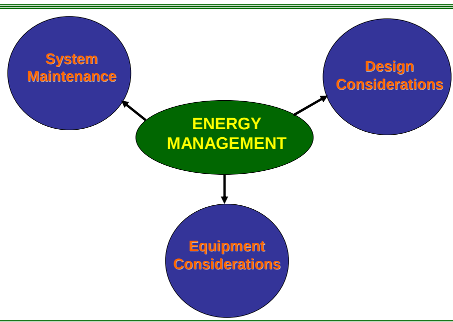
Module 9

Energy Management and Economics

Contents

Energy Management for Lighting



Design Considerations

Energy Management

- Incorporates design and application practices to provide the necessary amount of light using energy effectively
- Considers the following
  - Design practices
  - Equipment selection
  - Lighting maintenance

Design Considerations

Energy Management

- Design process involves
  - Collecting criteria about the space
  - Evaluating this data
  - Developing alternative solutions
  - Evaluation and comparing options in relation to the criteria
  - Selecting the optimum criteria used in the design.

Design Considerations

Energy Management

- Design Considerations
  - Light Distribution
  - Space & Workplace Consideration
  - Light on People & Objects

Design Considerations

Energy Management

- Light Distribution
  - Task & Ambient Lighting
  - Daylighting Integration
  - Light pollution & Light Trespass

Design Considerations

Energy Management

- Light Distribution
  - Task & Ambient Lighting
    - Task lighting are independent of the general lighting system such as display lighting in retail store.
    - Task lights can't light the balance of the room, and thus some other type of lighting system is needed to produce the ambient illumination in the room.
    - Options include
      - indirect luminaires mounted atop cobinetry or workstations
      - Suspended luminaires
      - Recessed luminaires

Design Considerations

Energy Management

- Light Distribution
  - Task & Ambient Lighting
    - Produce energy savings in three ways:
    - Locating the light source close to the task most efficiently produces the illumination levels needed for the task.
    - Task illumination levels don't have to be maintained uniformly thorugh out the space, so ambient levels can be lower.
    - Some occupants won't use their task lights, and empty offices or workstations with absent occupants don't have to be fully illuminated

Design Considerations

Energy Management

- Light Distribution
  - Clues to potential problems include
    - Directional luminaires such as troffers and downlights that tend to create a scallop patterns when near walls
    - Uplights within 2 ft of the ceiling (unless specifically designed for a close-to-ceiling application)
    - Poor balance of light (ceiling, wall or floor much brighter than each other)
    - Walls and ceiling grids that aren't alighted, with varying spacing of luminaires to walls
    - Wall-washing and accent lighting that is improperly located (too close to wall)

Design Considerations

Energy Management

- Light Distribution
  - Daylighting Integration
    - Practice of using windows, skylights and other forms of fenestration to bring light into the interiors of buildings using various means
    - Proper design requires integration of the following discipline
      - Architects design the mass and fenestration
      - Structural engineers design the structure
      - Mechanical engineers design HVAC
      - Electrical Engineers or lighting designers design the lighting

Design Considerations

Energy Management

- Daylighting
  - Incorporating daylighting in the lighting design can be done by:
    - Proper control of the fenestration luminance
    - Daylight sensing and compensation control systems which allow adjustments to electric electrical lighting system
    - Glare controls should also be incorporated in the design
    - New techniques for "piping" light into interior spaces can allow sunlight and daylight to furnish a higher percentage of illumination requirements and more uniform distribution

Design Considerations

Energy Management

- Light Distribution
  - Light pollution & light trespass
    - In outdoor lighting, electric light may illuminate adjacent properties which become offensive if unwanted is known as light trespass
    - Electric lights emitting light upward o reflecting light upward cause a condition called light pollution which causes moisture and particles in the air to glow at night.

Design Considerations

Energy Management

- Light Distribution
  - Several steps to minimize light pollution & light trespass
    - Use night lighting only when and where necessary
    - Use the minimum amount of light needed rather than the maximum
    - Use sources with cutoff optics that restrict light to the intend area of illumination
    - Use more sources, each of lower wattage, to improve uniformity in the intended illumination area and minimize trespass into adjacent areas.

Design Considerations

Energy Management

- Light Distribution
  - Several steps to minimize light pollution & light trespass
    - Use sharp cutoff light sources and other means to eliminate light directed upwards or sideways.
    - Use lighting strategies that allow nighttime adaptation of the eye to very low light levels unless security is an issue.
    - Use timers and occupancy sensors to limit the use of outdoor lighting to only the minimum time required for the purpose
    - Consider a "layered" approach which might involve one set of full cutoff luminaires that provides the low-level utilitarian lighting

Design Considerations

Energy Management

- Light Distribution
  - Several steps to minimize light pollution & light trespass
    - Avoid development near existing astronomical observatories; when outdoor lighting is unavoidable, apply rigid controls
    - Locate outdoor lighting below tree canopies, not above. The leaves of the trees then shield the light from the sky.
    - Provide reflective surfaces for lettering or other elements that need to be illuminated at night. Illuminate only the lettering, not the background.
    - Light from the top down, rather than from the bottom up particularly for signage lighting and building façade lighting.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Flexibility
  - Appearance & space of luminaires
  - Color appearance
  - Luminance of room surfaces
  - Flicker & strobe
  - Direct glare
  - Reflective glare

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Advance lighting designs should be flexible enough to ensure that:
    - Lights operate where needed, and are off where not needed, as people move around within a space and use rooms in different ways.
    - Spaces used for "hoteling" – the occasional or transient use of a workspace – remain dark unless needed.
    - The lighting space system can be rapidly reconfigured to match a changed floor plan or accommodate a different space use, and still operate at maximum energy efficiency.
    - The lighting system permits multiple uses and on-demand flexibility in multiple-use spaces such as conference rooms and modern A/V classrooms.

Design Considerations

- Space & Workplace Consideration
  - For desired flexibility in designs, consider these options in selecting lighting systems
    - Employ a control system that is easily configured and commissioned.
    - Use portable lighting equipped with a cord and plug
    - Use a modular wiring system
    - Use a lighting track busway
    - Use lightweight luminaires suspended from the ceiling

Design Considerations

- Space & Workplace Consideration
  - Appearance & space of luminaires
    - Luminaire efficiency and the ability to use efficacious sources have become increasingly important criteria for selecting luminaires.
    - Designer should find lighting systems that embody the project's style or aesthetic but to do so using high-efficacy sources and efficient principles.
    - For instance, choose luminaire that "hide" light source but avoid such as crystal chandeliers that require lamps with bare incandescent filaments

Design Considerations

- Space & Workplace Consideration
  - Color Appearance
    - Chromaticity
      - Preference for a narrow range of color temperature (known as Kruitof's Curve – the lower the ambient light level, the lower the preferred color temperature range.)
      - Color temperature may be affected by lattitude
      - match light color whenever possible

Design Considerations

- Space & Workplace Consideration
  - Color Appearance
    - Color Rendering
      - Color Quality is generally assessed using Color Rendering Index (CRI), a scale having a maximum rating of 100 for reference sources like natural daylight and laboratory-quality incandescent light.
      - Modern high performance windows modify the color of daylight which affect CCT and CRI
      - Employ sources have CRI of at least 70 for most applications

Preferred Color Temperature Ranges

Lamp CCT (Kelvin)	Applications
<2500	Bulk industrial and security (HPS) lighting
2500 – 3000 "Warm"	Low light levels in most spaces (<10 footcandles). General Residential Lighting. Hotels, fine dining and family restaurants, theme parks. Suitable high-efficacy sources include fluorescent and compact fluorescent, 2700 K or 3000 K and halogen IR lamps
2950-3500 "Neutral"	Display lighting in retail and galleries; feature lighting. Suitable high-efficacy sources include halogen IR, white sodium, and ceramic metal halide.
3500-4100 "cool"	General lighting in offices, schools, stores, industry, medicine; display lighting; sports lighting. Suitable high-efficacy sources include induction, fluorescent, compact fluorescent and metal halide

Preferred Color Temperature Ranges

Lamp CCT (Kelvin)	Applications
4100-5000 "very cool"	General lighting in offices, schools, stores, industry, medicine and sports lighting. Also special application lighting where color discrimination is very important. Suitable high efficacy sources include induction, fluorescent, compact fluorescent and metal halide
5000-7500 "cold"	Special application lighting where color discrimination is critical; uncommon for general lighting, Suitable high-efficacy sources include fluorescent, compact fluorescet and metal halide.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Luminance of room surfaces – lighting designer should:
    - Encourage the use of high diffuse reflectivity (light colored) surfaces and minimize the use of dark surfaces.
    - Use computer modeling to ensure that the average room surface luminance is at least 10% of the task background.
    - With indirect lighting systems, use computer calculations to check for uniformity and try to maintain 10:1 luminance ratio or better.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Flicker & strobe
    - Focal system can detect flicker up to about 60 Hz (the critical fusion frequency), but the peripheral system can only detect flicker up to about 18 Hz with a peak at 15Hz.
    - Flicker becomes the most troublesome when two cycling systems interact with each other to produce light modulations at frequencies approaching 15 Hz.
    - Can cause headaches and other problems in sensitive individuals.
    - Eliminate from consideration any lamp or light sources that does not operate on DC, high frequency AC (greater than 30 kHz) or AC square wave.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Flicker & strobe
    - Degree of oscillation from a lamp is a function of:
      - Lam type
      - Type of phosphor coating
      - Lamp configuration
      - Type of circuit
      - Type of ballast.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Direct Glare
    - Caused by a view of the light source, often with high contrast to the surroundings.
    - Glare is associated not just with lamps, but also with daylight, especially when one is exposed to low angle, direct sunlight.
    - Be concerned
      - more about the glare caused by lamps, lenses and other overly birght sources of manmade lights
      - less about glare of sunlight and small point sources
      - most concerned about sources of glares in relation to the stationary tasks when building occupants cannot easily relocate themselves or their tasks.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Reflective Glare
    - Have long been associated with gloss-coated paper, pencil paperwork and computer CRT (cathode ray tube) screen.
    - Indirect lighting, by creating a diffuse and uniform illumination has been advocated as solution.
    - Can create specular reflections that can cause glare reducing comfort or disabling the worker's vision in particular areas.

Design Considerations

Energy Management

- Space & Workplace Consideration
  - Reflective glare - when glare has been minimize, consider:
    - modifying the task to eliminate remaining glare problem such as use of flat screen CRT or active matrix.
    - Use of ink rather than pencil
    - Use of matte-coated or uncoated paper rather than gloss-coating paper.
    - Changing finishes of polished floors or shiny conference room tables.

Design Considerations

Energy Management

- Light on People & Objects
  - Modeling of faces or objects
  - Surface characteristics
  - Points of interest
  - Sparkle/Desirable reflected highlights

Design Considerations

Energy Management

- Light on People & Objects
  - Modeling of faces or objects
    - Diffuse light, like the light from a cloudy sky produces an even and relatively shadow-free light, which can fail to render changes in surfaces making a space or task less visible.
    - Consider using a blend of direct and indirect lighting in most designs to provide a combination of comfort and modeling.
    - To achieve a minimum modeling, a directional light for an object or area of interest should be at least 20-25% of the total illumination.

Design Considerations

Energy Management

- Light on People & Objects
  - Surface characteristics
    - Lighting techniques that reveal architectural nuance like texture enhance visual perception have become more commonly requested by building owners and architects
    - Employ light rendering programs like Radiance or Lightscape to confirm the effect of lighting designs in rendering building surfaces and other surface characteristics..

Design Considerations

Energy Management

- Light on People & Objects
  - Point of interest
    - In retail and museum lighting, designers use highlights of up to 10 times the ambient light level to draw attention to key display.
    - Recognize that it's wasteful to create lighting than is needed.
    - Carefully select highlights, and use a minimum effective highlight level.

Design Considerations

Energy Management

- Light on People & Objects
  - Point of interest - strategies include:
    - Creating highlights in contrast to lower ambient illumination levels
    - Creating highlights with efficient sources as close to the object or surface as possible.
    - Small points of light from fiber optic sources or LEDs may offer efficient ways to create highlights or attract attention where specifically desired.

Design Considerations

Energy Management

- Light on People & Objects
  - Sparkle/Desirable reflected highlights
    - Many commercial and industrial tasks where highlights are critical to the work.
    - Workers use specular highlights
      - judge workmanship
      - assess surface quality and
      - evaluate quality of materials.
    - Assess these nuances of task work and employ lighting systems that enhance or in some cases conceal these effects.

Equipment Considerations

Energy Management

- Equipment Considerations
  - Light Sources
  - Ballasts
  - Luminaires
  - Controls

Equipment Considerations

Energy Management

- Light Sources
  - Selection should be made in terms of the following
    - The most efficient light source applicable to achieve the desired results.
    - Use minimum lumen output in service, rather than basing the decision on initial lumens.
    - Alternately, use lamp efficacy (lumens/watt) when more than one light source can be used in the same luminaire package
    - Color Rendering Index (CRI)

Equipment Considerations

Energy Management

- Light Sources

Lamp Type: Incandescent
Lamp Watts: 100
CRI: 100
Initial Lamp Lumens: 1,750
Mean Lamp Lumens: 1,575
Mean Lamp Efficacy: 16

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

Lamp Type: Compact Fluorescent
Lamp Watts: 26
CRI: 82
Initial Lamp Lumens: 1,610
Mean Lamp Lumens: 1,370
Mean Lamp Efficacy: 53

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

Lamp Type: Standard Phosphor (T-12ES) Fluorescent Lamp
Lamp Watts: 34
CRI: 62
Initial Lamp Lumens: 2,650
Mean Lamp Lumens: 2,300
Mean Lamp Efficacy: 68

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

Lamp Type: Tri-Phosphor (T-8) Fluorescent Lamp
Lamp Watts: 32
CRI: 75
Initial Lamp Lumens: 2,800
Mean Lamp Lumens: 2,550
Mean Lamp Efficacy: 80

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

  Lamp Type: Tri-Phosphor (T-12) Fluorescent Lamp
  Lamp Watts: 40
  CRI: 70
  Initial Lamp Lumens: 3,200
  Mean Lamp Lumens: 2,880
  Mean Lamp Efficacy: 72

  Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

  Lamp Type: High CRI Tri-Phosphor (T-8) Fluorescent Lamp
  Lamp Watts: 32
  CRI: 85
  Initial Lamp Lumens: 2,950
  Mean Lamp Lumens: 2,800
  Mean Lamp Efficacy: 88

  Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

  Lamp Type: High CRI Tri-Phosphor (T-12) Fluorescent Lamp
  Lamp Watts: 40
  CRI: 85
  Initial Lamp Lumens: 3,300
  Mean Lamp Lumens: 2,950
  Mean Lamp Efficacy: 74

  Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

  Lamp Type: Clear Mercury Vapor
  Lamp Watts: 250
  CRI: 20
  Initial Lamp Lumens: 12,100
  Mean Lamp Lumens: 10,500
  Mean Lamp Efficacy: 42

  Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

  Lamp Type: Color Improved Mercury Vapor
  Lamp Watts: 250
  CRI: 45
  Initial Lamp Lumens: 13,000
  Mean Lamp Lumens: 10,700
  Mean Lamp Efficacy: 43

  - Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources

  Lamp Type: Clear Metal Halide
  Lamp Watts: 250
  CRI: 65
  Initial Lamp Lumens: 20,500
  Mean Lamp Lumens: 17,000
  Mean Lamp Efficacy: 68

  Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources
  - **Lamp Type:** Color Improved Metal Halide
  - **Lamp Watts:** 250
  - **CRI:** 70
  - **Initial Lamp Lumens:** 19,475
  - **Mean Lamp Lumens:** 16,000
  - **Mean Lamp Efficacy:** 64

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources
  - **Lamp Type:** Pulse Start Metal Halide
  - **Lamp Watts:** 250
  - **CRI:** 65
  - **Initial Lamp Lumens:** 26,300
  - **Mean Lamp Lumens:** 21,040
  - **Mean Lamp Efficacy:** 84

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources
  - **Lamp Type:** Clear High Pressure Sodium
  - **Lamp Watts:** 250
  - **CRI:** 21
  - **Initial Lamp Lumens:** 28,500
  - **Mean Lamp Lumens:** 25,600
  - **Mean Lamp Efficacy:** 102

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources
  - **Lamp Type:** Color Improved High Pressure Sodium
  - **Lamp Watts:** 250
  - **CRI:** 65
  - **Initial Lamp Lumens:** 23,000
  - **Mean Lamp Lumens:** 20,700
  - **Mean Lamp Efficacy:** 83

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Light Sources
  - **Lamp Type:** Low Pressure Sodium
  - **Lamp Watts:** 180
  - **CRI:** 0
  - **Initial Lamp Lumens:** 33,000
  - **Mean Lamp Lumens:** 33,000
  - **Mean Lamp Efficacy:** 183

Note: Values given are for sample reference, actual values may vary

Equipment Considerations

Energy Management

- Ballasts
  - Ballast Options for T-12 lamps
    - Magnetic
    - Hybrid ballasts
    - Electronic ballasts
  - Ballasts Options for T8 lamps
    - Magnetic
    - Electronic

Equipment Considerations

Energy Management

- Equipment Considerations
  - Ballasts
    - Ballast Factor – the relative luminous output of a lamp operated on a ballast compared to the same lamp on a "reference ballast," usually expressed in perent
    - Energy Losses

Equipment Considerations

Energy Management

- Luminaires
  - Luminaire evaluation
    - Compare the coefficient of utilization (CU) of various luminaires
    - Select one with good overall system efficacy
    - Consider luminaire dirt depreciation factor and chose a luminaire that provides acceptable maintained output
    - Final decision on lamp/ballast combination must consider net light output versus energy input.

Equipment Considerations

Energy Management

- Luminaires
  - System lumens describe the mean lumens emitted from the luminaire

Mean System Lumens = No. of lamps x Mean Lumens/Lamp x Ballast Factor x Luminaire Efficiency

Luminaire Efficacy = Mean System Lumens/Input Watts

Equipment Considerations

Energy Management

- Luminaires

System Description: 100 W Incandescent microBaffle Downlight
Ballast Type: N/A
Ballast Factor: N/A
System Watts:100
Mean Lamp Lumens: 1,575
Luminaire Efficiency: 47%
Mean System Lumens: 740
Luminaire Efficacy: 7

Equipment Considerations

Energy Management

- Luminaires

System Description: 26W CFL/TRT MicroBaffle Downlight
Ballast Type: Magnetic
Ballast Factor: 1.0
System Watts: 32
Mean Lamp Lumens: 1,370
Luminaire Efficiency: 60%
Mean System Lumens: 822
Luminaire Efficacy: 26

Equipment Considerations

Energy Management

- Luminaires

System Description: 26W CFL/TRT MicroBaffle Downlight
Ballast Type: Electronic
Ballast Factor: 1.0
System Watts: 27
Mean Lamp Lumens: 1,370
Luminaire Efficiency: 60%
Mean System Lumens: 822
Luminaire Efficacy: 30

Equipment Considerations

Energy Management

- Luminaires

System Description: 100W Incandescent Open Downlight
Ballast Type: N/A
Ballast Factor: N/A
System Watts: 100
Mean Lamp Lumens: 1,575
Luminaire Efficiency: 73%
Mean System Lumens: 1,150
Luminaire Efficacy: 12

Equipment Considerations

Energy Management

- Luminaires

System Description: 26W CFL/TRT Open Downlight
Ballast Type: Magnetic
Ballast Factor: 1.0
System Watts: 32
Mean Lamp Lumens: 1,370
Luminaire Efficiency: 74%
Mean System Lumens: 1,014
Luminaire Efficacy: 32

Equipment Considerations

Energy Management

- Luminaires

System Description: 26W CFL/TRT Open Downlight
Ballast Type: Electronic
Ballast Factor: 1.0
System Watts: 27
Mean Lamp Lumens: 1,370
Luminaire Efficiency: 74%
Mean System Lumens: 1,014
Luminaire Efficacy: 38

Equipment Considerations

Energy Management

- Luminaires

System Description: 32W Fluorescent, 841K 3 Lamp Lensed, 2 x 4 Troffer
Ballast Type: Electronic
Ballast Factor: 0.88
System Watts: 87
Mean Lamp Lumens: 2,550
Luminaire Efficiency: 75%
Mean System Lumens: 5,049
Luminaire Efficacy: 58

Equipment Considerations

Energy Management

- Luminaires

System Description: 40W Fluorescent, 841K 3 Lamp Lensed, 2 x 4 Troffer
Ballast Type: ES
Ballast Factor: 0.95
System Watts: 128
Mean Lamp Lumens: 2,880
Luminaire Efficiency: 75%
Mean System Lumens: 5,746
Luminaire Efficacy: 45

Equipment Considerations

Energy Management

- Luminaires

System Description: 32W Fluorescent, 841K 3 Lamp Louvered, 2 x 4 Troffer
Ballast Type: Electronic
Ballast Factor: 0.88
System Watts: 88
Mean Lamp Lumens: 2,550
Luminaire Efficiency: 52%
Mean System Lumens: 3,500
Luminaire Efficacy: 40

Equipment Considerations

Energy Management

- Luminaires
  - **System Description:** 40W Fluorescent, 841K 3 Lamp Louvered, 2 x 4 Troffer
  - **Ballast Type:** ES
  - **Ballast Factor:** 0.95
  - **System Watts:** 132
  - **Mean Lamp Lumens:** 2,880
  - **Luminaire Efficiency:** 45%
  - **Mean System Lumens:** 3,694
  - **Luminaire Efficacy:** 28

Equipment Considerations

Energy Management

- Luminaires
  - **System Description:** 32W Fluorescent, 841K 3 Lamp Parabolic, 2 x 4 Troffer
  - **Ballast Type:** Electronic
  - **Ballast Factor:** 0.88
  - **System Watts:** 88
  - **Mean Lamp Lumens:** 2,550
  - **Luminaire Efficiency:** 74%
  - **Mean System Lumens:** 4,982
  - **Luminaire Efficacy:** 57

Equipment Considerations

Energy Management

- Luminaires
  - **System Description:** 40W Fluorescent, 841K 3 Lamp Parabolic, 2 x 4 Troffer
  - **Ballast Type:** ES
  - **Ballast Factor:** 0.95
  - **System Watts:** 132
  - **Mean Lamp Lumens:** 2,880
  - **Luminaire Efficiency:** 70%
  - **Mean System Lumens:** 5,746
  - **Luminaire Efficacy:** 44

Equipment Considerations

Energy Management

- Controls
  - Installation of controls that de-energize the lighting system when the lighting is not needed is essential
  - Can be as simple as switches so that occupants can turn lights on and off as needed
  - Automatic energy controls are available to change the power input to the lighting system to maintain a constant light level.
  - Significantly reduce annual operating hours of electric lighting

Equipment Considerations

Energy Management

- Controls
  - Automatic energy controls adjust for
    - Daylight contribution
    - Lamp lumen depreciation
    - Luminaire dirt depreciation
    - Light loss factor

Equipment Considerations

Energy Management

- Controls
  - Programmable controllers
    - Turn on lighting at the beginning of the work day
    - Reduce levels during the lunch hour
    - Increase light levels after normal working hours for the cleaning crew
    - Turn off the lighting when the building or area is unoccupied

Equipment Considerations

Energy Management

- Controls
  - Occupancy sensors control lighting in low-to-medium traffic areas such as:
    - Rest rooms
    - Conference rooms
    - Private offices
    - Libraries
    - Kitchens

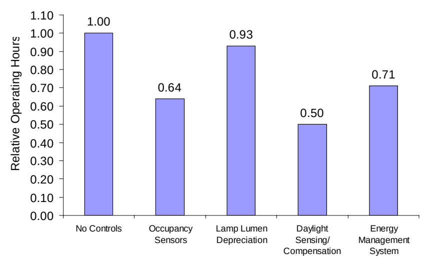
Equipment Considerations

Energy Management

- Controls
  - Lamp-Lumen Depreciation Controls reduce the power to the lamps initially to provide the maintained light level, then gradually increase lamp output to compensate for the lumen depreciation of the lamps as they age.
  - Daylight sensing and compensation controls use photocells to sense available daylight and automatically adjust the electric lighting to maintain a preset illuminance level.

Equipment Considerations

Energy Management



Annual Operating Hours for Lighting Systems Utilizing Controls

Equipment Considerations

Energy Management

- Other Considerations
  - Ambient temperature
    - Surrounding ambient temperature maybe a determining factor for selection of:
      - Light source
      - Control equipment
      - Luminaire materials
    - Light output will be below rated output if the bulb wall temperature is too low or too high and below a critical temperature the lamps may not start at all.

Equipment Considerations

Energy Management

- Other Considerations
  - Ambient temperature
    - Fluorescent lamps are sensitive to the temperature around the lamp.
    - Energy saving fluorescent lamps are designed to start in temperatures above 60°F
    - In low temperature areas, standard fluorescent lamps may require a low-temperature starting ballast.

Equipment Considerations

Energy Management

- Other Considerations
  - Ambient temperature
    - Luminaire materials must withstand temperature extremes encountered in the installation
    - High or low temperature may adversely affect some plastics.
    - If lighting is installed in areas with high ambient temperatures, ballasts must be rated to operate at high ambient temperature or be installed remote from the luminaire to have a satisfactory life.

Equipment Considerations

Energy Management

- Other Considerations
  - HVAC Effects
    - Lighting systems introduce heat into occupied space.
    - In the summer, air conditioning will be required to offset the heat introduced by the lighting.
    - If the heat is significant, the additional cost of operating air conditioning system should be considered.
    - Lighting system which operate at cooler temperatures offer benefits in terms of reduced HVAC costs.

Lighting Audit

Energy Management

- Definition
- Purpose
- Types of audit
- Lighting system auditor
- Evaluating lighting system
- Measuring and monitoring equipment requirement
- Potential of energy savings and payback period
- Lighting audit report
- Existing lighting system conditions

Definition

Energy Management

- A lighting audit is a detailed, systematic evaluation of the existing conditions of lighted spaces and the performance of lighting systems.
- The audit is characterized by detailed data collection, measurements, and an in-depth analysis of the data, usually performed by third-party lighting technical specialists.

Purpose of the Audit

Energy Management

- The main purpose of a lighting audit is:
  - To gather information concerning the characteristics and the current condition of lighting systems and the lighted environment.
  - To quantify the potential monetary savings and benefits for the owner/occupants.
  - To determine if lighting upgrade is possible within the constraints (time and budget) imposed by the building establishment owner or operator.

Types of Audit

Energy Management

- Walk-Thru Audit
- Intermediate or Preliminary Audit
- Comprehensive or Detailed Audit

Walk-thru Audit

Energy Management

- simplest type and usually performed during the lighting survey
- collect just enough information in a short period of time to make effective recommendations usually for a one-on-one lighting retrofit
- no fixtures are counted and no calculation of power density is made
- includes a brief report describing the existing lighting system, outline of proposed improvements and the estimated payback

Intermediate or Preliminary Audit

Energy Management

- Combination of walk-thru and detailed audit
- Data collection is done by a small team of 2 or 3 lighting technical specialists
- Financial analysis is more than a simple payback but also not a full scale life cycle costing
- Calculations are made on a project basis instead of fixture or component basis
- Reports usually include equipment inventories, power densities, limited evaluation of upgrade or relighting alternatives, and payback

Comprehensive or Detailed Audit

Energy Management

- Performed if extensive analysis is required which include visual tasks, workers' productivity, lighting quality improvements and include life cycle costing
- Accounting of all lighting equipment with great emphasis on actual mix of lamps and ballasts usage
- Comprehensive report describing the existing lighting system and outlines several upgrading options including relighting, calculated savings and potential productivity improvements
- Description of the upgraded or relighted spaces maybe included, both positive and negative, supported by drawings or computer graphics, for better client perspective

Lighting System Auditor

Energy Management

- Characteristics of a good lighting system auditor
  - Experienced in the field of energy efficiency with specialized experience in lighting energy audits and energy efficient lighting
  - Good interpersonal and communication skills
  - Highly skilled in interview techniques especially when dealing with key building personnel for critical information

Evaluating Lighting System

Energy Management

Step 1:	Step 2:	Step 3:
Perform a Lighting Audit	Identify Opportunities for Improvements	Calculate Savings and Potential Payback

Performing a Lighting Audit

Energy Management

- The characteristics of each lighting system need to be assessed which includes the following:
  - Operating conditions
  - Operating hours
  - Maintenance

Identifying Opportunities for Improvements

Energy Management

- Improvements are the changes that raise the existing condition of the lighted environment to a more desirable condition or to a more excellent quality, that is, that make the lighted environment better.
- What to change and how to change will depend on the particular focus of the analyst and the objectives of the upgrade or relighting project.

Calculating Savings and Potential Payback

Energy Management

- Savings may be calculated using either of the following:
  - Simple Payback (SPB)
  - Life-Cycle Costing (LCC)
- Different types of lighting system operating cost should also be considered before arriving at calculating the SPB and LCC.

Measuring and Monitoring Equipment Requirement

Energy Management

- Below are some of the measuring and monitoring equipment used in lighting system audit:
  - Clamp-on power meter. Measures, computes and display circuit load at a given time (measurement taken at the circuit breaker and other circuit disconnecting means).

Measuring and Monitoring Equipment Requirement

Energy Management

- Clamp-on data logger power meter. Automatically log and interface to laptop computer the recorded data for power consumption over a period of time.

Measuring and Monitoring Equipment Requirement

Energy Management

- True RMS AC Clamp Meter and Hybrid Recorder. Measure flow of current in a conductor, capable of measuring power consumption, line voltage, insulation resistance in mega-ohm and temperature. It can measure electrical parameters without interrupting power utilization.

Measuring and Monitoring Equipment Requirement

Energy Management

- Energy analyzer with computer interface. Records unit hour summary, peak/valley, demand summary and monitor phase angle. Automatic line monitoring is done thru connection of meter clamp.

Measuring and Monitoring Equipment Requirement

Energy Management

- Flexible transducer. Measure large ampere flow of current in a conductor to monitor its total ampere flow (accessory to the clamp meters).

Measuring and Monitoring Equipment Requirement

Energy Management

- Lux meter. Measure light illumination levels over the specific area (work plane and room surroundings).

Measuring and Monitoring Equipment Requirement

Energy Management

- **Two-way radio.** Use for fast communication and coordination of activity during the conduct of audit especially for large area.

Measuring and Monitoring Equipment Requirement

Energy Management

- Steel tape and roller measure. Use to measure distances and dimensions of rooms.

Measuring and Monitoring Equipment Requirement

Energy Management

- Binocular. Views nearer and closer readings to some far and elevated location of lighting system and installed meter and indicators in the site.

Lighting Audit Report

Energy Management

- The report should include at the minimum the following:
  - Overview of the activities at the area audited (existing lighting systems) and the main energy end-users;
  - Details of the scope of the Audit including the areas, systems and activities assessed;
  - The status of the energy management system at the site audited;

Lighting Audit Report

Energy Management

- The current energy performance of the site and of each of the energy systems assessed in the Audit;The recommendations should also match comprehensive solutions to current task needs and provide flexibility for future needs (several upgrade options, including relighting, with a detailed analysis of each). The Auditor should confirm the technical feasibility of each recommendation; and
- The Audit recommendations quantified in terms of energy savings and payback period.

Existing Lighting System Conditions

Energy Management

- To conduct a lighting audit, you need basic lighting information, such as the number of lights, their location and their time in use to help you understand the current energy use attributed to lighting in the facility.
- This information will help understand how much you are currently spending and the potential savings available from lighting efficiencies.
- The purpose of using this lighting system audit form is to ensure a consistent and systematic approach to and execution of a lighting audit.

Existing Lighting System Conditions

Energy Management

A sample worksheet below can be used to assess your current lighting conditions.

Name of Organization:
Address:
Contact Person:
Tel no. / e-mail Address :
Type of Audit Conducted :
Date Audit Conducted :
Name of Auditor/s :

S. No.	Plant Location	Lighting Device & Ballast Type	Rating in Watts Lamp & Ballast	Population Numbers	No. of hours / Day

Existing Lighting System Conditions

Energy Management

Note that not every parameter listed below will be relevant to every area.

1. Area and Location Audited : ____________
2. Dimensions of Area Audited : ____________
3. Visual task performed : ____________
4. Age of Person Performed the Task : ____________
5. Importance of Speed and Accuracy : ____________
6. Light Source
   - 6.1 Location of Lamps : ____________
   - 6.2 Type of Lamps : ____________
   - 6.3 Number of Lamps : ____________
   - 6.4 Lamp Wattage Rating : ____________
   - 6.5 Mounting Height : ____________

Existing Lighting System Conditions

Energy Management

7. Lamp ballast
   - 7.1 Type of ballast : ____________
   - 7.2 Number of lamps per ballast : ____________
   - 7.3 Watts per ballast : ____________
8. Type of Reflector : ____________
9. Type of Refractors : ____________
10. Surrounding Reflectances : ____________
11. Availability of daylight : ____________
12. Method of Control
    - 12.1 Type Manual Switching : ____________
    - 12.2 Type of Automatic Switching : ____________
13. Light Level at Workplane : ____________
14. Area Light Power Density (W/m^2) : ____________
15. Hours per week the fixture in operation : ____________

Existing Lighting System Conditions

Energy Management

16. Maintenance/Cleaning Schedule : ____________
17. Conditions of the space for dirt depreciation : ____________
18. Safety and Security Measures Required : ____________
19. Energy Consumption per month
20. Electricity cost per kilowatt hour (kWh) : ____________
21. Electricity Demand Charges : ____________
22. Others (Observations/Comments)

Maintenance and Practices

Energy Management

- Lumen Depreciation Factors
  - The Atmosphere in which a lighting system will operate is important for design calculation and for planning maintenance.
  - Adherence to group relamping and luminaire cleaning schedules maintain high levels of light and reduces energy requirements.
  - Luminaires with ventilated reflectors help reduce dirt collection on lamps and reflectors by creating convective air flow that carries dirt past the lamp and out of the luminaire.

Maintenance and Practices

Energy Management

- Lumen Depreciation Factors
  - Cleaning schedules
    - Ambient air conditions
  - Group relamping schedule
    - Economics
    - Energy conservation

Maintenance and Practices

Energy Management

- Regular Maintenance Program
  - Reduces the number of luminaires required to provide a given illuminance by as much as 50 %.
  - Energy requires may also be reduced by asmuch as 50%.

Demand Side Management

Energy Management

- Demand Side Management
  - Incorporates both conservation an load management tools and programs designed by utilities or government agencies.
  - Provides incentives to minimize lighting energy waste and promote the use of efficient lighting system.
  - Include comprehensive set of options designed to increase the value of efficient lighting to the end user for the energy cost spent.

Demand Side Management

Energy Management

- Many utilities offer incentives, including rebates for use of
  - Efficient lamps, ballasts, reflectors
  - Controls systems
  - Energy management systems
- Rebates may be offered in the form of peso per unit of equipment or peso per watt saved.
- Rebates assists in the economic justification of energy efficient lighting systems by lowering the overall cost of the building owner.

Demand Side Management

Energy Management

- Process
  - Supply-side process that minimizes the cost of serving the customer's load while maintaining a constant level of reliability
  - Demand-side process identifies and evaluates customer's actions that reduce energy costs, while increasing or maintaining customer value.

Demand Side Management

Energy Management

- Complete Economics Analysis
  - Insures proper balance between the initial investment in the lighting systems and the energy savings made possible by energy management principles
  - A complete cost/benefit analysis should be performed for several reasonable alternatives offering the most energy efficient lighting within the codes and standards

Lighting Economics

- Lighting Economics
  - Utility Rate Structure
  - Cost of Light
  - Cost Analysis
  - Evaluation of the Cost Analysis

Lighting Economics

- Provide a method by which one can make logical comparisons between lighting alternatives based on cost consideration.
- Cost issues:
  - Does “cost” include the initial purchase only?
  - Does it include the labor to install lighting system?
  - Does it include those costs necessary to operate and maintain the lighting system?

Module 9 – Energy Management and Economics
Philippine Efficient Lighting Market Transformation Project (PELMATP)

Utility Rate Structure

Lighting Economics

- **Energy**
  - The active or actual electric energy needed to operate an electrical loads/appliance during a given period of time
  - Measured in ‘kilowatthour (kWh)’ or 1,000 watthours
  - It varies with the electrical load or appliance and the number of hours the load was used

Module 9 – Energy Management and Economics
Philippine Efficient Lighting Market Transformation Project (PELMATP)

Utility Rate Structure

Lighting Economics

- **Demand**
  - The amount of electric power needed to run an electrical load/appliance at any given instant
  - Varies from time to time depending on the actual loads in use
  - Measured in ‘kilowatts (kW)’ or 1,000 watts

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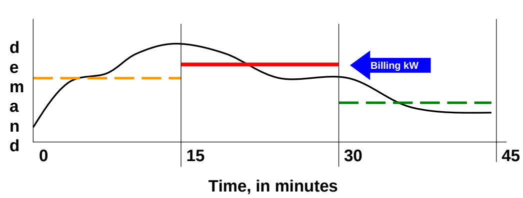
Philippine Efficient Lighting Market Transformation Project (PELMATP)

Utility Rate Structure

Lighting Economics

Billing Demand - the highest 15 minutes average demand measured during the billing period



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Philippine Efficient Lighting Market Transformation Project (PELMATP)

Utility Rate Structure

Lighting Economics

- **Measurement/Computation of Demand & Energy Consumption**

kW = (Highest 15 min. Demand Reading)Dem Mtr x Demand Meter Multiplier

kWh = (Present - Previous Rdg) kWh Mtr x kWh Meter Multiplier

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Philippine Efficient Lighting Market Transformation Project (PELMATP)

Utility Rate Structure

Lighting Economics

- **Reactive Energy**
  - additional energy required to run or operate certain electrical loads
  - measured in 'reactive kilovoltampere-hours (rkVAh)' or 1,000 reactive voltampere hours
  - it varies with the type of load and the number of hours the load was used
  - used to compute for the Power Factor (PF)

List of Typical Electrical Loads

Lighting Economics

'Pure Active' Loads	'Active - Reactive' Loads
* Incandescent Bulbs	* Fluorescent Lamps
* Electric Range	* Water Pumps
* Flat Irons	* Air Conditioners
* Water Heaters	* Washing Machines
* Bread Toasters	* Vacuum Cleaners
* Electric Ovens, etc ...	* Electric Fans, etc ...
Pure 'kWh' Energy	'kWh'+ 'rkVAh' Energy

Utility Rate Structure

Lighting Economics

RELATIONSHIP BETWEEN TYPE OF LOAD & POWER FACTOR

TYPE OF LOAD	Consumption	PF
Purely Active	kWh	100%
Active-Reactive	kWh & rkVAh	> 0% TO < 100%
Purely Reactive	rkVAh	0%

Utility Rate Structure

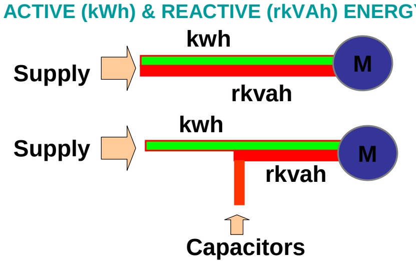
Lighting Economics

- **Power Factor**
  - a measure of how much additional energy is required by the load to 'run' or 'operate'
  - determines the rating of service facilities required to be installed by the utilities - the lower the PF, the higher the rating of facilities
  - has values ranging from 0% to 100%

Utility Rate Structure

Lighting Economics

ACTIVE (kWh) & REACTIVE (rkVAh) ENERGY



Utility Rate Structure

Lighting Economics

- Measurement/Computation of Reactor (rkVAh) Consumption

For Conventional Type of Reactive Meter

rkVAh = (Present - Previous Rdg) rkVAh Mtr x Reactive Meter Multiplier

For Q-Meter Type of Reactive Meter

kQh = (Present - Previous Rdg) rkVAh Mtr x Q - Meter Multiplier

Utility Rate Structure

Lighting Economics

Relationship between Active (kWh) & reactive (rkVAh) Consumption

$$PF = \frac{kWh}{\sqrt{kWh^2 + rKVAh^2}}$$

kQh to rkVAh Conversion

$$rKVAH = \frac{2 \times kQh - kWh}{\sqrt{3}}$$

Cost of Light

Lighting Economics

- Cost of Light
  - Provides a quick and easy method of comparing lighting systems
  - Similar to an efficacy rating for lamps, which provides economic information regarding the light output per watt.
  - Evaluates the cost required to deliver light over a period of time, or pesos per lumen-hour.
  - Convenient method of analysis because it is relatively easy to calculate.

Cost of Light

Lighting Economics

$$\text{Cost per lumen hour} = \frac{\text{Total Cost}}{(\text{Total Lumens Delivered}) \times (\text{Hours of Operation})}$$

Cost of Light

Lighting Economics

However, cost per lumen hour is very small, for convenience it is generally expressed as cost per million lumen hours.

$$\text{Cost per lumen hour} = \frac{1{,}000{,}000 \times \text{Total Cost}}{(\text{Total Lumens Delivered}) \times (\text{Hours of Operation})}$$

Cost of Light

Lighting Economics

- Include all significant costs in the total costs.
  - Initial cost
  - Maintenance cost
  - Operating costs

Cost of Light

Lighting Economics

- Coefficient of Utilization (CU)
  - Product of luminaire efficiency and room efficiency
- Light Loss Factors (LLF)
  - Required to properly determine the lighting system's efficiency over time.

Cost of Light

Lighting Economics

- Operating hours
  - Are included to account for variations between lighting alternatives that operate for different lengths of time.
  - Useful when using control systems such as infrared or motion detectors and with the use of daylight.

Comparison of Two Systems

Lighting Economics

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

Comparison of Two Systems

Lighting Economics

Parameters	2x4 Lamp Parabolic ES lamps and Ballast	2x4 Lamp Parabolic T8 Electronic System
Delivered Lumens		
-Lumens/Lamp	2650	2950
-Number of Lamps	3	3
-Coefficient of Utilization	0.69	0.79
-Light Loss Factor	0.85	0.85
Total Delivered Lumens	4,663	5,943
Operating Hours		
Operating Hours per Year	4,000	4,000
Number of Years	5	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)

Cost Analysis

Lighting Economics

- Life Cycle Costing
  - Considers the following
    - Significant Cost of Lighting System
    - Significant Cost over its useful life
    - Cost in terms of equivalent pesos

Cost Analysis

Lighting Economics

- Cost Factors Comparison
  - Evaluations are made based on equivalent lighting systems.
  - Equivalence is determined primarily by the lighting designer or building owner and is based on the requirements of the job.
  - If the system is not equivalent, the cost analysis is virtually meaningless.

Cost Analysis

Lighting Economics

- Cost Factors Comparison
  - Equivalence is determined based on the following factors
    - Illuminance provided
    - The construction of the lighting products
    - Flexibility of the lighting system
    - Quality of light provided
    - Color of the light produced

Cost Analysis

Lighting Economics

- Cost of lighting systems
  - Evaluation is much more complex than simple comparison of the cost of one luminaire to another.
  - Should consider all costs associated with:
    - Purchasing
    - Installing
    - Operating
    - Maintenance

Cost Analysis

Lighting Economics

- Cost Criteria
  - Initial Cost
  - Energy Cost
  - Maintenance Cost

Cost Analysis

Lighting Economics

- Cost Criteria
  - Initial Cost
    - Includes the purchase of equipment and labor to install
    - Computed as follows:

Initial Cost = (Equipment cost) + [(Installation Hours) x (Labor Rate)]

Cost Analysis

Lighting Economics

- Cost Criteria
  - Initial Cost
    - Includes the purchase of equipment and labor to install
    - Computed as follows:

Initial Cost = (Equipment cost) + [(Installation Hours) x (Labor Rate)]

Cost Analysis

Lighting Economics

- Cost Criteria
  - Initial Cost
    - Myriads of lighting alternatives are available, which impact the equipment cost.
    - Some luminaires are designed fro a specific lamps and ballast type, others accommodate a variety of lamps or ballasts.
    - For instance, a recessed troffer requires a lamp of specific length and electric characteristics for which dozens of lamps with different phosphor coatings, operating wattage, or lamp lives may be used.
    - These different type of lamps may be use with several different ballast.

Cost Analysis

Lighting Economics

- Cost Criteria
  - Initial Cost

    Lighting Controls
    - Also affect initial cost of lighting system
    - Can be simple as switches and Dimmers
    - Can be sophisticated as an energy management system that controls lighting of the entire building

Cost Analysis
Lighting Economics

- Cost Criteria
  - Initial Cost
  - Installation Cost
    - Many lighting products are equipped with optional equipment that makes the system easier and faster to install.
    - Options:
      - Prewiring
      - Plug-in circuits
      - Flexible wiring that connects directly to the branch wiring.
    - Products that reduce the amount of time required to install them reduce the installed cost due to significant labor savings.

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Philippine Efficient Lighting Market Transformation Project (PELMATP)

Lighting Economics
Lighting Economics

Relative Initial Cost of Various Fluorescent Lamps

Lamp Type	Color Temp K	CRI	Relative Cost
F40 T12 41K	4100	70	1.00
F40 T12 41K-High CRI	4100	85	2.04
F40 T12 CW/ES	4100	62	0.28
F40 T12 41K/ES	4100	70	0.63
F40 T12 CW/ES-High CRI	4100	85	2.14
F32 T8 41K	4100	78	0.35
F32 T8 41K-High CRI	4100	86	0.49

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Philippine Efficient Lighting Market Transformation Project (PELMATP)

Cost Analysis
Lighting Economics

- Cost Criteria
  - Initial Cost

    Labor Cost
    - Influences installation Cost
    - Vary quite dramatically by geographical region.
    - In areas where rates are high, an increased incentives exists to utilize labor saving options to keep the installation cost to a minimum

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Philippine Efficient Lighting Market Transformation Project (PELMATP)

Cost Analysis
Lighting Economics

- Cost Criteria
  - Initial Cost

    Upgrade Cost
    - Cost require for replacement of lamps, ballasts, or lenses to meet the necessary quality.
    - Compared to the cost associated with a new system and is generally less expensive than installation in new construction
    - A retrofit application has electrical wiring in place and is reused for the new system.
    - This reduces the cost of replacement and provides incentives to upgrade to a higher quality, energy efficient lighting system.

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Cost Analysis
Lighting Economics

- Cost Criteria
  - Energy Cost
    - Single Significant Cost Factor
    - Efficient use of lighting energy is necessary criterion in lighting design due to increasing power rates

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Cost Analysis
Lighting Economics

- Cost Criteria
  - Energy Cost

    Annual Energy Cost
    - Function of the following:
      - Power used by the lighting system
      - The energy rate charged by the utility company
      - Amount of time the system will operate over the course of a year

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Cost Analysis

- Cost Criteria
  - Energy Cost
    - Annual Energy Cost is expressed as
    - Annual Energy Cost = N x (kW/Luminaire) x (P/kWH) x (Hours/Yr)
      - Where:
      - N = total number of luminaires
      - kW/Luminaire = kilowtts per luminaire (1 kW = 1000 Watts)
      - P/kWH = energy rate in persos per kilowatt-hour
      - Hours/Year = the number of hours the lighting system will operate over the period of a year

Cost Analysis

Lighting Economics

- Cost Criteria
  - Energy Cost
    - Power Cost
    - Energy Rate
    - Demand Charge
    - Burning Hours

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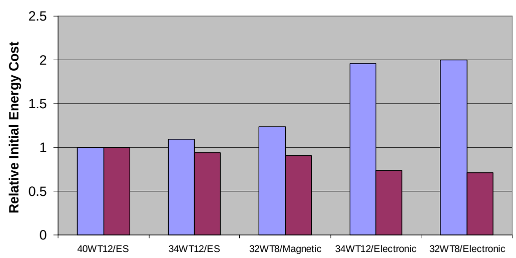
Philippine Efficient Lighting Market Transformation Project (PELMATP)

Lighting Economics

Lighting Economics

Relative Initial and Energy Cost for Various Lamp Ballast Combination



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Cost Analysis

Lighting Economics

- Cost Criteria
  - Energy Cost

    Power Cost
    - Analysis begins with the total power consumed by the lighting equipment used in the application
    - While some options cost more initially, they provide significant savings in long-term energy costs.

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Cost Analysis

Lighting Economics

- Cost Criteria
  - Energy Cost

    Energy Rate
    - Rate charge by the utility company
    - Utility company determine energy rates based on the following criteria
      - Location of the power plants
      - Efficiency of the plants
      - Local demand for the power
    - Many utility companies vary the energy rate according to the time of day.

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Cost Analysis

Lighting Economics

- Cost Criteria
  - Energy Cost

    Demand Charge
    - Applied to electricity supplied
    - Is designed to encourage moving the energy use during peak periods to an off-peak time when energy rates are lower.
    - Similar to the method some long distance companies use to bill customer for phone calls.
    - If in effect for a specific lighting application, this cost must be accounted for in addition to the standard energy cost

Module 9 – Energy Management and Economics
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Cost Analysis

Lighting Economics

- Cost Criteria
  - Energy Cost

Burning hours

- The number of hours the lighting system will operate during the year.
- Necessary to effectively evaluate energy costs.
- Lighting controls significantly reduce the overall hours the lighting system operates
  - Occupancy sensors
  - Daylight sensing
  - Energy management systems

Cost Analysis

Lighting Economics

- Cost Criteria
  - Maintenance Cost
    - Incurred as lighting system ages and requires cleaning or minor repairs.
    - May be related to the following:
      - Replacing old lamps
      - Cleaning luminaires
      - Replacing ballasts
      - Replacing old or broken lenses and louvers.

Cost Analysis

Lighting Economics

- Cost Criteria
  - Maintenance Cost

Computed as follows:

Maintenance Cost = (Cost of Materials required for Maintenance) +[(Hours Required for Maintenance) x (Labor Rate)]

Cost Analysis

Lighting Economics

- Cost Criteria
  - Maintenance Cost

Lamp Replacement

- The most significant maintenance cost
- Cost of materials is simply the number of lamps replaced, multiplied by the cost of each lamp.
- The number of lamps replaced can be expressed as:

$$\text{No. of Lamps Replaced per Year} = \frac{(\text{Total Number of Lamps}) \times (\text{Operating Hrs/Yr})}{(\text{Lamp Life in Hrs})}$$

Cost Analysis

Lighting Economics

- Cost Criteria
  - Maintenance Cost

Lamp Replacement

- Number of lamps replaced each year varies.
- Very few lamps are replaced in the first few years when the lamps are new
- As lamp age, an increasing number fail and must be replaced
- Designs utilizing lamps with extended lamp life or control systems to reduce operating hours per year become very attractive.

Cost Analysis

Lighting Economics

- Cost Criteria
  - Maintenance Cost

Group Relamping

- Replacing all lamps at one time.
- If all lamps are replaced every 2 to 3 years, then the number of lamps replaced is simply equal t the number of lamps in the application.
- If performed on a scheduled basis, the lamps will provide a higher maintained light level than occurs with spot relamping

Cost Analysis

Lighting Economics

- Cost Criteria
  - Maintenance Cost

    Group Relamping
    - May be more cost effective when replacing a large quantity of lamps because of economics in purchasing a large quantity of lamps and reducing the overall time to replace each lamp.
    - Based on industry statistics relamping costs are approximately $3 per lamp for group relamping versus $23 per lamp for spot relamping)

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Total System Cost
  - Simple Payback
  - Return on Investment

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Total System Cost
    - Determined simply by adding the following:
      - Initial Cost
      - Energy Cost
      - Maintenance Cost
    - Extremely Useful because it describes the cost of purchasing the lighting system as well as operating and maintaining the system.

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis

  Total System Cost
  - Total initial cost is a one-time lump sum value, while the energy and maintenance costs are generally annual costs.
  - To compensate for these difference, the evaluation estimates annual payments on the initial investment.
  - Another method determines the total energy and maintenance costs over the useful life of the lighting system and sums that value to the initial cost.

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis

  Cost comparison
  - The total cost of each lighting alternative are compared
  - The lowest cost identifies the system that costs the least over its entire life.
  - Useful when the building owner intends to maintain ownership for a long period of time and is less concerned with costs associated with the purchase of the equipment

Lighting Economics

Lighting Economics

Parameters	System 1 100W Incandescent Downlight	System 2 26 W Fluorescent Downlight
Number of luminaires	100	100
Initial Cost Luminaire Cost	$45 x 100 luminaires = $4,500	$85 x 100 luminaires = $8,500.00
Installation Cost (assumes 0.75 hours to install each luminaire and electrical labor rate is $60/hr)	0.75 x $60 x 100 = $4,500	0.75 x $60 x 100 = $4,500
Total Initial Cost	$4,500 + 125 + 4,500 = $9,125	$8,500 + 1,416 + 4,500 = $ 14,416

Lighting Economics

Parameters	System 1	System 2
Maintenance Cost		
Type of Relamping Method	Spot	Spot
Lamp Life (Hours)	750	10,000
#Lamps Replaced per Year	(100 x 3500)/750 = 467	(100 x 3500)/10,000 = 35
Hours to replace each Lamp	0.25	0.25
Labor Rate to Replace Lamps	$30/hr	$30/hr
Relamping Cost per Year	467[1.25 + (0.25)(0.30)]=$4,086	35[14.16+(0.25)(0.30)]=$758
Hours to Clean each Luminaire	0.20	0.20
Labor Rate to Clean the Luminaires	$30/hr	$30/hr
Cleaning cost per year	100 x 0.20 x 30 = $600	100 x 0.20 x 30 = $600

Lighting Economics

	100W Incandescent Downlight	26 W Fluorescent Downlight
Initial Cost	$ 9,125	$14,416
Maintenance & Operating Cost /yr	$7,486	$ 2,114

If the life of these lighting systems is assumed to be 10 years, then the total System Cost

Total System Cost	9,125 + 10 x 7,486	14,146+10 x 2,114
	$ 83,985	$ 35,556

Lighting Economics

Parameters	System 1	System 2
Operating Cost		
Input Power (Watts)	100	27
Energy Rate ($/kWH)	0.08	0.08
Operating Hours	3,500	3,500
Energy Cost per year	100 x (100/1000) x 0.08 x 3,500 = $ 2,800	100 x (27/1000) x 0.08 x 3,500 = $756
Total	2,800 + 4,086 + 600 = $7,486	756 + 758 + 600 = $ 2,114

Cost Analysis

- Evaluation of Cost Analysis

  Total System Cost
  - Sophisticated economic analysis include the time value of money.
  - Calculation of operating and maintenance costs include the effects of time and interest rate on the value of money.
  - Provide a realistic evaluation of cost parameters.

Cost Analysis

- Evaluation of Cost Analysis
  - Simple Payback
    - The period of time in years required for the savings in operating or maintenance cost to equal the additional initial investment required for the lighting system.
    - Expressed as:
      - Simple Payback period is relatively easy to calculate because it does not consider any changes in the future value of money
      - Discounted payback uses discounting methods to account for the time value of money.

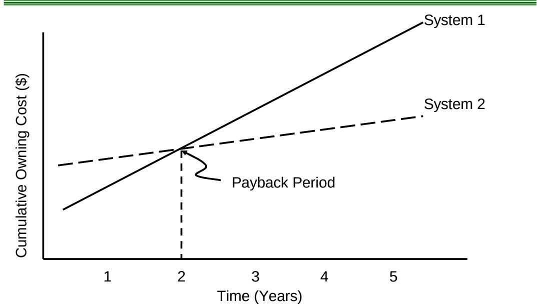
Cost Analysis

- Evaluation of Cost Analysis
  - Simple Payback
    - A method used to estimate the payback period is described by the following equation:

$$\text{Payback} = \frac{\text{(Incremental Initial Cost)}}{\text{(Annual Operating and Maintenance Savings)}}$$

Cost Analysis

Lighting Economics



Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Simple Payback
    - Also determined by graphing the cost associated with each lightning system
    - The point where the cost curves intersect indicates the payback period.
    - The point when the incremental cost of purchasing System B is "paid back" due to annual operating and maintenance savings.

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Simple Payback Example

The incremental initial cost of the fluorescent downlight over the incandescent downlight is:

$ 14, 416 – 9,125 = $ 5,291

The annual operating and maintenance savings of the fluorescent downlight over the incandescent downlight is:

$ 7,486 – 2,114 = $ 5,372 per year

The simple payback is determined by simply dividing:

$ 5,291 / 5,372 = 0.98 years

While the fluorescent downlight costs about $ 5,300 more initially, this incremental expense is paid back in just under one year due to the operating and maintenance savings.

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Simple Payback

  Payback period is useful in an economic analysis
    - Because it describes the amount of time required before the incremental savings offset the initial cost.
    - Beneficial If the building owner intends to resell the investment in a relatively short period of time.

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Return on Investment
    - Referred to as ROI
    - Describes the interest rate obtained due to the incremental savings as compared to the incremental initial investment over the life of the lighting system.
    - Accounts for the costs of the system over a relatively long period of time.

Cost Analysis

Lighting Economics

- Evaluation of Cost Analysis
  - Detailed Analysis

    Accounts for the following
    - Time value of money
    - Escalation
    - Taxes
    - Insurance
    - Other economic parameters

Sample Computations (Without Investment)

Lighting Economics

- Turning off fluorescent lights during a 1 hour break
  - Number of lamps = 1000 units of 40 watts FL
  - Hours of operation = 10 hours per day, 20 days per year
  - Lamp wattage (with ballast) = 53 W (lamp and ballast)

Sample Computations (Without Investment)

Lighting Economics

- Power Savings = 1hour/day x 250 days x 1000 lamps x 53 watts x 1 kW/1000 watts = 13,250 kWh/yr
- Cost Savings = 13,250 kWh/yr x PhP 8.00/kWh = PhP 106,000.00

Sample Computations (With Investment)

Lighting Economics

About 100 fittings of Incandescent Bulbs with a Wattage Rating of 100 W will be replaced by SL 18W. The cost of the incandescent bulbs is Php 32.75 while SL 18W is Php 155.00. The lamp life of the incandescent bulb is 1000 hrs while SL 18W has a lamp life of 6000 hrs. Assume 8760 burning hours/year

Energy saved/year = (100-18)/1000 x 8760 x 100 = 71,832 kWh

Energy cost saved/year = 71,832 x Php 8.00/kWh = Php 574,656

Sample Computations (With Investment)

Lighting Economics

No. of lamps to be purchased:

Incandescent = 8760/1000 = 8.76 lamps x 100 fittings = 876 lamps

SL 18W = 8760/6000 = 1.46 lamps x 100 fittings = 146 lamps

Total cost:

Incandescent = 876 x Php 32.75 = Php 28,689

SL 18W = 146 x Php 155.00 = Php 22,630

Cost difference = 28,689 – 22,630 = 6,059

Savings incurred = Php 574,656 + 6,059 = Php 580,715