Lighting Technology Update

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March 2nd 2004

"Good" Lighting

The Hallmarks of "Good" Lighting are:

- Aesthetically Pleasing
- Energy Efficient
- Adequate Task Light Level
- Is Visually Comfortable
- Easy to Maintain
- Enhance Productivity & Well-Being
- Be of minimal environmental impact

Today's Lighting Technology can do this!

"Yesteryear"

A room 25x30x12 feet in Central School, Glencoe, Ill., has an average intensity of twelve foot-candles provided by six 300-watt indirect units.

"Yesterday"

“Today”

The Technologies

Technologies

- Incandescent/Halogen
- Fluorescent Systems
- HID Systems
- Lighting Controls

The Technologies

Technologies

- **Incandescent/Halogen**
- Fluorescent Systems
- HID Systems
- Lighting Controls

Incandescent/Halogen

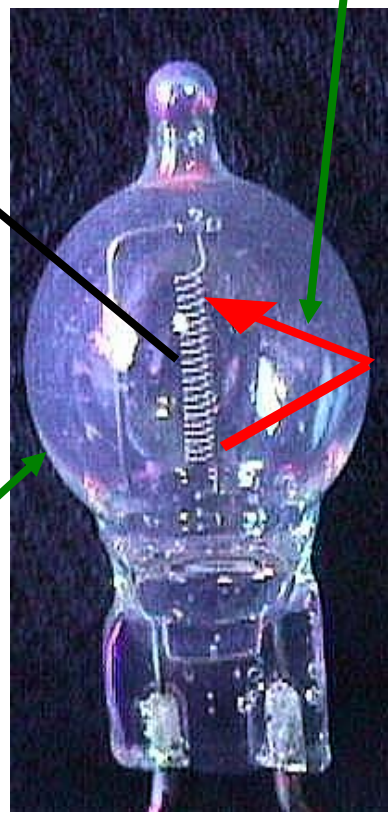
Principles of Operation

Incandescent

Halogen

IR Halogen

New Kid on the Block!



IR Halogen Technology

- More visible light generated for each watt consumed
- Lower energy costs and less heat generated
- Multi-layered thin film Infrared coating on outer surface of halogen capsule
- Infrared energy (heat) is recycled within the IR capsule

IR Halogen

PAR 38 Lamp Comparison:

LAMP	Wattage	Lumens	Life	LPW	%
• Incandescent	85 W	930	2000h	10.9	Base
• Halogen (Std.)	75 W	1060	2500h	14.1	22%
• Halogen-IR	60 W	1110	3000h	18.5	38%

The Technologies

Technologies

- Incandescent/Halogen
- **Fluorescent Systems**
- HID Systems
- Lighting Controls

Fluorescent Systems

The Lamps:

Linear Fluorescent

Compact Fluorescent

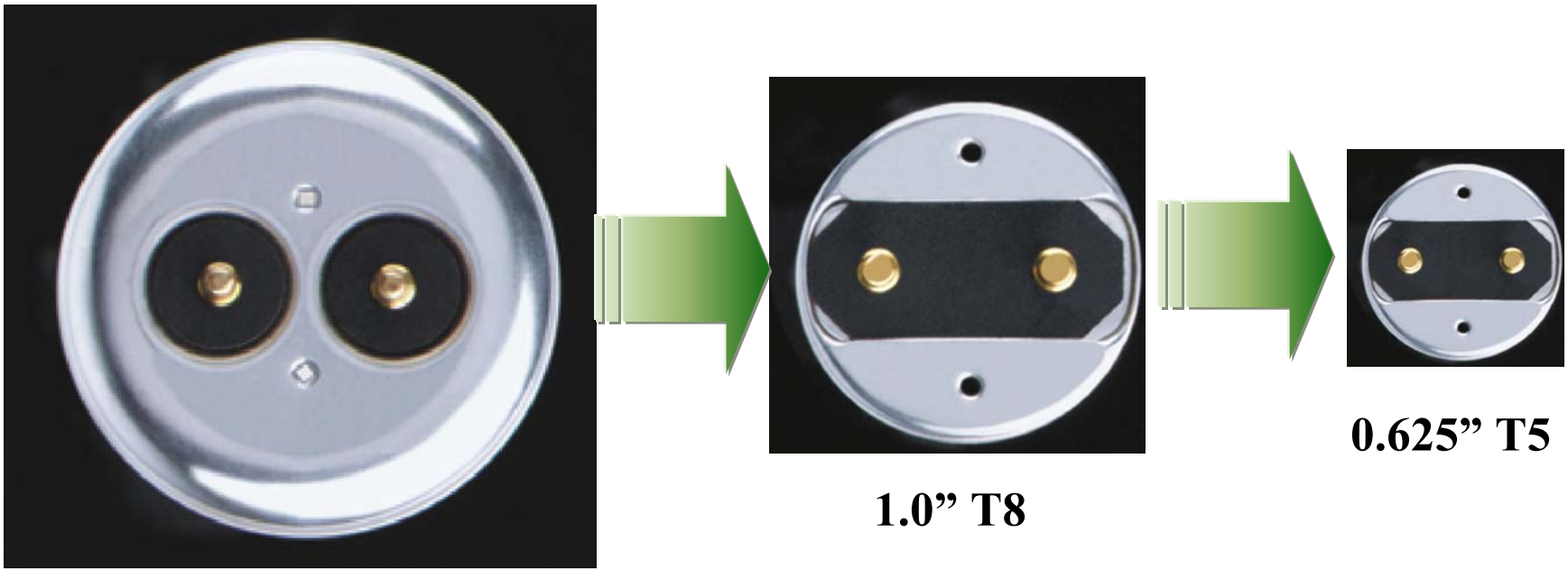
Fluorescent Systems

The Fluorescent System:

Fluorescent Systems

Principles of Lamp Operation:

Lamp Technology has Moved Forward



1.5” T12

1.0” T8

0.625” T5

Fluorescent Systems

T12 to T8 to T8Super toT5 to T5HO

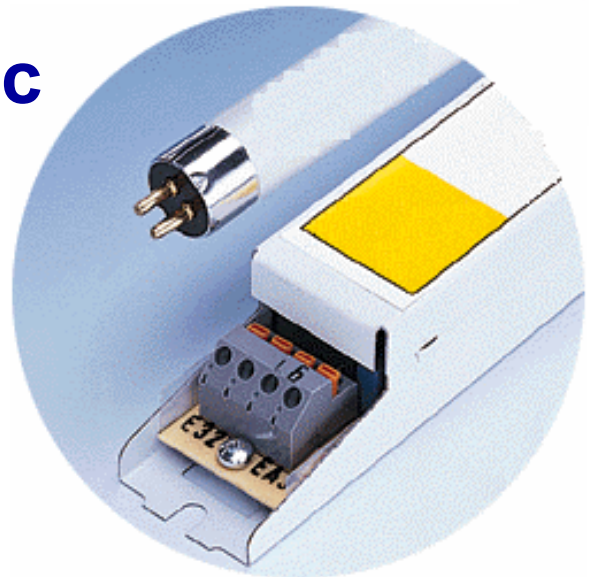
	T12	T12 (Energy Saving)	T8	T8 (Super)	T5	T5HO
Watts	40	34	32	32	28	54
Initial Lumens	3050	2650	2800	3150	2900	5000
Mean Lumens	2623	2280	2520	2990	2700	4650
Mean LPW	65.5	67.1	78.8	93.4	96.4	86
Lumen Maintenance	86%	86%	90%	95%	93%	93%
CRI	62	62	75	85	82	82

Fluorescent Systems

Fluorescent Ballast Types

- **Magnetic**

- **Electronic**



Types of Fluorescent Magnetic Ballasts

- **Standard**
- **Energy Saving**
  - **All T12 Ballasts after 1988**

    (National Appliance Energy Efficiency Act)
  - **2000 Amendments to Federal Energy Policy & Conservation Act**
    - **Shifts market from Magnetic T12 to Electronic T8**
    - **Effective Dates – 2005 - 2010**

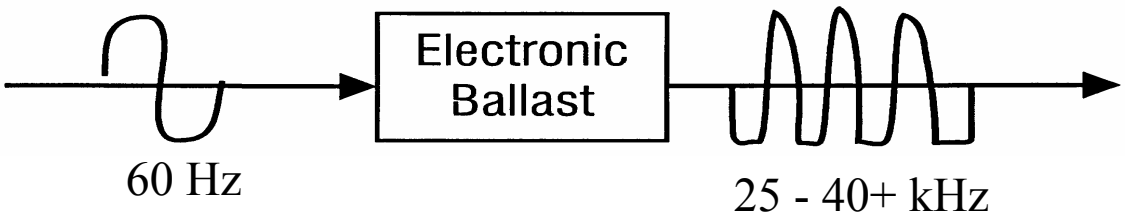
Fluorescent Systems

Fluorescent Electronic Ballasts

Advantages and Disadvantages

- Multiple lamp operation
- Very energy efficient
- Lower operating cost
- Relatively lightweight (potted/unpotted)
- Quieter and cooler operation
- Special functions/features available
  - Lamp End of Life Sensing
  - Programmed Starting
  - Dimming
  - Status Reporting
  - Universal input voltage

- Slightly higher per unit cost – lower per system cost

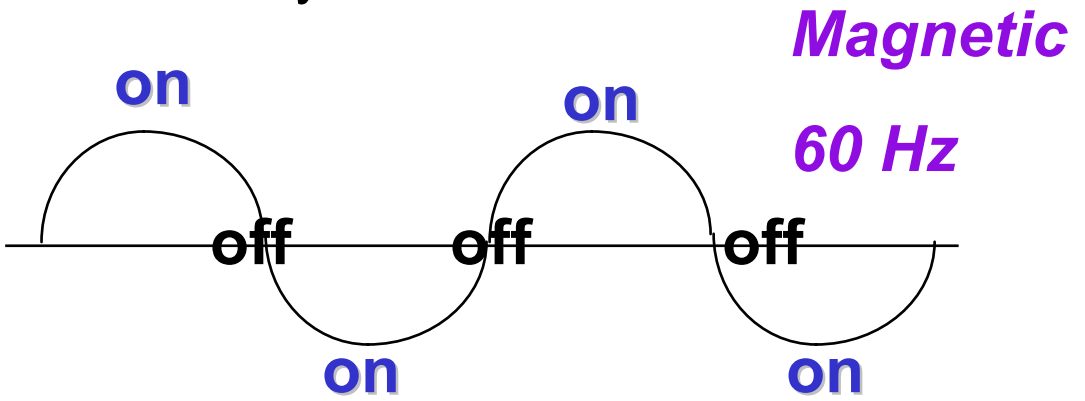


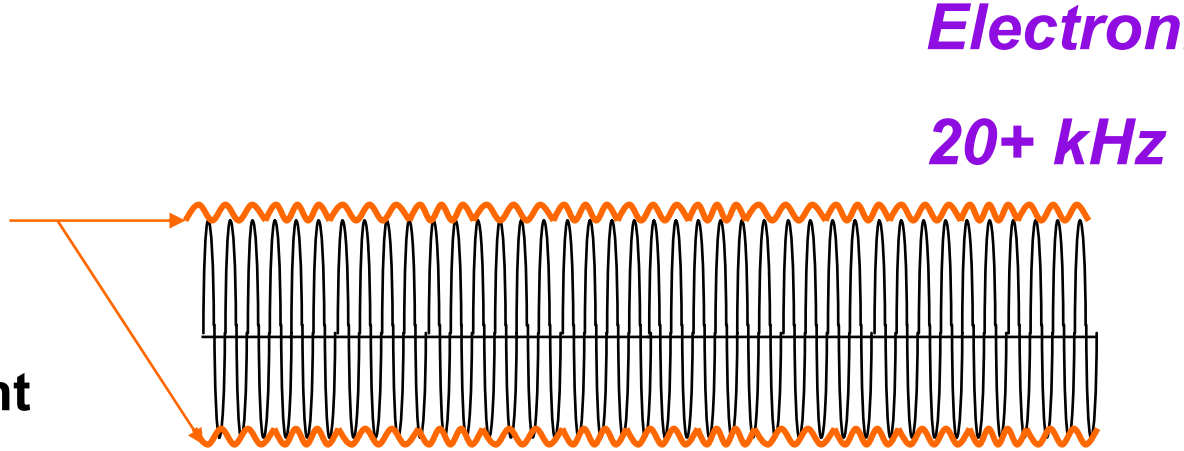
Fluorescent Systems

Fluourescent Electronic Ballasts:

How do they achieve superior efficiency?

Effectively, high frequency operation results in greater "Phosphor Persistence"





Lamps stay "on"

- **no flicker**
- **need less power to achieve rated full light output**

Fluorescent Systems

Fluorescent System Terminology:

- System Wattage
  - Ballast Losses (Watts consumed by the ballast)
  - Lamp Wattage
- Ballast Factor (BF)
  - % light (commercial system lumens ÷ reference ballast lumens)
- Ballast Efficacy Factor (BEF)
  - Ballast factor (as a whole number) ÷ input power
- System Lumens
  - Lumens generated by a specific ballast operating one or more lamps.
    - **System Lumens = Rated Lamp Lumens x No of Lamps x Ballast Factor**

Where are the Watts?

Std. magnetic two lamp F40T12 rapid start 95% BF

Ballast losses	(20% of total)	19 W
Circuit losses (coil heat)	1.5 W per lamp x 2 =	3 W
Lamp wattage	2 x (38.5W x 0.95BF) =	74 W
Ballast input wattage		96 W

Electronic two lamp FO32 instant start 90% BF

Ballast losses	(12% of total)	7 W
Circuit losses	no coil heat	0 W
Lamp wattage	2 x (28W x 0.90BF) =	52 W
Ballast input wattage		59 W

Fluorescent Systems

Fluorescent Ballast Starting Modes

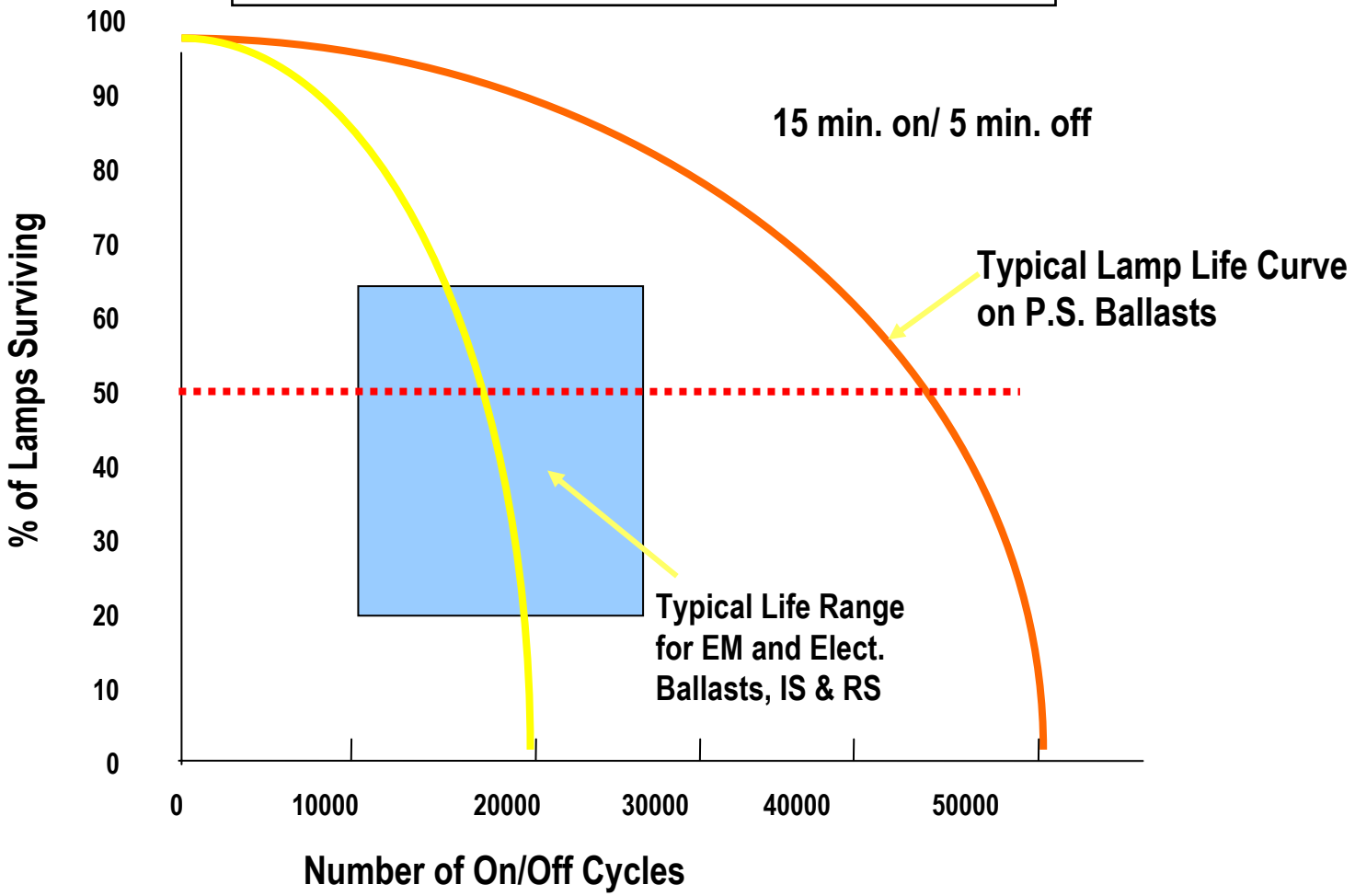
- Preheat
- Rapid Start
- Instant Start
- Programmed Start

Fluorescent Ballast Starting Modes

	GOOD Instant Start	GOOD Rapid Start	BEST Programmed Start
Cathode Voltage	0V	4V	6V 3V
Starting Voltage	600V	250V	heating delay 600V
Start Cycles	up to 15k	up to 15k	50k +
Start Temp	0 deg F	50 deg F	0 deg F
Input Power (2L)	59W	63W	60W
Wiring	Parallel	Series	Series (Parallel)

Fluorescent Systems

Programmed Start Ballasts
Longer Lamp Life in Short Cycle Applications



T8 Systems

Options, Options, Options……

T8 Lamp Options

	T8	T8	T8	T8	T8	T8
Watts	32	32	32	32	30	28
Initial Lumens	2800	2950	3000	3150	2850	2725
Mean Lumens	2520	2715	2850	2990	2680	2560
Mean LPW	78.8	85	89	93.4	89	91.5
Lumen Maintenance	90%	93%	95%	95%	94%	94%
CRI	75	82	85	85	82	82

T8 Electronic Ballast Options

- **Instant Start**
  - **30%-40% energy savings compared to T12 magnetic systems**
  - **<20% THD**
  - **BF – 0.77 –0.88 – 1.20**
- **High Efficiency Instant Start**
  - **35%-45% energy savings compared to T12 magnetic systems**
  - **<10% THD**
  - **BF – 0.78 – 0.88**
- **Programmed Rapid Start**
  - **Up to 43% energy savings and up to 30,000hr lamp life**
  - **<20% THD**
  - **BF – 0.71 – 0.88**

32 Watt T8 System Performance

	Input Power/ **Relative Power**	T8 Lamp Lumen Rating	BF = % Lumens	Initial System Lumens	LLD = Lumens @ 40% Life	**@40% Relative Light Output**	Rated Lamp Life (3hr/start) 12hr/start	**Minimum Relative Lamp Life @ 12hr/sta**	**4000 hrs/y Operating Cost/Each** (.06/**.08**/.10
Base Case T8 3 – 32 Watt T8/741 2800 lumen BF = .88 IS Electronic Ballast	**100%** 87W	2800 75 CRI	.88	**100%** (7392)	.90	**100%** (6653)	24,000 (15K)	**100%**	$20.88 **$27.84** $34.80
3 – 32 Watt T8/841 3000 lumen BF=.88 High Efficiency IS Electronic Ballast	**80%** 83W	3000 85 CRI	.88	**107%** (7920)	.95	**113%** (7524)	28,000 (18K)	**117%**	$19.92 **$26.56** $33.20
3 – 32 Watt T8/841 3000 lumen BF=.88 PS Electronic Ballast	**86%** 85W	3000 85 CRI	.88	**107%** (7920)	.95	**113%** (7524)	30,000 (24K)	**125%**	$20.40 **$27.20** $34.00
3 – 32 Watt T8/841 3000 lumen BF=.78 High Efficiency IS Electronic Ballast	**80%** 73W	3000 85 CRI	.78	**95%** (7020)	.95	**100%** (6669)	28,000 (18K)	**117%**	$17.52 **$23.36** $29.20
3 – 32 Watt T8/841 3000 lumen BF=.78 PS Electronic Ballast	**80%** 71W	3000 85 CRI	.71	**86%** (6390)	.95	**91%** (6071)	30,000 (24k)	**125%**	$17.04 **$22.72** $28.40
3 – 32 Watt T8/841 3000 lumen BF=.71 PS Electronic Ballast	**80%** 71W	3150 86 CRI	.71	**91%** (6710)	.95	**96%** (6374)	36,000 (30K)	**150%***	$17.04 **$22.72** $28.40

30 Watt T8 System Performance

	Input Power/ **Relative Power**	T8 Lamp Lumen Rating	BF = % Lumens	Initial System Lumens	LLD = Lumens @ 40% Life	**@40% Relative Light Output**	Rated Lamp Life (3hr/start) 12hr/start	**Minimum Relative Lamp Life @ 12hr/sta**	**4000 hrs/yı Operating Cost/Each** (.06/**.08**/.10
Base Case T8 3 – 32 Watt T8/741 2800 lumen BF = .88 IS Electronic Ballast	**100%** 87W	2800 75 CRI	.88	**100%** (7392)	.90	**100%** (6653)	24,000 (15K)	**100%**	$20.88 **$27.84** $34.80
3 – 30 Watt T8/841 2850 lumen BF = .88 High Efficiency IS Electronic Ballast	**89%** 77W	2850 82 CRI	.88	**102%** (7524)	.95	**107%** (7148)	28,000 (18K)	**117%**	$18.48 **$24.64** $30.80
3 – 30 Watt T8/841 2850 lumen BF = .88 PS Electronic Ballast	**92%** 80W	2850 82 CRI	.88	**102%** (7524)	.95	**107%** (7148)	30,000 (24K)	**125%**	$19.20 **$25.60** $32.00
3 – 30 Watt T8/841 2850 lumen BF = .78 High Efficiency IS Electronic Ballast	**79%** 69W	2850 82 CRI	.78	**90%** (6669)	.95	**95%** (6336)	28,000 (18K)	**117%**	$16.56 **$22.08** $27.60
3 – 30 Watt T8/841 2850 lumen BF = .71 PS Electronic Ballast	**77%** 67W	2850 82 CRI	.71	**82**% (6071)	.95	**87%** (5767)	30,000 (24k)	**125%**	$16.08 **$21.44** $26.80

28 Watt T8 System Performance

	Input Power/ **Relative Power**	T8 Lamp Lumen Rating	BF = % Lumens	Initial System Lumens	LLD = Lumens @ 40% Life	**@40% Relative Light Output**	Rated Lamp Life (3hr/start) 12hr/start	**Minimum Relative Lamp Life @ 12hr/sta**	**4000 hrs/yı Operating Cost/Each** (.06/**.08**/.10
Base Case T8 3 – 32 Watt T8/741 2800 lumen BF = 0.88 IS Electronic Ballast	**100%** 87W	2800 75 CRI	.88	**100%** (7392)	.90	**100%** (6653)	24,000 (15K)	**100%**	$20.88 **$27.84** $34.80
3 – 28 Watt T8/841 2725 lumen BF = 0.88 High Efficiency IS Electronic Ballast	**83%** 72W	2725 82 CRI	.88	**97%** (7194)	.95	**103%** (6834)	28,000 (18K)	**117%**	$17.28 **$23.04** $28.80
3 – 28 Watt T8/841 2725 lumen BF = 0.88 PS Electronic Ballast	**86%** 75W	2725 82 CRI	.88	**97%** (7194)	.95	**103%** (6834)	30,000 (24K)	**125%**	$18.00 **$24.00** $30.00
3 – 28 Watt T8/841 2725 lumen BF = 0.78 High Efficiency IS Electronic Ballast	**72%** 63W	2725 82 CRI	.78	**86%** (6376)	.95	**91%** (6058)	28,000 (18K)	**117%**	$15.12 **$20.16** $25.20
3 – 28 Watt T8/841 2725 lumen BF = 0.71 PS Electronic Ballast	**71%** 62W	2725 82 CRI	.71	**78**% (5804)	.95	**83%** (5514)	30,000 (24k)	**125%**	$14.88 **$19.84** $24.80

Fluorescent Applications

T8

Office Lighting

Parabolic

Louvers

Fluorescent Applications

Retail Lighting

Fluorescent Applications

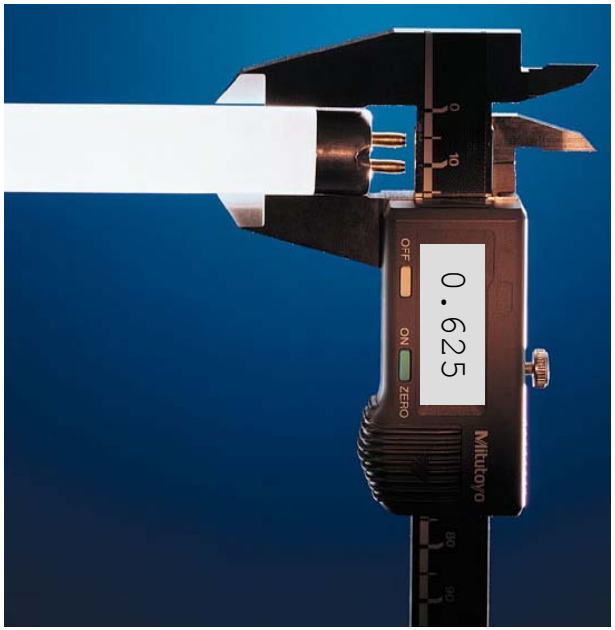
Lighting

For

Computer

Users

T5 Systems



T5 vs. T8

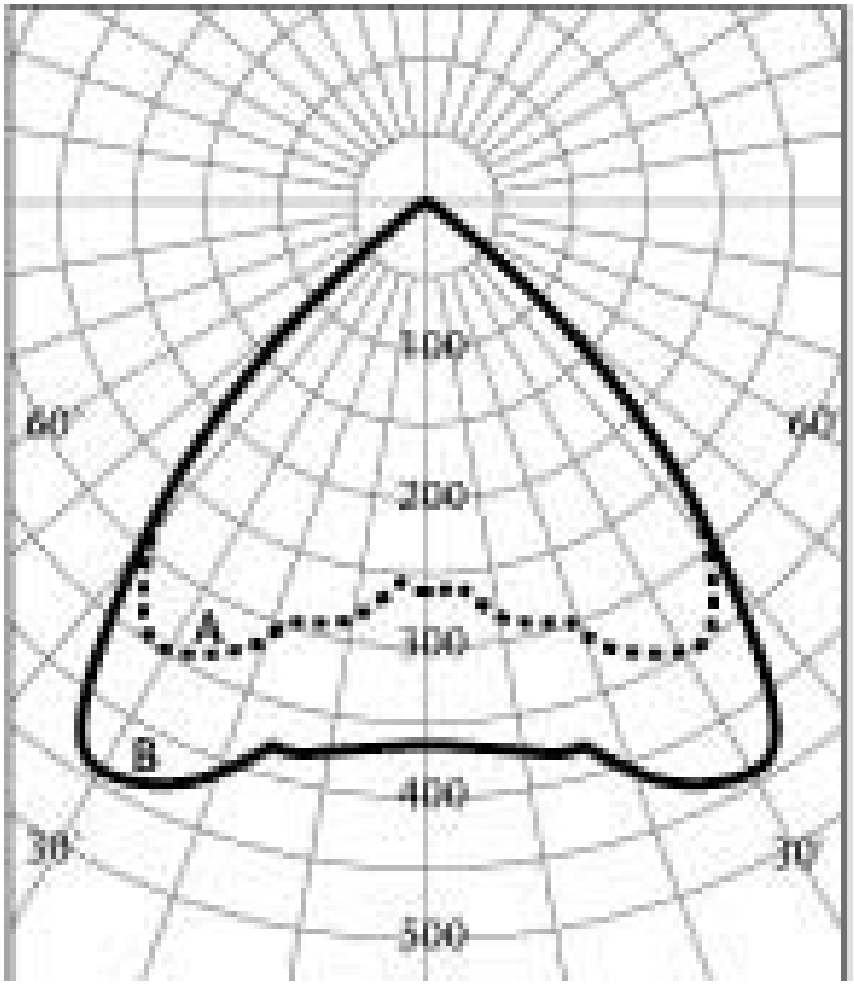
T8 Applications

- Retrofitting T12 fixtures
- New direct fixtures

T5 / T5HO Applications

- New indirect fixtures
- Multi-lamp high bay fixtures
- Not really a retrofit

Light Output Comparison

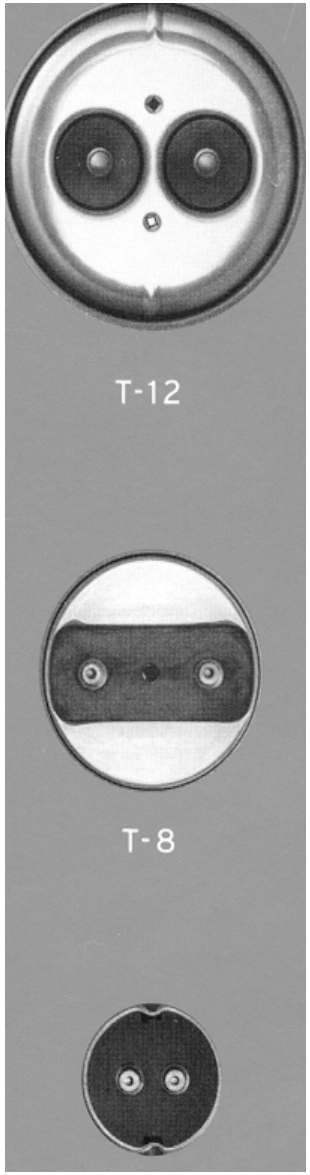


T8 vs. T5

Fixture

Efficiency

A=T8 B=T5

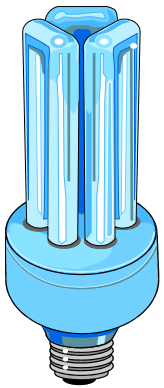


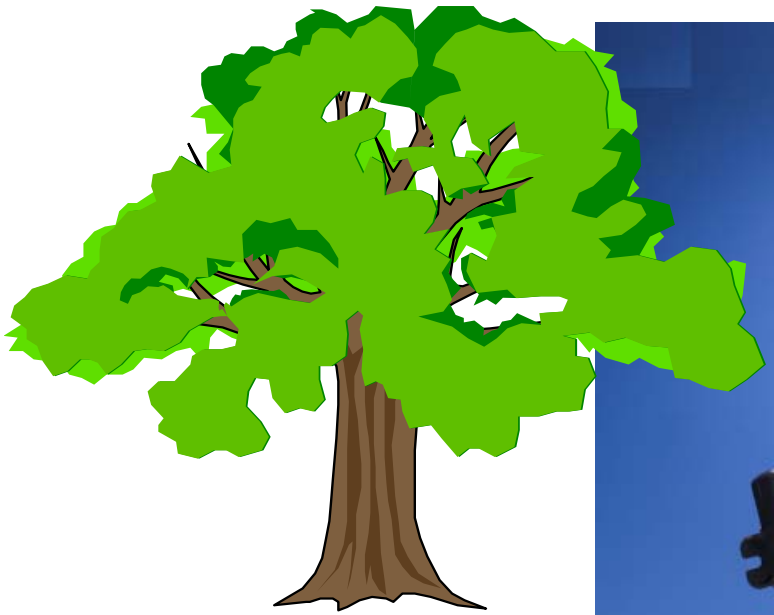
Fluorescent Applications

T5 – Direct/Indirect

Compact Fluorescent Lamps

- **Up to 75% more efficient than incandescent**
- **6 - 13 times the life of incandescent (10,000 hrs)**
- **Reduce maintenance and re-lamp labor costs**
- **Good for the environment**



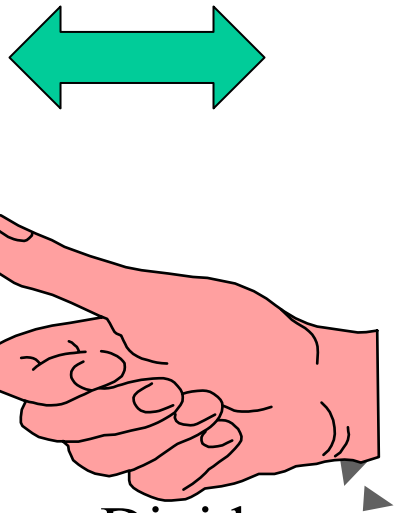


Compact Fluorescent
Light Output Equivalency

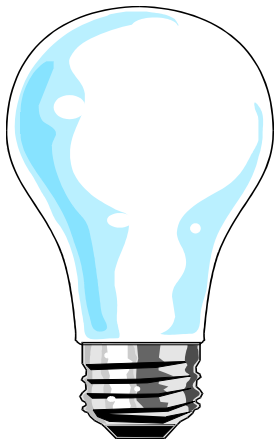
15 - watts

20 - watts

23 - watts



Divide Incandescent wattage by 4



60 - watts

75 - watts

90 - watts

Technologies

- Incandescent/Halogen
- Fluorescent Systems
- **HID Systems**
- Lighting Controls

The Technologies

Technologies

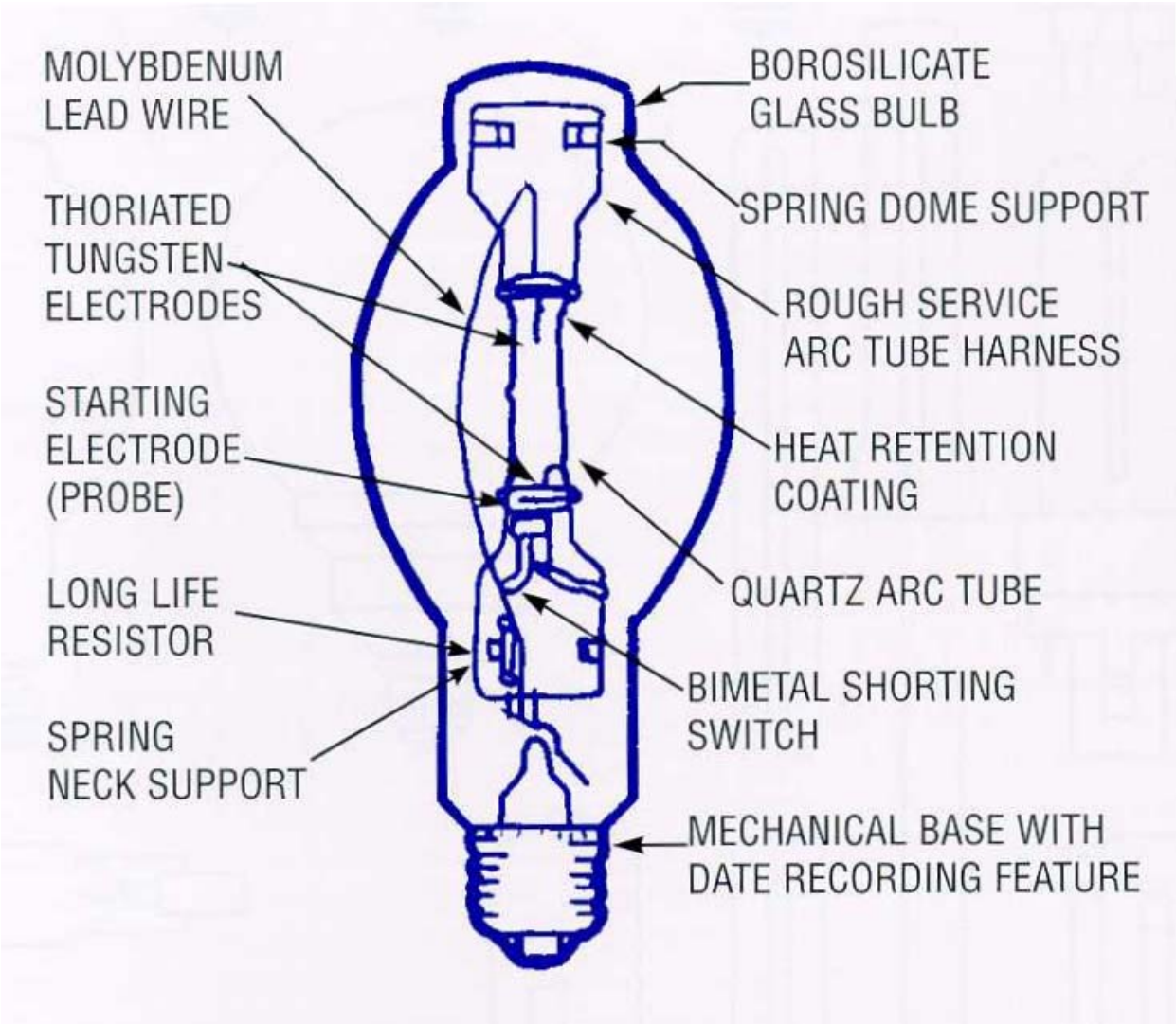
- Incandescent/Halogen
- Fluorescent Systems
- **HID Systems**
  - **Metal Halide**
- Lighting Controls

Why Use HID Lighting?

- Crisp white light source
- High light output in compact sources
- Requires fewer lamps
  - Lower installation & maintenance costs
  - Less cluttered, more attractive design

- Uses less energy (very efficient)
  - Compact HID lamps are 3 to 6 times more efficient than incandescent (100W 1HID=5 incandescent)
  - Full size Metal Halide and standard HPS lamps are ~2 times more efficient than Mercury Vapor lamps

Principles of Operation: Metal Halide Lamps



HID Applications

DIY Stores, Gymnasiums, Superstores, Outdoor

- Quality
- Color Rendering
- Color Temperature
- Open Fixtures (Indoor only)
- Ease of Maintenance
- Increased Illumination Levels

Ceramic Metal Halide

QUARTZ ARC TUBE

CERAMIC (PCA) ARC TUBE

New Alternatives for High Bay Lighting

Why re-examine High Bay lighting?

- Improvements in HID and fluorescent lamp technology
- Improvements in fixture efficiency
- Potential energy savings
- Potential maintenance savings
- Retrofits seen in
  - Schools, Retail, Industrial, Warehousing, etc.

Fluorescent Systems

HID lighting advantages over fluorescent

- Constant light output at any temperature
- Refractor fixtures provide uplight
- Compact lamp and fixture size
- Fewer lamps and ballasts to maintain
- Adjustable light distributions
- Low initial cost

Fluorescent advantages over HID lighting

- Excellent lumen maintenance
- Excellent color stability
- High CRI
- Multiple color temperatures
- Instant on
- Instant restrike
- Dimmable, occupancy sensor compatible

Retrofit of Standard 400W Metal Halide

If you have…

Standard 400W metal halide in an aluminum fixture

Retrofit Options

- **360W Energy Saving MH Lamp (lamp change only)**
- **320W MH Pulse Start**
- **250W Ceramic MH**
- **T5HO 4 lamp Fluorescent**
- **T5HO 5 lamp Fluorescent**
- **T8 Highest Performance 6 Lamp System**

Fluorescent Systems

Retrofit of Standard 400W Metal Halide

Lamp Type	MH 400	MH 320 PS	MH 250 PS	6 lamp T8 3150 lumen BF= 1.2	4 lamp T5 HO	5 lamp T5 HO
Initial Lumens	36,000	29,500	23,500	22,300	20,000	25,000
Mean Lumens	23,500	21,000	19,000	20,964	18,600	23,250
Lumen Maintenance	65%	71%	82%	94%	93%	93%
System Wattage	452	365	292	224	234	295
Fixture Type	Alum. high bay	High bay prismatic	High bay prismatic	High bay Indust.	High bay Indust.	High bay Indust.
Typical Fixture Efficiencies	65-75%	80-90%	80-90%	80-90%	80-95%	80-95%

By converting to more efficient fixtures, lower lumen lamps may provide equivalent light output

Fluorescent Systems

Energy and Economic Estimates

Lamp Type	MH 400	MH 320 PS	MH 250 PS	6 lamp T8 3150 lumen BF= 1.2	4 lamp T5 HO	5 lamp T5 HO
Lamp Life	20,000	20,000	20,000	24,000	20,000	20,000
Initial LPW	79	81	82	100	85	85
Mean LPW	51	58	65	94	79	79
System Wattage	452	365	292	224	234	295
Energy Cost Per Year	$211	$171	$135	$105	$109	$138
Installed Retrofit Costs/Fixt.	---	$193	$193	$209	$242	$293
Payback		4.8	2.5	2.0	2.4	4.0

•Based on $0.08/kwh. 5840 burn hours per year.
•Lamp life taken at 10 hour/start for MH, 12 hours per start for T8 and 3 hours per start for T5HO
•All costs are estimates and vary widely.

Uplight

- Uplight can
  - Increase apparent ceiling height
  - Improve horizontal and vertical illumination
  - Reduce “cave” effect
- Metal halide refractor fixtures provide excellent uplight
- Fluorescent fixtures
  - Not available on all fixtures
  - Slotting for uplight
  - Additional lamps on top
- Improving reflectivity on ceilings, walls and floors can improve illumination

Vertical light levels

- Critical for retailing and warehousing
- Controlled by the light distribution of the fixture

Occupancy sensors

- Occupancy sensor can provided additional energy savings
  - It is not unusual for energy savings of 30-40% in warehouse applications
- Typical fluorescent systems degrade after 12,000 to 15,000 on/off cycles
- Programmed Rapid Start ballasts rated for up to 100,000 on/off cycles
- Specify Programmed Rapid Start ballasts where you may use lighting controls

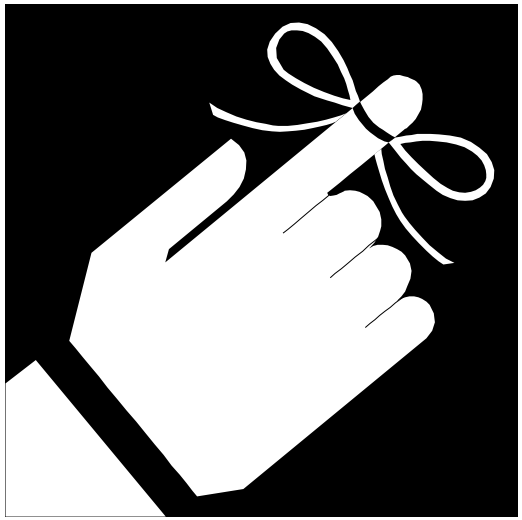
Technologies

- Incandescent/Halogen
- Fluorescent Systems
- HID Systems
- **Lighting Controls**

Lighting Controls

General Rule of Thumb

- The installation of properly applied controls to a lighting system will reduce energy consumption by one third.



PURPOSE OF CONTROLS

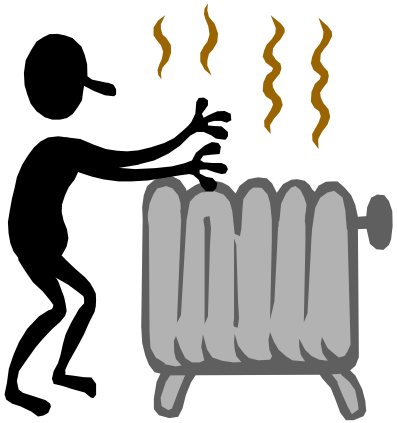
- Enhance Building Environment
- Visual Comfort
- Lighting Quality
- Adaptability
- Conserve Energy
- Conserve Money
- Conserve Equipment

DIRECT BENEFIT OF CONTROLS

- Straight energy savings
- Maintenance savings
- System life extension
- Reduction in demand charges
- Cost savings on “Time of Use” energy rates

INDIRECT BENEFITS OF CONTROLS

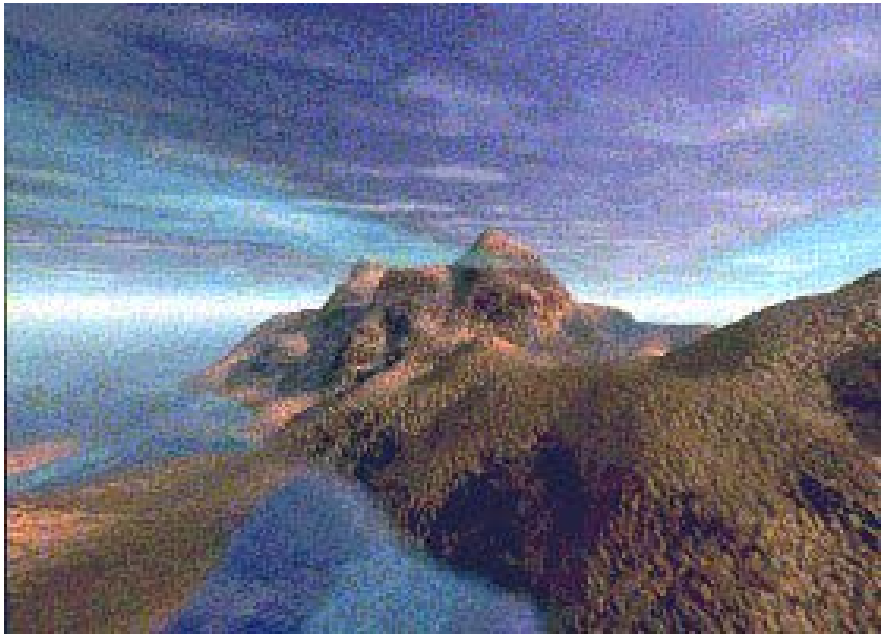
- Impact on building HVAC system
  - for every 4-5 Watts of Light, 1 Watt heat



- Lower maintenance cost due to longer effective lamp life.

CONTROL EFFECTS

- Quality of Lighting
- On/Off
- Timed
- Reaction to event (Dawn, Dusk)
- Daylight
- Occupancy
- Dimming
- Energy Management



Lighting Controls

CONTROL METHODOLOGIES

- On/Off
- Dimming
- Total/Partial Load Control
- Direct
- Staged
- Remote

Lighting Controls

MAJOR STRATEGIES FOR LIGHTING CONTROL

- Time based
- Occupancy based
- Light level based

Can be mixed and matched for effectiveness

Lighting Controls

Occupancy Sensor Types:

- Infrared - Direct Line of Sight
- Ultrasonic - Indirect, Spatial limits
- Microwave - Indirect, Similar to Ultrasonic
- Dual Technology - False Tripping
- Ceiling and Wall Mounted
- Line and Low Voltage

Control Mediums/Features & Protocols

- Line Voltage
- Low Voltage Direct
- Low Voltage Addressable
- Wireless - RF, Ultrasonic, Infrared
- Power Line Carrier
- DALI, LONworks, CEBus, Echelon
- Uni/Bi-directional
- Artificial Intelligence

Application of Controls

- Effects of controls on Lighting Quality
- Different light sources require special consideration with regard to control
- Short cycling of fluorescent and HID may shorten lamp life
- Dimming of fluorescent and HID may also effect lamp life and is more costly to implement
- Careful study of the savings possible vs. costing is required for effective application of controls

Other Lighting Control Strategies

- Non-Electrical Controls
- Drapes, Blinds, Shutters
- Fixed Window Films
- LCD Window Film
- Daylighting

Building Energy Savings through Control Strategies

	Option 1	Option 2	Option 3	Option 4	Option 5
Scheduling Control	●	●	●	●	●
Load Shedding & Daylight Dimming		●	●	●	●
Optimized High Performance Luminaires and Layout			●	●	●
Workspace Occupancy Sensing				●	●
Personal Dimming					●
Total Energy Cost Savings Realized	**5%**	**10%**	**40%**	**60%**	**70%**

Source: BC Hydro Study – 8’ X 8’ Commercial Office Application

Energy Savings from Lighting Controls

- Typically 35%-45% in Commercial and Institutional Buildings
  - California Energy Commission
- 58 Office Study – 43% Energy Savings from Occupancy Sensors increases to 61% when combined with manual dimming capability
  - Lighting Research Center

Lighting Technology Update

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March 2nd 2004