

LED Streetlight Replacement Program for the San Juan Municipality

Mariano Perez Portocarrero

Master in Engineering Management

Dr. Héctor J. Cruzado

Department of Civil & Environmental Engineering and Land Surveying

Polytechnic University of Puerto Rico

Abstract — *This project focuses on addressing the consequences of past storms, specifically Hurricane Maria in 2017 and Hurricane Fiona in 2022, on the street lighting system of the municipality of San Juan, Puerto Rico. The project's primary objective was to develop a comprehensive forecast plan for replacing damaged luminaries with energy-efficient alternatives. To achieve this objective, the research entailed determining the total quantity of luminaries in the San Juan Municipality and applying a 70% damage assumption to account for the existing LED streetlights. An estimate was prepared, considering assessments, materials replacement, and contingency costs. This estimate served as the basis for creating a detailed scope of work that will facilitate the scheduling of an execution plan and the validation of the budget as well as for calculating the necessary contractor capacity required for assessments and construction to ensure the successful completion of the project. The outcome was a comprehensive forecast plan report encompassing monthly costs and a well-defined schedule, aiming for project completion before the end of 2030. Importantly, compliance with Puerto Rico Energy Public Policy Law No. 17, which mandates the replacement of existing High-Pressure Sodium (HPS) luminaries with LED technology, will be a crucial consideration throughout the project. By implementing this program, Puerto Rico seeks to achieve multiple objectives, including providing affordable, reliable, sustainable, and modern energy access and enhancing the region's public safety and energy efficiency.*

Key Terms — *Energy, Forecast, Replacement HPS for LED initiative before 2030, Streetlighting*

INTRODUCTION

Natural disasters like hurricanes devastate public infrastructures such as streetlights, leaving

many areas with insufficient illumination to mitigate car accidents or crimes like assaults and robberies. The San Juan, Puerto Rico, municipality was not spared by the impact of Hurricanes Maria and Fiona, leading to damage to streetlights in the area.

However, even before the hurricanes, streetlights had been neglected in maintenance and upgrading, resulting in poor maintenance of luminaries and old, damaged components that jeopardized the safety and a sustainable energy system. Replacing and maintaining these luminaries are essential to ensure access to affordable, reliable, sustainable, and modern energy for every country worldwide.

OBJECTIVES

The main objective of this project is to analyze and develop a forecast plan to replace damaged high-pressure sodium (HPS) luminaires with light emitting diode (LED) luminaires in San Juan Municipality before 2030. This project aims to determine the monthly cost of all replacements and contractor capacity required for completion before 2030.

TECHNICAL DATA

This section will briefly define the HPS and LED components for streetlight luminaries. Advantages and disadvantages will be described, as to why new technology could be better than old one. It will present how this technology has been developed in different cities and how it impacts the economy and efficiency.

HPS was a technology introduced into the market around 1970. Is one of the most used streetlights because of its high illumination due to a mix of gases. These gases are a compound of mercury, sodium, and xenon. Arc tube is a

component of this type of lamp where these gases are activated by electric pulses, creating heating, and resulting in a spectrum light typically yellow due to sodium [1]. Some of the advantages are:

- Minimum costs
- Full spectrum illumination
- Better than traditional mercury lamps on the warmup time spans
- Long life +24,000 hours
- Some disadvantages that we can mention are:
- High consumption.
- Environment Hazards due to chemical components.
- No directional illumination could result in a waste of light
- Require other components like ballast for their functionality.

LED is a modern technology used for streetlights, parks, and exteriors, replacing HPS due to their advantages and better properties that will discuss later. Since 2013 was getting into the market, taking over faster but more expensive than the old tech. The way that works is when two electrodes react by current passes. This process interacts within the semiconductor, producing energy resulting in seeing the light [2]. Some of the advantages are:

- Minimum consumption
- Directional illumination
- Turn immediately, not require a warmup
- Up to 50,000 hours
- Green environment

Some disadvantages that can be mentioned are:

- High costs.
- Some LED streetlights can produce blinding glare to pedestrians and drivers, especially in fog or other low visibility conditions.

LED is a considerable energy saving with an ROI (return on investment) more favorable to any city implementing this replacement program. HPS costs about \$380, and LED costs about \$480, including lamp, post, labor, bucket truck, and other related activities [3].

METHODOLOGY

This project applied the Waterfall project management methodology. It follows sequential phases with distinct aims toward team goals:

- **Research:** The total quantity of luminaries in San Juan Municipality. LUMA obtained historical data that it is the actual operator of this asset. They have already started maintenance and replacement in different municipalities with an estimated cost of 90M for promptly 250,000 luminaries that will be changed [4]. It was assumed the 70% damage, considering there are already LED streetlights without problems.
- **Estimate:** Using the final amounts of luminaries, an estimate was developed considering different categories such as assessments, materials replacement, and management costs.
- **Scope of work:** A scope for assessments and labor was developed considering the estimate considered, a schedule for an execution plan, and budget validation.
- **Forecast:** The contractor's capacity for completion before 2030 energy compliance is analyzed. The data analyzed regarding cost and tasks considered in a replacement program are used to determine resource availability to make assumptions about project success.
- **Quality:** After the forecast is completed, a quality review was performed on what was assumed, the budget, and forecast results to consider a second option with lowered costs.
- **Final forecast plan report:** Final plan is presented with monthly costs on a schedule before the end of 2030. Costs for different categories such as assessments, materials, replacement, and management costs are presented.

RESEARCH

LUMA historical data obtain the total quantity of luminaries in San Juan Municipality that it is the actual operator of this asset. They have already

started maintenance and replacement in different municipalities with an estimated cost of 90M for promptly 250,000 luminaries that will be changed [4]. Assumed the 70% damage, considering there are already LED streetlights without problems. Based on historical and detailed research of other municipalities, the plan focused on the city of San Juan, knowing it is the most critical municipality due to its high number of visitors and tourist population.

ESTIMATE

After validating the data with LUMA's engineering department, the project team developed an estimate with the final quantities, including assessments, material replacement, and management costs. This estimate was developed based on the assumption that 70% of the existing HPS luminaries were damaged and required replacement with LED luminaries. A&E, Construction Labor, and materials further broke down the estimate, as seen in *Figure 1*. The final estimate indicated that the total cost of replacing the damaged HPS luminaries with LED luminaries would be \$ \$259,000,694.

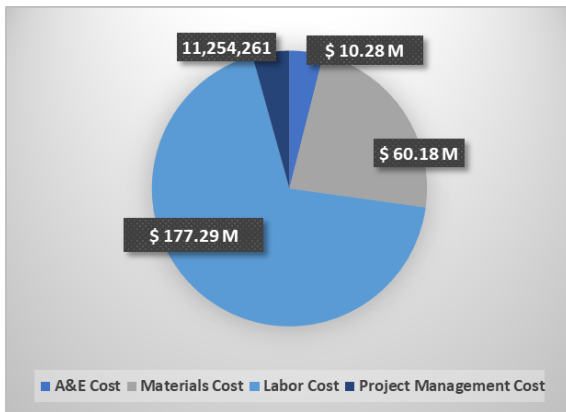


Figure 1
Main Categories Costs

SCOPE OF WORK

Once the estimate was developed and validated, the project team created a scope of work based on the estimate for scheduling an execution plan and budget validation. The scope of work outlines the tasks required to complete the project, including assessments, material procurement, construction

labor, and project management. These variables and categories already defined by previous steps will present how the plan will be. With a total inventory divided by zones, each zone has several luminaries to schedule its development to meet the deadline before 2030.

FORECAST

The team also calculated a forecast considering contractor capacity for completion before 2030 energy compliance. The forecast indicates that the project will be completed before the end of 2030, as required by the Puerto Rico Energy Public Policy Law No. 17. Table 1 presents a summary high-level of the scope of work and forecast results.

Table 1
High-Level San Juan Streetlight Scope of Work

San Juan Zones	80
Inventory	36863
% By Zone	70.0%
Inventory Assumed	26173
Daily Capacity	22
Start Date	Thursday, June 1, 2023
Finish Date	Wednesday, December 17, 2025
A&E +Mgmt. (Avg unit Costs)	\$279
A&E. Total Cost	\$10,284,829
Materials. (Avg unit Costs)	\$2,299.16
Materials Total	\$60,175,409
Labor (Avg unit Costs)	\$6,776.70
Labor Total Cost	\$177,286,195
Project Management Costs (6%)	\$11,254,261
TOTAL	\$259,000,694

QUALITY

The project team conducted a quality review of the assumptions, budget, and forecast to consider a second option with lower costs. The team explored alternative solutions to reduce the project's cost without compromising the work's quality. After a thorough review, the team determined that the

current estimate and forecast were the most feasible options for the project.

- **Assessment Costs:** Analyze the existing street lighting system, determine the type of fixtures needed for replacement, and plan the installation process. The assessment cost per zone is estimated to be \$93,345.32. The total assessment cost for the entire project is \$10,284,829. A monthly cost breakdown is performed using the scope of work considered the schedule deadline, as seen in Table 2.

Table 2
Monthly Forecast for Management and Assessments

Month	Management	Assessment
Jun-2023	\$72,853.35	\$1,214,222.49
Jul-2023	\$66,230.32	\$1,103,838.63
Aug-2023	\$76,164.87	\$1,269,414.43
Sep-2023	\$66,230.32	\$1,103,838.63
Oct-2023	\$72,853.35	\$1,214,222.49
Nov-2023	\$66,230.32	\$1,103,838.63
Dec-2023	\$59,607.29	\$993,454.77
Jan-2024	\$69,541.83	\$1,159,030.56
Feb-2024	\$218,022.68	\$809,951.65
Mar-2024	\$429,130.13	\$313,016.32
Apr-2024	\$562,171.95	\$0.00
May-2024	\$588,942.05	\$0.00
Jun-2024	\$535,401.86	\$0.00
Jul-2024	\$588,942.05	\$0.00
Aug-2024	\$588,942.05	\$0.00
Sep-2024	\$535,401.86	\$0.00
Oct-2024	\$615,712.14	\$0.00
Nov-2024	\$508,631.77	\$0.00
Dec-2024	\$508,631.77	\$0.00
Jan-2025	\$562,171.95	\$0.00
Feb-2025	\$535,401.86	\$0.00
Mar-2025	\$562,171.95	\$0.00
Apr-2025	\$562,171.95	\$0.00
May-2025	\$562,171.95	\$0.00
Jun-2025	\$562,171.95	\$0.00
Jul-2025	\$437,350.74	\$0.00
Aug-2025	\$374,912.10	\$0.00
Sep-2025	\$374,912.10	\$0.00
Oct-2025	\$214,329.52	\$0.00
Nov-2025	\$160,753.56	\$0.00
Dec-2025	\$116,099.79	\$0.00
TOTAL	\$11,254,261.41	\$10,284,828.61

- **Material costs:** Include the purchase of LED fixtures and related components. The material cost per zone is estimated to be \$672,494.18.

The total material cost for the entire project is \$60,175,409.

- **Labor costs:** Include the cost of hiring contractors for the installation process. The labor cost per zone is estimated to be \$2,041,153.71. The total labor cost for the entire project is \$177,286,195.
- **Project Management Costs:** Include any costs related to the management and administration of the project, overhead, and other administrative charges. It is assumed a 6%. The total management cost for the entire project is \$11,254,261.
- **Monthly Cost of Replacements:** A monthly cost breakdown is necessary to implement the project to ensure smooth progress. The monthly average cost breakdown by category is as follows:
 - Management \$363,040.69
 - Assessment \$1,028,482.86
 - Labor \$7,708,095.43
 - Materials \$2,616,322.12

FINAL FORECAST PLAN REPORT

The final forecast plan report includes monthly costs and a schedule before the end of 2030. The report outlines the tasks required to complete the project, including assessments, material procurement, construction labor, and project management. The report also includes the estimated cost of each task and the project's total cost. They must consider the number of crews and contractors required for assessments and labor to develop a forecast plan and schedule before 2030.

Project Management and Assessments

Project management will be applied an estimated 6% to cover all external and overhead costs to complete the project assessments. It will be required that a team of 3 contractors complete the assessments within two months. Each contractor will work 8 hours daily, five days a week, and assess an average of 22 daily luminaries. Therefore, the total number of assessments per day will be 66

luminaries. The total number of assessments required will be 26,173, which will take approximately ten months to complete.

Labor and materials

To complete the labor for the project requires a team of 4 crews to complete the labor starting on Feb-2024 and finish by Dec-2025. Each crew will work 8 hours daily, five days a week, replacing an average of 22 daily luminaries. Therefore, the total number of luminaries replaced per day will be 88 luminaries. The total number of luminaries to be replaced will be 26,163, which will take approximately 298 days to complete. This information was used to develop the estimates presented in Table 3.

Table 3
Monthly Forecast for Labor and Materials

Month	Labor	Materials
Feb-2024	\$2,823,759.66	\$958,455.29
Mar-2024	\$6,839,152.55	\$2,321,380.98
Apr-2024	\$9,369,532.58	\$3,180,255.82
May-2024	\$9,815,700.80	\$3,331,696.58
Jun-2024	\$8,923,364.36	\$3,028,815.07
Jul-2024	\$9,815,700.80	\$3,331,696.58
Aug-2024	\$9,815,700.80	\$3,331,696.58
Sep-2024	\$8,923,364.36	\$3,028,815.07
Oct-2024	\$10,261,869.02	\$3,483,137.33
Nov-2024	\$8,477,196.15	\$2,877,374.32
Dec-2024	\$8,477,196.15	\$2,877,374.32
Jan-2025	\$9,369,532.58	\$3,180,255.82
Feb-2025	\$8,923,364.36	\$3,028,815.07
Mar-2025	\$9,369,532.58	\$3,180,255.82
Apr-2025	\$9,369,532.58	\$3,180,255.82
May-2025	\$9,369,532.58	\$3,180,255.82
Jun-2025	\$9,369,532.58	\$3,180,255.82
Jul-2025	\$7,289,179.00	\$2,474,131.31
Aug-2025	\$6,248,535.07	\$2,120,910.50
Sep-2025	\$6,248,535.07	\$2,120,910.50
Oct-2025	\$3,572,158.75	\$1,212,480.83
Nov-2025	\$2,679,225.92	\$909,396.89
Dec-2025	\$1,934,996.50	\$656,786.65
TOTAL	\$177,286,194.81	\$60,175,408.78

CONCLUSION

The LED streetlight replacement program in San Juan Municipality is necessary to improve the energy infrastructure and reduce power consumption. Intending to replace damaged HPS

luminaires with LED luminaires before 2030 has been analyzed, and a forecast plan has been developed. The project focused on determining the monthly cost of the replacements and the contractor capacity required for completion within the specified timeframe. The project team conducted a thorough quality review, considering the assumptions, budget, and forecast.

During the review, an alternative solution with lower costs was explored to reduce the overall project expenses without compromising the quality of work. However, after careful consideration, the team determined that the current estimate and forecast provided the most feasible options for the project. By clearly understanding the monthly cost breakdown, the project can proceed smoothly, ensuring that resources and finances are appropriately allocated throughout the duration of the project. With the proposed forecast plan and cost analysis, the streetlight replacement project in San Juan municipality can effectively progress towards its objective of replacing HPS luminaires with LED luminaires before 2030, while providing a more energy-efficient and sustainable lighting infrastructure for the municipality.

REFERENCES

- [1] Whelan, M. "Sodium Lamp High Lumen Output at High Efficiency (1920 - Today)." Edison Tech Center, 2013, <http://edisontechcenter.org/SodiumLamps.html>.
- [2] LED VS High-Pressure Sodium (HPS) – Which Outdoor Lights Are Better? - RC Lighting. (2021, March 12). RC Lighting. <https://rclite.com/blog/led-vs-high-pressure-sodium-lights/>
- [3] "How Much Do the Street Lights Cost?" ZGSM, February 24, 2023, <https://www.zgsm-china.com/blog/how-much-do-the-street-lights-cost.html#how-much-does-it-cost-to-run-street-lights>.
- [4] "Community Streetlight Initiative." Progreso, February 7, 2023, <https://progresodelumapr.com/en/our-progress/community-streetlight-initiative/>.