MFVI Energy Efficiency Audit Training

Module 1.2: Lighting Analysis

Gokul Paranjothi, Jonathan Morgenstein, and Hallie Lucas
National Renewable Energy Laboratory
May 2022

Photo from iStock-1371324114

Contents

Introduction to MFVI

MiPyMEs Futuros Verdes Initiative (MFVI) advances clean, reliable, and affordable energy solutions for micro-, small-, and medium-sized businesses (Spanish acronym “MiPyMEs”) in the Yucatan Peninsula through targeted technical training and affordable financial support. MFVI aims to increase financial inclusion, maximize the energy cost savings available to MiPyMEs, empower business owners to make strategic energy investments, and catalyze economic growth within the MiPyMEs sector.

The following modules were developed as part of a two-part targeted training series to equip university students with the skills and expertise needed to conduct Level-2 energy audits for local MiPyMEs. This module was designed for undergraduate students from different backgrounds to perform audits in small and micro business buildings. The energy savings measures will reflect this overall purpose.

What Is the Purpose of MFVI?

Help MiPyMEs implement energy efficiency

Determine simple energy conservation measure (ECM) savings through targeted energy efficiency audits

Enable MiPyMEs to qualify for affordable “green” loans

Begin a cyclical process of building green credit

MFVI Two-Part Training Process

Phase 1 Training

- Understand and measure energy efficiency via on-site audits

Phase 2 Training

- Conduct analysis of data collected during audits, and recommend ECMs

Training Breakdown

Module 1: Lighting

1.1 Introduction to Efficient Lighting

1.2 Lighting Analysis

Module 2: Plug Loads

2.1 Introduction to Plug Loads

2.2 Plug Load Analysis

Module 3: HVAC

3.1 Introduction to Heating, Ventilation, and Air Conditioning (HVAC)

3.2 HVAC Analysis

Lighting Analysis

Training Module 1.2

Module Map

1. Analyze data collected during audits:
    - Calculate energy saved if ECMs were implemented
    - Calculate cost of reducing energy through ECMs.
2. Recommend simple ECMs with payback periods:
    - Replacing lamps in a space
    - Removing lamps from a space.

Recap of Key Terms and Definitions

Illuminance: The metric used to measure light intensity within the space. It is the amount of light falling on a surface. The light intensity, or the luminous flux of the light source, is measured in lumens.

Lux (lx): Lumens per meter foot (Lumens/m^2)

Footcandles (fc): Lumens per square foot (Lumens/sf)

Conversions: 1 lx = 0.0929 fc

1 fc = 10.76391 lx

New Key Terms and Definitions

Payback period: The amount of time (in years) it would take for the additional cost of implementing an energy savings measure to be realized through cost savings due to efficient functioning of the measure.

Net cost: Total cost of installing new ECM, including labor and procurement costs.

Lighting Power Density (LPD): A measure of lighting power intensity of a space. Measured in watts/sq.m.

What You'll Need for the Analysis

- A copy of your field tool sheet with all information collected during audits
- A copy of the payback calculator provided with this module.

Analyze Data Collected During Audits

Step 1: Compare LPD To Recommended Values in the Field Tool

For each space in the building, compare the calculated LPD from your measurements to recommended LPDs in Appendix B of the field tool.

- If the calculated LPD is lower or within 5% over the recommended LPDs, the space is energy efficient.
- If the calculated LPD is over the recommended LPDs by more than 5%, the space needs improvement in lighting design.

Note that the recommended LPD values are also reproduced in the payback calculator provided.

Step 2: Calculate Annual Energy Use and Annual Energy Cost of the Lights in a Space

For each space in the building, input the following values into the payback calculator provided:

- Space name
- Lamp name and type
- Number of lamps of the particular type
- Lumens
- Wattage
- Weekday and weekend hours of operation.

The payback calculator will then calculate the annual energy use and energy cost of the lights in that particular space. Refer to the payback calculator for more information on how to calculate energy use and costs.

Let's Do the Math!

For each type of lamp in every space in the building, the following are calculated:

1. $$\textbf{\textit{Annual Hours of Usage}} = (weekday\ hours\ of\ use\ * 260\ weekdays\ per\ year) + (weekend\ hours\ of\ use\ * 100\ weekends\ per\ year)$$

2. $$\textbf{\textit{Annual Energy Use}}\ (\textbf{\textit{kWh}}) = \frac{(Annual\ Hours\ of\ Usage * lamp\ wattage\ (W) * number\ of\ lamps)}{1000}$$

3. $$\textbf{\textit{Annual Energy Cost}}\ (\textbf{\textit{USD}}) = Annual\ Energy\ Use\ (kWh) * electricity\ tariff\ rate\ (\$/kWh$$

Note: Revise the weekends or weekdays per year accounting for different holidays, if necessary, in the payback calculator. The numbers used are standard values.

Using the Payback Calculator

Simple Lighting ECM Analysis

This is a simple lighting payback calculator. It takes into account the total energy cost savings over a year due to lamp replacement, costs of new lamp procurement and installation, and calculates a simple payback. Row 13 provides an example.

Summary Metrics		
Total energy savings (kWh)	5208	
Energy cost savings ($/yr)	885	Discounted payback
Total number of fixtures	7	
Total lamp procurement costs ($)	0	
Total labor costs ($)	44	
Total cost savings ($)	842	
Simple payback	0.05	

Space Lighting Details

Space name	LPD over 5% of recommended values? Use field guide for reference. (Y/N)	Lamp name	Lamp type (CFL/LED/Halogen)	Number of lamps	Lumens	Watts
Room 1	Y	CFL1234-XX	CFL	2	1,500	300
Hallie Test	Y	Hallie Test	Hallie Test	5	1,500	300

The payback calculator can be used to calculate key financial metrics such as annual energy cost savings (in $) and simple payback periods for implementing a specific ECM.

Summary Metrics	
Total energy savings (kWh)	4166
Energy cost savings ($/yr)	708
Total number of fixtures	7
Total lamp procurement costs ($)	35
Total labor costs ($)	44
Total cost savings ($)	630
Simple payback	0.13

Applied Student Exercise

There is a room in an office with 4 CFL lamps of 100 W/1,500 lumens, 6 CFL lamps of 50 W/1,000 lumens and 3 LED lamps of 30 W/1,000 lumens each. The office operates from 9 a.m. to 7 p.m. Mon-Fri and does not work on weekends.

Calculate the annual energy use and energy cost of the building

Applied Student Exercise: Answer Key

There is a room in an office with 4 CFL lamps of 100 W/1,500 lumens, 6 CFL lamps of 50 W/1,000 lumens and 3 LED lamps of 30 W/1,000 lumens each. The office operates from 9 a.m. to 7 p.m. Mon-Fri and does not work on weekends.

Calculate the annual energy use and energy cost of the building

Energy use – 2,054 kWh, Energy cost - $350/year

Applied Student Exercise

Let’s use the payback calculator to calculate annual energy use and costs of the lights in one of your spaces in the building! ☺

Recommended Simple ECMs With Payback Periods

Replace existing lamps with lower wattage lamps

Step 3: Calculate Simple Payback of Replacement With Low-Wattage Lamps

For each space and lamp,

- Look for an LED replacement with a comparable lumens output to the lamp to be replaced
- If an LED is not available, look at CFLs, then incandescent lamps.
- The idea is to find the lowest wattage with the same lumens output.
- Input the replacement lamp wattage and cost in the spreadsheet.

Annual energy and monetary cost of a new lamp are calculated using the same formulas contained in Slide 15.

Let's Do More Math!

1. $$\textbf{\textit{Annual Energy Cost Savings}}\ (\textbf{\textit{kWh}}) = \textit{energy cost of existing lamp} - \textit{energy cost of replacement lamp}$$

2. $$\textbf{\textit{Labor Cost}} = \textit{labor rate per hour}\ (\$) * 0.25\ \textit{hours}$$

   Note: These calculations assume it will take 15 minutes on average to replace each lamp.

3. $$\textbf{\textit{Total Cost Savings}}\ (\$) = \textit{Annual Energy Cost Savings} - \textit{total labor costs} - \textit{procurement costs of lamps}$$

   Note: Procurement cost of lamps might vary from location to location.

4. $$\textbf{\textit{Simple payback ratio}} = \textit{Total Cost} \div \textit{Total Cost Savings}$$

A payback of 0-2 years is generally considered good for lighting ECMs.

What Is *Not* Considered in These Simple Payback Period Calculations

- Service and maintenance of lamps
- Net present value calculations
- Discounted rate calculations
- Contingency and factor of safety application
- Interest rate of loans.

Note: The simple payback period calculated is a high-level estimate. Depending on the factors mentioned above, the payback periods may change a lot. These factors were not included for this module, taking in mind complexity and time constraints for preparing the module.

Pause and Recap

Questions?

Recommend Simple ECMs With Payback Periods

Remove existing lamps

Removing Lamps in the Space

- Compare illuminance values in your illuminance map to the recommended values in Appendix B of the field tool.
- If the illuminance values are higher (>10%) than the recommended values, a case for removing fixtures in the space can be made.

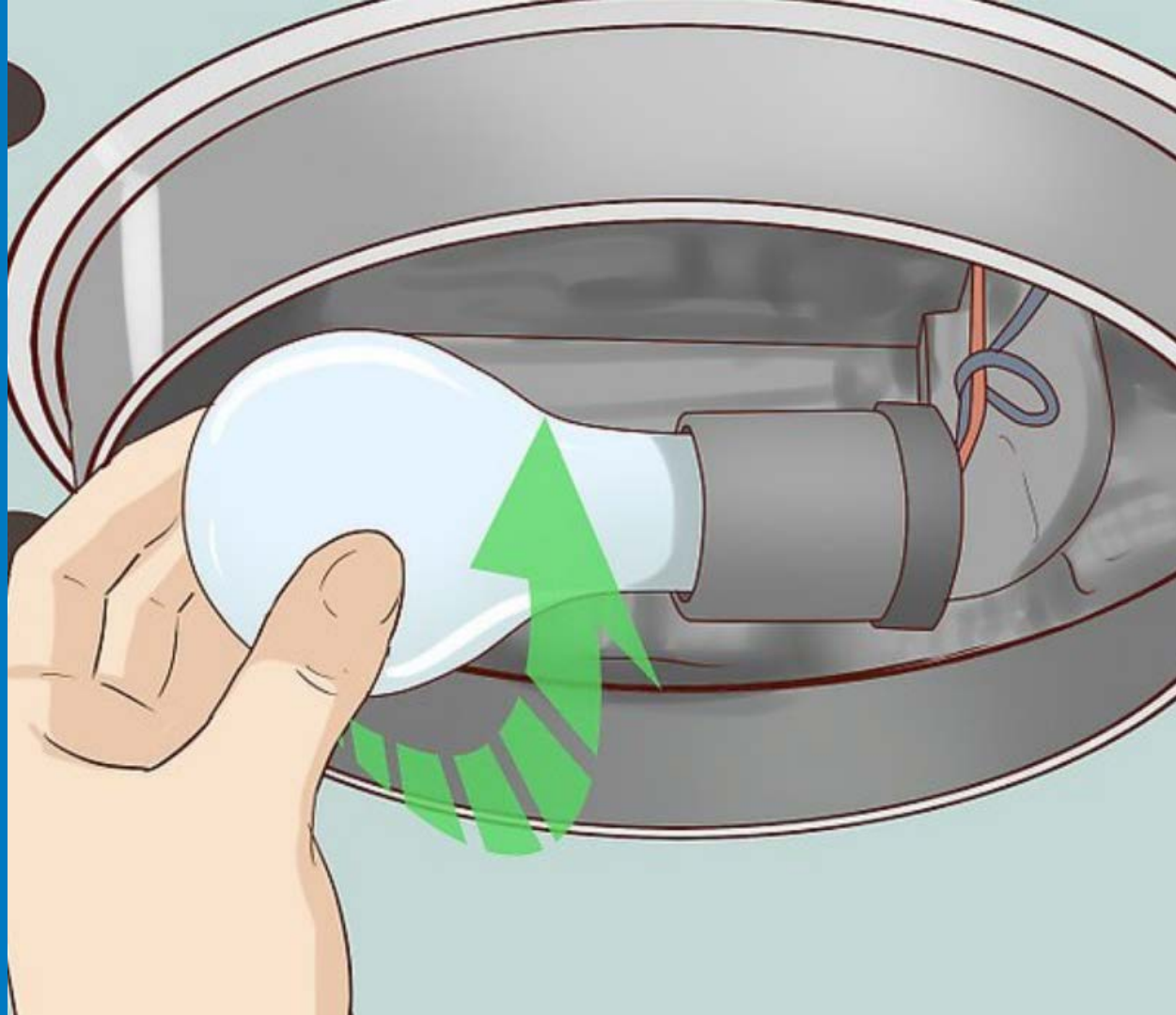


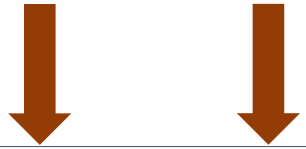
Image by wikihow.com

Additional Considerations for Removing Lamps

- The illuminance of the entire space—removing a lamp might not affect illuminance requirement at one spot but might make a neighboring spot darker!
- Employees—if employees describe a space as being just right or too dark, DO NOT remove lights, even if the illuminance levels are higher than recommended values. EMPLOYEES ARE PRIORITY #1!
- Daylighting—sometimes, daylight might be enough to light an entire space. However, if the space is being used at night, it may still need lighting! One good question to ask is if task lights can serve the purpose in the night. If so, removing existing lights is an option.

Calculating Energy and Cost Savings for Removing Lamps

- To calculate energy and cost savings for removing a lamp, simply enter the replacement lamp wattage and procurement costs as 0, in the respective columns in the spreadsheet.
  - Note that labor costs will remain non-zero.



Replacement Lamp Metrics			Energy Efficiency Metrics		Total Savings		Total Costs		
Replacement lamp wattage	Replacement lamp cost	Watt-hours per year for replacement	Annual energy use after replacement (kWh)	Annual energy cost ($/yr)	Annual energy use savings (kWh/yr)	Energy cost savings ($/yr)	Lamp procurement cost ($)	Labor costs ($)	Net costs ($)
0	$ -	-	-	$ -	1,488	$ 252.96	$ -	$ 12.50	$ 240.46
0	$ -	-	-	$ -	3,720	$ 632.40	$ -	$ 31.25	$ 601.15
		-	-	$ -	-	$ -	$ -	$ -	$ -
		-	-	$ -	-	$ -	$ -	$ -	$ -

Applied Student Exercise

- Discuss whether any of your lamps can be removed.
- What metrics indicate that a lamp should be removed?
- What are some of the considerations you might make to remove a lamp that is not required?

Questions?

www.nrel.gov

NREL/PR-5500-83244

NREL
Transforming ENERGY

Questions?

www.nrel.gov

NREL/PR-5500-83244

NREL
Transforming ENERGY

Photo from iStock-1371324114