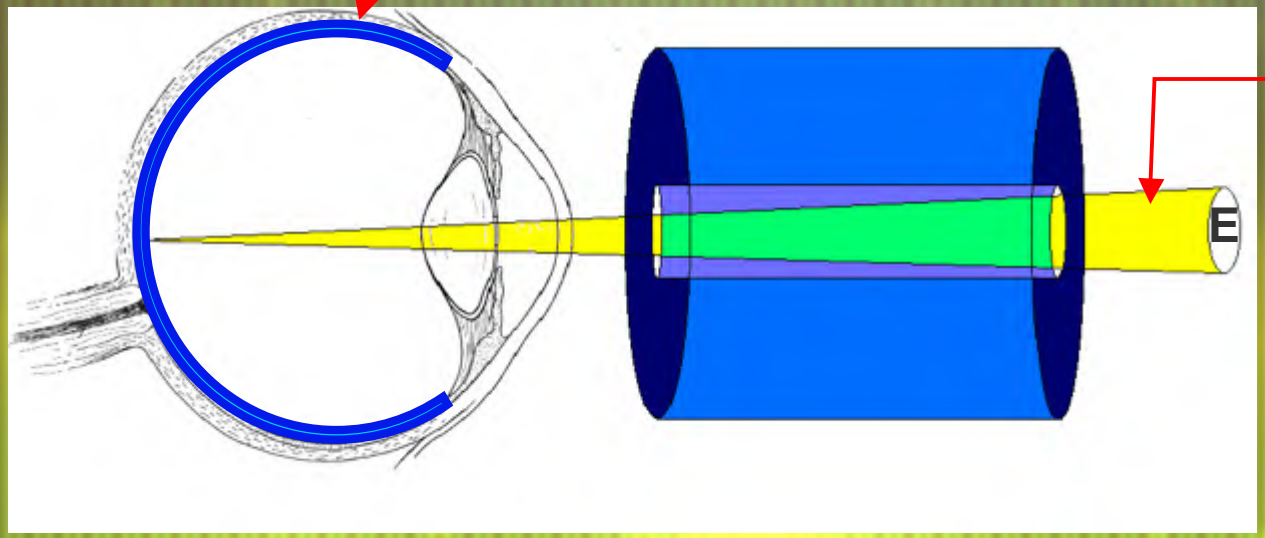
STANDARD LIGHTING MEASUREMENT

PHOTOPIC:

The Photopic Response was determined under the very constrained conditions of a limited field of view.

This ignores the influence of the peripheral photoreceptors that take in lighting from the rest of the real Field of View



2º Field of View

This is less than 1/10 of 1% of the natural Field of View!

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SCIENCE OF SPECTRALLY ENHANCED LIGHTING

WHEN YOU HAVE A FULL FIELD OF VIEW:

- Six separate vision studies ranging from school children to older people demonstrate that spectrum affects visual acuity - Higher CCT, better VA.
- Increased visual acuity is due to smaller pupil sizes, driven by recently discovered non-visual peripheral photoreceptors.
- Empirically derived formulas using the S/P Value account for the peripheral photoreceptor effect on visual acuity and are the basis of S.E.L.

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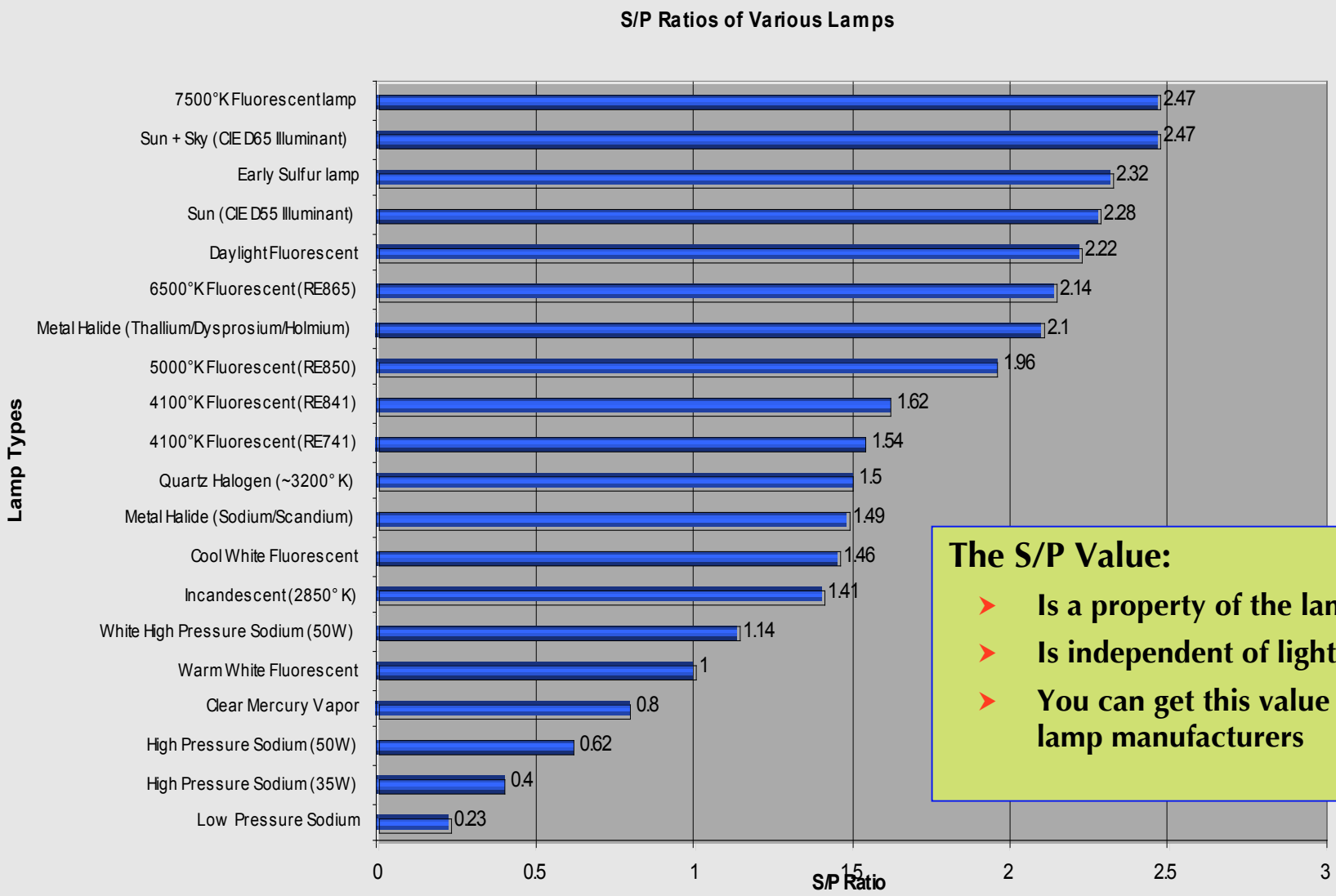
S/P VALUES



The S/P Value:

- Is a property of the lamp
- Is independent of light level
- You can get this value from lamp manufacturers

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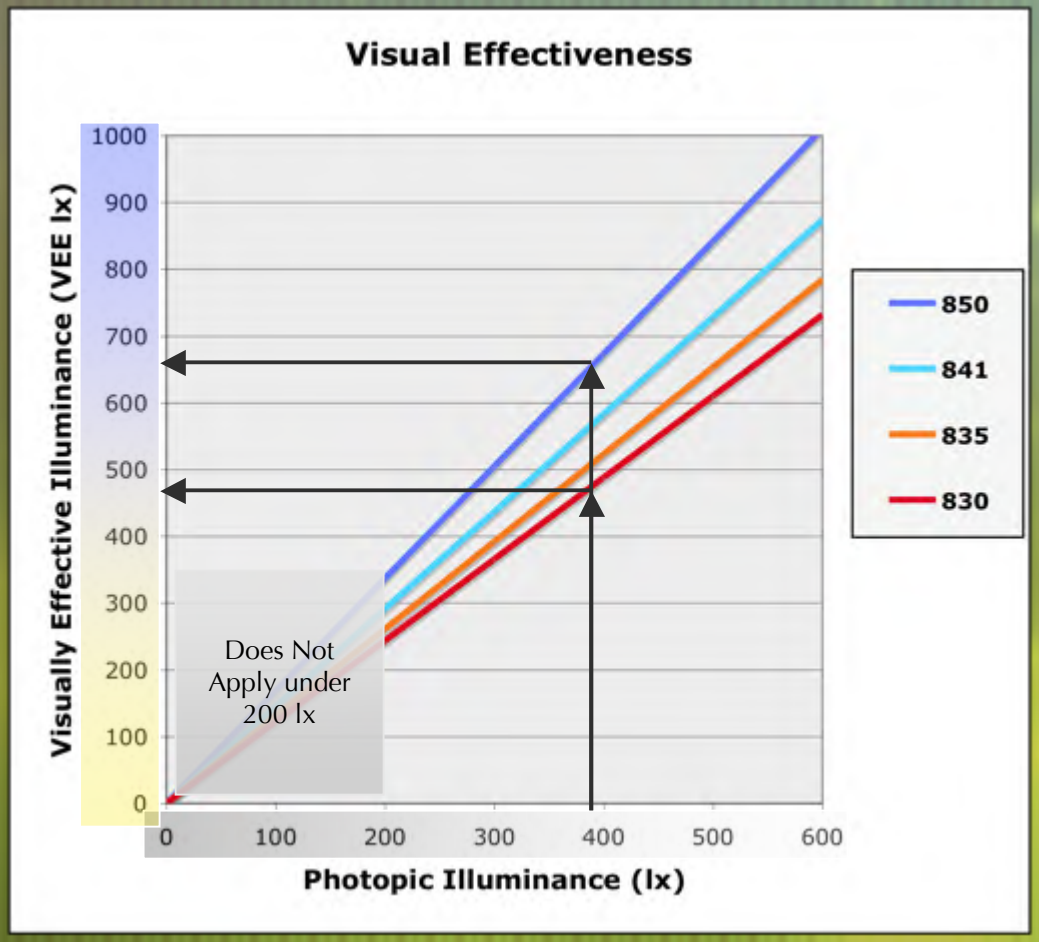
THE CONCEPT OF VISUAL EFFECTIVENESS

Visual Effectiveness Illuminance (VEE)



For Visual Acuity,

Visually Effective Illuminance:

$$VEE = P \times (S/P)^{.78}$$

(= Photopic Value x S/P Value)

Lamp	S/P	VEE @ 400 lx
850	1.95	646
841	1.65	583
835	1.41	523
830	1.29	488

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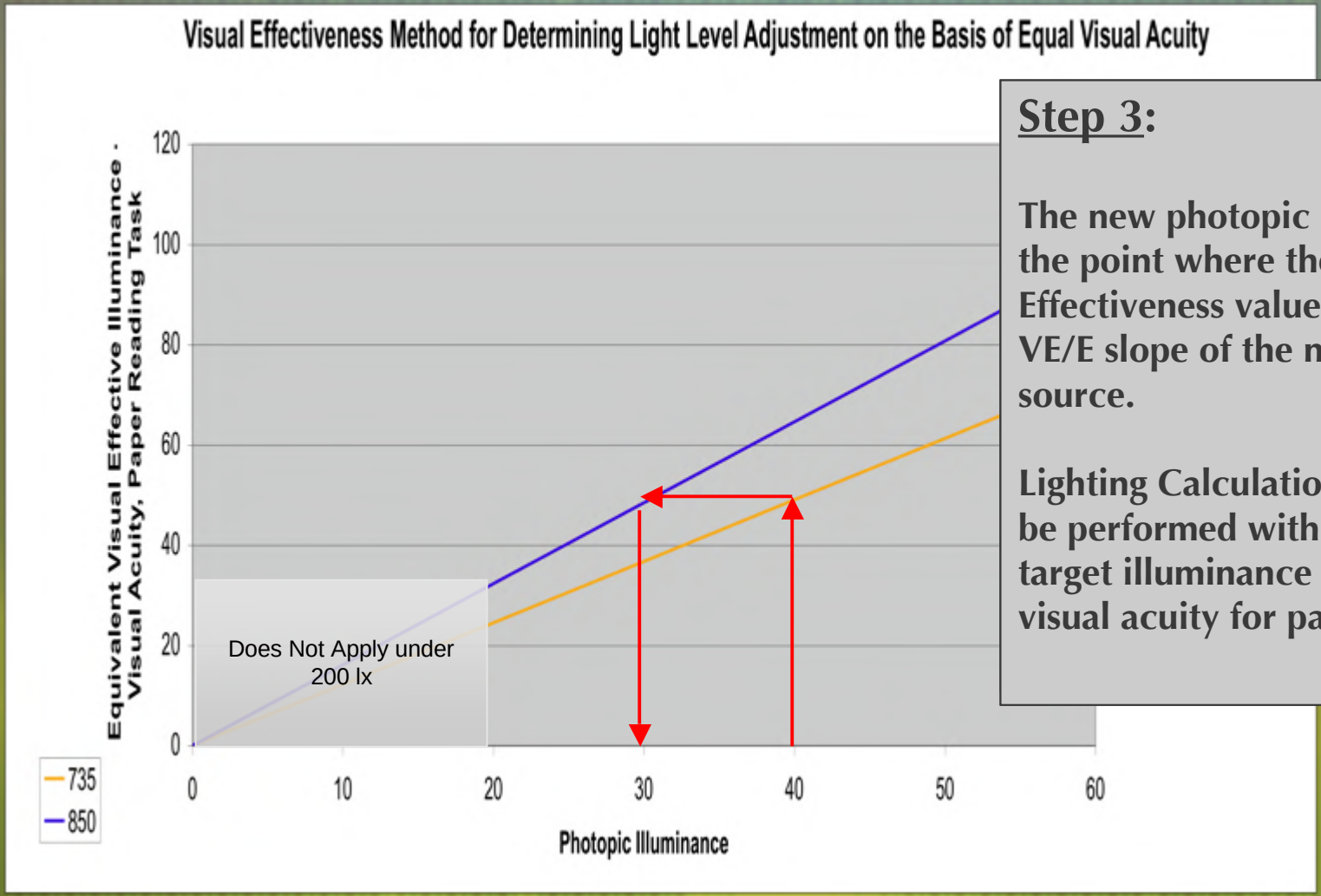
THE CONCEPT OF VISUAL EFFECTIVENESS



Step 3:

The new photopic illuminance is the point where the Visual Effectiveness value intersects the VE/E slope of the new light source.

Lighting Calculations can now be performed with this as the target illuminance - with equal visual acuity for paper tasks.

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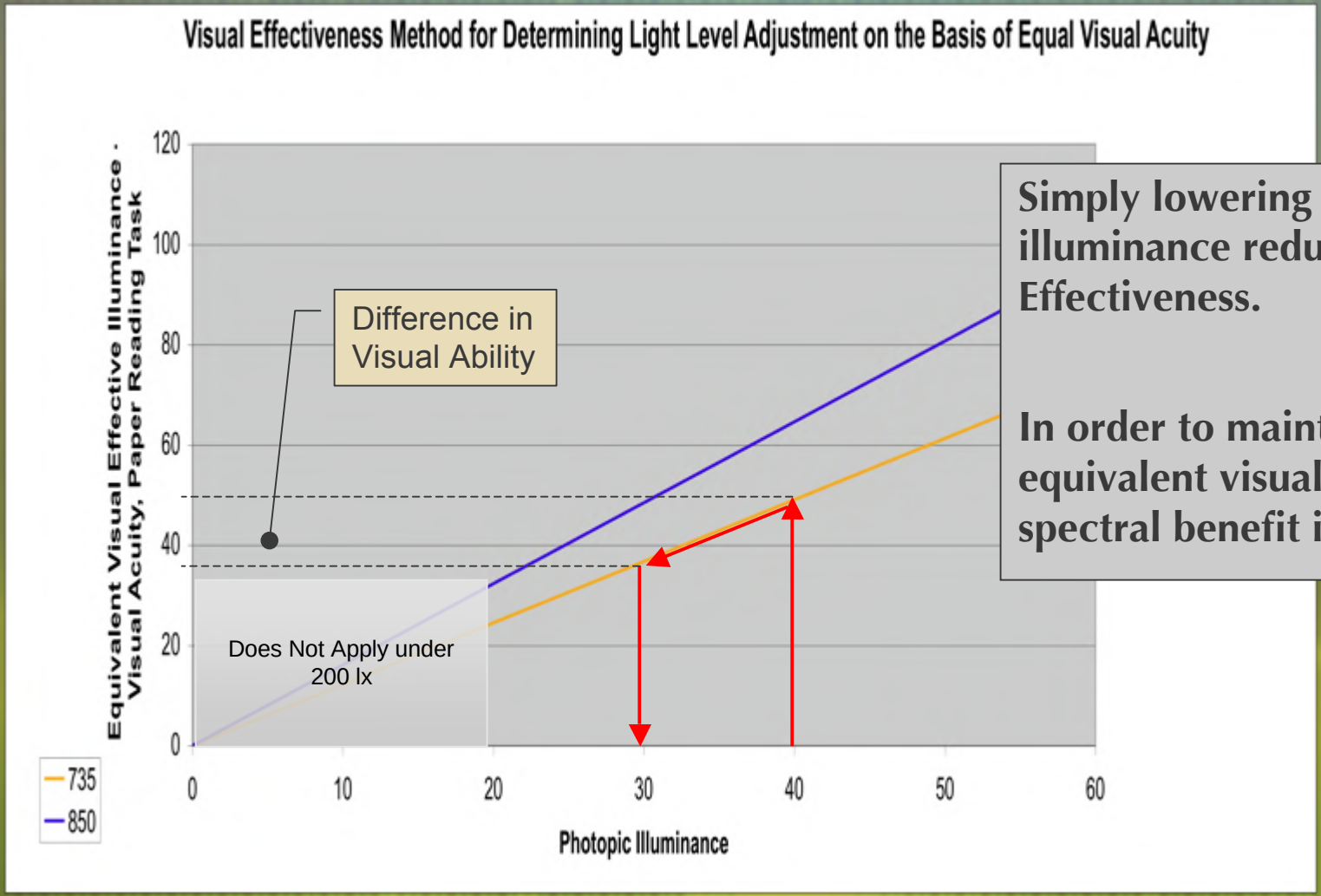
THE CONCEPT OF VISUAL EFFECTIVENESS



Simply lowering the illuminance reduces Visual Effectiveness.

In order to maintain equivalent visual ability, spectral benefit is necessary.

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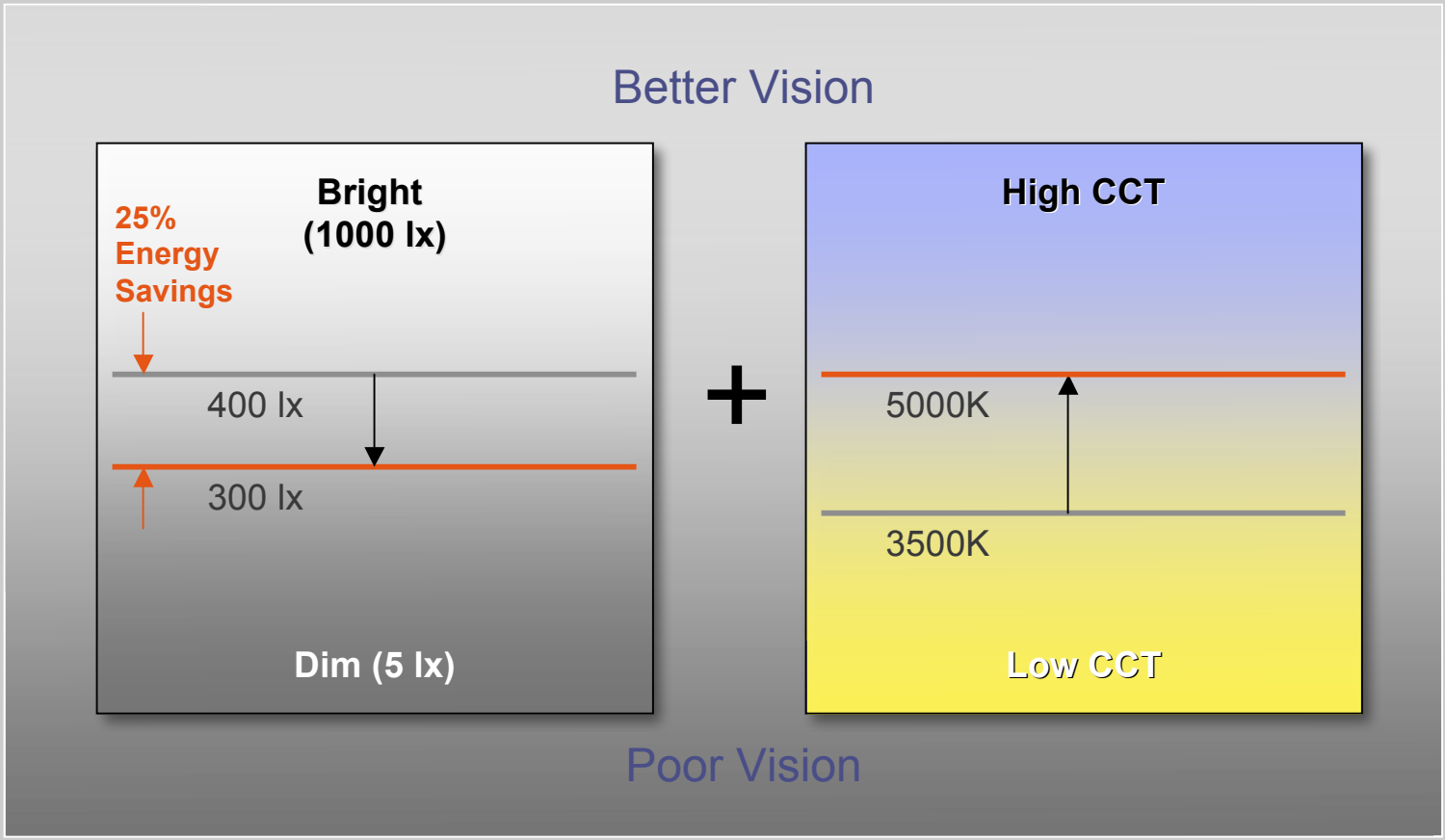
OPTIMAL DESIGN: ILLUMINANCE + SPECTRUM

Combines visual benefits from light level AND spectrum



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OLD NEW

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S.E.L. ENERGY SAVINGS

S.E.L. Retrofits Based on Lamp Change Alone

Lamp	Mean Lumens (Catalog)	S/P Value	Equiv. Visual Efficacy	Energy Savings
850 3rd	2860	1.95	4815	
F32T8 730	2650	1.19	3035	37%
F32T8 735	2650	1.3	3252	32%
F32T8 830 2nd	2800	1.29	3415	29%
F32T8 830 3rd	2950	1.29	3598	25%
F32T8 835 2nd	2800	1.41	3661	24%
F32T8 741	2650	1.56	3749	22%
F32T8 835 3rd	2950	1.41	3857	20%
F32T8 841 2nd	2800	1.62	4079	15%
F32T8 841 3rd	2950	1.62	4298	11%

Energy savings are significant compared to commonly used T8 Lamps, even assuming same ballast efficiency…

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S.E.L. ENERGY SAVINGS

S.E.L. Retrofits + New Ballasts = Success!

Lamp	Ballast Tech	EOL Lumen Maint	EOL Efficacy	Energy Savings
850 3rd	EE IS	92%	145	
F34T12WW	Mag RS	78%	45	69%
F34T12CW	Mag RS	78%	60	59%
F32T8 730	SE IS	90%	82	44%
F32T8 735	SE IS	90%	88	40%
F32T8 830 2nd	SE IS	92%	94	35%
F32T8 830 3rd	SE IS	92%	99	32%
F32T8 835 2nd	SE IS	92%	101	31%
F32T8 741	SE IS	90%	101	30%
F32T8 835 3rd	SE IS	92%	106	27%
F32T8 841 2nd	SE IS	92%	113	23%
F32T8 841 3rd	SE IS	92%	119	18%

Optimum energy savings come through S.E.L. and new extra efficient electronic ballasts.

40% Energy savings from traditional 735 lamps!

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S.E.L AND TAX INCENTIVE

Space Type	Existing LPD's & S.E.L.		Max Tax Incentive	
	US Lighting Market Characterization 2001		ASHRAE 90.1 - 2001	
	Existing	S.E.L.	Code	Max. tax incentive - 40%
Office	1.8	0.8	1.3	0.8
Warehouse/Storage	1.4	0.6	1.2	0.7
Education	1.8	0.9	1.5	0.9
Service	1.7	0.9	1.5	0.9
Public Assembly	1.4	0.8	1.4	0.8
Health Care	1.7	0.8	1.6	1.0
Retail	1.9	1.2	1.9	1.1
Public Order	1.3	0.8	1.3	0.8
Food Sales	1.9	1.1	1.8	1.1

S.E.L and Extra Efficient Electronic Ballasts will achieve 100% of the tax incentive targeted values in most installations!

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STEP-BY-STEP APPROACH

Step 1:

- **Assess Existing Light Level (Retrofit):**
  - Is the existing lighting too dim, too bright, or just right?
  - Determine Light Adjustment Factor **(LAF)**

Step 2:

- **Determine existing lamp/ballast Lumens (EL):**
  - Existing Lumens = #Lamps x Lumens/Lamp x BF.

Step 3:

- **Calculate Target Lumens** $= LAF \times EL \times \left(\frac{S/P_{(existing)}}{S/P_{(proposed)}} \right)^{.78}$

(Remember, S/P is just a number!)

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STEP-BY-STEP APPROACH

Step 4:

- **Select Lamp/Ballast combination that yield Target Lumens**
  - Trade-off between lamp lumens and ballast factor
  - Try several variations with high efficiency lamps and Premium electronic ballast.
  - VERY IMPORTANT:
    - Choose only lamps and ballasts that are compatible:
    - Some low-wattage lamps can be finicky!

Step 5:

- **Confirm new light level meets IES Minimum Recommendation**
  - Confirm with IES Category Recommendation

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TESTING SEL IN REAL APPLICATIONS

2001: 7 Buildings, 300,000 square feet

- Informal study using 850 lamps: NO objections to the color of the lighting, even with lowered light levels.

2004 UCOP Study: Occupant Acceptance

- Formal Study. Compared 850 vs. 835; Demonstrated Occupant acceptance of 850 under lower light level.

2006 Field Study: Economics Validation

- 3 Buildings completely retrofit with 850 lamps and standard ballasts; demonstrated equal occupant satisfaction between pre-retrofit lighting and SEL.

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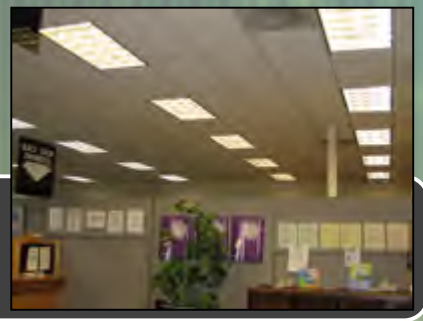
2006 STUDY

3 Buildings Selected…

Building A
(735, T12)



Building B
(730, T8)

Building C
(741, T8)

Similarities of Pre-Retrofit Conditions:

- Parabolic Luminaires
- Mixed Private & Open Offices
- Mixed Daylit & non-Daylit Areas
- Over 100 Full-time Workers

Differences of Pre-Retrofit Conditions:

- Lamp Color
- Lamp & Ballast Technology
- Energy Savings Potential

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2006 STUDY

Findings:

- Nearly 50% energy savings on T12 conversion
- 20% energy savings on T8 conversions
- NO increase in task lighting usage
- NO difference in occupant satisfaction

The math behind Spectrally Enhanced Lighting works, and building occupants are equally satisfied with the new color of light.

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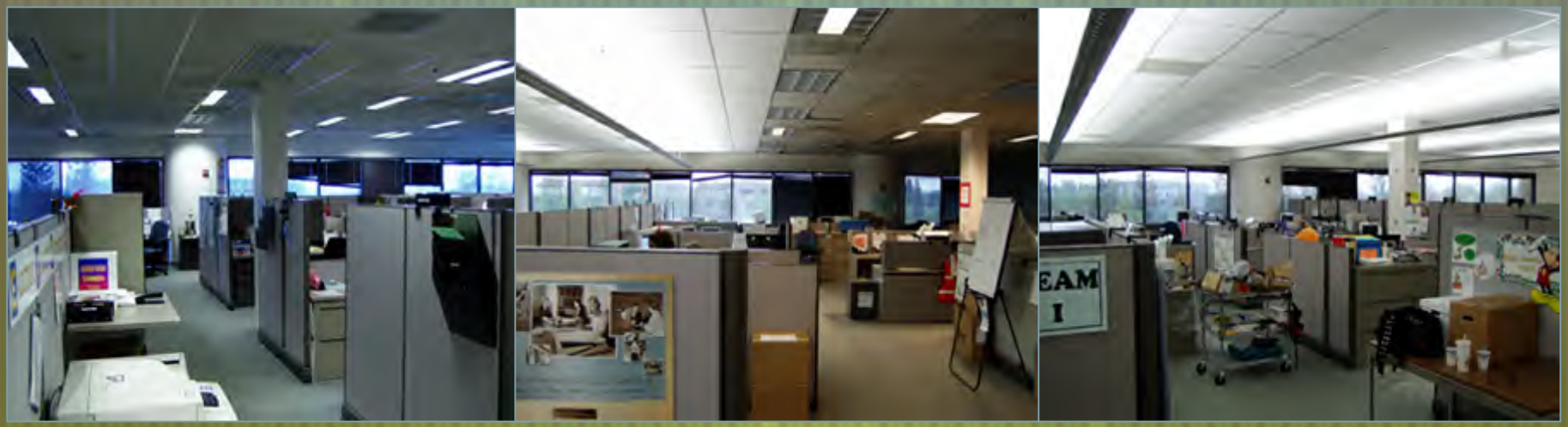
PARABOLIC TO INDIRECT/DIRECT CONVERSION



Before **During** **After**

This SEL conversion resulted in Lighting Power Density of .5 Watts per Sq. Ft.!

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THE S.E.L. 850 LAMP – WHO'S USING IT?

Companies/Institutions using 850 lamps:

- Pacific Gas & Electric Company
  - PG&E now calls SEL one of the top 5 strategies for lighting energy efficiency.
- San Diego Unified School District
- Cities of San Diego and Oakland
- Counties of Napa and San Mateo

All these have adopted S.E.L. 5000K lighting as their standard for retrofits and new construction.

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S.E.L. AND THE IES

IES Committee: Visual Effects of Lamp Spectral Distribution Committee (VELSD)

- **Two Subcommittees:**
  - Visual Effort
  - Brightness Perception
- **Visual Effort Subcommittee working on these issues, Technical Memorandum TM-24 forthcoming.**

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CURRENT STATUS WITH IES

- **IES Issued PS-02-09, states that the IES recognizes only photopic metrics**
  - PS-02-09 confused many in the industry
- **VELSD Committee has proposed alternate language for PS-02-10**
- **Revision will be voted on by IES Board August 21**

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UPCOMING IES PS-02-10

Proposed Language:

"At this point, the IES maintains that the photopic illuminance levels prescribed in the IES Lighting Handbook apply; that is, as long as the photopic illuminances used in practice are consistent with IES recommendations, the methods by which these are achieved are not specific to spectrum and the IES neither advocates nor precludes the use of spectrum in lighting calculations."

This language is up for Board Approval August 21

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USING S.E.L. IN COMPLIANCE WITH IES PS-02-10

What does this mean?

- As long as the resulting light levels meet IES Recommendations, the IES does not preclude the use of spectrum in calculations.
- IES Recommendations: Average Maintained Illuminance Values with ranges that are equal to ± 1/3 the recommended value (page 10-15, IES Handbook, 9th Ed.)

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HOW TO USE S.E.L. AND MEET IES RECOMMENDATIONS

IESNA Illuminance Levels:

Category F:

- Recommended Level = 1000 lx
- Minimum Illuminance = 667 lx

Category E: 500 lx

- Recommended Level = 500 lx
- Minimum Illuminance = 334 lx

Category D: 300 lx

- Recommended Level = 300 lx
- Minimum Illuminance = 200 lx

Light Levels for "Common Tasks"

As long as the end result is at least the minimum value, S.E.L. can be used and meets IES criteria.

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CONCLUSIONS

Spectrally Enhanced Lighting is…

- More like daylight
- More energy-efficient
- Easy to implement
- Cost Effective for Retrofits
- Immediate Savings for New Construction
- OK with IES as long as it meets minimum level.

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