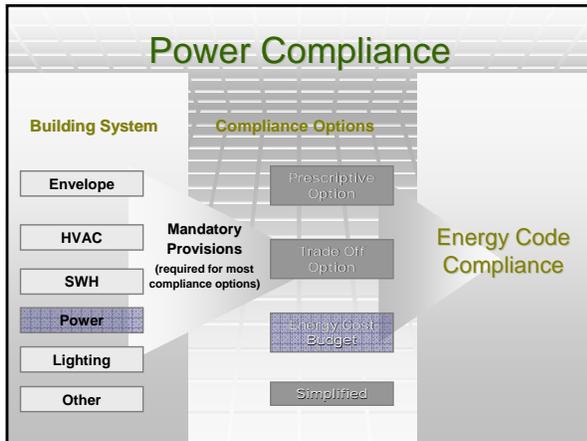
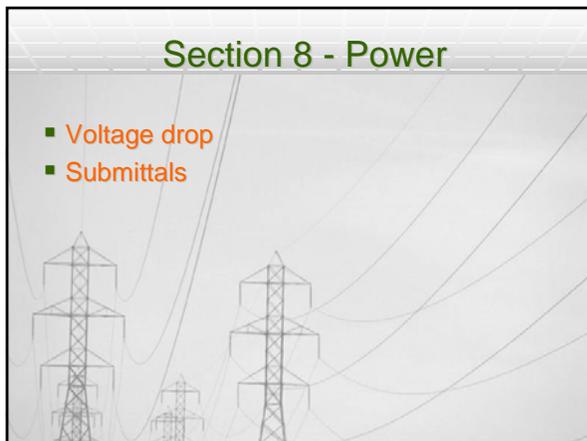


Lighting & Power

Standard 90.1

Carl M. Watson, PE, LC
Consulting Engineer





Voltage Drop

- Two types of conductors
 - Feeder conductors
 - Run between the service entrance equipment and the branch circuit distribution equipment
 - 2% maximum voltage drop allowed at design load
 - Branch circuit conductors
 - Run from the final circuit breaker to the outlet or load
 - 3% maximum voltage drop allowed at design load
- These are more stringent than non-enforceable requirements in the National Electric Code (NEC)

Section 8.4.1

Power Submittals

- Owner gets information about the building's electrical system
 - Record drawings of actual installation within 30 days
 - Single-line diagram of electrical distribution system
 - Floor plans showing location and areas served for all distribution
 - Manuals
 - Submittal data stating equipment rating
 - O&M manuals for equipment
 - Qualified service agency
 - Complete narrative of system as it's normally intended to operate

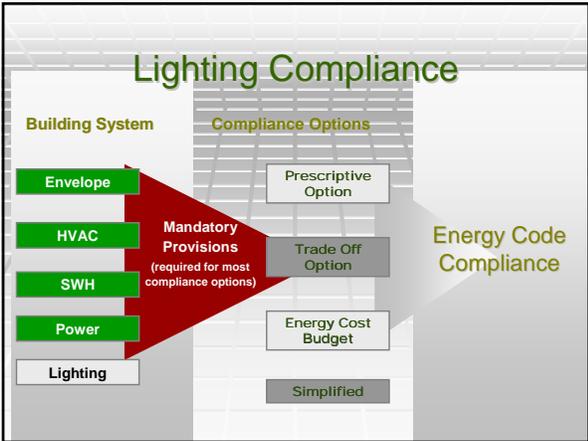
Section 8.7

Section 10 - Other Equipment

- Sole requirement is to require the use of motors that meet the requirements of the Energy Policy Act of 1992. Since this Act sets manufacturing standards for motors, all motors in the US meet this requirement.
- Requirements function is primarily to provide a motor baseline for the ECB trade-off

Section 9 - Lighting





- ## Section 9 - Lighting
- Key Concepts*
- Use current lighting product performance data and current new building construction data
 - Apply current lamp/ballast efficacy and light loss factors and incorporate IES recommended light levels
 - Apply professional lighting design consensus of quality lighted environments
 - Combine these elements into building space models to calculate lighting power densities
 - Use controls

Section 9

Lighting Overview

- General Application (Section 9.1)
 - Scope
 - Lighting Alterations
 - Installed Interior Lighting Power
 - Luminaire Wattage
- Compliance Paths (Section 9.2)
- Mandatory Provisions (Section 9.4)
 - Lighting controls
 - Tandem wiring
 - Exit signs
 - Exterior building grounds lighting
 - Exterior building lighting power
- Building Area Method Compliance Path (9.5)
- Alternative Compliance Path: Space-by-Space Method (9.6)
 - Interior Lighting Power Allowance
 - Additional Interior Lighting Power



Section 9

Lighting General– Scope (9.1.1)

- Applies to lighting for:
 - Interior spaces 
 - Exterior building features (facades, roofs, entrances, exits, loading docks, canopies) 
 - Exterior building grounds 

Section 9

Lighting scope-continued (9.1.2)

- New construction
- Existing nonresidential and high-rise residential
 - If > 50% of existing luminaires are replaced
 - If renovation increases lighting power
- Control must be readily accessible and located so occupants can see the controlled lighting
- Control devices can't control
 - > 2500 ft² in spaces < 10,000 ft²
 - > 10,000 ft² in spaces > 10,000 ft²
- Exceptions
 - Emergency lighting
 - Lighting required by health or life safety statute
 - Lighting within living units of buildings
 - Decorative gas lighting

Section 9
Installed Interior Lighting Power
(section 9.1.3)

- Includes all permanent and portable interior lighting intended for general, ambient, or task illumination
- Includes lamp, power used by ballast, the control (when applicable), current regulators, and any other power draws associated with the lighting system
- Only one exception

Section 9
Installed Interior Lighting Power
(section 9.1.3)

- Exception -
 "If 2 or more independently operating lighting systems in a space can be controlled to prevent simultaneous operation, can base IILP on lighting system with highest wattage"

Section 9
Luminaire Wattage (section 9.1.4)

- Medium screw incandescent or tungsten-halogen shall be maximum labeled wattage of the luminaire 
- Luminaires with ballasts shall be the wattage of the lamp/ballast or lamp/transformer combination 
- Line voltage track
 - Minimum of 30 W per linear foot, or the wattage of all of the track heads, whichever is greater 
- Low voltage track
 - Maximum transformer wattage 
- Wattage of all other luminaires shall be as specified

Section 9

Luminaire Wattage (section 9.1.4) - example

Example #1:
Calculate the total lighting Wattage of a room containing the following fixtures:



- A. Eight 2'- 4' Fluorescent Fixtures
 - Three 4' fluorescent T8 lamps per fixture, 32 Watts
 - 1 three-lamp electronic ballast
 - Ballast Input Wattage - 90 watts
- B. 6 Incandescent Downlights
 - Specified Lamps - 60 Watt, A-line, Medium Screw Base
 - Maximum labeled wattage of fixture - 75 Watts
- C. 16 Feet of Line Voltage Track
 - Specified - 5 Track Heads
 - 90 Watt Halogen PAR38 lamps

Section 9

Luminaire Wattage (section 9.1.4) - example

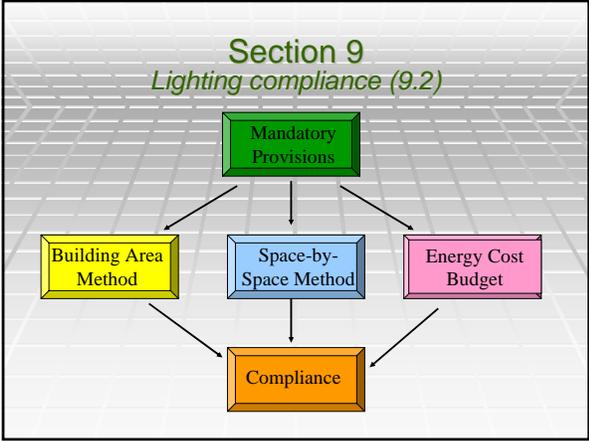
Solution #1: Total Lighting Wattage Calculation

Wrong Way!

- ✗ 8 Fixtures x 3 Lamps x 32 Watts per Lamp = 768 Watts
- ✗ 6 Downlights x 60 Watts/A-line lamp = 360 Watts
- ✗ 5 Track Heads x 90 Watts/Halogen Par Lamp = 450 Watts
- ✗ Total Wattage = 1578 Watts

Right Way!

- ✓ 8 Fixtures x 90 Ballast Input Watts = 720 Watts
- ✓ 6 Downlights x 75 Watt Labeled A-line Fixture = 450 Watts
- ✓ 16' Track x 30 Watts/Foot = 480 Watts
- ✓ Total Wattage = 1650 Watts



Section 9
Compliance Path(s)
Interior Lighting Power Exceptions
(section 9.2.2.3)

- Display or accent lighting that is an essential element for museums, monuments, and galleries
- Integral to equipment or instrumentation installed by manufacturer
- Lighting only for medical and dental procedures or integral with equipment
- Integral to both open and glass-enclosed refrigerator and freezer cases
- Integral to food warming and food preparation equipment
- Plant growth or maintenance
- For use in areas specifically designed for the visually impaired
- Retail display windows, provided the display is enclosed by ceiling-height partitions
- Interior spaces specifically designated as registered interior historic landmarks
- Integral part of advertising or directional signage
- Exit signs
- Lighting for Sale or lighting educational demonstration systems
- Theatrical, stage, film, and video production
- Lighting for television broadcasting in sporting activity areas
- Casino gaming areas

Section 9
Mandatory Provisions – Lighting Control
Automatic Lighting Shutoff (section 9.4.1.1)

- Applies to buildings > 5000 square feet
 - Time-scheduling devices that accommodate separate schedules for each floor or each space no > 25,000 sf
 - OR**
 - Occupant-sensing devices that turn off lights in each controlled space within 30 minutes of last occupant detection
 - OR**
 - Signal from another control or alarm system that indicates area is unoccupied
- Exceptions
 - Lighting intended for 24-hour operation
 - Spaces where patient care is rendered
 - Spaces where automatic shutoff would endanger safety or security of room or building occupants

Section 9
Mandatory Provisions – Lighting Control
Space Control (section 9.4.1.2)

- Minimum of 1 control device per space to independently control general lighting –
 - Switch or occupancy sensor
 - Control device automatically turns lights off within 30 minutes of occupants leaving space except with multi-scene control, in:
 - Classrooms (not including shop classrooms, laboratories and preschool through 12th grade)
 - Conferences rooms
 - Employee lunch and break rooms
 - Note: These spaces not required to be connected to other automatic lighting shutoff controls
- Each manual device readily accessible and located so occupants can see the controlled lighting

Section 9

Mandatory Provisions – Lighting Control Space Control (section 9.4.1.2) (continued)

- All other spaces - Control devices activated manually or automatically and shall:
 - Control 2,500 sf max. \leq 10,000 sf space
 - Control 10,000 sf max. $>$ 10,000 sf space
 - Max. 4 hr. override of time-of-day control
- Remote location OK for safety or security -- with clearly labeled indicator/pilot light

Occupancy Sensors

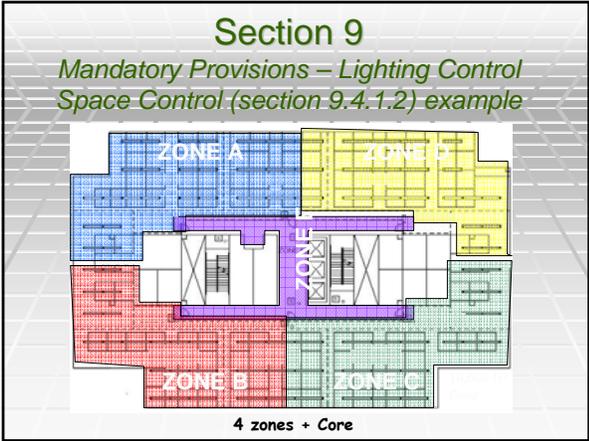
- For high usage areas with irregular schedules
- Applications
 - Private offices
 - Classrooms
 - Conference rooms
 - Break rooms
 - Restrooms



"Unscheduled Basis"

- For limited usage areas
- Inexpensive
- Requires occupant activation
- Applications
 - Supply/storage closets
 - Outdoor tennis courts





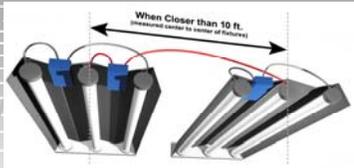
- Light Reduction Controls –
 IECC Only**
- Bi-level switching (50% reduction) via either:
 - Switching independent lamps within a luminaire
 - Controlling all lamps or luminaires
 - Dual switching of alternate rows, luminaires, or lamps
 - Switching individual luminaires or lamps
 - Exceptions:
 - Areas with 1 luminaire
 - Areas controlled by occupancy sensors
 - Spaces that use < 0.6 W/ sq. ft
 - Corridors, storerooms, restrooms, public lobbies, guestrooms

- Section 9**
*Mandatory Provisions
 Exterior Lighting Control (section 9.4.1.3)*
- Automatic controls required to turn off all lighting not exempted in 9.1 when sufficient daylight available or when not required at night
 - When not required for dusk-to-dawn operation – use astronomical time switch
 - When designated for dusk-to-dawn – control with astronomic time switch or photo sensor
 - Astronomic time switches must operate for at least 10 hours if there after a loss of power
 - Exceptions – lighting for
 - Covered vehicle entrances
 - Exits from buildings or parking structures (where required for safety, security, or eye adaptation)

Section 9
Mandatory Provisions
Additional Control (section 9.4.1.4)

- Many special lighting applications must have a separate control:
 - Display/accent lighting
 - Case lighting
 - Hotel/motel guest room lighting – master control at room entry for permanent luminaires and switched receptacles
 - Task lighting
 - Nonvisual lighting – such as food warming
 - Demonstration lighting

Section 9
Mandatory Provisions
Tandem Wiring (section 9.4.2)



- Luminaires using 1 or 3 linear fluorescent lamps >30 W
- When 2 or more luminaires are in the same space and on the same control device

Section 9
Mandatory Provisions
Tandem Wiring (section 9.4.2)

Exceptions

- Recessed luminaires more than 10 ft apart
- Separated surface or pendant luminaires
- Other luminaires
 - With one lamp, high frequency, electronic ballast
 - With three-lamp high frequency, electronic ballasts or three lamp electromagnetic ballasts
 - On emergency lighting circuits
 - With no available pair

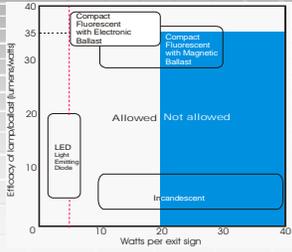
Section 9

Mandatory Provisions
Exit Signs (section 9.4.3)



Exit Sign Requirements

Internally illuminated exit signs shall not exceed 5 watts per face.



Efficacy

- The ratio of light output to watts input
 - lumens per watt
- The higher the efficacy, the more efficient the light source
 - 40 watt incandescent = 480 lumens
 - 40 watt fluorescent = 2640 lumens

Section 9

Mandatory Provisions
Exterior Building Grounds Lighting (section 9.4.4)

- In 2003 the ASHRAE 90.1 lighting subcommittee undertook re-writing of the 90.1-2001 Exterior Lighting Requirements
 - Reviewed existing exterior lighting documents including
 - the Outdoor Lighting Research proposal for California Outdoor Lighting Standards
 - IESNA RP-33, RP-02, RP-20, RP-10 (draft), DG-5, and the 9th Edition Handbook
 - Multiple lighting solution models were created and analyzed for; parking areas, walkways, plazas, building entries, canopies, façade lighting, and outdoor sales
 - Metal halide was used as the base case!

Section 9

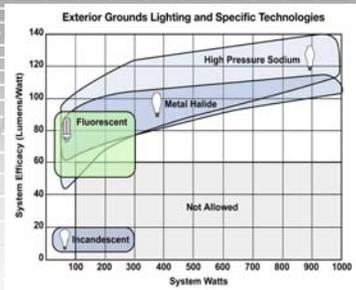
Mandatory Provisions

Exterior Building Grounds Lighting (section 9.4.4)

- Luminaires that operate at > 100 Watts shall have efficacy > 60 lumens/Watt
- Exceptions, when independently controlled
 - Traffic signals
 - Lighting of outdoor advertising or signs
 - Lighting used to illuminate public monuments or registered historic landmarks
 - If an occupancy sensor or motion sensor controls the lighting application



Exterior Lamp Efficacy



Section 9

Mandatory Provisions

Exterior Building Grounds Lighting (section 9.4.5)

- Lighting used for the following exterior applications is exempt when equipped with a control device independent of the control of the nonexempt lighting:
 - specialized signal, directional, and marker lighting associated with transportation;
 - lighting that is integral to advertising signage or directional signage;
 - lighting that is integral to equipment or instrumentation and is installed by its manufacturer;
 - lighting for theatrical purposes, including performance, stage, film, and video production;
 - lighting for athletic playing areas;
 - temporary lighting;
 - lighting for industrial production, material handling, transportation sites, and associated storage areas;
 - theme elements in theme/amusement parks;
 - lighting used to highlight features of public monuments and registered historic landmark structures or buildings.

Section 9

Mandatory Provisions

Exterior Building Grounds Lighting (section 9.4.5)

- The total exterior lighting power allowance for all exterior building applications is the sum of the individual lighting power densities permitted in Table 9.4.5 for these applications plus an additional unrestricted allowance of 5% of that sum
- Trade-offs are allowed only among exterior lighting applications listed in "Tradable Surfaces" section

Section 9

Mandatory Provisions

Exterior Building Grounds Lighting (Table 9.4.5)

Tradable Building Surface Requirements

Uncovered Parking Areas	0.15 W/ft ²
Building Grounds	
• Walkways less than 10ft wide	1 W/linear foot
• Walkways 10+ ft, Plaza & Special feature areas	0.2 W/ft ²
• Stairways	1 W/ft ²
Building Entrances and Exits	
• Main Entrances	30 W/lf of door width
• Other doors	20 W/lf of door width
Canopies and Overhangs	1.25 W/ft ²
Outdoor Sales	
• Open Areas (including vehicle sales lots)	0.5 W/ft ²
• Street Frontage for vehicle sales lots in addition to "open area" allowance	20 Watts/linear foot

Section 9

Mandatory Provisions

Exterior Building Grounds Lighting (Table 9.4.5)

Non-Tradable Surfaces

▪ Building Facades –	0.2 W/ft ² for each illuminated wall or surface or 5.0 Watts/linear foot for each illuminated wall or surface length
▪ ATM's and night depositories per additional ATM per location	270 watts per location plus 90 watts
▪ Entrances and gatehouses	1.25 W/ft ² of uncovered area
▪ Loading areas for law enforcement and public safety	0.5 W/ft ² of uncovered area
▪ Drive-up windows at fast food restaurants	400 watts per drive-through
▪ Parking near 24-hr retail entrance	800 watts per main entry

Section 9

Exterior Building Lighting Power (section 9.4.5)

ELPA = sum of lighting power allowance for all applicable exterior areas/applications, other than building facades

Example:

- 3 exits w/ 12 ft. of door width
- 2-100 ft² entrances with canopy
- 25,000 ft² Building Façade

$$\begin{aligned} \text{ELPA}_{\text{ext}} &= 1(30 \text{ W/ft} \times 12 \text{ ft}) + 2(20 \text{ W/ft} \times 12 \text{ ft}) + \\ & 2(100 \text{ ft}^2 \times 1.25 \text{ W/ft}^2) = \mathbf{1090 \text{ W}} \\ \text{ELPA}_{\text{façade}} &= 25,000 \text{ ft}^2 \times 0.20 \text{ W/ft}^2 = \mathbf{5,000 \text{ W}} \\ \text{Total} &= \mathbf{1090 + 5,000 = 6,090 \text{ W}} \end{aligned}$$

Section 9

Prescriptive Path

Interior Lighting Power (section 9.5 and 9.6)

Two Compliance Paths



Trade-offs of interior lighting power allowance among portions of the building for which a different calculation method has been used is not permitted

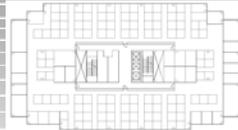
Section 9

Prescriptive Path

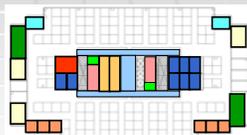
Interior Lighting Power (section 9.5 and 9.6)

2 methods

1. Building Area Method
2. Space-by-space Method



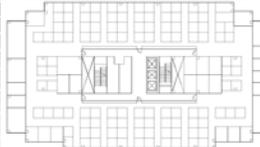
The installed interior lighting power shall not exceed the interior lighting power allowance determined by one of the two methods



Section 9

Building Area Method (section 9.5.1)

ILPA = LPD_{BAM} X gross lighted floor area



- ILPA: Interior Lighting Power Allowance
- LPD_{BAM}: Lighting Power Density – Building Area Method
- So for a 100,000 sq.ft. office building:
ILPA = 1.0 W/ft² X 100,000 ft²= 100 kW

Section 9

Building Area Method (section 9.5.1)

Lighting Power Density Method

Building Area Type ^a	(W/ft ²)
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Health Care-Clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0

^a In cases where both general building area type and a specific building area type are listed, the specific building area type shall apply.

Section 9

Building Area Method (section 9.5.1)

Lighting Power Density Method

Building Area Type ^a	(W/ft ²)
Motion Picture Theater	1.2
Multi-Family	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

^a In cases where both general building area type and a specific building area type are listed, the specific building area type shall apply.

Section 9

Building Area Method (section 9.5.1)

- Used for projects involving
 - An entire building
 - A single, independent, and separate occupancy in a multi-occupancy building
- Gross Lighted Area is multiplied by allowance from Table 9.5.1
- Limitations
 - Insensitive to specific space functions and room configurations
 - Generally is more restrictive
 - Does not apply to all building types - but "selection of a reasonably equivalent type" is permitted

Section 9

Prescriptive Path
Building Area Method (section 9.5.1)

Example #2:
Calculate Total Lighting Power Allowance using the Building Area Method:

A. An Office Building:

- 6 Floors
- Outside Dimensions 200' x 350'
- Office Building Power Allowance = 1.0 Watts/sq.ft.



Solution #2

⇒ 200' x 350' = 70,000 sq. ft. per floor

⇒ 6 Floors x 70,000 sq. ft per floor = 420,000 sq. ft.

⇒ 420,000 sq. ft. x 1.0 watts per sq. ft = 420,000 watts

► **Total Lighting Power Allowance = 420 kilowatts**

Section 9

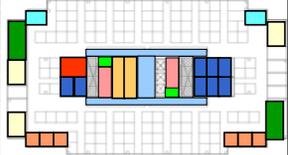
Prescriptive Path
Space by Space Method (section 9.6.1)

- Identify different building types in your project
- Divide gross lighted area of the building into each of the space types
- Calculate lighting power allowance by multiplying area of space type by lighting power density for that specific space type
- Sum all the allowances
- Advantages
 - More flexible
 - Applicable to all building types
 - Accounts for room geometry (e.g., lighting needs of enclosed office vs. open office)

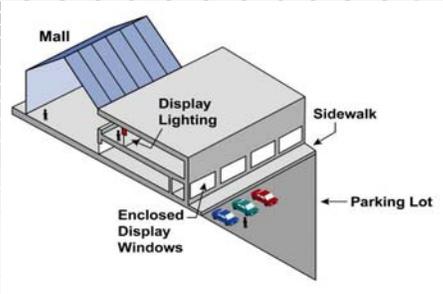
Section 9
Prescriptive Path
Space by Space Method (section 9.6.1)

ILPA_{space} = LPD_{space} X gross lighted area in ft²
Total ILPA = Sum of ILPA for each space

Tradeoffs are permitted between spaces as long as you don't exceed the total!



Section 9
Prescriptive Path
Space by Space Method (section 9.6.1)
Lighting Power Allowance Exemptions



Section 9
Prescriptive Path
Space by Space Method (section 9.6.1)



- **Office Building**
 - Office Enclosed - 1.1 W/ft²
 - Office Open - 1.1 W/ft²
 - Conference - 1.3 W/ft²
 - Training - 1.4 W/ft²
 - Lobby-general - 1.3 W/ft²
 - Lounge - 1.2 W/ft²
 - Dining - 0.9 W/ft²
 - Food Prep - 1.2 W/ft²
 - Corridor - 0.5 W/ft²
 - Restroom - 0.9 W/ft²
 - Active Storage - 0.8 W/ft²

Section 9
Prescriptive Path
Space by Space Method (section 9.6)

Example #3:
Calculate Total Lighting Power Allowance using the Space by Space Method:



A Retail Building:

- 5000 sq. ft. of Sales Area - General Accent Lighting
- 1000 sq. ft. of Active Storage Area
- 3 Enclosed Offices - 200 sq. ft. each
- 1 Conference Room - 400 sq. ft.
- 2 Rest Rooms - 150 sq. ft. each
- Corridors - 6' wide x 25' long

Section 9
Prescriptive Path
Space by Space Method (section 9.6)

Solution, Step #1:
Identify the Watts per Square Foot allowed for Each Space

Retail Building:

- Sales Area – 1.7 Watts per Square Foot
=> Additional Power Allowance
 - Accent Lighting - 1.6 W/ft²
- Active Storage Area – 0.8 W/ft²
- Enclosed Offices - 1.1 W/ft²
- Conference Room - 1.3 W/ft²
- Rest Rooms – 0.9 W/ft²
- Corridors - 0.5 W/ft²



Section 9
Prescriptive Path
Space by Space Method (section 9.6)

Solution, Step #2:
Multiply W/ft² allowance by the area of each space. Add to calculate total power allowance.



Retail Building:

<input type="checkbox"/> Sales: 1.7 W/ft ² x 5000 ft ²	= 8,500 Watts
<input type="checkbox"/> Active Storage Area: 0.8 W/ft ² x 1000 ft ²	= 800 Watts
<input type="checkbox"/> Enclosed Offices: 1.1 W/ft ² x (3) 200 ft ²	= 660 Watts
<input type="checkbox"/> Conference Room: 1.3 W/ft ² x 400 ft ²	= 520 Watts
<input type="checkbox"/> Rest Rooms: 0.9 W/ft ² x (2) 150 ft ²	= 270 Watts
<input type="checkbox"/> Corridors: 0.5 W/ft ² x 6' x 25'	= 75 Watts
TOTAL POWER ALLOWANCE =	10,825 WATTS
Additional Power Allowance - Accent Lighting Only	
1.6 W/ft ² x 5000 ft ²	= 8,000 WATTS

