IBTM 5680 Lighting Engineering

http://ibse.hk/IBTM5680/

Lighting Energy Management

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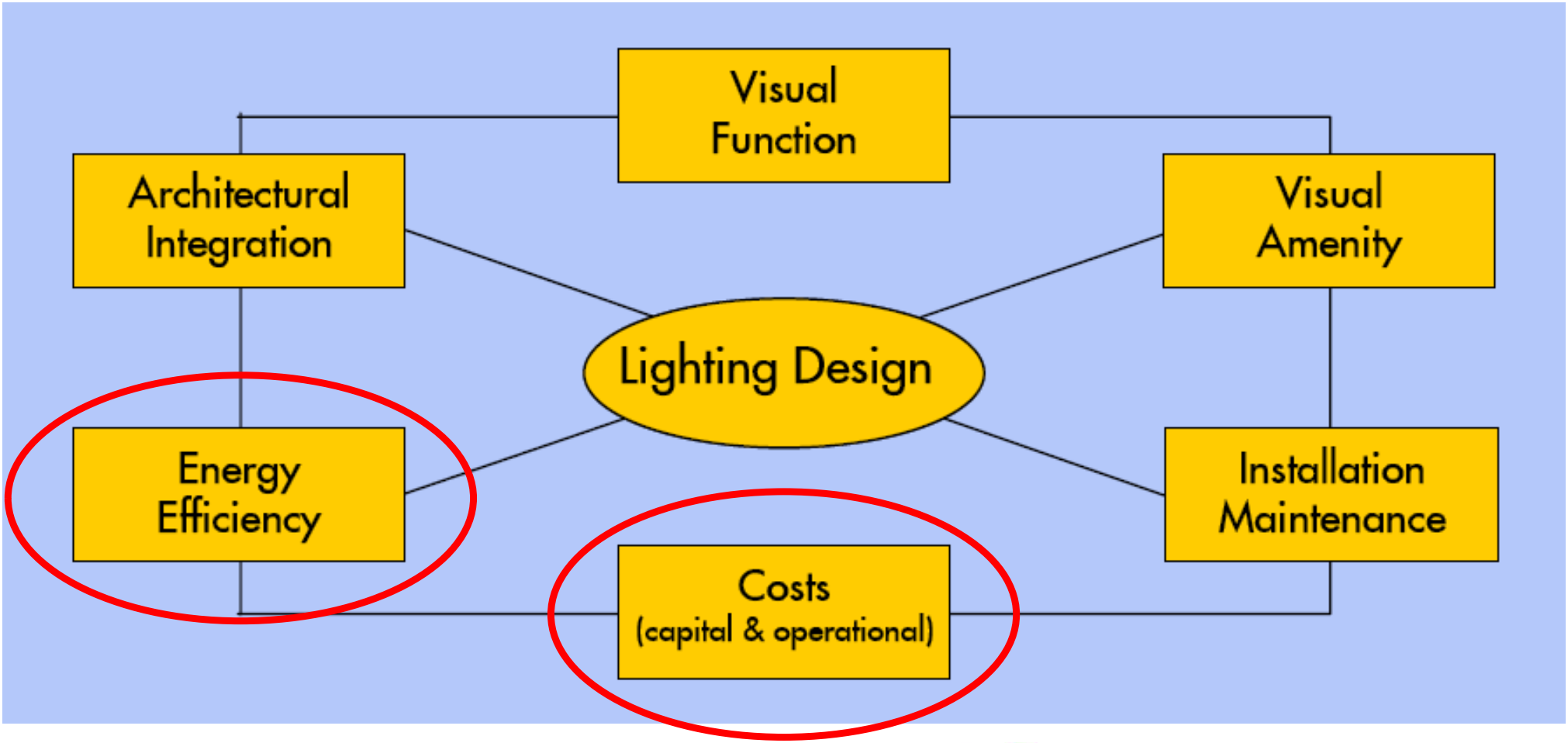
Content

- Lighting energy use
- Energy efficient lighting
- Lighting economics
- Existing buildings
- Lighting surveys & audits

Energy efficiency & costs are two important criteria for lighting design

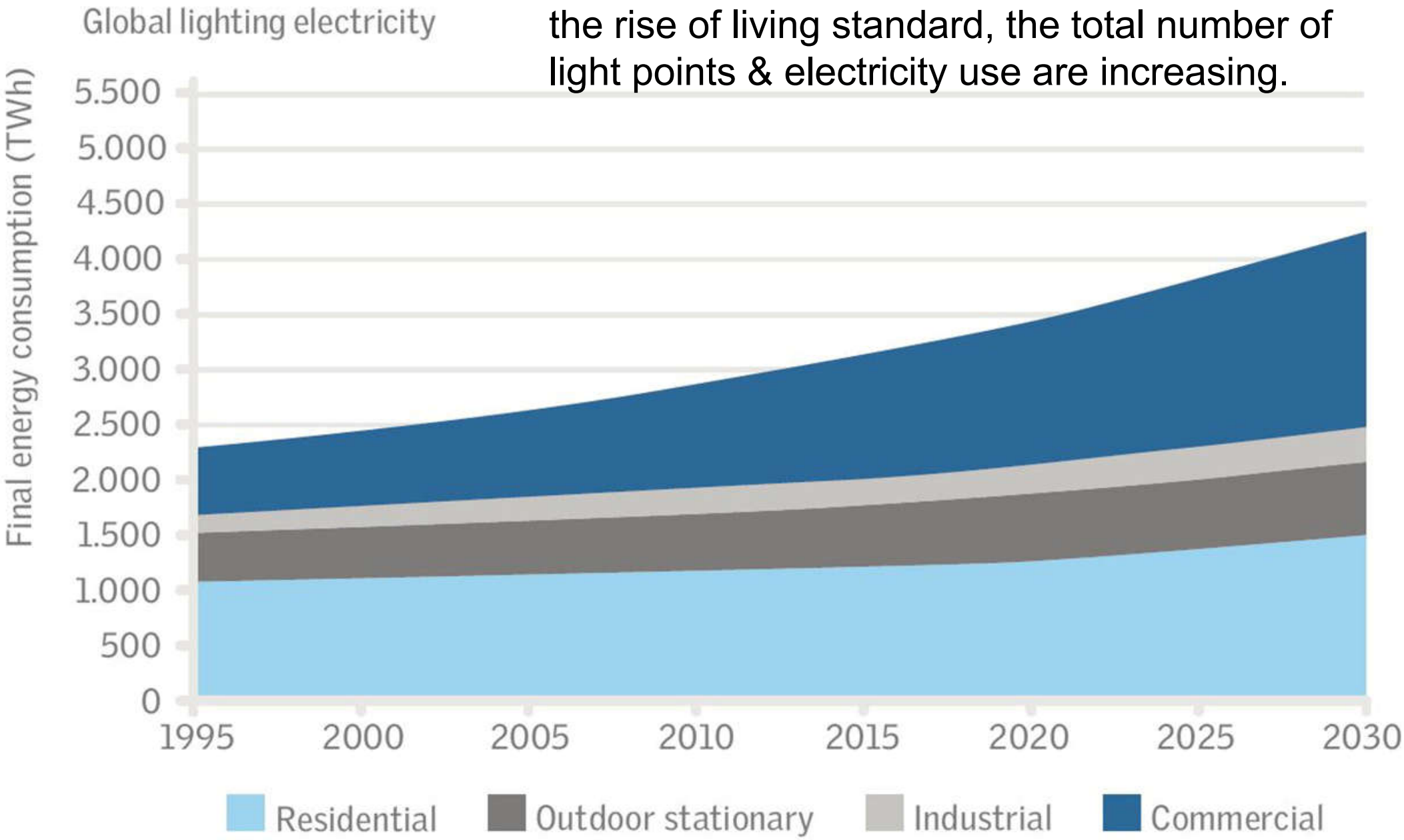


Lighting energy use

- Lighting consumes a great share of energy use in buildings & facilities
  - Direct consumption of electricity
  - Indirectly affect the cooling systems (due to heat)
  - Operation & maintenance issues
- The need to manage the lighting energy
  - Prevent energy wastage & reduce running costs
  - Ensure good quality visual environment
  - Reduce greenhouse gas or CO_2 emissions

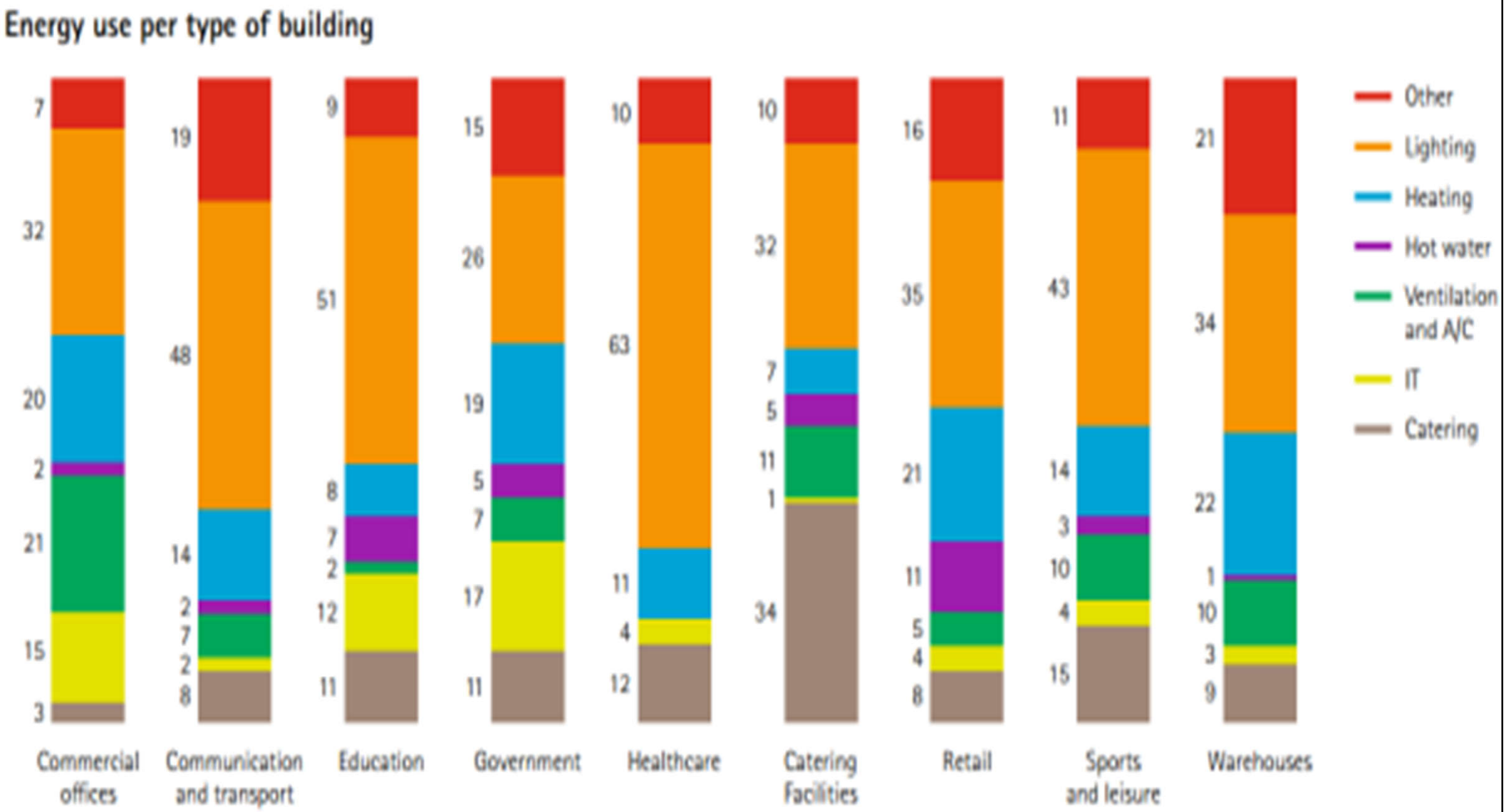
Global electricity consumption for lighting

Due to population growth, urbanization, and the rise of living standard, the total number of light points & electricity use are increasing.



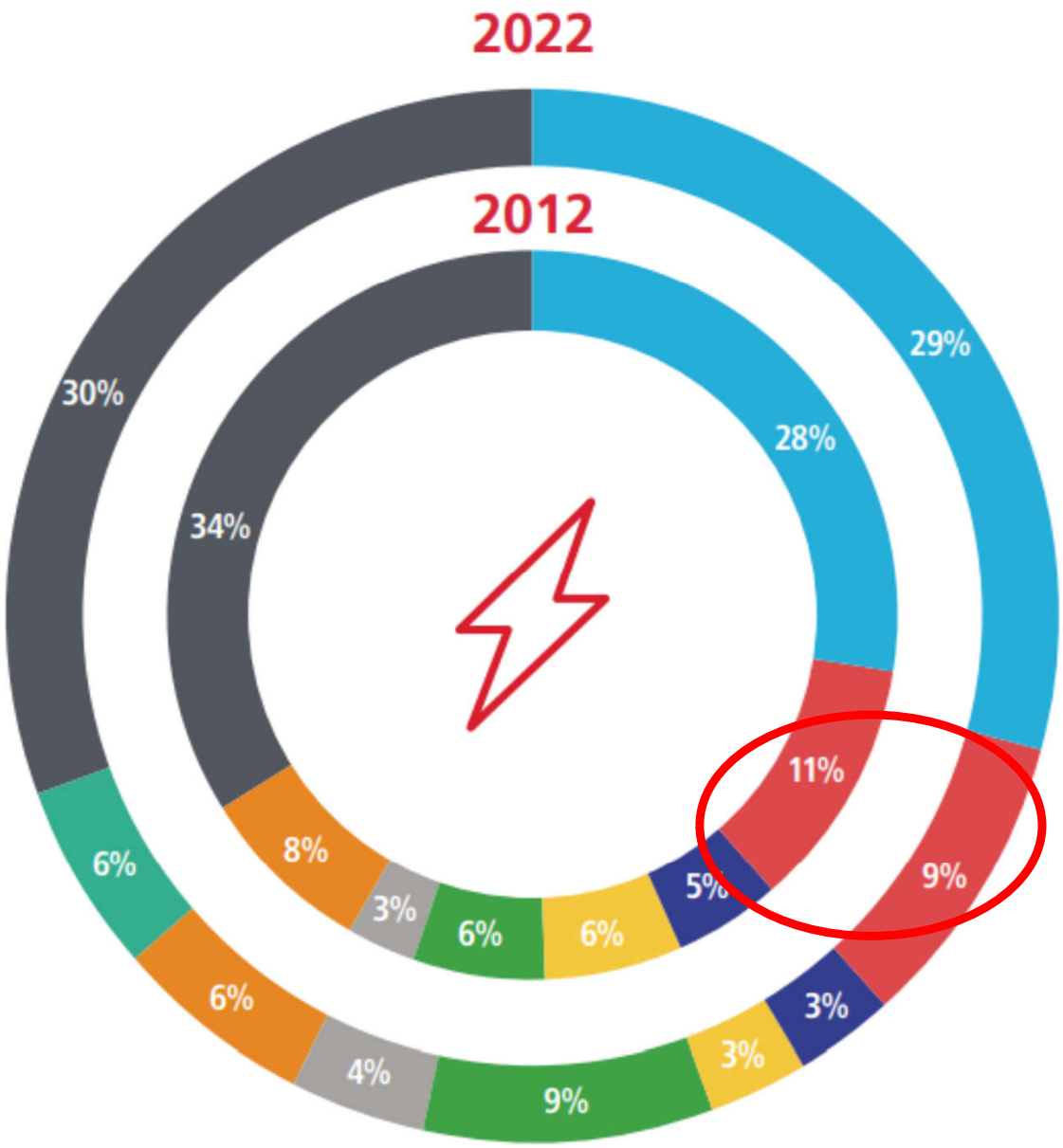
(Source: https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight/benefits-of-daylight)

Energy end-use for different types of buildings



(Source: https://www.researchgate.net/figure/C-Energy-use-per-type-of-building_fig1_298910945)

Electricity consumption by end-use in Hong Kong



空氣調節
Air Conditioning

垂直運輸
Vertical Transport

照明
Lighting

其他
Others

冷凍
Refrigeration

工業生產 / 設備
Industrial Process/ Equipment

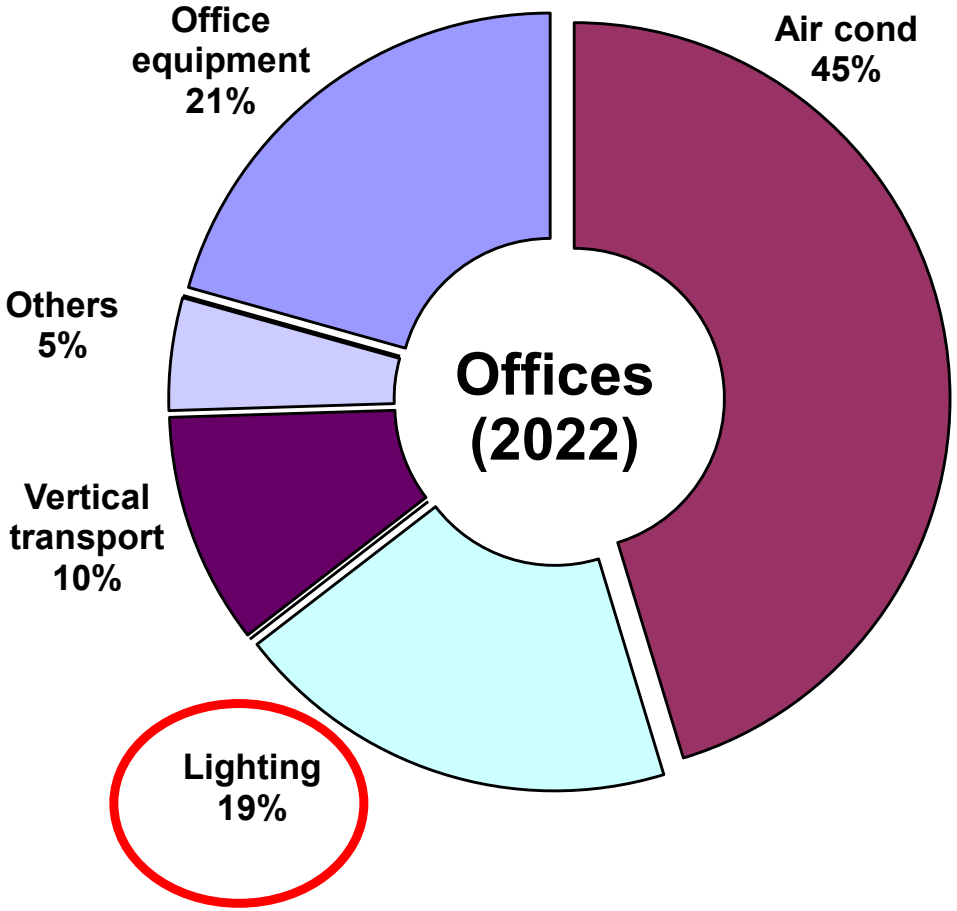
煮食
Cooking

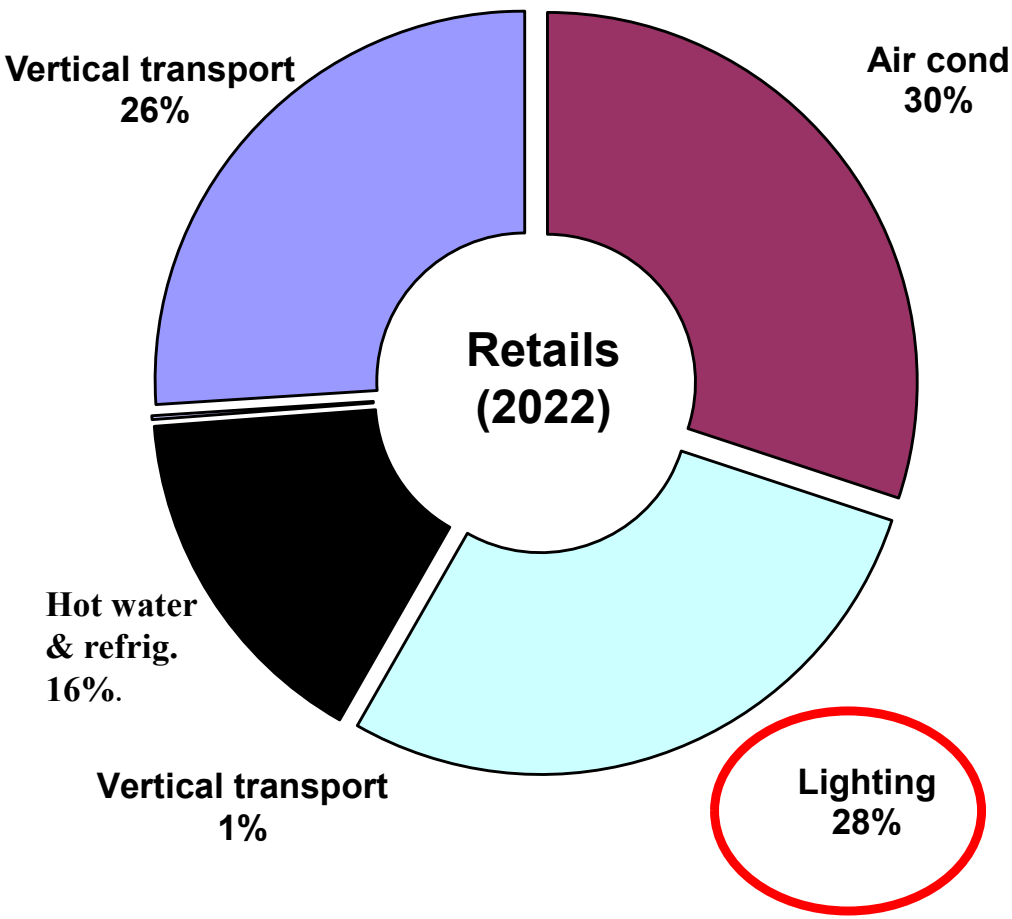
熱水
Hot Water

辦公室設備
Office Equipment

(Source: Hong Kong Energy End-use Data 2021)

Energy consumption patterns in offices & retails in Hong Kong (2022)

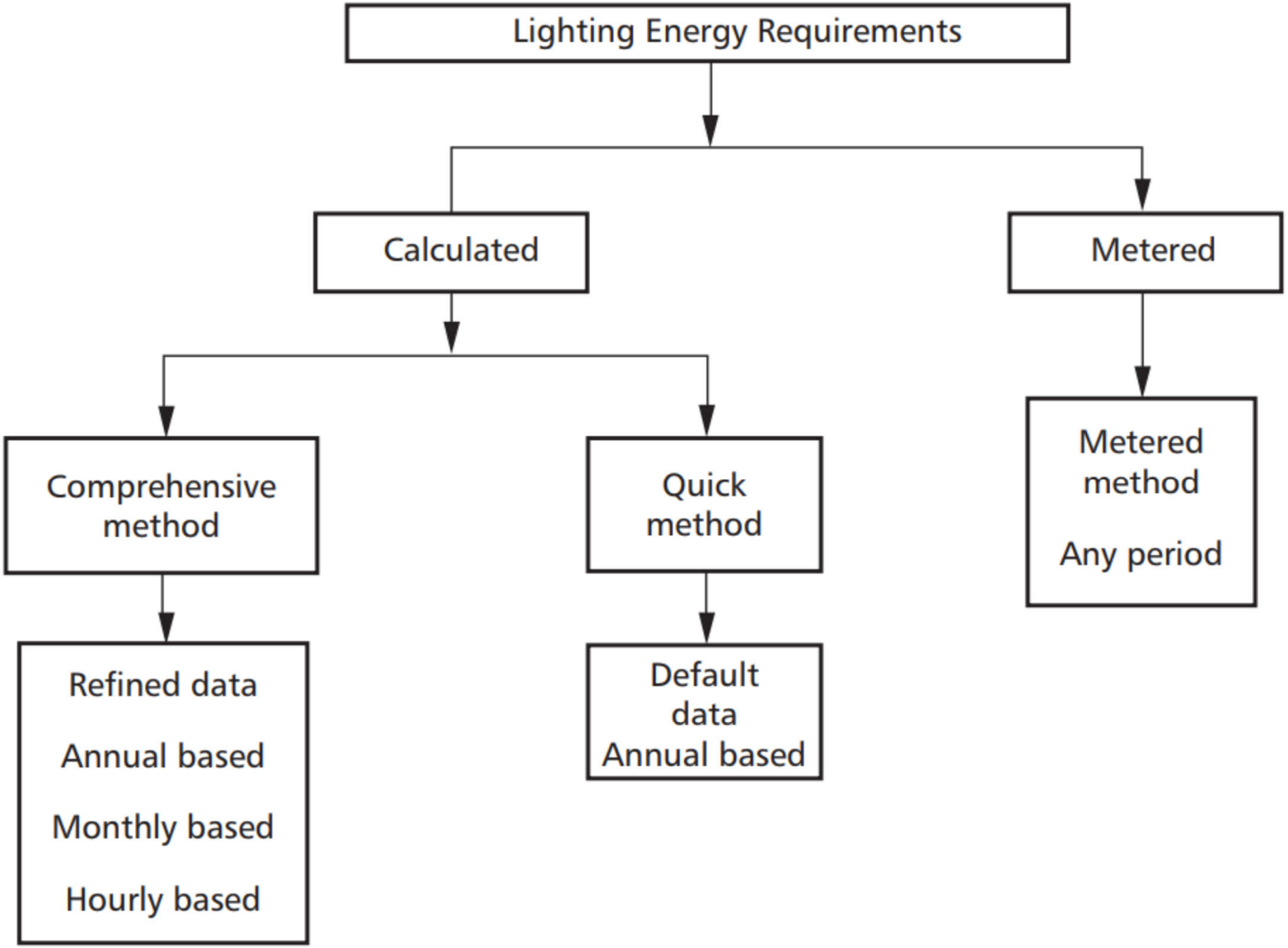




Do you know what are the direct and indirect energy consumption of lighting?

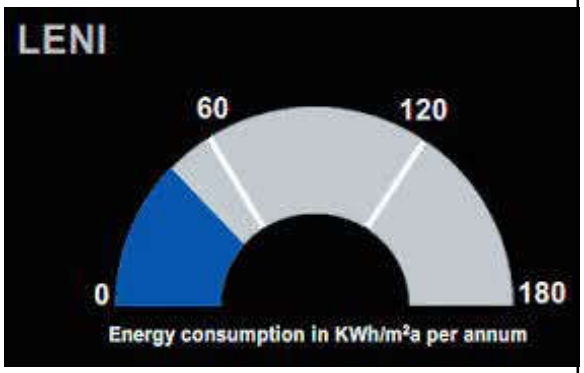
(Data source: Energy Efficiency Office, HK)

Methods for determining lighting energy use



(Source: SLL Code for Lighting 2012)

Lighting Energy Numeric Indicator (LENI)
(based on EN 15193 standard)



$LENI = W / A$ [kWh per m^2 per year]

where W = annual estimate of energy use (kWh)

A = useful floor area assessed (m^2)

$LENI = \sum (P_n \times F_C) \times \{(t_D \times F_O \times F_D) + (t_N \times F_O)\} / A$

– The installed load (P_n)

– Multiplied by the annual hours of use by day (t_D) & at night (t_N)

– Reduced by the factors (≤ 1) for daylight-based control (F_D), presence-based control (F_O) & a constant lighting control system (F_C) (e.g. maintenance control)

(LENI also takes charging energy for emergency lighting & standby energy into account)

* Further information on LENI: https://eeabs.co.uk/leni-lighting-energy-numerical-indicator/

(Source: The Lighting Handbook (Zumtobel) http://www.zumtobel.com/PDB/teaser/EN/lichthandbuch.pdf)

Lighting energy use

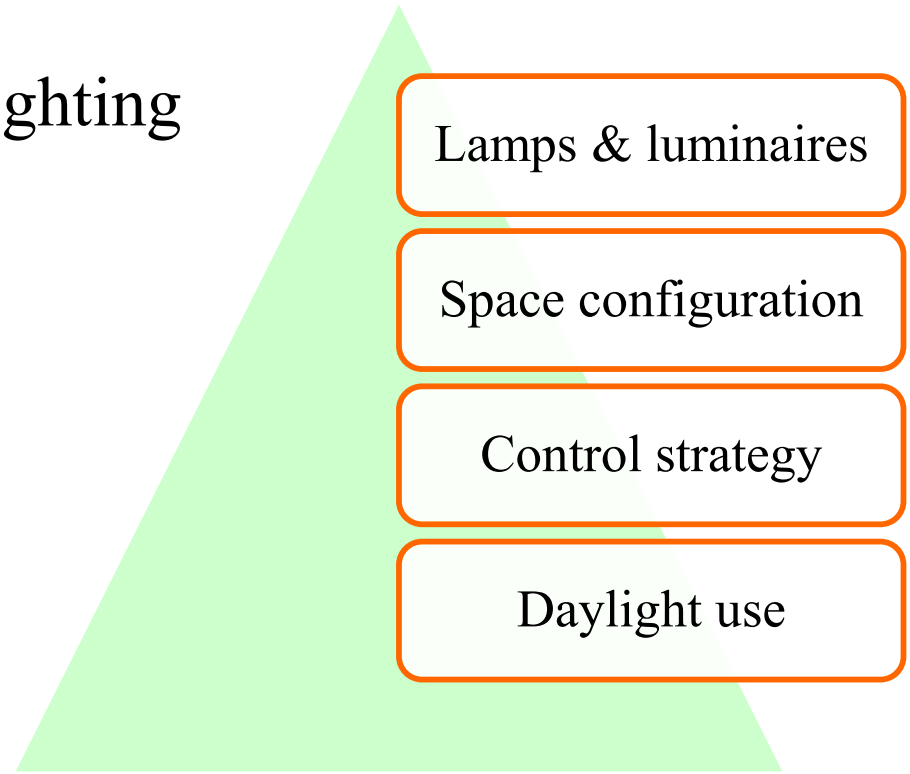
- Energy management for lighting
  - 1. Design considerations
    - Codes & legislation, design practice
  - 2. Equipment considerations
    - Light sources, ballasts, luminaires, controls
  - 3. System maintenance
- Lighting economics
  - Cost & financial analysis
- Lighting audit (evaluate & identify savings)

Basic strategies for lighting energy management

New Construction	Existing Buildings (System Upgrades)
• Designing for daylighting • Electric lighting equipment • Lighting controls • Space design & material selection • Lighting system maintenance	• Lamps • Ballasts • Luminaires • Lighting controls • Exist sign upgrades • Disposal

Simple guidance for energy efficient lighting

- The right amount of light
- Light in the right place
- Light at the right time
- The right lighting equipment



Lighting energy use

- Lighting system efficiency principles:
  - 1. Lighting hardware efficiency
    - Includes light source, control gear, optical system, luminaire housing, etc.
  - 2. Lighting installation efficiency
    - Largely dependent on the choice, location & setting up (e.g. aiming) of the lighting hardware
  - 3. Usage efficiency
    - Depends largely on the type of lighting controls & space design

Lighting energy use

- Video: Energy 101: Light Bulbs (4:47)

  - http://youtu.be/Pk60-D61h34
  - Our animated correspondent, 'Little Lee Patrick Sullivan,' kicks off our "Energy 101" series with an inside look -- literally -- at light bulb technology. He goes inside an incandescent, a compact fluorescent and an LED bulb to see what makes them work, and their potential drawbacks.

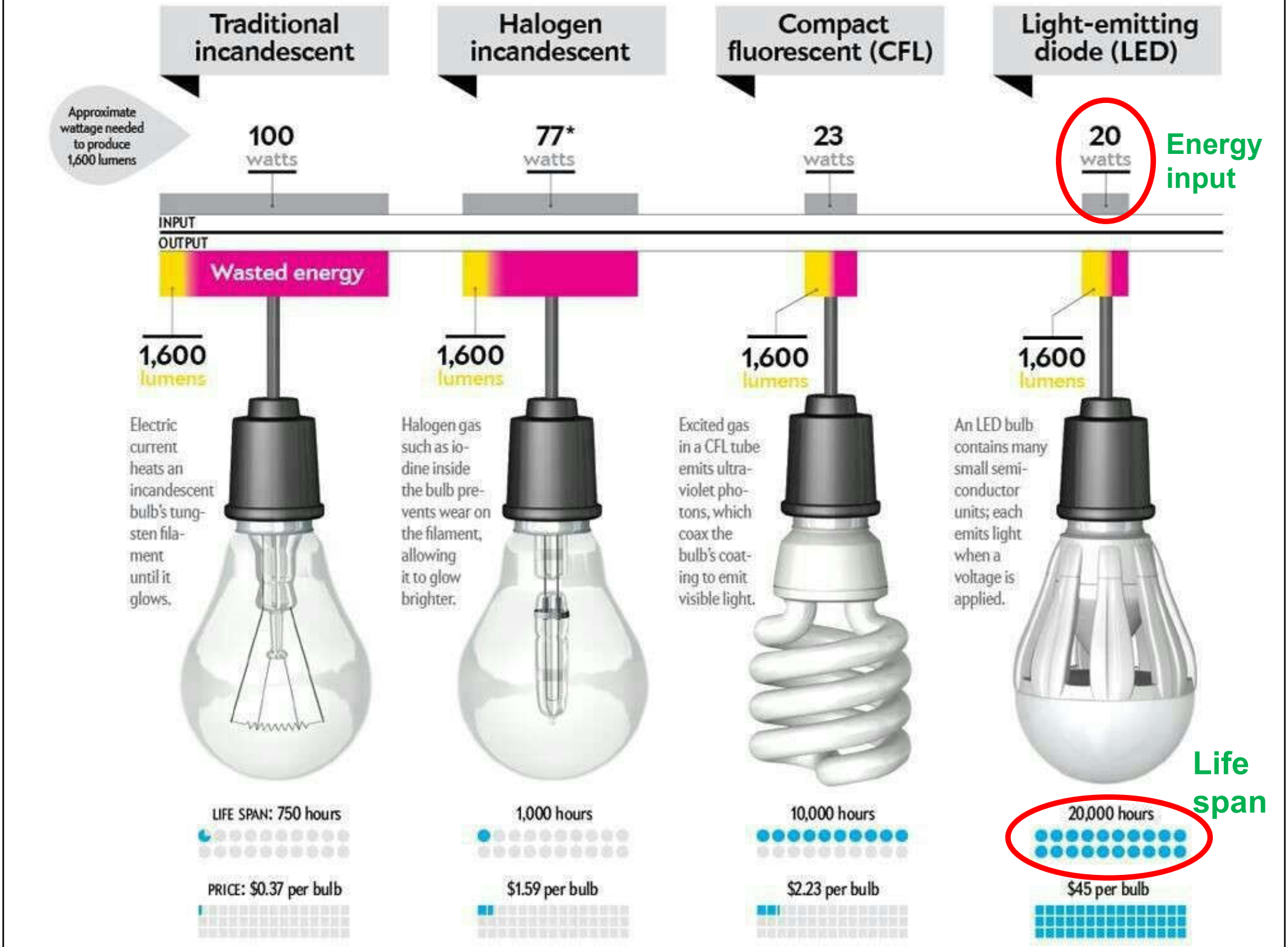
Evolution of light bulbs

Edison lamp

Incandescent lamp

Compact fluorescent lamp

LED lamp


Traditional incandescent
Halogen incandescent
Compact fluorescent (CFL)
Light-emitting diode (LED)
Approximate wattage needed to produce 1,600 lumens
100 watts
77* watts
23 watts
20 watts
Energy input
INPUT
OUTPUT
Wasted energy
1,600 lumens
1,600 lumens
1,600 lumens
1,600 lumens
Electric current heats an incandescent bulb's tungsten filament until it glows.
Halogen gas such as iodine inside the bulb prevents wear on the filament, allowing it to glow brighter.
Excited gas in a CFL tube emits ultraviolet photons, which coax the bulb's coating to emit visible light.
An LED bulb contains many small semiconductor units; each emits light when a voltage is applied.
LIFE SPAN: 750 hours
1,000 hours
10,000 hours
20,000 hours
Life span
PRICE: $0.37 per bulb
$1.59 per bulb
$2.23 per bulb
$45 per bulb

Comparison of capital cost & electricity cost among different lamps

	Incandescent Bulb	Compact Fluorescent Lamp	LED Lamp
Wattage (W)	60	12	7
Lumen Output (lm)	710	700	600
Luminous Efficacy (lm/W)	12	58	86
Average Life Expectancy (hrs.)	1,000	8,000	15,000
Annual Electricity Consumption for Each Bulb (kWh) [1.3]	131	26	15
Annual Electricity Cost for Each Bulb [1.4]	HK$158	HK$32	HK$18
Retail Price for Each Bulb	HK$18	HK$40	HK$52
Number of Bulb Required for Operating 15,000 Hours (No.)	15	2	1
Total Capital Cost and Electricity Cost for Operating 15,000 Hours	HK$1,350	HK$291	HK$178
Photo			

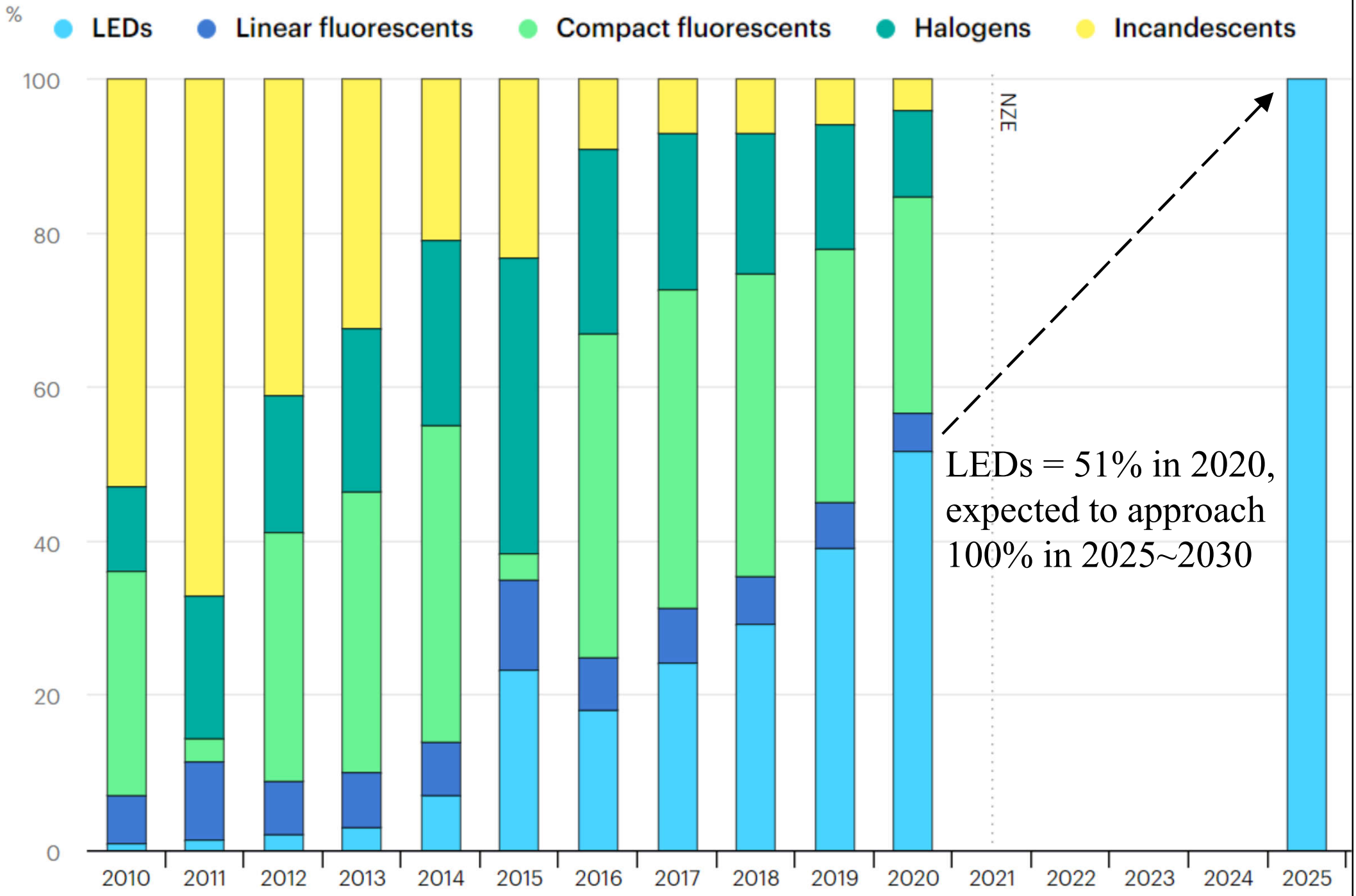
(Source: https://www.emsd.gov.hk/energyland/en/appAndEquip/equipment/lighting/example.html)

Comparison of capital cost & electricity cost for decorative lamps

	Halogen Lamp	LED Lamp
Wattage (W)	50	5.5
Centre Beam Luminous Intensity (cd)	1200	1030
Average Life Expectancy (hrs.)	2,000	25,000
Annual Electricity Consumption for Each Lamp (kWh) [2.3]	110	12
Annual Electricity Cost for Each Lamp [2.4]	HK$131	HK$14
Retail Price for Each Lamp	HK$10	HK$102
Number of Lamp Required for Operating 25,000 Hours (No.)	13	1
Total Capital Cost and Electricity Cost for Operating 25,000 Hours	HK$1,625	HK$267
Photo		

(Source: https://www.emsd.gov.hk/energyland/en/appAndEquip/equipment/lighting/example.html)

Global lighting sales, historical & in the net-zero energy (NZE) scenario



(Source: IEA Report Lighting https://www.iea.org/reports/lighting)

Classifications of LED lighting products & examples of application

Type of LED lighting products	Application category
• Directional lamp • Non-directional lamp • Strip light • Integrated LED luminaire • Integrated downlight • Planar (or Panel) LED luminaire • Linear batten LED luminaire • Troffer LED luminaire • High/Low bay LED luminaire • Outdoor (Floodlight) integrated luminaire • Roadway integrated luminaire	**1. Residential lighting products** • Non-directional & directional lamps for general lighting service • Linear strip light (flexible or rigid) • Integrated LED downlight luminaires **2. Commercial & industrial lamps** (typical retrofit lamps for linear fluorescent & HID Lamps) • Linear double-capped LED lamps • Single-capped high luminous flux LED lamps **3. Commercial & industrial indoor luminaires** • Integrated LED luminaires (planar/panel, linear batten, troffer) • Retrofit kits for fluorescent troffer luminaires • High/Low bay LED luminaires **4. Outdoor luminaires** • Roadway/street lighting integrated luminaires • Outdoor integrated luminaires

(See also: https://www.ledlightsinindia.com/information/types-of-led-lights-available-applications)

(Source: https://www.iea-4e.org/ssl/news/quality-and-performance-requirements-for-led-lighting-products-public-review-draft/)

Energy efficient lighting

- HK Building Energy Code (BEC)*
  - Code of Practice for Energy Efficiency of Building Services Installations
    - 2024, 2021, 2018, 2015 & 2012 Editions (3-year cycle)
    - Requirements for lighting installation
  - Technical Guidelines on Building Energy Code
    - 2024, 2021, 2018, 2015 & 2012 Editions
- Energy Efficiency Labelling Scheme (HK)*
  - Compact fluorescent lamps (CFLs), LEDs

(* See also https://www.emsd.gov.hk/beeo/ and https://www.emsd.gov.hk/energylabel/)

Buildings Energy Efficiency Ordinance (BEEO)

https://www.emsd.gov.hk/beeo/

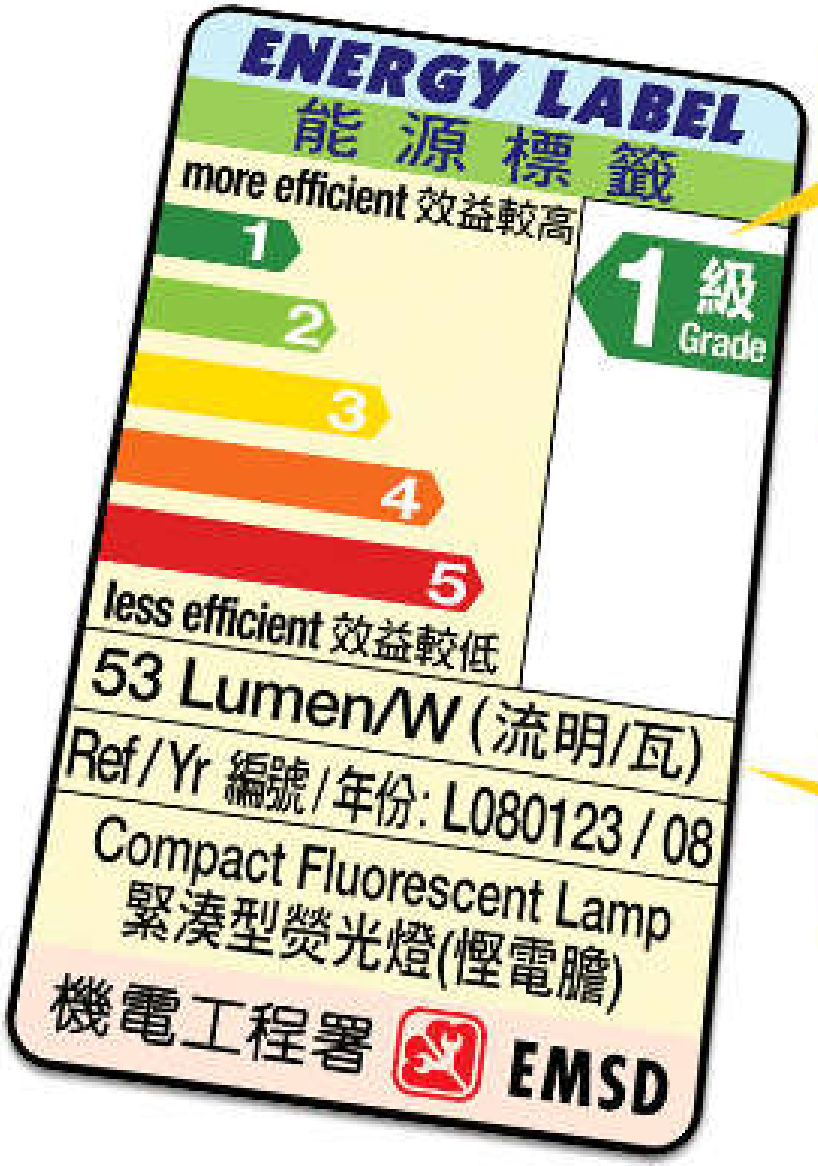
(Source: EMSD)

Energy Efficiency Labelling Scheme

https://www.emsd.gov.hk/energylabel/

UNDERSTANDING THE LABEL

Compact Fluorescent Lamps (CFLs)



This indicates the energy efficiency grading of the model. Grade 1 products are most efficient (green) and have an average lamp life of 8,000 hours or above. Grade 5 products have an average lamp life of below 6,000 hours (red).

Lamp luminous efficacy of the model. A higher number indicates that the product is more efficient.

PERCENTAGE OF ENERGY SAVING

Compact Fluorescent Lamps (CFLs)

Grade 1 vs Grade 5

18%

TIPS

Switch off lights that are not in use.

(Source: EMSD)

Energy efficient lighting

- HK Building Energy Code: energy efficiency requirements for lighting installation
  - 1. Lighting power density (LPD)
    - Reduce lighting power
  - 2. Lighting control point
    - Facilitate effective operation; reduce energy use
  - 3. Automatic lighting control
    - Such as daylight responsive control, occupant sensor, time scheduling, dimmer control system

HK Building Energy Code (BEC): Lighting power density (LPD)

UPDATED

LPD for office spaces:

	LPD (W/m^2)
BEC 2012	15
BEC 2015*	13 / 12
BEC 2018**	12 / 10 / 9
BEC 2021**	9.5 / 8.9 / 7.8
BEC 2024**	9.0 / 8.5 / 7.2

* For enclosed office ≤ 15 m^2 & open plan office > 15 m^2.

** For enclosed office ≤ 15 m^2, office with area between 15 to 200 m^2 & office > 200 m^2.

Section 5 Lighting Installation	BEC 2021	BEC 2024
1) Max allowable lighting power density (LPD), Table 5.4		
Type of space	LPD (W/m2)	
Bar / Lounge	13.0	10.0
Banquet Room / Function Room / Ball Room	17.0	12.7
Car Park	4.0	3.0
Changing Room/ Locker Room	10.0	8.1
Clinic	15.0	12.4
Conference / Seminar Room	12.8	10.6
Corridor	7.0	6.0
Dormitory	6.2	6.1
Entrance Lobby	11.5	10.0
Exhibition Hall / Gallery	15.0	12.0
Fast Food / Food Court	14.0	12.0
Guest room in Hotel or Guesthouse	11.5	9.9
Laboratory	13.5	10.4
Library - Reading Area or Audio Visual Centre	12.0	10.2
Library - Stack Area	15.0	12.7
Lift Lobby	9.2	7.5
Long Stay Ward for elderly	15.0	12.9
Medical Examination Room	15.0	12.3
Office, enclosed (with internal floor area at or below 15m²)	9.5	9.0
Office, with internal floor area above 15m² and of or below 200m²	8.9	8.5
Office, with internal floor area above 200m²	7.8	7.2
Pantry	10.2	8.5
Patient Ward / Day Care	13.0	11.2
Plant Room / Machine Room / Switch Room (with internal floor area above 15m²)	8.8	8.4
Public Circulation Area	11.5	9.9
Restaurant	13.6	12.0
Retail	13.4	11.1
Server Room / Hub Room	8.9	8.2
Sports Arena, Indoor, for recreational purpose (with internal floor area at or below 1,000m²)	17.0	16.0
Sports Arena, Indoor, for recreational purpose (with internal floor area above 1,000m²)		17.0
Staircase	6.0	5.6
Storeroom / Cleaner (with internal floor area at or below 15m²)	7.9	7.4
Storeroom / Cleaner (with internal floor area above 15m²)		6.3
Toilet / Washroom / Shower Room	9.7	9.0
Workshop	11.5	9.4

(Source: BEC 2024, 2021, 2018)

Sample calculation for lighting power density (LPD)

Table 5.7 : LPD Calculation for Multi-functional Space

Space Function	Function-specific Luminaires			LPD (W/m²)	
	Luminaire Designation	Quantity	Total Circuit Wattage (W)	Calculated	Max Allowable
Banquet room	LT1	96	480	[480 + 2880 + 1104] / 264 = 16.9	17.0
	LT2	90	2880		
	LT3	8	1104		
	LT4	Excluded in LPD			
Ball room	LT2	90	2880	[2880 + 1104] / 264 = 15.1	17.0
	LT3	8	1104		
	LT4	Excluded in LPD			
Seminar room	LT1	96	480	[480 + 2016] / 264 = 9.5	12.8
	LT5	112	2016		

(Source: Technical Guidelines on Building Energy Code 2021)

Energy efficient lighting

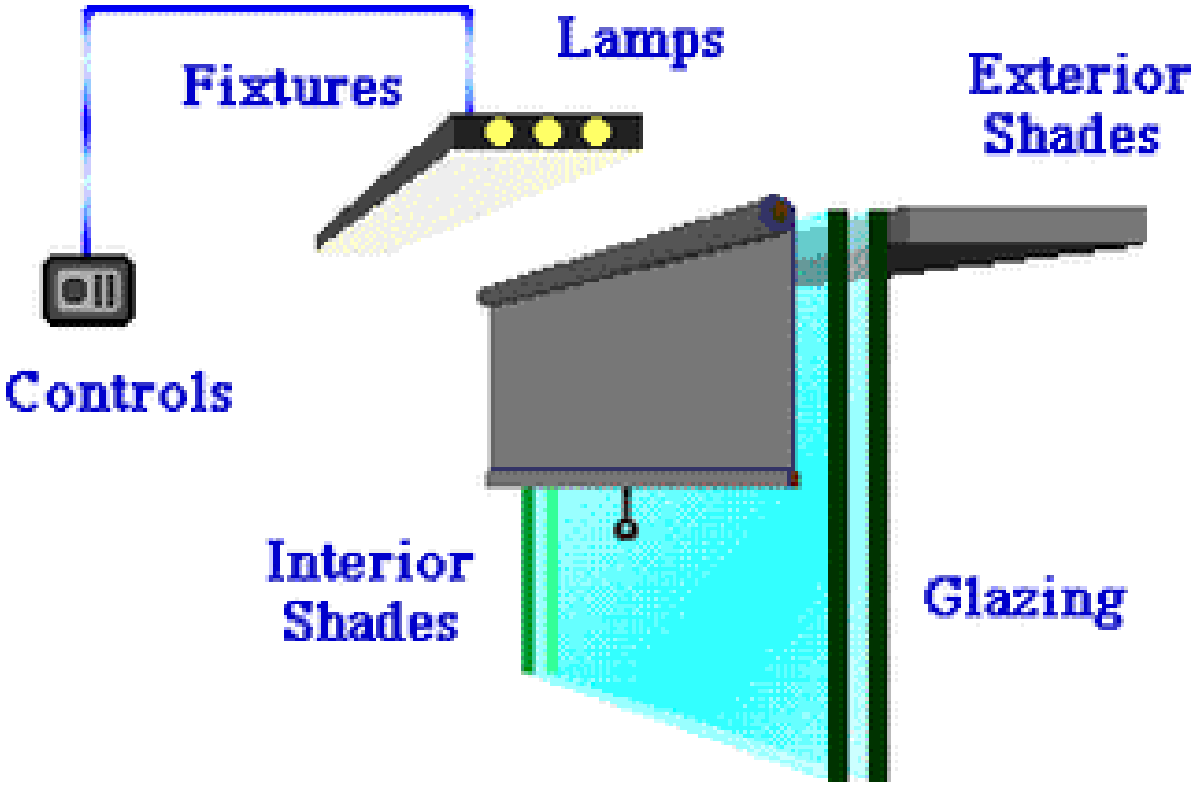
- **Typical lighting requirements**
  - Minimum allowable luminous efficacy
    - Choose appropriate type of lamps
  - Maximum allowable lamp controlgear loss
    - Energy efficient ballast for fluorescent lamps
  - Maximum allowable lighting power density (LPD)
    - Design suitable amount and type of lighting systems
  - Interior lighting controls (switching)
    - Number of control points (to facilitate effective operation)

Energy efficient lighting

- Principles of efficient lighting design
  - Meet target light levels
  - Efficiently produce light
    - Use natural light or efficient light sources
  - Efficiently deliver light
    - Balance efficiency with aesthetics, lighting quality, visual comfort
  - Automatically control lighting operation
    - Switch off or dim unnecessary lighting equipment

Energy efficient lighting design strategies

Energy efficient fittings (e.g. compact fluorescent lamps, LED)



Lighting controls and interactions with windows

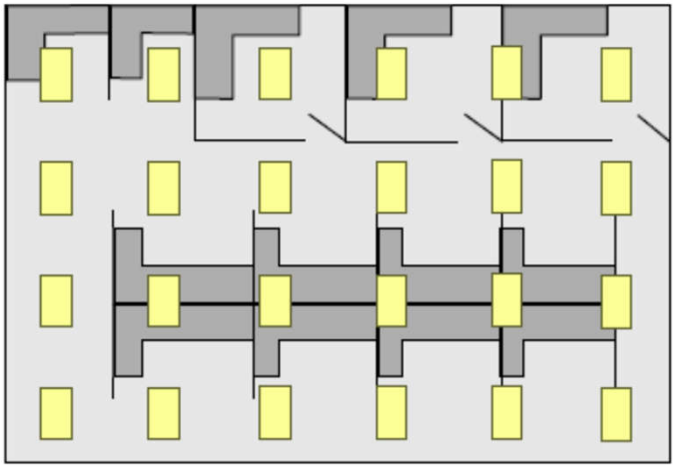
Example: Integrated controls for lighting luminaires

Vertically Integrated Design

Personal Control Features:

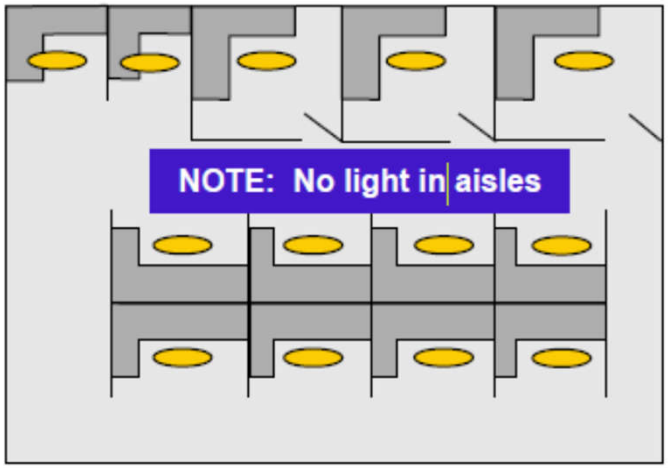
- Direct/ Indirect Pendant Luminaire
- Task light: 2T8-PS Dimmable EB (64W)/ 100%-5%
- Ambient light: 1T8-PS EB (31W)/ ON/OFF only
- Photocell Sensor built in
- Occupancy Sensor built in

Comparison to a Standard Troffer Layout:



- 2x4 Parabolics
- **24 Luminaires**
- 72 lamps
- **~2300 watts**

- Direct Indirect
- **13 Luminaires**
- 39 lamps
- **~1250 watts**



(Source: http://lightingdesignlab.com)

Energy efficient lighting

- The key is to understand lighting needs & operation
  - Space design & utilisation
  - Daylighting potential
  - Light sources
  - Luminaires
  - Lighting controls
  - Operation & maintenance

Energy efficient lighting

- Recommendations by IESNA
  - Design lighting for expected activity (higher light levels for "working“, lower levels for "walking")
  - Design with more effective fixtures & fenestration
  - Use efficient light sources (higher lumen per watt output)
  - Use more efficient fixtures
  - Use thermal controlled fixtures
  - Use lighter finish on ceilings, walls, floor & furnishings

Energy efficient lighting

- Recommendations by IESNA (cont'd)
  - Use efficient incandescent lamps
  - Turn off lights when not needed
  - Control window brightness
  - Use daylighting as practicable
  - Keep lighting equipment clean and in good working condition
  - Post instructions covering operation & maintenance

Checklist for lighting energy-saving guidelines

Lighting needs

- Visual tasks: specification
- Safety & aesthetics
- Overlighted application
- Groupings: similar visual tasks
- Task lighting

Space design & utilization

- Space plan & activities
- Room surfaces
- Space utilization: flexibility & operation periods

Daylighting

- Use daylight in suitable spaces
- Daylight compensation
- Daylight sensing & control

Light sources: lamps & ballasts

- Source efficacy
- Control compatibility
- System change

Luminaires

- Direct/indirect lighting
- Luminaire efficiency
- Heat removal
- Maintained efficiency
- Lamp replacement schedule

Lighting controls

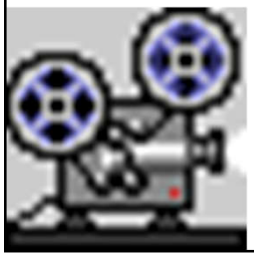
- Local control & selective switching
- Master control system
- Multipurpose spaces
- Tuning, dimming & scheduling
- Occupant & motion sensors
- Lumen maintenance
- Ballast switching

Operation & maintenance

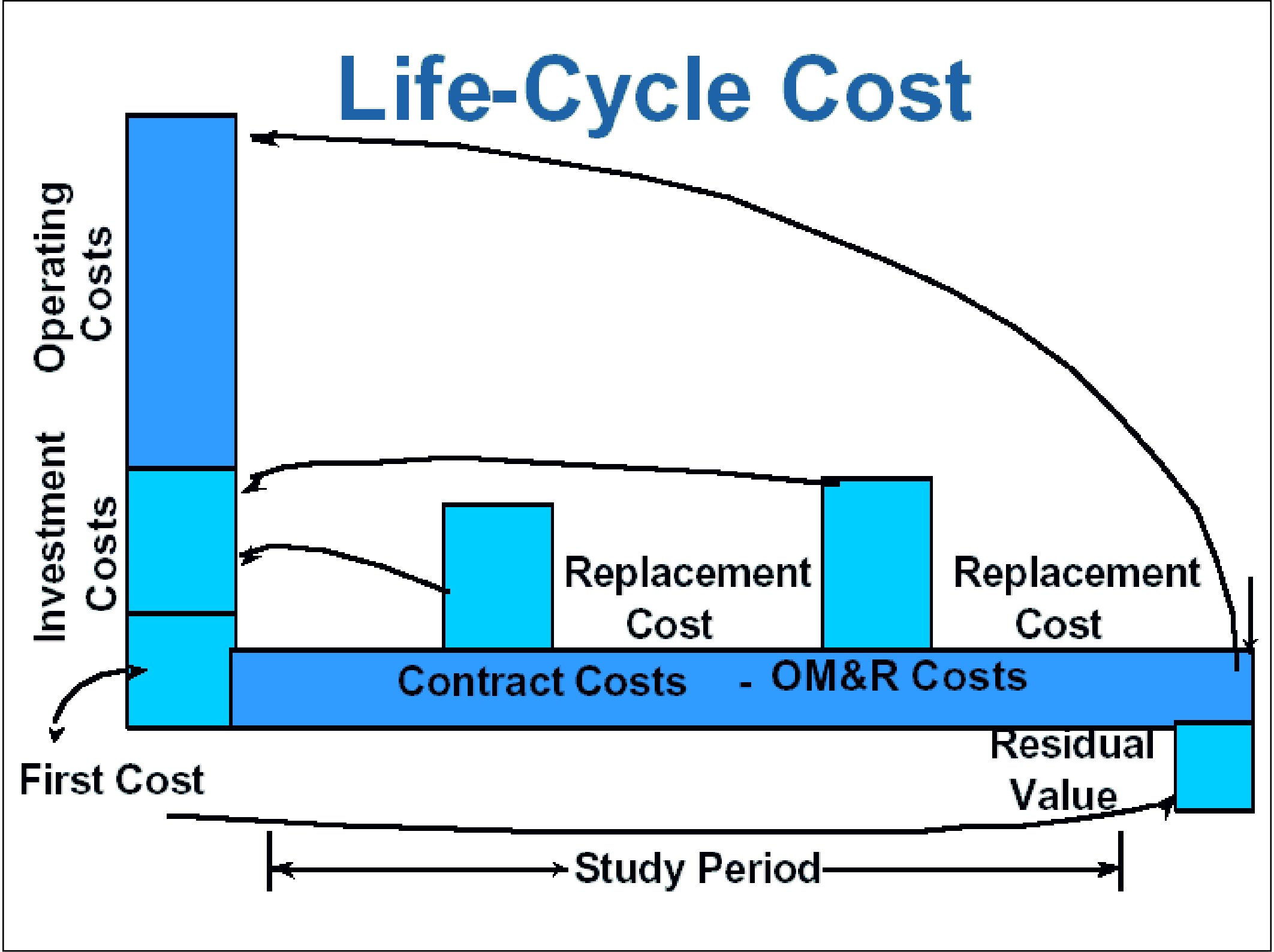
- Cleaning & relamping schedule
- Regular system checks
- Renovation of luminaires
- Education & promotion

Lighting economics

- Lighting costs
  - Financial costs
    - Lamps, luminaires, control systems & installation
    - Operating & maintenance costs
    - Disposal costs
  - Environmental costs
    - Electricity consumption & greenhouse gas emissions
    - Chemical pollution (lamps & control gear are scrapped)
    - Light pollution (light trespass & sky glow)



(Video: What does lighting cost (4:30) https://youtu.be/wflEn2mWCcI)


Life-Cycle Cost
Operating Costs
Investment Costs
Replacement Cost
Replacement Cost
Contract Costs - OM&R Costs
First Cost
Residual Value
Study Period

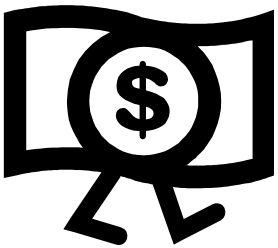
Lighting economics

- Lighting systems --- Life Cycle Costs (LCC)
  - Initial costs
    - Equipment, installation, wiring, HVAC
  - Energy costs
    - Direct lighting costs
      - Energy use (kWh) = lighting power (kW) x operating time (hr)
    - Lighting-related HVAC (indirect) costs
      - Lighting heats up the space & require cooling
    - Total cost savings = energy costs + demand costs
  - Maintenance costs

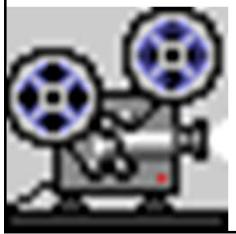
Lighting economics

- Lighting maintenance
  - Relamping
  - Reballasting
  - Cleaning
  - Miscellaneous maintenance
    - e.g. replace lenses or louvers, damaged parts
- Other related costs:
  - Working at height
  - Insurance, property taxes, depreciation

Lighting economics

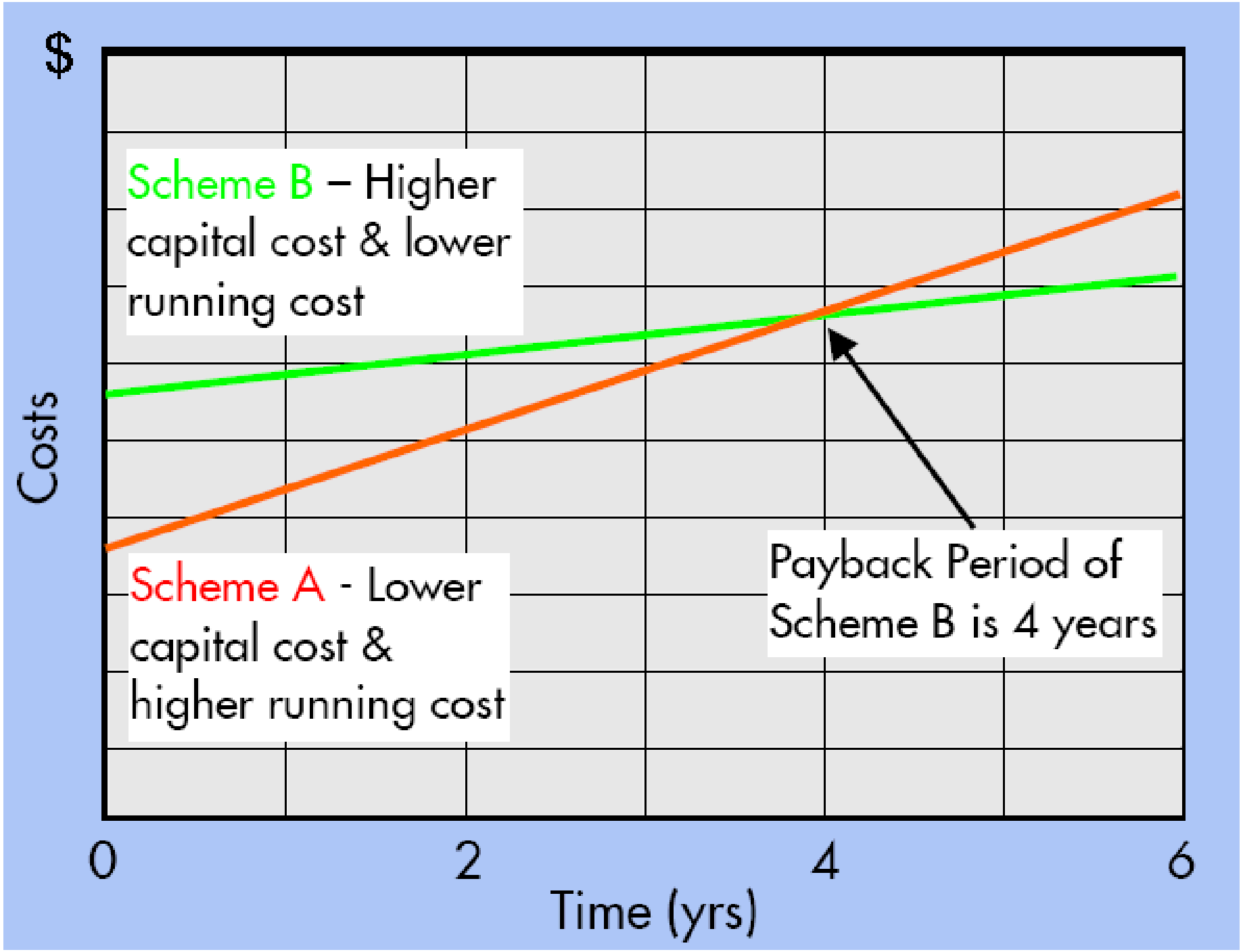


- Investment costs
  - Luminaire, including control gear (where applicable)
  - Lighting control systems (e.g. dimmers)
  - Mounting accessories
  - Electrical wiring
  - Installation costs
- Running costs
  - Energy
  - Lamp replacement
  - Maintenance
  - Amortization (disposal)



(Video: Economics of Light (3:22) https://youtu.be/QzSAKWR_zv4)

Payback period of lighting scheme



(Source: Thorn Lighting)

Example: comparison of two lighting systems (1/2)

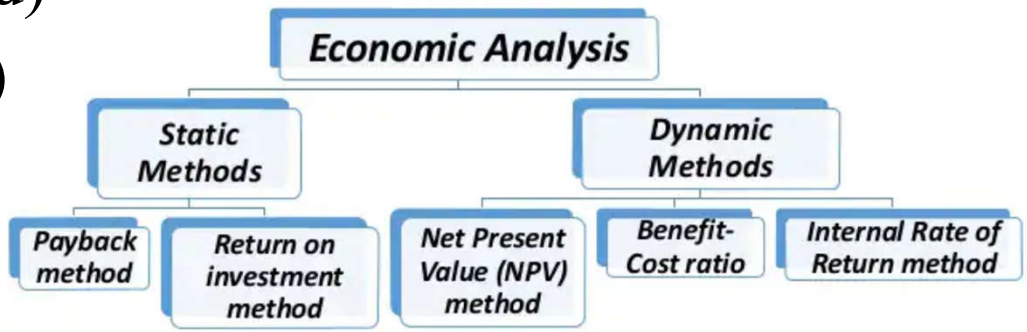
Parameters	2x4 Lamp Parabolic ES lamps and Ballast	2x4 Lamp Parabolic T8 Electronic System
Number of Fixtures	100	100
Initial Cost Luminaire and Lamps	80	90
Total	$ 8,000	$ 9,000
Maintenance & Operating Cost/Year	$ 2,616	$ 2,040
Total (5 years)	$13,080	$ 10,200
Total Cost	$ 21,080	$ 19,200

Example: comparison of two lighting systems (2/2)

Parameters	2x4 Lamp Parabolic ES lamps and Ballast	2x4 Lamp Parabolic T8 Electronic System
Delivered Lumens -Lumens/Lamp -Number of Lamps -Coefficient of Utilization -Light Loss Factor	 2650 3 0.69 0.85	 2950 3 0.79 0.85
Total Delivered Lumens	4,663	5,943
Operating Hours Operating Hours per Year Number of Years	 4,000 5	 4,000 5
Total Operating Hours	20,000	20,000
Total Cost per Million Lumen Hours	$ 226 (21,080 x 1,000,000) /(4663 x 20,000)	$ 161 (19,000 x 1,000,000) /(5943 x 20,000)

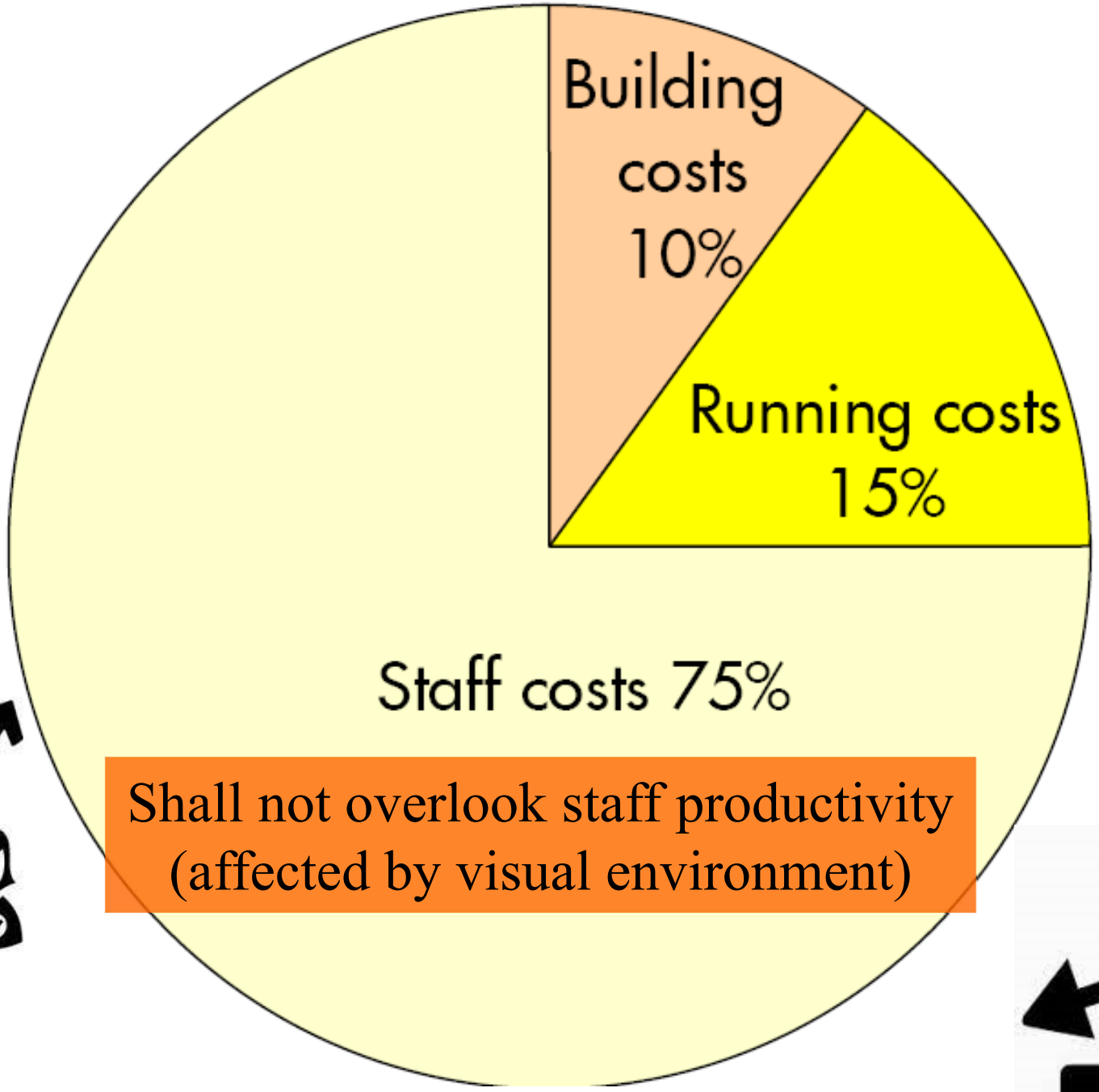
Lighting economics

- Economic analysis techniques:
  - Payback (simple, discounted)
  - Return on investment (ROI)
  - Net present value (NPV)
  - Benefit-cost ratio (BCR)
  - Internal rate of return (IRR)
  - Total life cycle cost (TLCC)



- Lighting economic analysis tools:
  - Simple Economic Tool https://www.visual-3d.com/tools/payback/
  - Visual Economic Tool https://www.visual-3d.com/tools/economicpro/

Building, running & staff costs



Shall not overlook staff productivity (affected by visual environment)

(Source: Thorn Lighting)

Existing buildings

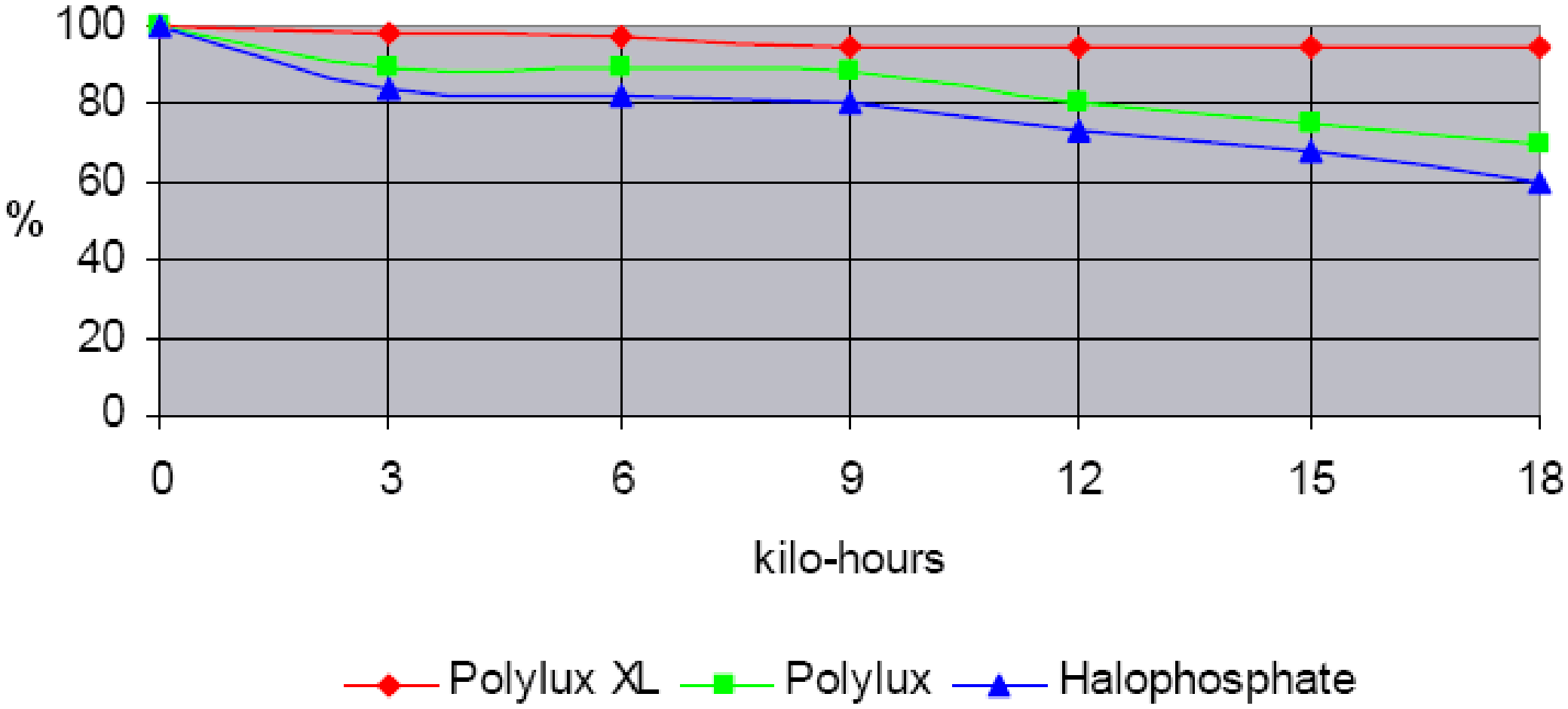
- Energy management for existing buildings
  - Building survey
  - Power budget & limit determination
  - Energy limit determination
  - Energy limit analysis
- Critical issues to consider
  - Maintenance of lighting systems
  - Lighting upgrade strategies
  - Environmental aspects

Existing buildings

- Maintenance of lighting system
  - Periodic cleaning of lighting fixtures & lamps
    - Decreases light loss & improve light levels
  - Spot or group replacement of lamps based on the economics of the system
  - Periodic repainting or cleaning of the room surfaces (ceiling, walls, and floor) to maintain optimum light reflection characteristics
- "Lumen maintenance" & lamp life/failure

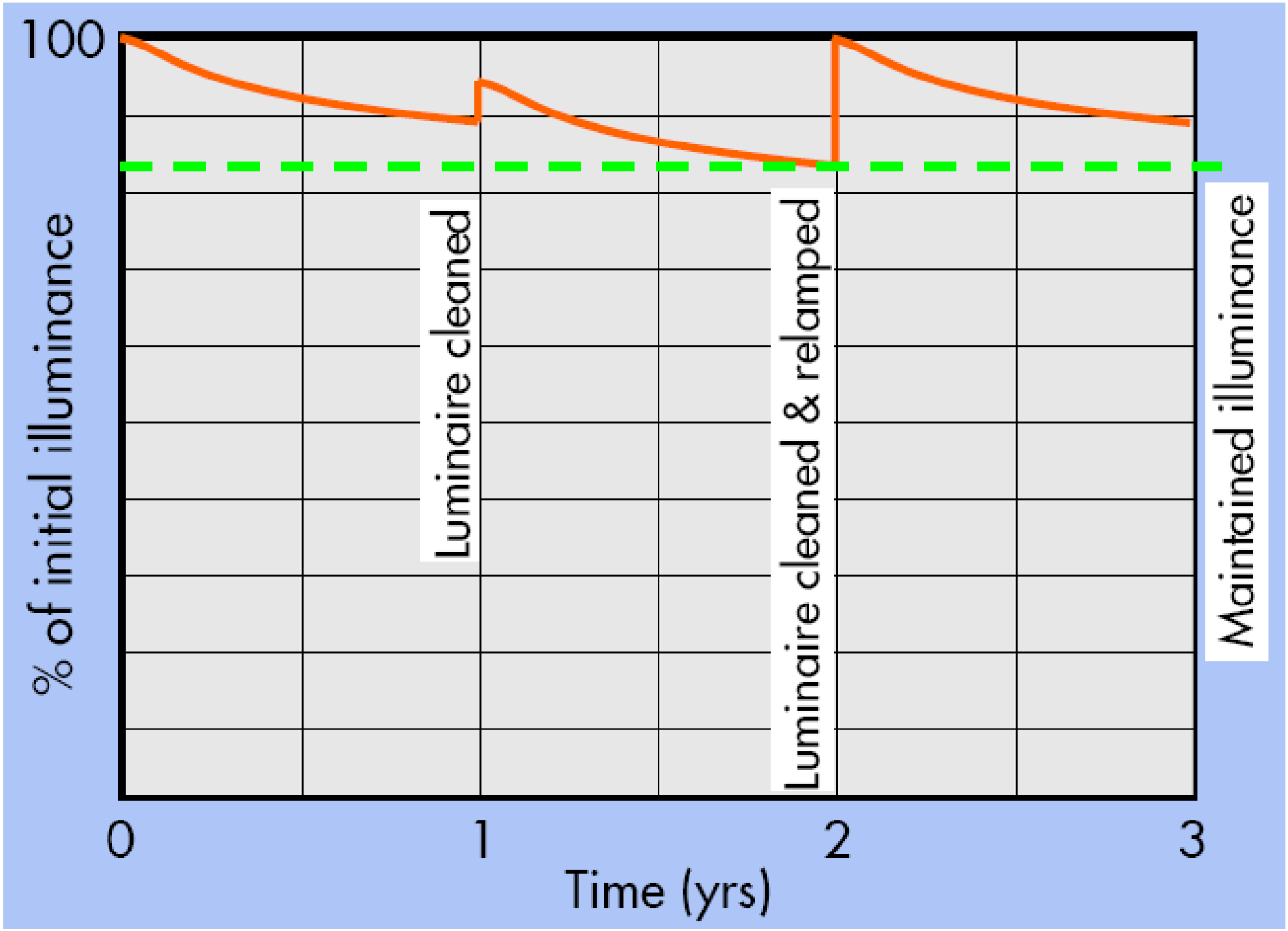
(See also: Lumen maintenance - Wikipedia https://en.wikipedia.org/wiki/Lumen_maintenance)

Examples of lumen depreciation for different luminaires
(Lumen maintenance = ratio of the light output at a particular time relative to the initial output)
(Lamps with high lumen maintenance levels can contribute to energy savings)



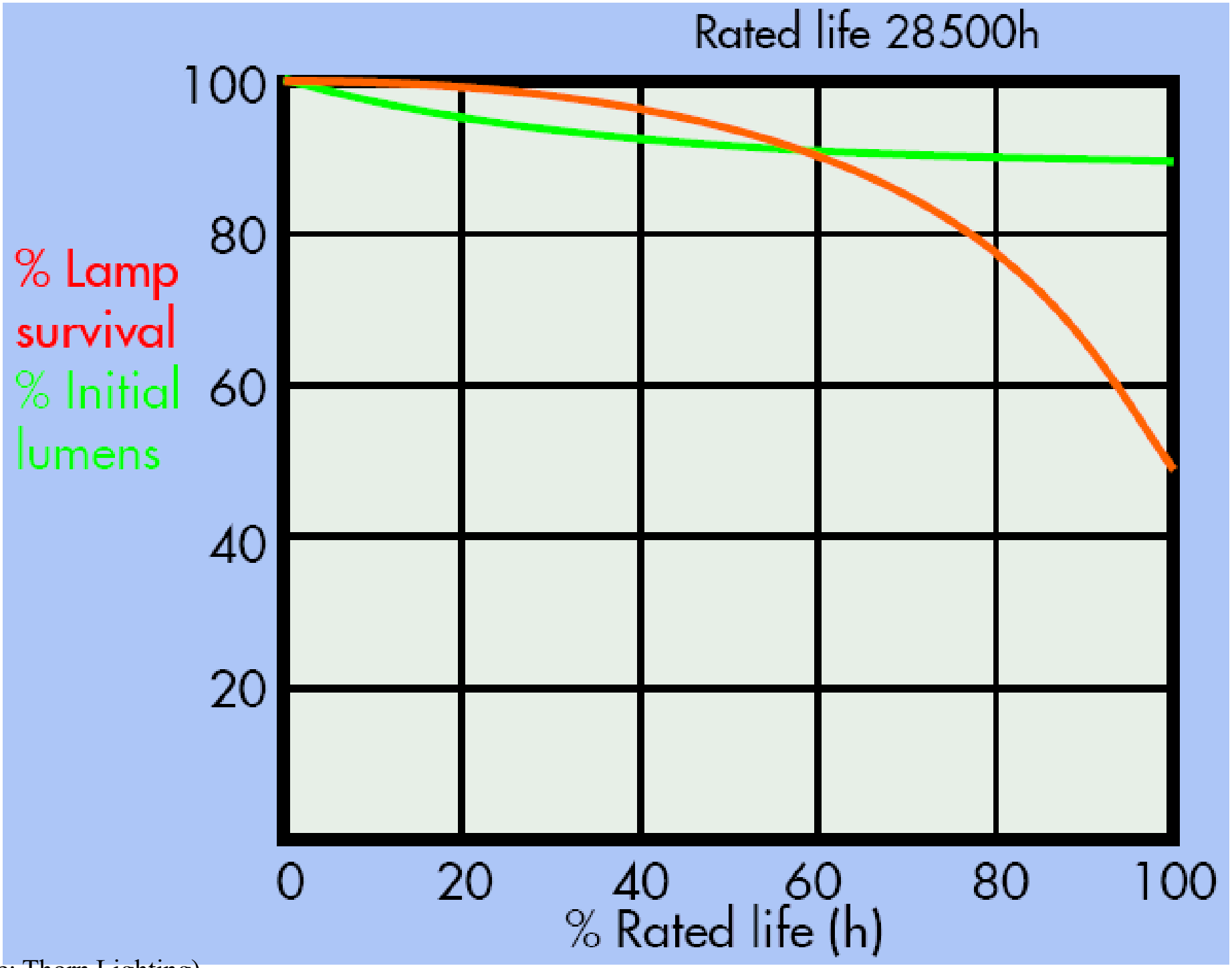
(Source: Thorn Lighting)

Lamp maintenance effect & maintained illuminance



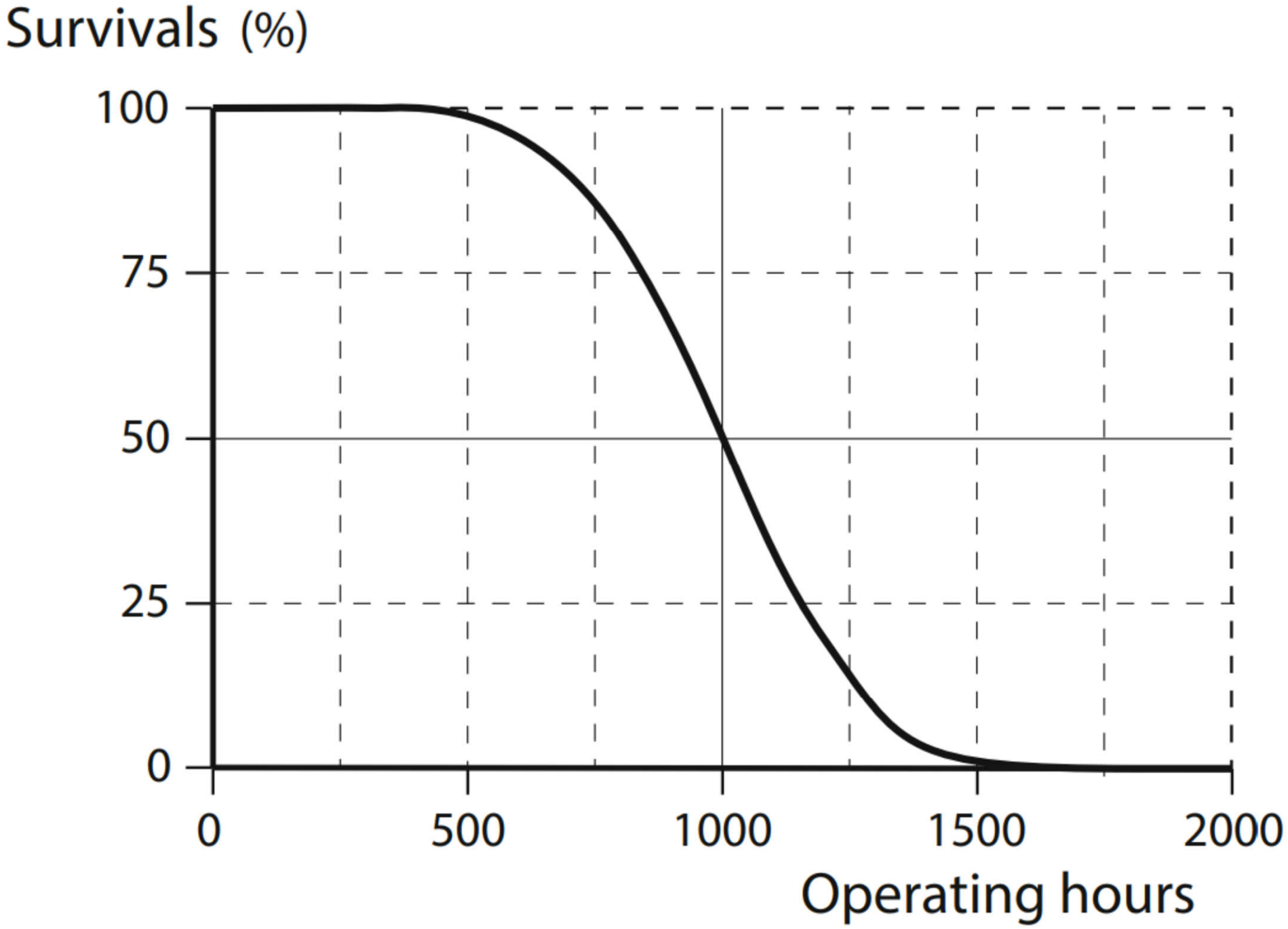
(Source: Thorn Lighting)

Lamp survival & rated life



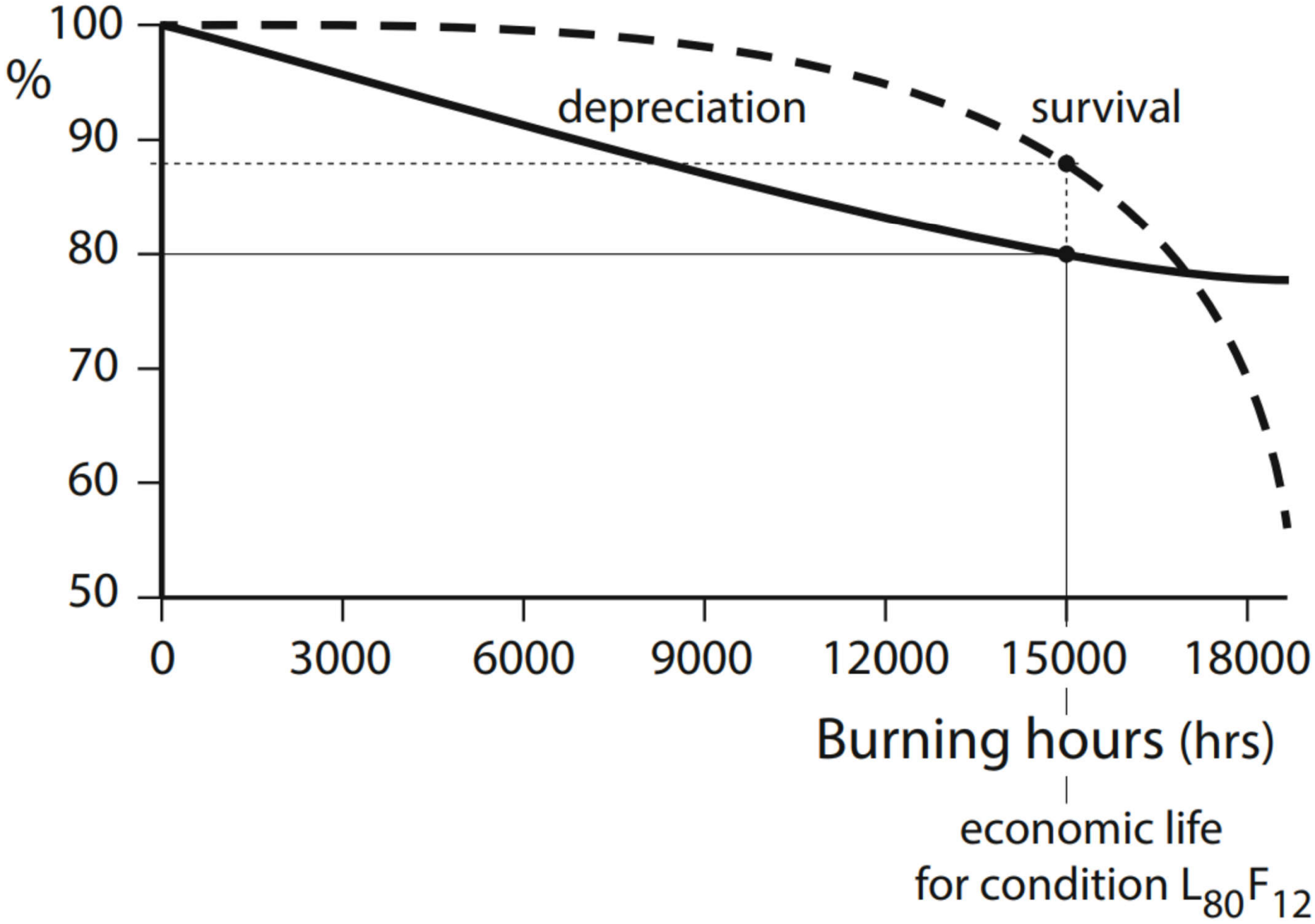
(Source: Thorn Lighting)

Typical life survival curve of an incandescent lamp for general lighting



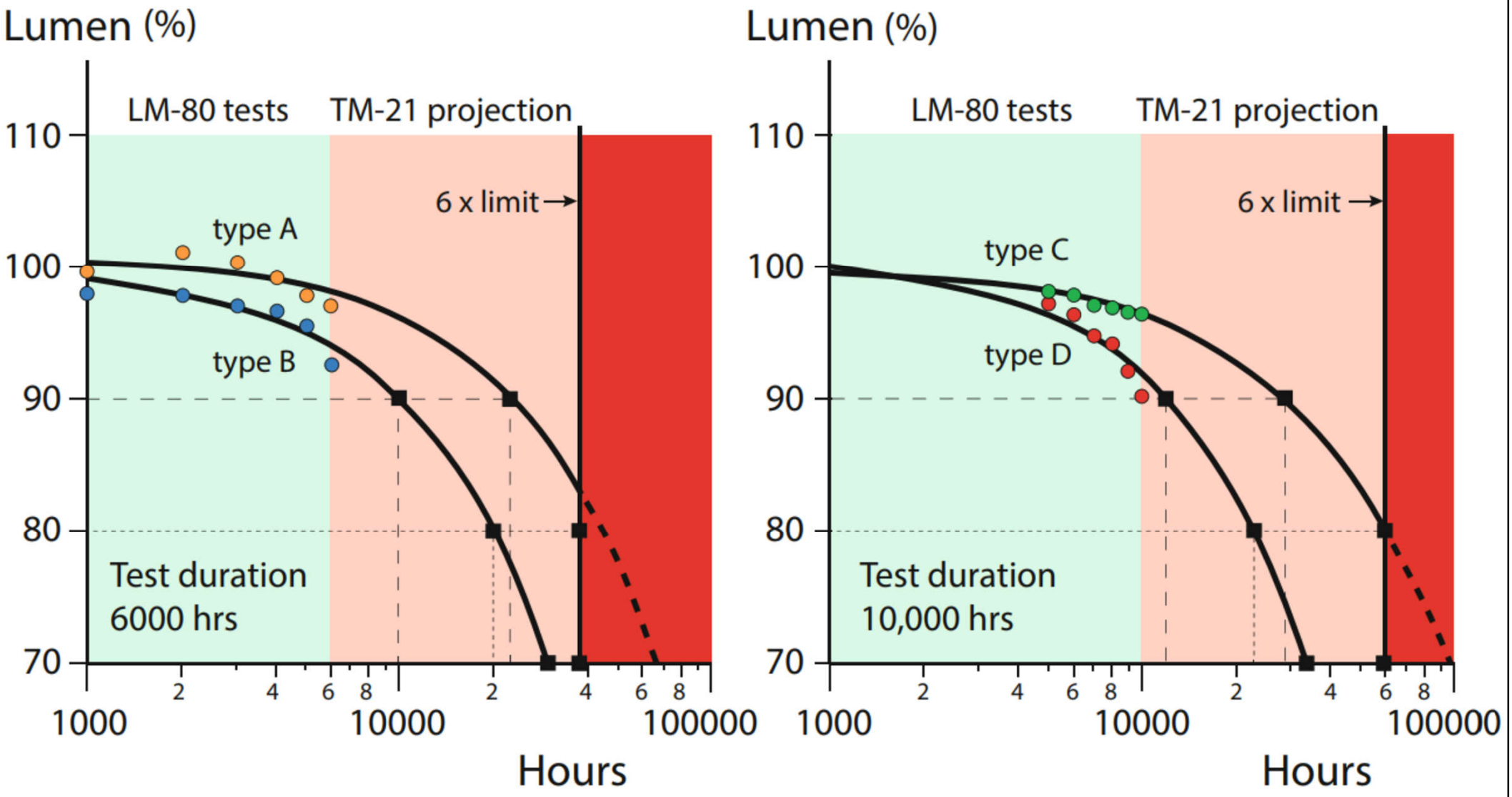
(Source: van Bommel W., 2019. *Interior Lighting: Fundamentals, Technology and Application*, Springer International Publishing, Cham.)

Example of a lamp survival & a lamp lumen depreciation curve of a typical gas-discharge lamp



(Source: van Bommel W., 2019. *Interior Lighting: Fundamentals, Technology and Application*, Springer International Publishing, Cham.)

Examples of lumen maintenance interpolated curves for four different LED types. The coloured circles are measuring points; the black squares represent the projected lifetime for the conditions L_{90}, L_{80} and L_{70}



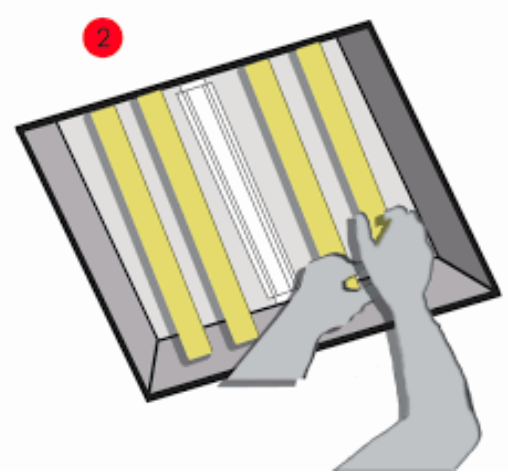
(Source: van Bommel W., 2019. *Interior Lighting: Fundamentals, Technology and Application*, Springer International Publishing, Cham.)

Existing buildings

- Common lighting upgrade strategies
  - Upgrade with reduction in light levels
    - If original design is excessive
  - Increase light levels
  - Maintain light levels
  - Focus light levels
    - Task lights or accent lighting
  - Reduce hours of use
    - Add time schedule or automatic controls

Existing buildings

- Upgrade fluorescent fixtures
  - Improved fluorescent lamps
    - T-8, T-10. T-12 tri-phosphor lamps
    - New T-5 lamps
    - New induction lamps (long life)
  - Electronic ballasts
    - Standard non-dimmable
    - Consider dimming balasts
    - New programmable balasts
  - Reflectors



Existing buildings

- Typical fluorescent fixture upgrades
  - T8 lamp/ballast system
  - T5 twin-tube lamp/ballast system
  - Specular reflectors/delamping
  - Current limiters
  - Daylight-dimming systems
  - 25W T12 lamps/T8 ballasts
  - Premium magnetic, cathode cut-out (hybrid), electronic ballasts (full output, dimmable, light-level switching and low-wattage)
  - Lens/Louvre upgrades
  - Indirect lighting w/task lighting
  - Task lighting w/reduced ambient lighting
  - New fixtures

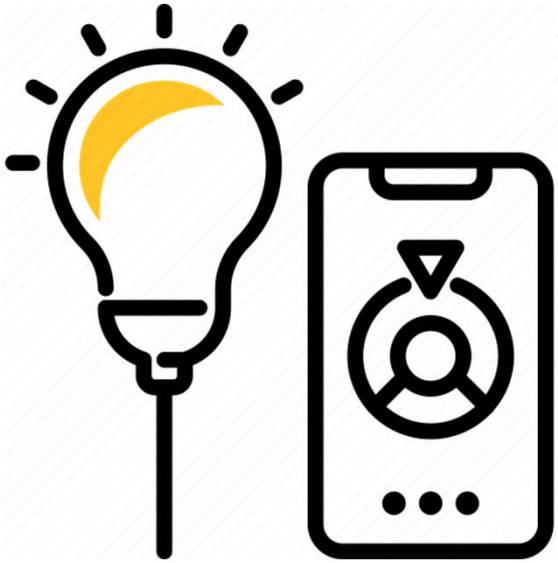
Existing buildings

- LED lighting upgrade
  - Retrofits using tubular LEDs or LED retrofit kits
    - Minimal impact to the architecture or other systems
    - Existing layouts may not be optimized for the LEDs
  - Replace fixtures with integrated LED luminaires
    - Opportunity for customization & optimization
    - May require a more substantial space renovation
  - Upgrade of controls (occupant/daylight sensors)
    - Also, new requirements of building energy codes

(See also: https://www.facilitiesnet.com/energyefficiency/article/How-to-Plan-An-LED-Upgrade--18504)

Existing buildings

- Typical exit sign upgrades
  - Compact fluorescent lamps
  - Low-wattage incandescent lamps
  - LEDs
  - Electroluminescent panels
  - New exit signs
- Typical control upgrades
  - Lighting management systems
  - Dimmable fluorescent & HID ballasts
  - Daylight- & lumen maintenance-dimming systems
  - Electronic timeclocks
  - Occupancy sensors (many options available)
  - Manual, step-level & panel-level dimming systems
  - Current limiters
  - Capacitive-switching HID systems



Existing buildings

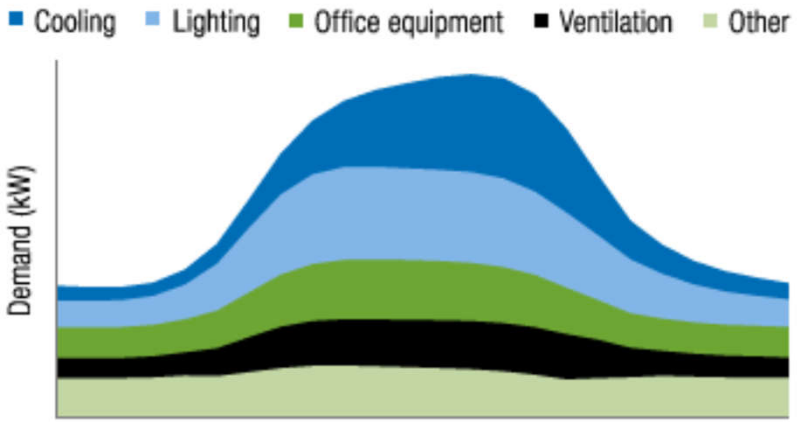
- Lighting retrofit economics ($$$)
  - Must understand current energy consumption
  - Payback & return on investment (ROI)
    - Simple payback usually
  - Life cycle cost (LCC) analysis

- Impact of lighting on building HVAC
  - Lighting & HVAC interactions
  - Cooling energy savings

(See also: Lighting Retrofit Adviser https://task50.iea-shc.org/lighting-retrofit-adviser)

Existing buildings

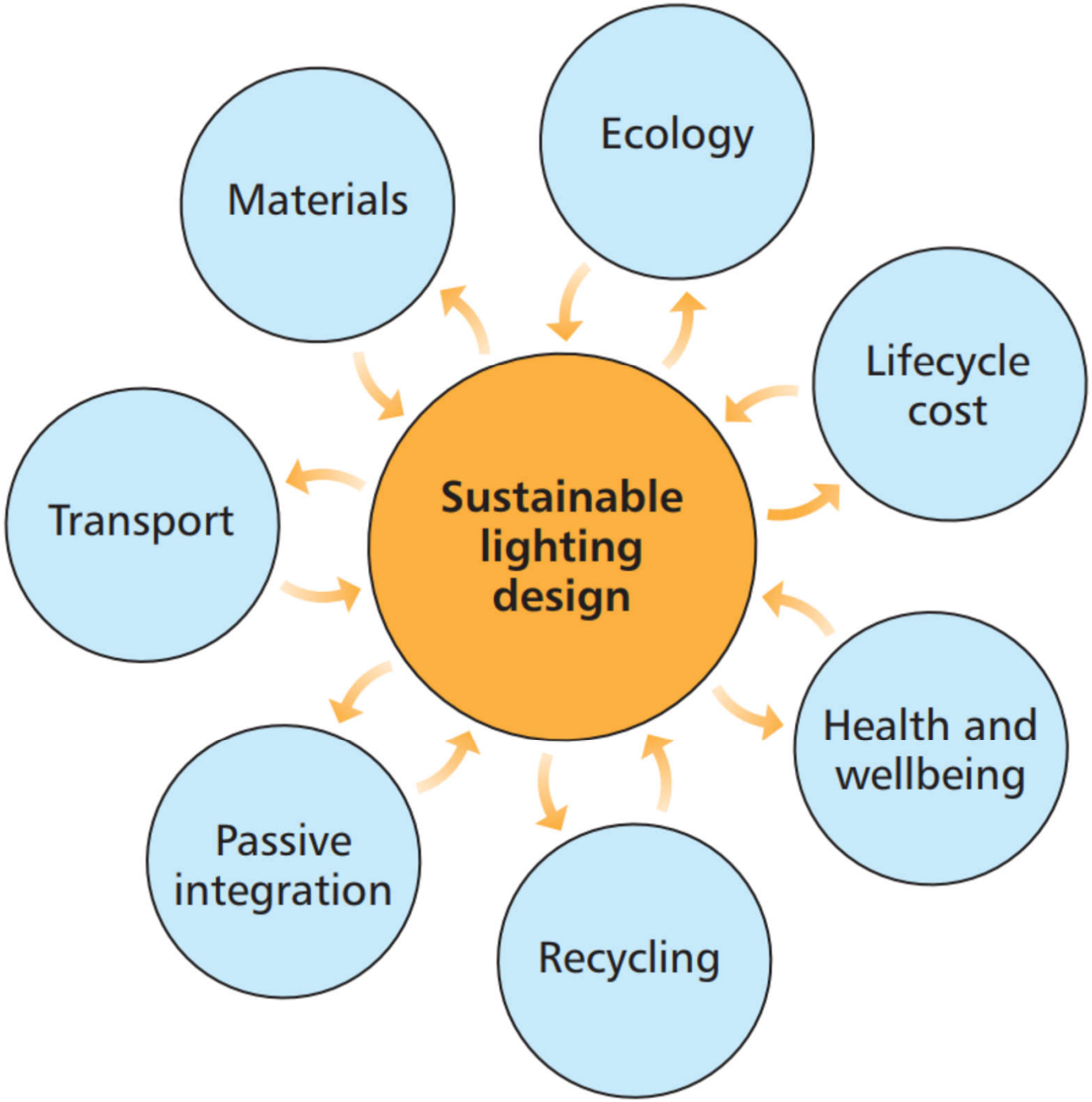
- Other considerations:
  - Calculate energy usage & costs
  - Power quality: power factor & harmonic distortion
  - Daylighting
  - Lighting vs. HVAC
  - Energy audit & lighting studies
  - Economic analysis
  - Load shape impacts



Existing buildings

- Environmental aspects of lighting
  - Disposal & recycling
    - Lighting waste disposal (e.g. lamp & ballast)
  - Green lights
    - Minimum efficacy standards for lamps
  - Emissions (e.g. mercury)
    - During manufacturing
    - During operation

Considerations for sustainable lighting design



(Source: SLL, 2011. *Lighting for Education*, Lighting Guide 5, Society of Light and Lighting (SLL), London.)

Lighting surveys & audits

- Lighting audit 照明審計
  - A detailed, systematic evaluation of the existing conditions of lighted spaces & the performance of lighting systems
  - Data collection, measurements & in-depth analysis of the data
  - To identify & quantify the potential energy/cost savings & benefits for the owner/occupants
  - To determine if lighting upgrade is possible within the constraints (time & budget)

Lighting surveys & audits

- Types of audit
  - Walk-through audit (simplest)
  - Intermediate or preliminary audit
  - Comprehensive or detailed audit
- Evaluating lighting system
  - 1. Perform a lighting audit
  - 2. Identify opportunities for improvements
  - 3. Calculate the potential savings (using simple payback or life cycle costing)

Lighting surveys & audits

- Major tasks:
  - Collect financial information
    - Utility rate & tariff structure, average charges for energy (kWh) and demand (kW), rebates or subsidies
  - Collect general information
    - Floor plans, reflected ceiling plan, room dimensions
    - Operating conditions/hours, maintenance practice
  - Collect occupant information
    - How they feel about the lighting system

Lighting surveys & audits

- Major tasks: (cont'd)
  - Collect lighting information
    - Hours of operation
    - Type, size & nos. of fixtures
    - Nos. of lamps per fixture, no. of lamps per ballast
    - Type of lamps, type of ballasts, specular reflectors (if any)
    - Fixture condition, whether fixtures are air-handlers
    - Availability of daylight
    - Tasks performed in the space
    - Use of partitions
    - Unique fixture types or physical features
    - Area dimensions, height of the tasks, fixture mounting height
    - Surface reflectances, colours of major objects & room surfaces

Lighting surveys & audits

- Instrumentation
  - Illuminance measuring equipment
  - Luminance measuring equipment
  - Daylight factor meters
  - Electrical measuring tools
- Survey methods
  - Number of measuring points
  - Presentation of information
  - Method of evaluating daylight & artificial lighting
  - Calculation using lumen method

Lighting measuring equipment

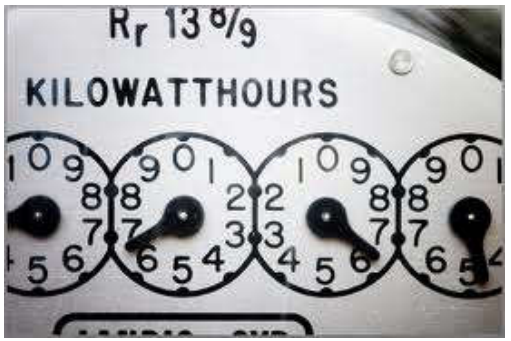
Minolta Illuminance Meter
T-10 (luxmeter)

Minolta Luminance Meter
LS-110

(Source: http://www.konicaminolta.com.cn/instruments/)

Lighting surveys & audits

- What to look for?
  - Lighting equipment inventory
  - Lighting loads
  - Room dimensions
  - Illumination levels
  - Hours of use
  - Lighting circuit voltage & control



Lighting surveys & audits

- Potential lighting energy saving measures
  - Fluorescent upgrades
  - Delamping
  - Incandescent upgrades
  - HID upgrades
  - Control upgrades
  - Daylight compensation

- Three major areas of lighting improvement
  - Replace incandescent lamps with fluorescent or CFL/LED
  - Upgrade fluorescent fixtures with improved components
  - Install lighting controls to minimise energy costs

Electromagnetic vs. Electronic Ballasts

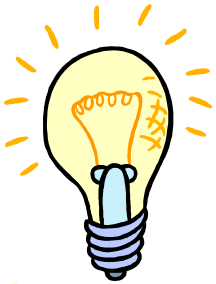
	Electromagnetic Ballast	Electronic Ballast
Heat	Generates about 30 deg. C more heat than electronic	Internal losses are less than 8 watts
Light Flicker	60 Hz frequency causes light flicker levels of 30% or higher	20,000-25,000Hz frequency produces virtually no detectable flicker
Noise	Vibrations induced by electromagnetic field causes humming noise	No audible noise
Weight	Heavy components coated in heavy protective material	Weighs about half as much as electro-magnetic type

(See also http://en.wikipedia.org/wiki/Electrical_ballast)

Lighting surveys & audits

- Lighting audit report
  - Overview of the area audited (existing lighting systems) & the main energy end-users
  - Details of the scope of the audit including the areas, systems & activities assessed
  - The status of the energy management system
  - The current energy performance of the site and of each of the energy systems assessed
  - Recommendations & feasibility (with energy savings & payback period)

Further reading



- Green Lighting: Towards Smart Energy Management (HKPC)
  https://www.hkpc.org/images/pdf/greenlighting.pdf
- Energy Efficient Equipment - Lighting
  https://www.emsd.gov.hk/energyland/en/appAndEquip/equipment/lighting/
- Performance Assessment of Lighting Systems
  https://pdhonline.com/courses/e153/e153content.pdf