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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.

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
- ✓ Long life +24,000 hours

Some disadvantages that we can mention are:

- * High consumption.
- * Environment Hazards due to chemical components.
- * Require other components for their functionality.

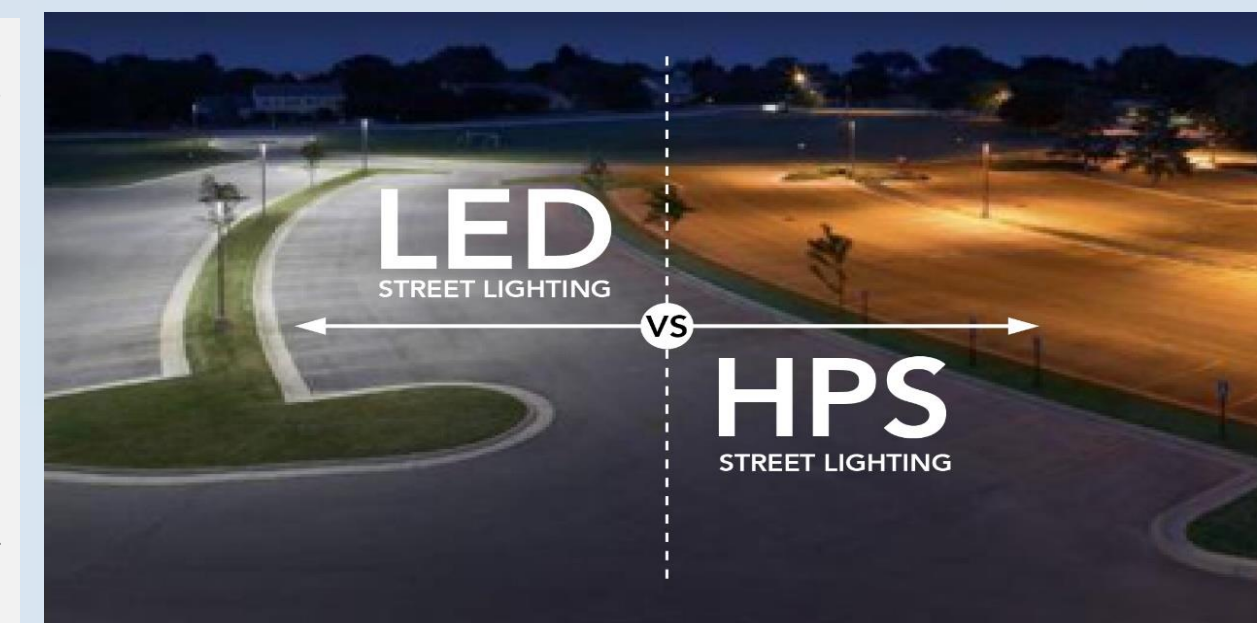
LED is a modern technology used for streetlights, parks, and exteriors, replacing HPS due to their advantages and better properties that will discuss later. Since 2013 was getting into the market, taking over faster but more expensive than the old tech. The way that works is when two electrodes react 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
- ✓ Up to 50,000 hours
- ✓ Green environment

Some disadvantages that can be mentioned are:

- * High costs.
- * Some LED streetlights can produce blinding glare

LED is a considerable energy saving with a 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:** LUMA historical data obtain the total quantity of luminaries in San Juan Municipality that it is the actual operator of this asset. Assumed the 70% damage, considering there are already LED streetlights without problems.

➤ **Estimate:** The project team developed an estimate with the final quantities, including assessments, material replacement, and management costs. This estimate based on the assumption that

70% of the existing luminaries. A&E, Construction Labor, and materials further broke down the estimate, as seen in *Figure 1*.

➤ **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.

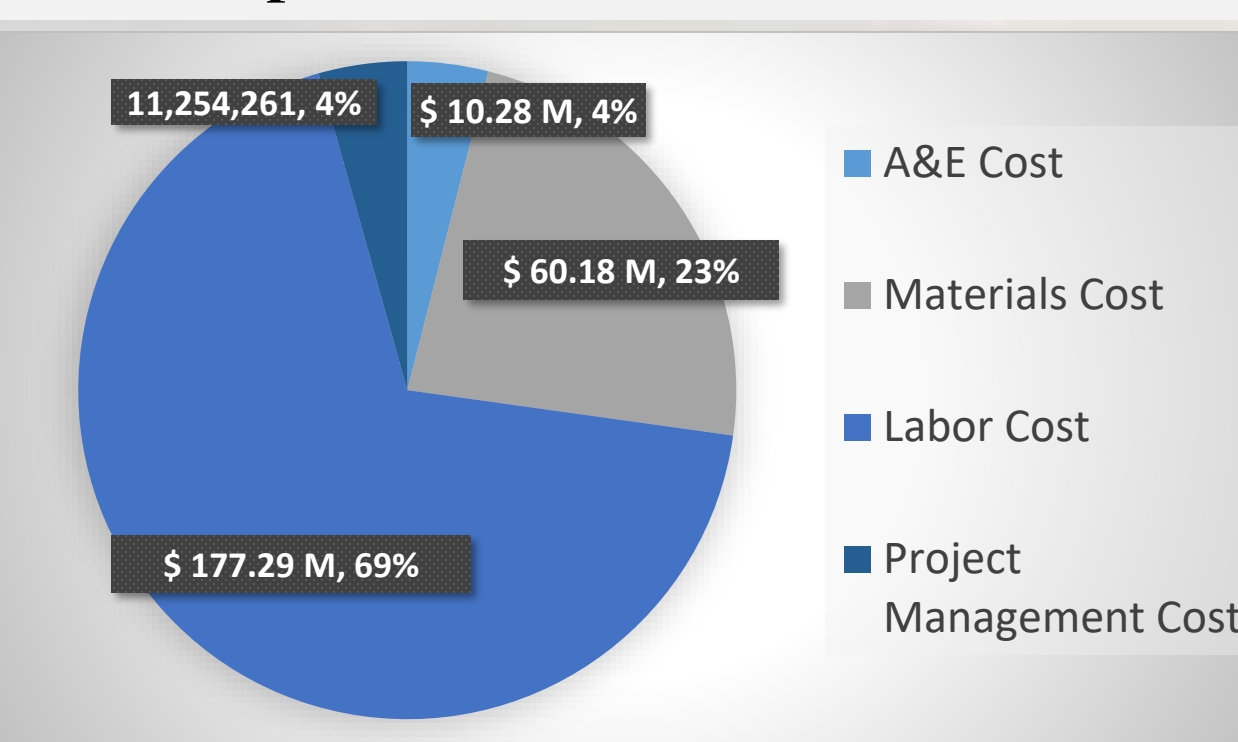


Figure 1: Main Categories Costs

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.

➤ **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. A monthly cost breakdown is performed using the scope of work considered the schedule deadline.

➤ **Final forecast plan report:** The final forecast plan report includes monthly costs and a schedule by the end of 2025, as seen in *Figure 2*. 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.

➤ Project management will be applied an estimated 6% to cover all external and overhead costs.

➤ Assessments will require a team of 3 contractors and assess an average of 66 daily luminaries. The total number of assessments which will take approximately ten months to complete.

➤ To complete the labor will require a team of 4 crews starting on Feb-2024 and finish by Dec-2025. Replacing an average of 88 daily luminaries. The total number of luminaries to be replaced, which will take approximately 298 days to complete. This information was used to develop the forecast presented in *Table 2*.

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	June 1, 2023
Finish Date	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

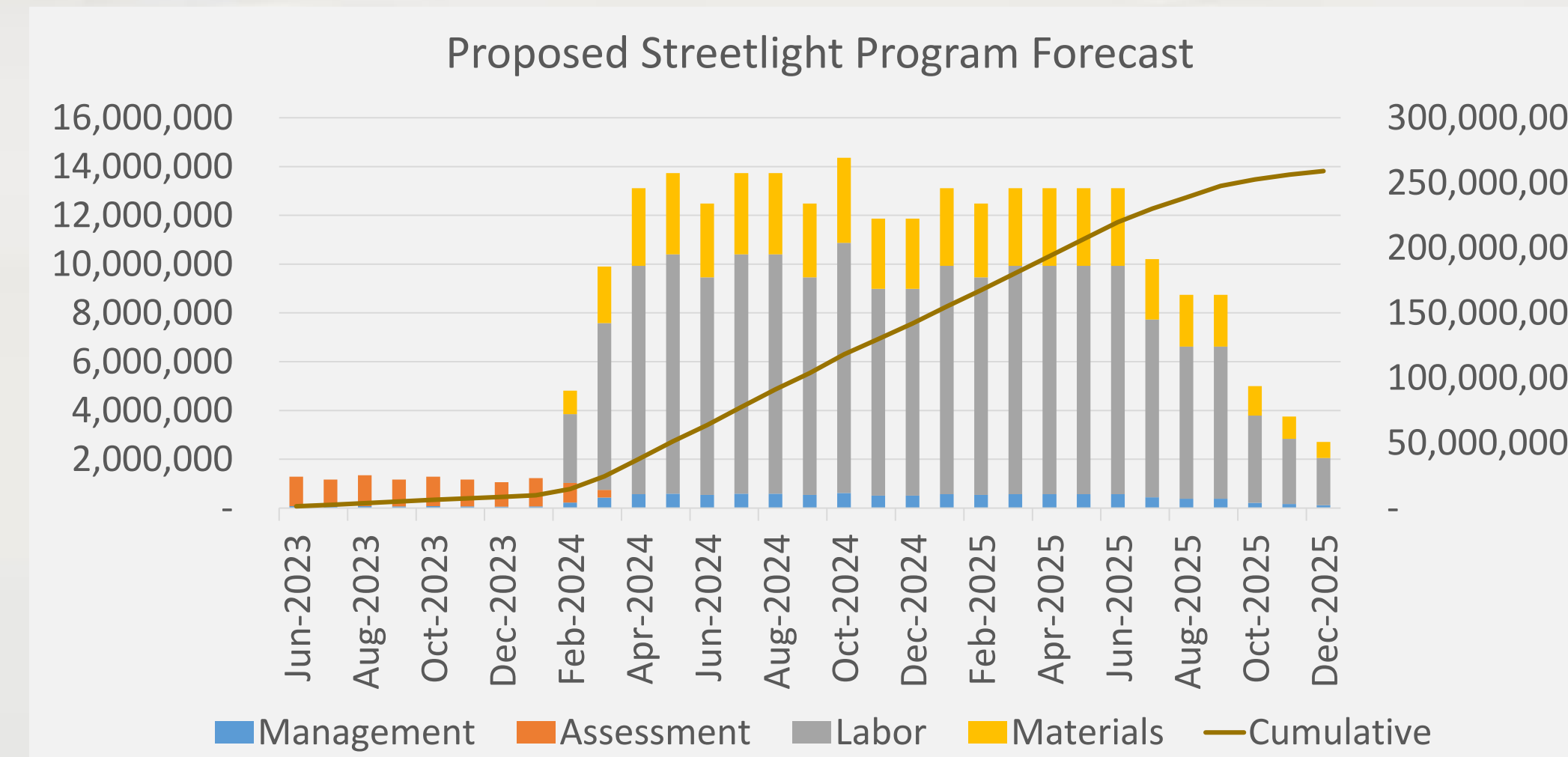


Figure 2: Monthly Forecast Costs

Table 2: Schedule Forecast Categories Costs

Month	Management	Assessment	Labor	Materials
Jun-2023	\$72,853.35	\$1,214,222.49	\$0.00	\$0.00
Jul-2023	\$66,230.32	\$1,103,838.63	\$0.00	\$0.00
Aug-2023	\$76,164.87	\$1,269,414.43	\$0.00	\$0.00
Sep-2023	\$66,230.32	\$1,103,838.63	\$0.00	\$0.00
Oct-2023	\$72,853.35	\$1,214,222.49	\$0.00	\$0.00
Nov-2023	\$66,230.32	\$1,103,838.63	\$0.00	\$0.00
Dec-2023	\$59,607.29	\$993,454.77	\$0.00	\$0.00
Jan-2024	\$69,541.83	\$1,159,030.56	\$0.00	\$0.00
Feb-2024	\$218,022.68	\$809,951.65	\$2,823,759.66	\$958,455.29
Mar-2024	\$429,130.13	\$313,016.32	\$6,839,152.55	\$2,321,380.98
Apr-2024	\$562,171.95	\$0.00	\$9,369,532.58	\$3,180,255.82
May-2024	\$588,942.05	\$0.00	\$9,815,700.80	\$3,331,696.58
Jun-2024	\$535,401.86	\$0.00	\$8,923,364.36	\$3,028,815.07
Jul-2024	\$588,942.05	\$0.00	\$9,815,700.80	\$3,331,696.58
Aug-2024	\$588,942.05	\$0.00	\$9,815,700.80	\$3,331,696.58
Sep-2024	\$535,401.86	\$0.00	\$8,923,364.36	\$3,028,815.07
Oct-2024	\$615,712.14	\$0.00	\$10,261,869.02	\$3,483,137.33
Nov-2024	\$508,631.77	\$0.00	\$8,477,196.15	\$2,877,374.32
Dec-2024	\$508,631.77	\$0.00	\$8,477,196.15	\$2,877,374.32
Jan-2025	\$562,171.95	\$0.00	\$9,369,532.58	\$3,180,255.82
Feb-2025	\$535,401.86	\$0.00	\$8,923,364.36	\$3,028,815.07
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May-2025	\$562,171.95	\$0.00	\$9,369,532.58	\$3,180,255.82
Jun-2025	\$562,171.95	\$0.00	\$9,369,532.58	\$3,180,255.82
Jul-2025	\$437,350.74	\$0.00	\$7,289,179.00	\$2,474,131.31
Aug-2025	\$374,912.10	\$0.00	\$6,248,535.07	\$2,120,910.50
Sep-2025	\$374,912.10	\$0.00	\$6,248,535.07	\$2,120,910.50
Oct-2025	\$214,329.52	\$0.00	\$3,572,158.75	\$1,212,480.83
Nov-2025	\$160,753.56	\$0.00	\$2,679,225.92	\$909,396.89
Dec-2025	\$116,099.79	\$0.00	\$1,934,996.50	\$656,786.65
TOTAL	\$11,254,261.41	\$10,284,828.61	\$177,286,194.81	\$60,175,408.78

Conclusions

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.

After a 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://rcelite.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>.