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Designers Lighting Forum

First Look: ANSI/IES Recommended Practice for the Calculation of Lighting Power Density Values in Energy Codes

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Continuing Education AIA

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Learning Objectives

At the end of this course, participants will be able to:

1. Recognize how real-world lighting design practice was utilized to validate model inputs for various applications.
2. Explain how the lumen method was applied in the lighting power methodology and the difference between lighting power allowance and lighting power density.
3. Understand the criteria used to establish lighting power density values and how this can improve your ability to evaluate energy code addenda.
4. Learn why the calculation of lighting power density values will be designated an IES Recommended Practice and not another type of IES Standard.

I'M NOT LAZY I'M ON
ENERGY SAVING MODE.

Introduction

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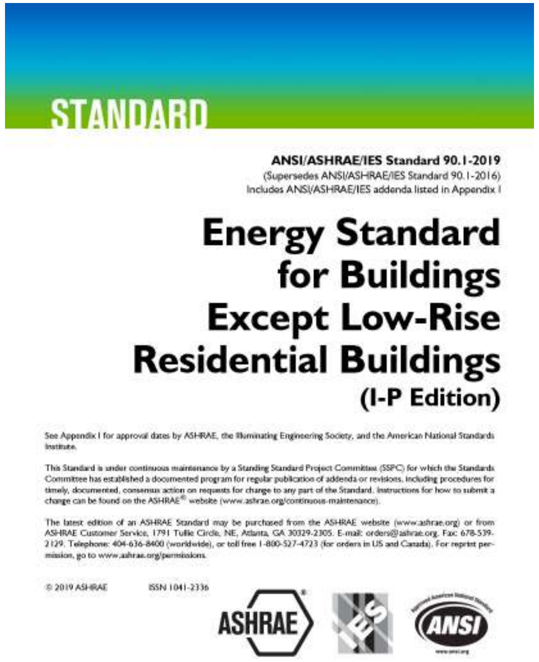
ANSI/ASHRAE/IES Standard 90.1

- The Energy Standard for Buildings Except Low-Rise Residential Buildings
- National model energy code for commercial buildings
- IES co-sponsors Standard 90.1
- Applies to all non-residential buildings >3 stories in height (inc. multi-family >3 stories)

Scope	All non-residential buildings > 3 stories in height
Lighting Scope	Lighting in the building, attached to the building, and on the building site that serves the building occupants
Construction Type	New construction including major renovation, tenant fit-out, and additions; existing building alterations and existing building system retrofits


STANDARD

ANSI/ASHRAE/IES Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2016)
Includes ANSI/ASHRAE/IES addenda listed in Appendix I

Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

See Appendix I for approval dates by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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ASHRAE

- American Society for Heating, Refrigeration, and Air-Conditioning Engineers, founded in 1894
- Has 53,000 members from over 132 nations
- Mission is to advance the arts and sciences of heating, ventilation, air conditioning and refrigeration to serve humanity and promote a sustainable world
- ANSI-accredited Standard Development Organization (SDO) that sets standards for building systems, energy efficiency, indoor air quality, refrigeration, and sustainability

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Lighting Power Allowance (LPA)

- **Lighting Power Allowance (LPA)**: Maximum lighting power in watts allowed for the interior (or exterior) of the building
- Code developers assume this much power will meet the designer's needs
- LPA inputs
  - Project area
  - Applicable lighting power density

Example: Office Project

Space Type	Area (sq. Ft.)	x	LPD (w/sq. Ft.)	Space LPA
Open plan office	3,000	x	0.61	1,830 W
Enclosed office	300	x	0.66	198 W
Employee lounge	500	x	0.59	295 W
Corridor	150	x	0.41	62 W
Lighting Power Allowance				2,385 W

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Lighting Power Density

- **Lighting power density (LPD):** *the lighting power (W) per unit area (sq. ft) of a building, space, or outdoor area expressed in Watts / sq. Ft.*
- LPDs are used to calculate the project's lighting power allowance for code compliance
- Code compliance does not require that each space's LPD must be met

Common *Space* Types[1]	*LPD*, W/ft²
Office	
Enclosed and ≤250 ft²	0.74
Enclosed and >250 ft²	0.66
Open plan	0.61
Parking Area, Interior	0.15
Pharmacy Area	1.66
Restroom	
Facility for the visually impaired (and not used primarily by the staff)[3]	1.26
All other restrooms	0.63
Sales Area[4]	1.05
Seating Area, General	0.23

Source: ASHRAE/IES 90.1-2019, Table 9.5.1 excerpt

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Lighting Power Density Notes

- LPDs are not arbitrary
- They are a *rule of thumb* for setting how much power is 'enough' for a practitioner to provide good lighting
- Development of LPD values *must consider lighting criteria* such as meeting IES recommendations, efficacy, surface reflectance values, design constraints, room geometries, etc.
- LPDs *cannot be as low as possible.* They must address human factors, lighting design practice, and application considerations.

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Background

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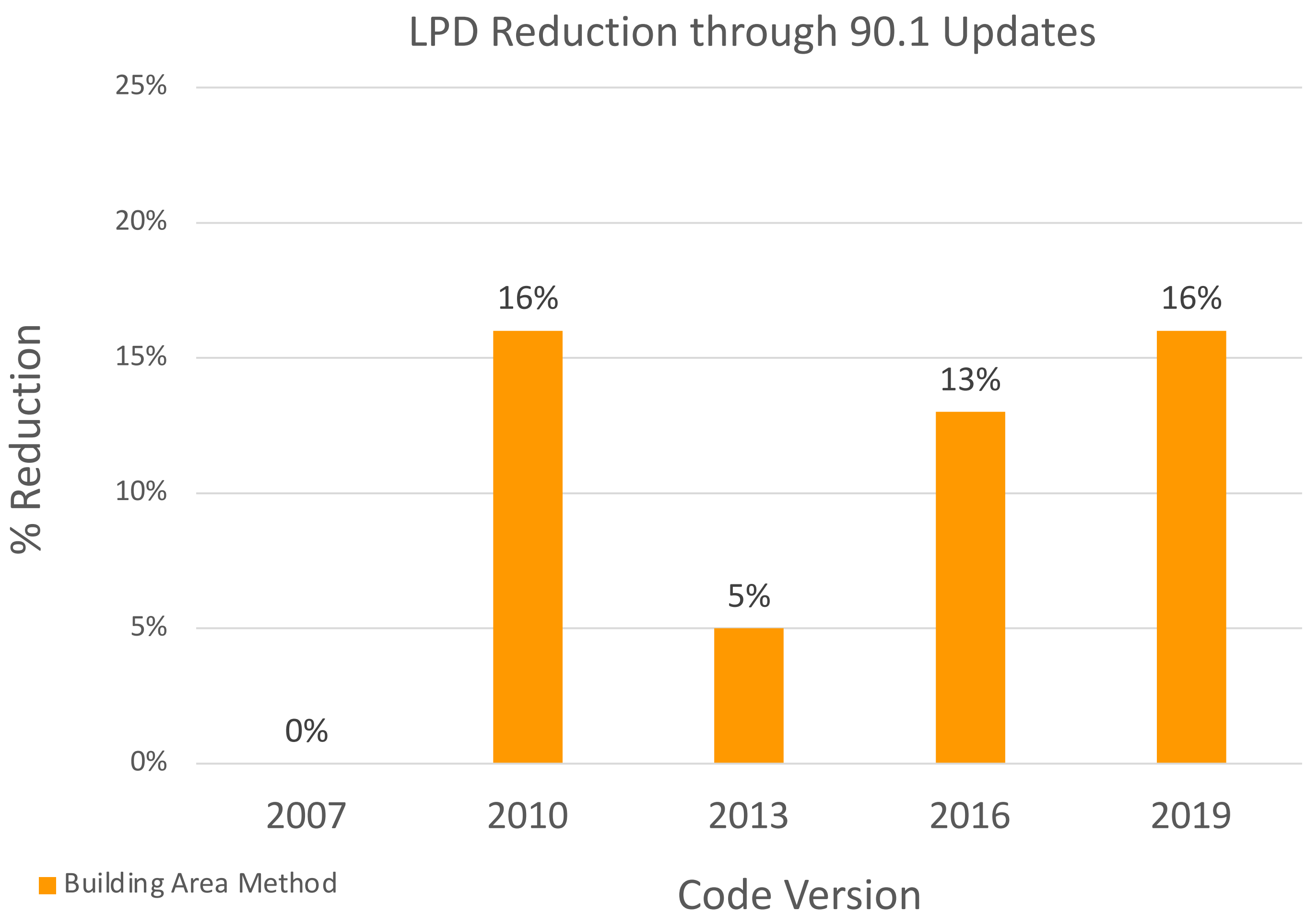
Modeling RFP

- In 2016 the need to verify that quality lighting design could still be achieved as the baseline changed from traditional lighting sources to LEDs was identified
- An RFP was developed, and project partners and funders were solicited.
- IES, IALD, ASHRAE, and BC Hydro stepped up to provide funding and support
- Applications and parameters for the research were vetted in the lighting subcommittee of ASHRAE SSPC 90.1
- The project was awarded in early 2018
- Results demonstrated the need for a consistent methodology and parameters, and a process that was replicable -> 90.1-2019 Lighting Power Methodology

The 90.1-2019 Lighting Power Methodology



- First holistic reconstruction since its creation in the 1990s
- Technology baseline became 100% LED
- More representative of real-world conditions
- Many accuracy improvements
- Raised the bar on collaboration and transparency

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ASHRAE / IES Standard 90.1 Lighting Power Methodology

LP Methodology: Contributor Lighting Systems

LPD = Lighting System 1 + Lighting System 2 + Lighting System 3 + Lighting System 4

- General
- Task
- Supplemental
- Wall washing / vertical surface lighting

LP Methodology: Calculation/Lumen Method

$$LPD = \frac{\%\,LS_1 * Eh}{[RSDD * TF_1]} + \frac{\%LS_2 * Eh}{[RSDD * TF_2]} + \frac{\%LS_3 * E_h}{[RSDD * TF_3]} + Wall\ Washing\ System$$

- E_h = horizontal illuminance (fc)
- % LS = portion of horizontal illuminance from each lighting system
- RSDD = room surface dirt depreciation
- Total Factor (TF) = luminous efficacy x CU (coefficient of utilization x LLF (light loss factors)
- Light loss factors include both luminaire dirt depreciation (LDD) and lamp lumen depreciation (LLD)

Conversion from Lumen Method to LPD

- Conversion from lumen method to LPD
- $E = \frac{Lumens\ x\ \#_{Fixtures}\ x\ CU\ x\ LLF}{Area}$
- (A)$E = Lumens\ x\ CU\ x\ LLF$
- (A)$E = W(Efficacy) x\ CU\ x\ LLF$
- $\frac{(A)E}{CU\ x\ LLF} = W(Efficacy)$
- $\frac{E}{CU\ x\ LLFx\ Efficacy} = \frac{W}{A}$
- LPD = $\frac{E}{CU\ x\ LLFx\ Efficacy}$

Efficacy = $\frac{Lumens}{Watt}$

Lumens = W(Efficacy)

CU = coefficient of utilization

LLF = light loss factors

LPD Calculation Example: Enclosed Office

- $LPD = Lighting\ System\ 1 + Lighting\ System\ 2 + Lighting\ System\ 3 + Lighting\ System\ 4$
- $LPD = \frac{\%LS_1 * fc}{[RSDD * TF_1]} + \frac{\%LS_2 * fc}{[RSDD * TF_2]} + \frac{\%LS_3 * fc}{[RSDD * TF_3]} + 0$
- $LPD = \frac{33\ fc}{RSDD * [100\% * LE * CU * LDD * LLD]}$
- $LPD = \frac{33\ fc}{0.96 * (116\frac{lm}{W} * 0.56 * 0.85 * 0.85)}$
- $LPD = \frac{33\ fc}{0.96 * (116\frac{lm}{W} * 0.56 * 0.72)}$
- $LPD = \frac{33\ fc}{0.96 * (116\frac{lm}{W} * 0.40)}$
- $LPD = \frac{33\ fc}{44.54\frac{lm}{W}} = \frac{33\frac{lm}{sf}}{44.54\frac{lm}{W}}$
- $LPD = 0.74\frac{W}{sf}$

LPD Calculation: Varying Inputs

Original Calculation:

$$LPD = \frac{33\ fc}{44.54\ \frac{lm}{W}} = \frac{33\ \frac{lm}{sf}}{44.54\ \frac{lm}{W}} = 0.74\ \frac{W}{sf}$$

Increase Illuminance:

$$LPD = \frac{\mathbf{40\ fc}}{44.54\ \frac{lm}{W}} = \frac{\mathbf{40\ \frac{lm}{sf}}}{44.54\ \frac{lm}{W}} = 0.90\ \frac{W}{sf}$$

Increase Efficacy:

$$LPD = \frac{33\ fc}{\mathbf{60.04\ \frac{lm}{W}}} = \frac{33\ \frac{lm}{sf}}{\mathbf{60.04\ \frac{lm}{W}}} = 0.55\ \frac{W}{sf}$$

Decrease Surface Reflectance Values:

$$LPD = \frac{33\ fc}{\mathbf{37.86\ \frac{lm}{W}}} = \frac{33\ \frac{lm}{sf}}{\mathbf{37.86\ \frac{lm}{W}}} = 0.87\ \frac{W}{sf}$$

Inputs:
Room surface reflectance values
Horizontal illuminance values
Room surface dirt depreciation
RCR
Fixture selection
- fixture CUs
- Efficacy

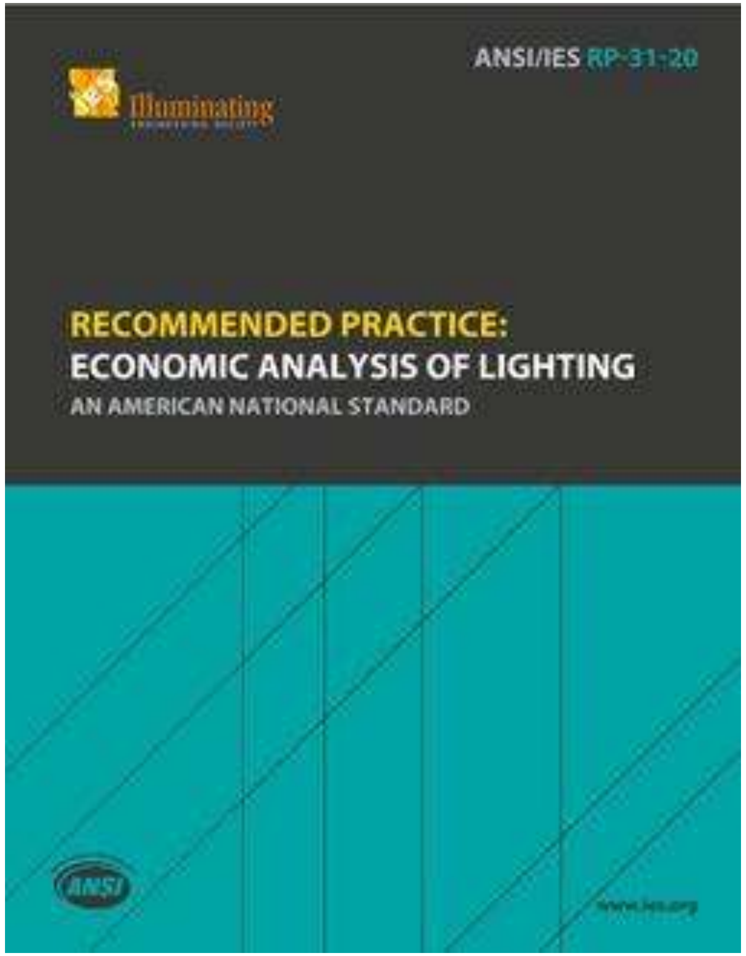
Wall washing
Fixture LLD
Fixture LDD

Lighting (and thus LPD) cannot be separated from the space

The IES Recommended Practice

What is an IES Recommended Practice?

- The Recommended Practice is the highest level IES Standard
- It is approved by the American National Standards Institute (ANSI)
- Written around best practices
- Developed by a technical committee of experts



IES Recommended Practice on the Calculation of LPDs in Energy Codes

- Provide guidance and a robust, real-world, replicable methodology to enable codes & standards writers to develop lighting power allowances that will yield quality lighted environments while using responsible amounts of energy
- Provide the context, define challenges, and identify qualitative and quantitative lighting design criteria

Precedents

- RP-31-20 Economic Analysis of Lighting
  - Framework for selecting from a group of competing lighting designs
  - Methods for gauging the profitability of a capital investment in a lighting system
- RP-36-20 Lighting Maintenance
  - Recommendations for good maintenance practices and careful product selection
  - Can be used to develop a maintenance plan
  - Guidance for properly maintaining lighting systems to ensure optimal performance

Why is an RP on LPDs Needed?

- To protect lighting quality
- To ensure that ANSI/IES recommendations are incorporated into the calculations
- To ensure that reasonable, appropriate assumptions are used for efficacy, surface reflectance values, and other criteria
- To ensure that proper design & application considerations are implemented
- To standardize the process for establishing lighting power allowances in the U.S. energy codes

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First Look

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First Look: Chapters

- DATA SET
- EQUIPMENT LIST
- SPACE TYPE LIST
- SPACE GEOMETRY
- DESIGN CONSIDERATIONS
- LIGHTING CONDITIONS

1. The Data Set

- Establish rules for quality, data collection, dealing with outliers, etc.
- Assemble a comprehensive listing of manufacturers & fixtures
- Build awareness of energy efficiency programs and other values
- Include designer validation and contextual feedback
- Each fixture in the data set is ~150 data point!

2. The Equipment List

- The first step!
- Comprises the luminaires, lamps, and light sources that will serve as inputs for the methodology and models therein
- List should be sufficiently robust, yet manageable
- Typical, commonplace equipment; periodic updates will be needed
- A good starting point is 12 fixture types
- Within each fixture type there will be (2-7) sub-categories depending on that type of fixture, e.g., clean-room troffer, open troffer

- Coves
- Recessed downlights
- Decorative
- High-bay
- Indirect/direct linear pendants
- Fully indirect pendants
- Low-bay
- Parking garage
- Task lights
- Recessed troffers
- Wall grazers
- Wall washers

3. The Space Type and Building Type Lists

- Energy codes in the U.S. have at least 2 compliance paths

Space Types

- ~100 different space types is typical
- Each space type requires a lighting power model
- Space types should serve the scope of the Standard or Code
- Consider additional space types that have unique geometry, e.g., high ceiling heights, atypical layouts, unique occupant needs etc.
- Differentiate spaces with unique lighting needs to populations, e.g., dining for the visually impaired, seating areas in gymnasiums, performing arts seating areas
- Review and assess each code cycle
- Add new spaces and remove obsolete ones

Building Types

- Lighting power is analyzed at the building level
- Buildings are comprised of spaces, so building LPD values are derived from space LPD values
- The benchmark is 25 – 30 building types
- Employs a weighted average approach

Space Type	LPD (w/sf)	Office Building Type	School Building Type
Classroom	0.71	5%	60%
Office	0.66	75%	18%
Corridor	0.41	20%	22%
Building LPD		0.61	0.64

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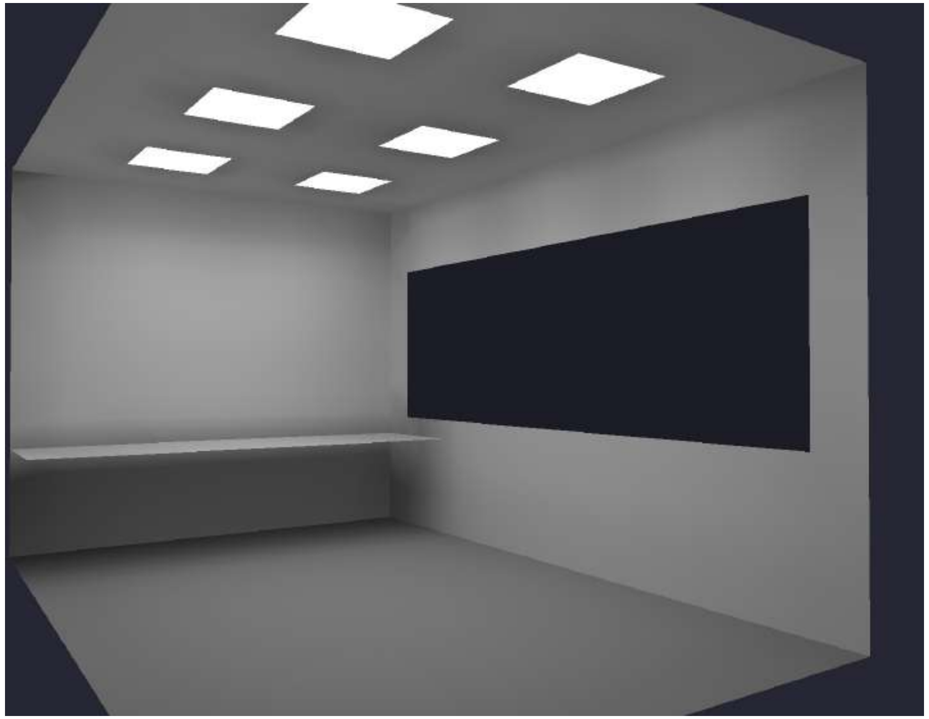
4. Understanding Space Geometry



- 3D modeling or spreadsheet
- What is the geometry of the space?
- The spreadsheet relies on CU values and an RCR look up table

2004 2.5 < RCR < 7

2010 Even Numbers

2019 0 - 10

4. Understanding Space Geometry: Example Office Data

Office in Building Types	Length	Width	Perimeter	Area	CH	RCR
Other-Arts Center	16	14	60	224	10	5.02
Hotel	13	12	50	156	9	5.21
Warehouse	12	10	44	120	8	5.04
Medium Office	16	10	52	160	10	6.09
College/University	15	10	50	150	10	6.25
Retail	22	12	68	264	13	6.76
Primary School	13	9	44	117	9	6.11
Hospital	14	14	56	196	12	6.79
Secondary School	12	8.5	41	102	9	6.53
College/University	10	9	38	90	9	6.86
Performing arts	14	13	54	182	13	7.79
Secondary School	12	9	42	108	10	7.29
Restaurant	8	6.5	29	52	8	7.67
Hotel	16	8	48	128	12	8.91

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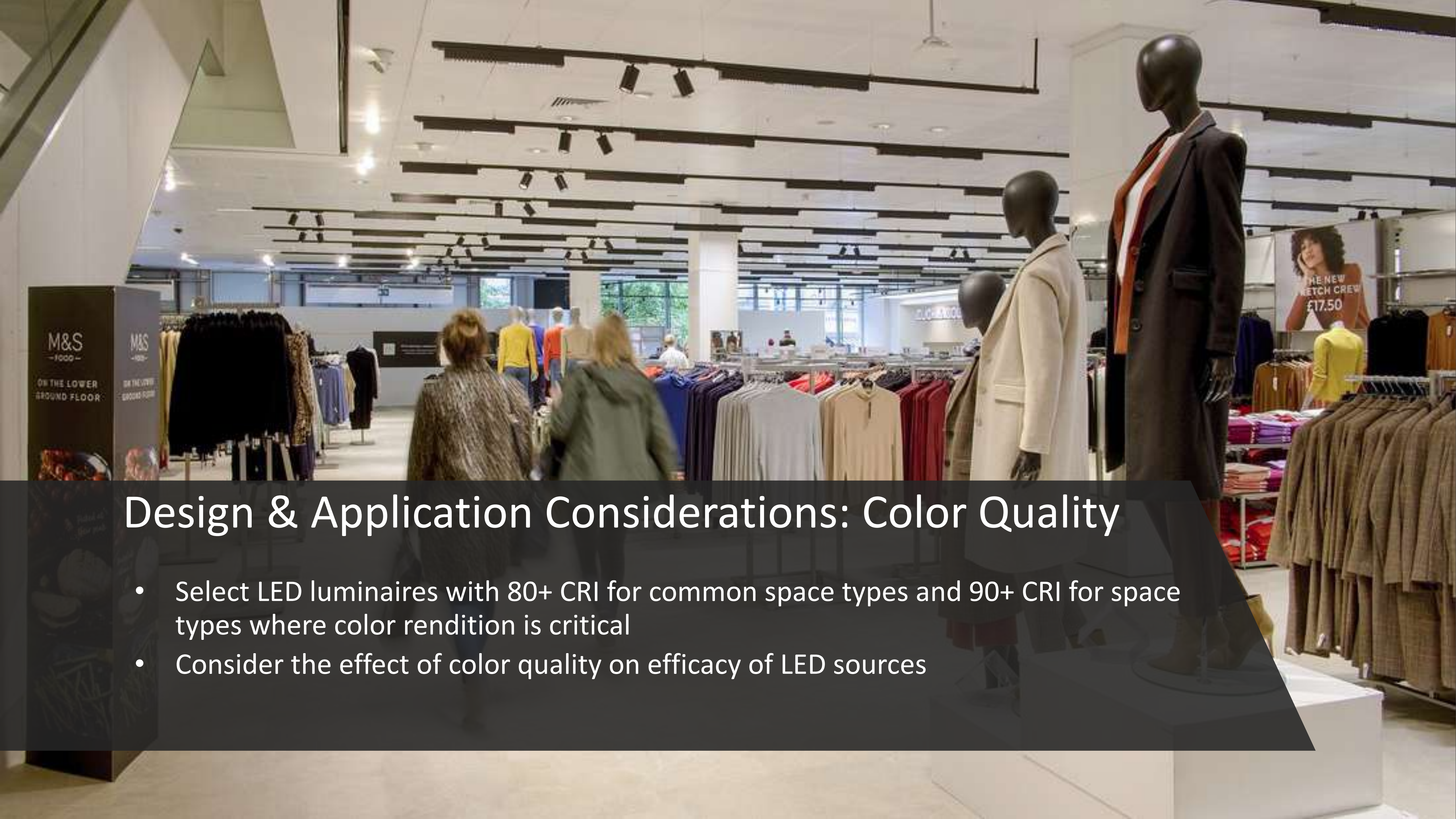
5. Design & Application Considerations: Fixture Selection

- Selections should mimic a real project

Cove Ind.	Linear Wall indirect Cove – concealed
Cove Ind.	Linear Wall indirect fixture on wall Surface
Downlight	Dnlt open or lensed Small apert. spot 90 CRI
Downlight	Dnlt open or lensed Small apert. flood 90 CRI
Downlight	Dnlt open or lensed Small apert. flood 80 CRI
Downlight	Dnlt. open Medium apert. flood 90 CRI
Downlight	Dnlt open-Medium apert. 90 CRI
Downlight	Dnlt open-Medium apert. 80 CRI
Downlight	Dnlt lensed Medium apert. 90 CRI
Downlight	Dnlt lensed Medium apert.
Downlight	Dnlt. open or lensed High lm output spot,
Downlight	Dnlt. open or lensed High lm output flood
Downlight	Dnlt open- Wide flood 80CRI high lm

High Bay	High Bay/ Industrial, Surf/suspend
High Bay	High Bay, Surf/suspend
High Bay	Extra High Bay, Surf/suspend
Ind/direct	Linear Indirect/direct suspended
Indirect	Indirect Pendant –suspended
Indirect	Indirect Pendant – high output, suspended
Low Bay	Low bay Lensed, Surf/suspend
Low Bay	Low bay lensed-lin. Industrial- reflector
Parking	Parking Garage, Surf/suspend
Task	Task linear, surface
Task	Task – puck style, surface
Task	Task -- High abuse lensed surf. wall mntd.

Troffer	Recessed Troffer Hi Perf. Lensed,
Troffer	Recessed Troffer Hi Perf. Lensed 90+ CRI,
Troffer	Troffer Direct K12 acrylic Lens
Troffer	Narrow Linear – 4 -6" wide, Recessed
Troffer	High abuse lensed troffer--
Wallwash	90 CRI WW Open, Medium apert.
Wallwash	90CRI WW angled lens Medium apert.,
Wallwash	80 CRI WW Open Medium apert., Recessed
Wallwash	Linear WW open, Recessed



Design & Application Considerations: Color Quality

- Select LED luminaires with 80+ CRI for common space types and 90+ CRI for space types where color rendition is critical
- Consider the effect of color quality on efficacy of LED sources

Design & Application Considerations: The Aging Eye

- Reference current IES Recommended Practices for spaces with special design considerations, such as facilities for the visually impaired

6. Lighting Conditions

- Photopic illuminance is used to set lighting conditions for the space
- Recommendations are generated, then applied to each space
- There are two major methods for the application of lighting conditions in spaces:
  - Sub-characterization of the space into task and circulation areas
  - Uniform application of IES recommendations across the entire space

Looking Forward

This concludes The American Institute of Architects Continuing Education Systems Course

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