# LED STREET LIGHTING BEST PRACTICES

## Lessons Learned from the Pilot LED Municipal Streetlight and PLN Substation Retrofit Project (Pilot LED Project) in Indonesia

ASIAN DEVELOPMENT BANK

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April 2017

ASIAN DEVELOPMENT BANK

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org

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Printed in the Philippines.

ISBN 978-92-9257-771-1 (Print), 978-92-9257-772-8 (e-ISBN)
Publication Stock No. TIM168482
http://dx.doi.org/10.22617/TIM168482

Cataloging-In-Publication Data

Asian Development Bank.
LED street lighting best practices: Lessons learned from the pilot LED municipal streetlight and PLN substation retrofit project (pilot LED project) in Indonesia.
Mandaluyong City, Philippines: Asian Development Bank, 2016.

1. Energy. 2. Technology. 3. Roads and pavements. I. Asian Development Bank.



Notes:
In this publication, "$" refers to US dollars.
Corrigenda to ADB publications may be found at http://www.adb.org/publications/corrigenda

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# Acknowledgments

This report was prepared under two technical assistance grants administered by the Asian Development Bank (ADB): Java–Bali Electricity Distribution Performance Improvement Project (Grant 0198-INO) and Asia Energy Efficiency Accelerator – Street Lighting Pilot Projects (TA 8483-REG), financed under regional capacity development technical assistance and supported by the Government of the United Kingdom and the Clean Energy Fund under the Clean Energy Financing Partnership Facility.

The report was prepared by Thomas K. Dreessen (team leader) and My Ton (international lighting expert) for Econoler under the technical assistance grants. The work conducted by Econoler was under the technical supervision of Pradeep Tharakan (senior energy specialist [Climate Change], Energy Division, Southeast Asia Department, ADB) and Priyantha Wijiyatunga (principal energy specialist, Sector Advisory Service Division, Sustainable Development and Climate Change Department, ADB). Pil-Bae Song (consultant, ADB) served as the report's peer reviewer and Julie Casabianca (consultant, ADB) reviewed and helped guide the final preparation of the report.

The report team gratefully acknowledges the support provided by the personnel of the Directorate General of Electricity of Indonesia and the State Electricity Company (PLN), Director of Energy Conservation at the Ministry of Energy and Mineral Resources (MEMR) Farida Zed, former Director of Energy Conservation (MEMR) Maritje Hutapea, Semarang Mayor Hendrar Prihadi and Batang Mayor Yoyok Riyo Sudibyo, and their staff.

# Abbreviations

| | |
|---|---|
| ADB | Asian Development Bank |
| ANSI | American National Standards Institute |
| CIE | *Commission Internationale de l'Eclairage* (International Commission on Illumination) |
| DAK | *dana alokasi khusus* (specific allocation fund) |
| DAU | *dana alokasi umum* (general allocation fund) |
| ESCO | energy services company |
| GI | *gardu induk* (substation) |
| GITET | *gardu induk tegangan ekstra tinggi* (extra high-voltage substation) |
| HID | high-intensity discharge (lamps) |
| HPS or HPSV | high-pressure sodium or high-pressure sodium vapor (lamps) |
| IEC | International Electrotechnical Commission |
| IES or IESNA | Illuminating Engineering Society of North America |
| LED | light-emitting diode |
| LPS or LPSV | low-pressure sodium or low-pressure sodium vapor (lamps) |
| MEMR | Ministry of Energy and Mineral Resources |
| MRV | measurement, reporting, and verification |
| MSLP | Municipal Street Lighting Program |
| PEA | Provincial Electricity Authority (Thailand) |
| PLN | *PT Perusahaan Listrik Negara* (State Electricity Company) |
| Pilot LED Project | LED Municipal Streetlight and PLN Substation Retrofit Project |
| PPP | public–private partnership |
| SNI | *Standar Nasional Indonesia* (Indonesian National Standard) |
| PMK | *peraturan menteri keuangan* (Ministry of Finance Regulation) |

# Executive Summary

Street and public area lighting is a key service provided by local and municipal governments. Good lighting at night is essential for road safety, personal safety, and urban ambience, and it indirectly prevents crime and provides security of properties. Well-lit streets also boost economic opportunities by expanding the hours of commercial activity after dark.

Providing street and public lighting is one of the most expensive responsibilities of a municipality and can account for up to 38% of energy consumption and greenhouse gas emissions in some cities. New energy-efficient technologies and design can cut street lighting costs dramatically (up to 60%) and reduce greenhouse gas emissions by the same amount. These savings can reduce the need for new generating plants and redeploy scarce capital to delivering energy access to populations in remote areas. The savings also allow municipalities to expand street lighting coverage to additional areas that include low-income and other underserved areas.

With the exception of a few areas and small highway sections, most municipal street lighting systems throughout Indonesia are outdated, use inefficient technologies, and are poorly designed and maintained, resulting in high energy and maintenance costs that account for a significant portion of a municipality's operating budget. This is due to a number of reasons that include:

- The current requirement for governments to procure the lowest up-front cost products does not take into account the life-cycle cost, resulting in the purchase and use of older and less-efficient technologies.
- Lack of knowledge, standards, testing facilities, and measurement equipment applicable to the new and energy-efficient light-emitting diode (LED) technology.
- Lack of knowledge of best practices in street lighting installation, maintenance, and the measurement, reporting, and verification of lighting system performance.
- Limited options for the financing and scale-up of street lighting programs.
- A nascent market for LED technologies.

Recognizing the opportunity to provide more efficient street lighting in Indonesia, the Asian Development Bank (ADB), the state-owned utility PT Perusahaan Listrik Negara (PLN), and the Ministry of Energy and Mineral Resources (MEMR) collaborated on the implementation of a pilot LED Municipal Streetlight and PLN Substation Retrofit Project (Pilot LED Project). The objective of the Pilot LED Project was to demonstrate reductions in the peak electricity demand in select municipalities and pilot PLN substations by focusing on demand side management through street lamp retrofits using the relatively new energy-efficient LED technology.

With a view toward scaling up the efforts of the Pilot LED Project and supporting larger energy efficiency projects in municipalities throughout Indonesia, this report aims to describe lessons learned during the implementation of the Pilot LED Project, identify possible financing options for future municipal street lighting projects, and offer technical and policy recommendations.

The Pilot LED Project was successful in demonstrating significant savings and in developing new specifications for LED luminaires that focused on luminaire performance, quality of delivered illumination, and vendor qualifications. The new specifications were localized from international best practices, and then used for the procurement and retrofit of 1,439 LEDs in two municipalities in Central Java as well as several PLN power generating and substation facilities in West Java.

Table E1 contains a summary of the luminaires procured and installed as part of the Pilot LED Project in each of the pilot municipalities and PLN facilities.

### Table E1: LED Luminaire Installation Locations and Quantities

| Installation Locations - LED Luminaires | Quantity |
|---|---|
| Batang | 257 |
| Semarang | 259 |
| **Total Municipalities** | **516** |
| PLN substation and power generating facilities | 923 |
| **Total LED Pilot Project** | **1,439** |

LED = light-emitting diode.

Source: Authors' calculations.

The Pilot LED Project resulted in significant energy reductions that were measured and verified for both municipalities and the PLN facilities. The post-retrofit meter readings in Table E2 show an average energy savings for both municipalities of 50%, with Batang realizing an average 59% savings and Semarang realizing an average 44% savings. Energy savings at PLN's Cilegon generation station and Gardu Induk substations were measured at over 44%.

### Table E2: Measured Energy Savings in Batang and Semarang

| | Baseline | Measured | |
|---|---|---|---|
| | kVA | kVA | Savings |
| **Batang** | 4.236 | 1.749 | 59% |
| | 2.898 | 1.303 | 55% |
| | 3.160 | 0.952 | 70% |
| | 1.651 | 0.803 | 51% |
| | 1.678 | 0.733 | 56% |
| **Total Batang** | **13.623** | **5.540** | **59%** |
| **Semarang** | 2.678 | 1.496 | 44% |
| | 4.274 | 2.207 | 48% |
| | 7.029 | 3.386 | 52% |
| | 2.204 | 1.673 | 24% |
| | 3.582 | 2.280 | 36% |
| **Total Semarang** | **19.765** | **11.042** | **44%** |
| **Total Municipalities** | 33.388 | 16.582 | 50% |

kVA = kilovolt-ampere.

Source: Authors' calculations.

The measured energy savings correlate to an estimated investment payback of 5 years for Batang and 10 years for Semarang. Adding in the cost savings from lower maintenance and replacement costs attributable to the longer lifetime of LEDs, the payback periods are reduced to 3.6 years for Batang and 7.0 years for Semarang. The significantly longer payback period for Semarang was due to the increased cost of LED lamps needed to meet the city's abnormally high light levels desired and the addition of a control technology in the lamps.

**Figure E1: Lighting Conditions at Cilegon Substation Before and After the LED Retrofit**


LED = light-emitting diode.

Source: Authors' photographs.

In addition, the Pilot LED Project found that, for virtually all locations, the LED retrofit provided similar or improved average illumination levels and light distribution, and it also delivered more light to previously dark areas. The improved lighting is illustrated in Figure E1 pre- and post-LED retrofit pictures at a PLN Substation.

For both municipalities and PLN's power substations, the Pilot LED Project provided an opportunity to see firsthand the potential benefits and challenges of implementing the new LED technology, as well as key lessons learned. Significant challenges and recommendations follow.

## 1. Ensure Electric Bill is Based on Actual Consumption

The Pilot LED Project identified a critical national barrier to LED implementation: Municipalities are often not willing or able to implement LED retrofits because a significant portion of the generated electricity savings will not be realized through reduced operating costs. This is due to the fact that PLN, in many cases, does not bill municipalities for street lighting based on actual electricity consumed, but rather on a flat fee (lump sum) or other bases which are not related to actual electricity consumed, even where PLN meters are installed. It is imperative that PLN provide actual kilowatt-hour consumption in a transparent and verifiable manner so that municipalities are able to realize the energy cost reductions needed to finance citywide LED retrofits with debt or with energy services companies (ESCOs) on a paid-from-savings basis.

The recommended short-term solution is for PLN to have meters on all municipal streetlights that are read monthly and that can be verified by the municipalities, and then bill the municipality based on actual kilowatt-hours consumed. The long-term solution is for PLN to install smart metering with open access to all municipalities.

## 2. Increase Technical Knowledge and Capacity

The limited knowledge of LEDs and capacity to retrofit, operate, and maintain LEDs in most municipalities create an unwillingness to retrofit city streetlights. They also increase the chance that any completed LED retrofits will include inferior products or a design that delivers far less savings and lighting quality than possible.

The recommended solution includes the development of a national standard on street lighting that addresses LED technology and incorporates the best practices and lessons learned in this report and other donor-funded street lighting programs. The Ministry of Transportation of Indonesia is currently drafting a regulation on street lighting with ADB support. In addition, the implementation of multiple demonstration LED projects with different retrofit and financing structures and a nationwide capacity-building program are recommended to increase understanding and build capacity within municipalities.

## 3. Increase Opportunities for Project-Based Financing

Municipalities do not have sufficient budgets nor access to financing for citywide LED retrofit programs. Project-based financing is needed to enable financial institutions and ESCOs to finance retrofit programs for municipalities from long-term realized savings. One of the barriers for municipalities is the difficulty to make multiyear payments. This barrier has been addressed in Presidential Regulation No. 38/2015 by specifying that energy conservation is deemed an infrastructure project under the public–private partnership (PPP) model, which means municipalities can use the availability payment scheme[1] to fund LED retrofits with the private sector (i.e., ESCOs or vendors). However, this Presidential Regulation needs to be incorporated into a regulation that the municipalities can apply in their implementation.

New financial products need to be developed that allow banks and third-party entities like ESCOs to provide the needed long-term financing such as a national credit guarantee to back up payments by municipalities for a municipal street lighting program, as well as an energy savings insurance product to guarantee the savings on municipal street lighting programs to finance the capital cost.

In addition, a national energy efficiency finance team needs to be established, trained with experienced experts, and made available to municipalities to develop LED savings-based projects and related loan structures, perform risk assessments, and manage and/or evaluate the technical analyses that include investment grade audits.

[1] See Appendix 2 for an overview of the availability payment scheme.

## 4. Access to Energy Services Companies

ESCOs can be major contributors to scaling up the implementation of LED street lighting retrofits in municipalities by funding up-front costs and being repaid by the savings. However, municipalities and other government agencies in Indonesia experience the following barriers to accessing ESCO services, common to many governments in the world:

- **Multiyear contracts.** Presidential Regulation No. 38/2015 has introduced the capability for governments to enter into contracts over multiple years. However, this needs to be formalized into new regulations that specifically apply to ESCOs.
- **Procurement procedures.** The government's procurement procedures are designed to purchase equipment and services on a low-cost, competitive basis, which requires detailed specifications of the equipment and services being purchased to be identified upfront to ensure all bids are evaluated on the same basis. However, this approach is not viable for acquiring energy efficiency projects from ESCOs under long-term paid-from-savings contracts.
- **Budget disincentive.** The energy budget for government-owned facilities is typically allocated from a "general fund" specific for the governmental agency responsible to operate the applicable facility. The annual budgeted amount is usually based on the previous year's actual costs and is, therefore, reduced when an energy efficiency project (like an LED retrofit) creates savings, thus leaving no funding available to finance the project.

The issuance of a new ESCO regulation (ESDM No. 14 of 2016) on 8 June 2016 provides definitions and guidelines for ESCO services. However, further regulation is still required to allow governments to access ESCO services on a paid-from-savings basis.

# Introduction

Street and public area lighting is a key service provided by local and municipal governments. Good lighting at night is essential for road safety, personal safety, and urban ambience, and it indirectly prevents crime and provides security of properties. Well-lit streets also boost economic opportunities by expanding the hours of commercial activity after dark.

As noted in *Energy Efficient Street Lighting Guidelines* by the United States Agency for International Development in India (USAID India) and the Indian Bureau of Energy Efficiency, "[s]treet lighting is a particularly critical concern for public authorities in developing countries because of its strategic importance for economic and social stability."[1] Quite often, as in Indonesia, street lighting is poorly designed, is inadequately maintained, and uses obsolete lighting technology, thus consuming larger amounts of energy and financial resources than necessary while failing to provide high-quality lighting (footnote 1). Municipalities in Indonesia are also facing recent increases in the electricity tariff and looking for ways to implement more energy and cost-efficient street lighting, while improving the delivered level of service.

Providing street and public lighting is one of the most expensive responsibilities of a municipality and can account for up to 38% of energy consumption and subsequent greenhouse gas emissions in some cities.[2] New energy-efficient technologies and design can cut street lighting costs dramatically (often by 25%–60%) and reduce greenhouse gas emissions by the same amount (footnote 1). These savings can reduce the need for new generating plants and redeploy scarce capital to delivering energy access to populations in remote areas. The savings can also allow municipalities to expand street lighting coverage to additional areas that include low-income and other underserved areas.

Recognizing the opportunity to provide more efficient street lighting in Indonesia, the Asian Development Bank (ADB), PT Perusahaan Listrik Negara (PLN), and the Ministry of Energy and Mineral Resources (MEMR) collaborated on the implementation of a pilot LED Municipal Streetlight and PLN Substation Retrofit Project (Pilot LED Project). The objective of the Pilot LED Project was to demonstrate reductions in the peak electricity demand in select municipalities and pilot PLN substations by focusing on demand side management through street lamp retrofits using the relatively new energy-efficient light-emitting diode (LED) technology.

Based on the activities and results of the Pilot LED Project, the purpose of this report is to

- document the current state of Indonesia's street and area lighting in municipalities and utility power stations (as typified by PLN's facilities);
- document the process and specifications used to implement the Pilot LED Project—from specification development to procurement, installation, commissioning, and measurement, reporting, and verification (MRV) procedures;
- describe "lessons learned" during the implementation of the Pilot LED Project;
- identify "best practices" recommended for future use by municipalities in Indonesia and possible inclusion in a new national standard for LED street lighting; and
- identify possible financing options for municipalities in Indonesia to fund future street lighting projects.

[1] United States Agency for International Development (USAID) India and Government of India, Bureau of Energy Efficiency (BEE). 2010. *Energy Efficient Street Lighting Guidelines*. Delhi.

[2] New York City Global Partners (NYCGP) 2009. *Best Practice: LED Street Lighting Energy and Efficiency Program.* Los Angeles. Quoted in Footnote 1, p1.

# Pilot LED Retrofit Project

The main objectives for the Pilot LED Project in Indonesia were to

- develop replicable pilot projects that incorporate international best practices, including procurement, light source technology, luminaire design and application, installation, operation and maintenance, and MRV practices, in order to achieve best-in-class energy-efficient and quality lighting; and
- document the relevant processes and lessons learned so that they can be widely shared.

## ADB Support

ADB provided technical assistance funding for the Pilot LED Project that included the following:

- $200,000 from its regional capacity development technical assistance (RCDTA) project Asia Energy Efficiency Accelerator for (i) LED street lighting lamps installed by two pilot cities, Batang and Semarang; and (ii) new metering equipment to Batang, Semarang, and MEMR for their future measuring of street lighting power consumption and lumen levels. The RCDTA funding was provided by the Government of the United Kingdom and the Clean Energy Fund under the Clean Energy Financing Partnership Facility.
- $400,000 for vendor-installed LED lamps at PLN locations through the grant Java–Bali Electricity Distribution Performance Improvement Project, plus $640,000 for funding to Econoler (the consultant selected by ADB) to implement the Pilot LED Project under a contract with PLN in the two pilot cities (Batang and Semarang) and several of PLN's power stations, with the aim that these pilot sites could become demonstration street lighting projects for replication throughout Indonesia.

## Challenges to the Pilot LED Project

From the outset, the project team recognized that the Pilot LED Project would face the following challenges:

- lack of knowledge about LED technology, plus limited capacity and resources for managing, operating, and retrofitting street lighting, including installation, maintenance, and MRV of lighting system performance;
- restrictions in municipal government procurement processes that favor a least-cost approach, rather than a life-cycle cost approach;
- differences in the streetlight inventories of municipalities and what is reported to PLN (e.g., unregistered or undocumented lamps);
- differences in the amount of street lighting electricity billed to municipalities by PLN and the actual kilowatt-hours consumed;
- lack of coordination between departments of municipalities in charge of different aspects of street lighting;
- lack of access to financing by municipalities to scale up the project; and
- undeveloped or underdeveloped market for LED streetlights and lighting controls.

# Overview of Street Lighting

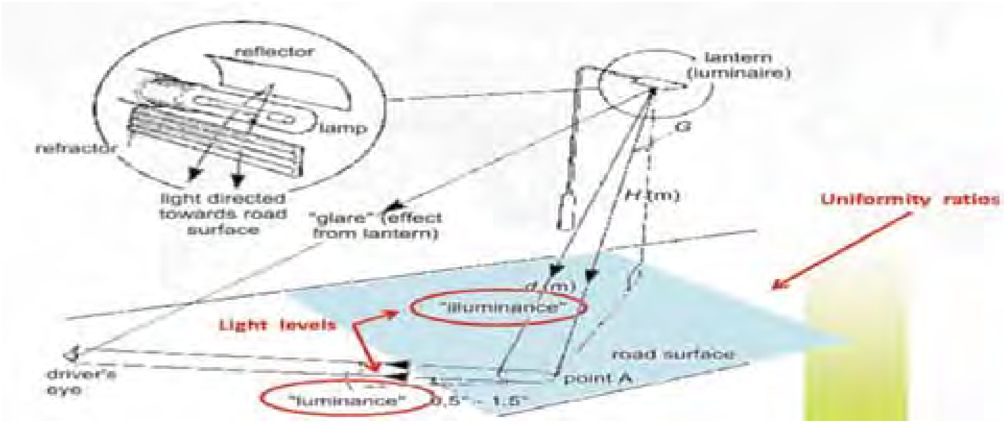
## Illumination and Luminaire Standards

To ensure that street lighting provides effective nighttime visibility to reduce road accidents and increase personal safety, a number of international standards have been developed. This section reviews illumination standards that cover the level and characteristics of delivered light and luminaire performance.

Internationally, there are two main bodies responsible for developing and setting standards for baseline street lighting quality: the International Commission on Illumination (CIE) and the Illuminating Engineering Society of North America (IES or IESNA). The standards that address street illumination include CIE 115 – Lighting of Roads for Motor and Pedestrian Traffic, CIE 180 – Road Transport Lighting for Developing Countries, and American National Standards Institute (ANSI)/IESNA RP-8 – American National Standard Practice for Roadway Lighting.

These standards emphasize two important street lighting criteria: (i) minimum average light levels, which ensure a minimum useful light at the street surface level; and (ii) uniformity ratios, which ensure even light distribution suitable for a particular area or road application, such as an intersection, arterial road, or highway. Figure 1 illustrates these two main street lighting criteria.

### Figure 1: Street Lighting: Key Criteria




Source: International Commission on Illumination (CIE). 2007. *Technical Report 180:2007: Road Transport Lighting for Developing Countries.* Vienna: CIE. Quoted in S. Phon-Amnuaisuk. 2012. *Energy Efficient Street Lighting Programs: Case Studies from Thailand and Tonga.* Pacific Power Association 21st Annual Conference and 6th Engineer's Workshop. Vanuatu. 17 July.

In addition to illumination standards, there are standards for street and area luminaires governing their performance, reliability, and electrical and mechanical characteristics. Luminaire standards are the purview of a number of international and regional standards bodies, including CIE, IES/IESNA, the International Electrotechnical Commission (IEC), the American National Standards Institute, and others.

Some of the key performance parameters for a street or area luminaire include

- light output (typically reported as the total output of the lamp, measured in lumen);
- energy efficiency (generally measured in lumen per watt, or lm/W);
- color rendering (ability to distinguish a standard color palette as illuminated by the light source);
- light distribution pattern (the pattern of light cast by the luminaire);
- color temperature of the light source;
- photometric performance (amount and direction of light emission from the luminaire);
- luminaire efficacy (ratio of light produced by source versus emitted from the luminaire);
- lifetime and warranty (both of the lamp and ballast or driver);
- lumen retention (how much the light source dims over time);
- up-light, glare, wet location rating, and electrical and mechanical fitness; and
- others, such as safety, compatibility with controls, and mounting methods.

These parameters help to define the performance and reliability of the luminaires, as well as their impacts on the immediate surrounding, such as the amount of light that “trespasses” into homes or reflects upward and results in light pollution (“sky glow”).

## Traditional Lamp Technology

Most current and past generations of streetlights that are not LED-based rely on a number of key light source technologies. High-intensity discharge (HID) lamp technologies are the most prevalent and include high-pressure sodium vapor (HPS or HPSV), low-pressure sodium vapor (LPS or LPSV), metal halide and ceramic metal halide, and mercury vapor. Other gas-discharge technologies used for street lighting include induction lamps and linear and compact fluorescent lamps.

Table 1 shows the characteristics of streetlight lamps typically used.

HPSV or HPS lamps are very energy-efficient and have a long useful life, but produce a yellowish light with poor color-rendering properties, and have an unappealing long restrike and warm-up period. Metal halide and ceramic metal halide lamps are also energy-efficient and, because they produce a white light, are the most frequently used alternative to HPSV in new installations due to their better color rendering. However, these lamps tend to have a shorter lamp life (some below 10,000 hours) and poor lumen level retention over the lamp life. Recent developments have improved these areas, but the improved lamps are presently limited in supply and more expensive than traditional metal halide lamps. Mercury vapor lamps are the least efficient of the HID lamps and produce an orange light, with very poor color characteristics and poor lumen retention (footnote 1).

### Table 1: Typical Streetlight Lamp Characteristics

| Type of Lamp | Luminous Efficacy (lm/W) | Color Rendering Properties | Lamp Life (hrs) | Remarks |
|---|---|---|---|---|
| High-pressure mercury vapor (MV) | 35–65 | Fair | 10,000–15,000 | High energy use, poor lamp life |
| Metal halide (MH) | 70–130 | Excellent | 8,000–12,000 | High luminous efficacy, poor lamp life |
| High-pressure sodium vapor (HPSV) | 50–150 | Fair | 15,000–24,000 | Energy-efficient, poor color rendering |
| Low-pressure sodium vapor | 100–190 | Very poor | 18,000–24,000 | Energy-efficient, very poor color rendering |
| Low-pressure mercury fluorescent tubular lamp (T12 and T8) | 30–90 | Good | 5,000–10,000 | Poor lamp life, medium-energy use; only available in low wattages |
| Energy-efficient fluorescent tubular lamp (T5) | 100–120 | Very good | 15,000–20,000 | Energy-efficient, long lamp life; only available in low wattages |
| Light-emitting diode (LED) | 70–160 | Good | 40,000–90,000 | High energy savings, low maintenance, long life, no mercury; high investment cost, nascent technology |

hrs = hours, lm/W = lumen per watt.

Source: USAID India and Government of India, Bureau of Energy Efficiency (BEE). 2010. *Energy Efficient Street Lighting Guidelines.* Delhi.

## LED Technology

In the past, street lighting primarily included variants of HID technology, which provided the highest efficacy levels and the longest service life available. Today, solid-state lighting or LED technology has developed to the point where it can deliver significant energy savings and useful life advantages over traditional HID technology, when the applicable products are selected and properly deployed.

There are many advantages to using LEDs for public street lighting, including greater energy efficiency, long life, and better quality light. The Climate Group, an international nonprofit organization, conducted a study of 12 cities which had implemented LED lighting with smart system controls. On average, the cities reported a 53% savings from the increase in lumens per watt produced by LEDs compared with the older technologies.[3] Properly manufactured LEDs can provide more than double the useful life of current technologies and a more even light with better average illumination levels and uniformity.

Additional advantages of LED technology include the following (footnote 1):

- contains no toxic chemicals (e.g., mercury);
- no warm-up required (no time delay to reach optimum brightness levels);
- no production of ultraviolet light (which is what attracts insects);

[3] S. de Albuquerque and C. Saxon, eds. 2012. *Lighting the Clean Revolution: The Rise of LEDs and What It Means for Cities.* London: The Climate Group. https://www.theclimategroup.org/sites/default/files/archive/files/LED_report_web1.pdf

- useful for directing light on specific areas, since LED produces "directional" light, rather than a diffused glow;
- can be dimmed (unlike compact fluorescent lamps), allowing for flexibility in controlling light levels; and
- high color rendering index, providing bright, true colors during nighttime hours.

However, there are challenges with LED street lighting, including economic, technical, and application-related challenges. While the increased efficiency and useful life of LEDs reduce energy and maintenance costs, the up-front cost is much higher than that of traditional technologies. This barrier can be overcome by emphasizing the life-cycle energy and maintenance cost savings that LEDs can provide over their 10-year or longer lifetime.

As LED is a new technology, challenges remain related to quality, premature failure, poor design, and poor application design, especially from low-cost manufacturers and unqualified contractors. The technical challenges can be overcome by applying a rigorous set of performance and quality specification requirements in the procurement phase that address testing and lifetime evaluation of products. The primary application design challenges relate to color appearance and lighting uniformity and distribution, which define the characteristics of good lighting design. The most viable way to address application challenges is to set up pilot projects that can educate users and policy makers on the advantages of installing new LED technology versus traditional lighting technologies, and apply applicable product and procurement standards that ensure optimum performance.

## Configurations

The standard streetlight configuration uses a "cobra head" fixture (or luminaire), containing ballast, lamp, reflector, and dispersion lens, as shown in Figure 2. For area or public lighting, the available luminaires range from cobra head types to square-shaped "parking lot" types and "post top" models. On–off switching is accomplished either by a photocell or manual switching via a control panel. Where appropriate, the addition of electronic controls for remote lighting operation (as opposed to timer or photocell operation) may increase costs, but can increase luminaire functionality, and has the potential to further reduce energy use.

**Figure 2: Cobra Head (with Photocell), Parking Lot, and Post Top Fixtures**

Source: Various vendor brochures.

# Current Street Lighting Conditions in Indonesia

With the exception of a few areas and small highway sections, most municipal street lighting systems throughout Indonesia are outdated, use inefficient technologies, and are poorly designed and maintained, resulting in higher-than-required energy and maintenance costs that account for a significant portion of a municipality's operating budget. This is due to a number of reasons, including the following:

- current government procurement regulations that require the purchase of lowest up-front cost products, not taking into account the life-cycle cost and resulting in use of older or less-efficient, lower initial-cost technologies;
- lack of applicable standards;
- lack of knowledge of best practices; and
- limited options for the financing and scale-up of street lighting programs.

This section will address available Indonesian street and area lighting standards, current lamps and streetlight conditions, operational challenges, and options for financing energy-efficient street lighting programs.

## Standards

Indonesia has implemented several national standards related to the design and implementation of streetlights, collectively referred to as Standar Nasional Indonesia (SNI), which are summarized in Appendix 1. SNI defines minimum light levels based on different street classes, such as main or primary road, arterial road, and neighborhood street, for both national and urban road lighting. SNI also includes some standards covering luminaires and how streets should be illuminated by the lighting systems, but it does not address the components of such a system, luminaire performance, nor how illumination levels can be met and maintained. Municipalities typically add parameters for their local needs, including luminaire performance specifications and control requirements.

The current SNI standards for street lighting in Indonesia are not applicable to LED technology; therefore, a new set of LED luminaire specifications should be created for the Pilot LED Project procurement process (see *Developing Standards*).

**Lighting standards for utility facilities.** No national standards were identified for street or other area lighting at power-generating and substation facilities operated by PLN in Indonesia. Based on the observed lighting conditions at the locations in the Pilot LED Project, it was concluded that, even if standards did exist, they are currently not being uniformly applied.

## Type of Lamps Used

Based on observations and surveys of the locations in the Pilot LED Project, street lighting in Indonesia generally uses the typical variety of previous-generation HID lamp technologies that include HPS, LPS, metal halide, and mercury vapor. Linear and compact fluorescent lamps are also used. For the two pilot municipalities, most of the areas designated for retrofit were using HPS lamps. As in global markets, the standard street lighting configuration uses a "cobra head" fixture (or luminaire), containing a ballast, lamp, reflector, and dispersion lens. Linear and compact fluorescent lamps typically have their own protective covers and/or lenses, depending on the application.

LED technology for street lighting is not commonly used in Indonesian municipalities because of its much higher up-front cost compared with that of less-efficient alternatives. Often, current government procurement procedures require municipalities to select the lowest up-front cost products, ruling out LEDs. However, LEDs can easily be justified when viewed on a life-cycle cost basis.

## Illuminance and Uniformity Level

As mentioned, well-designed street lighting is defined by minimum illuminance levels (minimum level of light on the street surface) and uniformity ratios (evenness of light distribution).[4] With most conventional street lighting, the light is not well-dispersed and focuses mostly under the lamp itself, thus creating dark spots between each light pole (a phenomenon known as "hot spots"). This condition significantly reduces both the distance and object perception of drivers. This is especially acute in areas where light poles are either too far apart or are not mounted at a sufficient height. This situation is exacerbated where luminaires are not of the correct distribution type, or have aged to the point where the reflective lens or the covering lens (or both) no longer properly reflect or distribute the light.

It was observed in several Indonesian municipalities that well-maintained and properly positioned luminaires can provide relatively good illuminance levels immediately beneath the luminaires. However, during baseline measurements in the Pilot LED Project, it was noted that the dispersion pattern of existing lamps varies significantly, contributing to poor uniformity. The uniformity ratio can also be poor due to incorrect luminaire and technology choices.

A lighting system with a better uniformity ratio can effectively provide better-quality lighting with less energy consumption.[5] The uniformity ratio of a sample measurement of streets in Java, Indonesia (0.04) does not meet the national standard uniformity ratio of 0.40, and it is believed that the sample measurement may be typical in many areas in Indonesia. While the average illumination level of the sample (27.0 lux) can be adequate for a number of tasks, the actual lighting condition is quite poor due to the fact that the illumination levels range from 1.1 lux to 76.2 lux. This wide illumination range and the calculated uniformity ratio show that there is great unevenness in the illumination levels, with extremely bright and dark areas. Therefore, while many municipalities may complain that the lighting in their streets is insufficient, it may not be due to insufficient illuminance from the lamp, but rather due to poor distribution of the light (as represented by the uniformity ratio).

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[4] An even distribution of light at the street surface minimizes the need for the human eyes to constantly adjust to varying levels of light, thereby improving distance vision and object perception.

[5] It has been documented by the United States Department of Energy GATEWAY Demonstration programs that users perceive LED street lighting to be brighter due to better uniformity and a whiter light (compared with HPS), even if the average illumination levels may be lower.

## Operational Challenges for Municipalities in Indonesia

### Payment to PLN

There are two mechanisms under which the local government pays PLN for its electricity:

(i) **Consumption estimated by PLN and billed as a lump sum.** In this mechanism, PLN and the local government agree on a fixed lump-sum payment based on the estimated operating hours and total wattage to be consumed by the streetlights. The local government subsequently pays the lump-sum amount, even if some of the lights are not working and without verifying the actual usage.

(ii) **Consumption based on metered data.** For streetlights already metered by PLN, the payment is based on the usage read by the PLN meters.

Currently, only a few cities have their street lighting fully metered by PLN. In fact, most pay PLN a fixed lump sum for each pole, which has become a major source of dispute because most municipalities believe they are paying PLN more than what they should for the actual electricity they consume. However, metering often cannot be (or is not) accommodated by PLN due to unresolved issues regarding ownership and payment for illegal streetlights (see *Unregistered Streetlights*).

It was noted in Batang and Semarang that, even where municipal streetlights are metered by PLN, the amount billed by PLN was not based on actual kilowatt-hour consumption.

### Unregistered Streetlights

All streetlights in Indonesia are typically assets owned by the local government, while the streetlight connections and meters are owned by (and registered with) PLN. A registered streetlight will have a circuit or meter ID number, pole address, and other identifying information.

It was noted that, in many municipalities, not all of the streetlights are legally connected, resulting in differences between the local government's inventory and PLN's inventory. This can occur when the local community has installed streetlights without clearing the installation with the local government or PLN. These differences need to be remedied so that PLN can properly bill municipalities for their actual kilowatt-hour consumption or can use a lump-sum payment method that more closely reflects actual kilowatt-hour consumption in areas where it is unable to meter all of the streetlights (see *Payment to PLN*).

To obtain financing for a LED street lighting retrofit project, it is critical for all streetlights to be properly inventoried and metered so that the savings will be realized by the municipalities. In cases where an area is not yet properly inventoried, an institution funding the street lighting retrofit will need a written commitment from the local government that it will legalize any illegal connections and pay the necessary cost to apply for an ID number. Without such a commitment, PLN will likely refuse to meter the unregistered streetlights and instead charge a lump sum amount, which will remove the local government's ability to realize the LED's energy savings.

There are some cases, such as in the City of Surabaya and in the pilot City of Batang, where municipal governments and PLN are working together to establish a unified inventory that is agreed upon by both parties. However, this is not yet the norm for a majority of municipalities.

## Meter-Reading Mechanism

PLN uses grouped metering to measure the electricity consumption of a network of individual streetlights, which aggregates the electricity consumed by each pole (typically 10–20), as well as consumption from the line loss in distributing electricity to the network of poles. This means that, in cases where a municipality installs new electronic smart metering at each individual pole, its measured electricity consumption will be less than that measured by PLN's group meters. Consequently, such individual meter readings do not reflect the actual electricity provided by PLN and will not be accepted as a basis for its billing.

The metering of new streetlights is sometimes grouped in a nonstructured manner by PLN, such that new streetlights are added to an existing network in a different location, which causes difficulty in monitoring and accounting for actual electricity consumption.

## Current Indonesian Power Station Lighting

Power station facilities at PLN generally have different lighting practices specific to their needs and functions. Generally, public lighting standards call for a base or minimum level for pedestrian safety, with higher levels or focus in designated areas, such as commercial areas or areas of cultural interest.

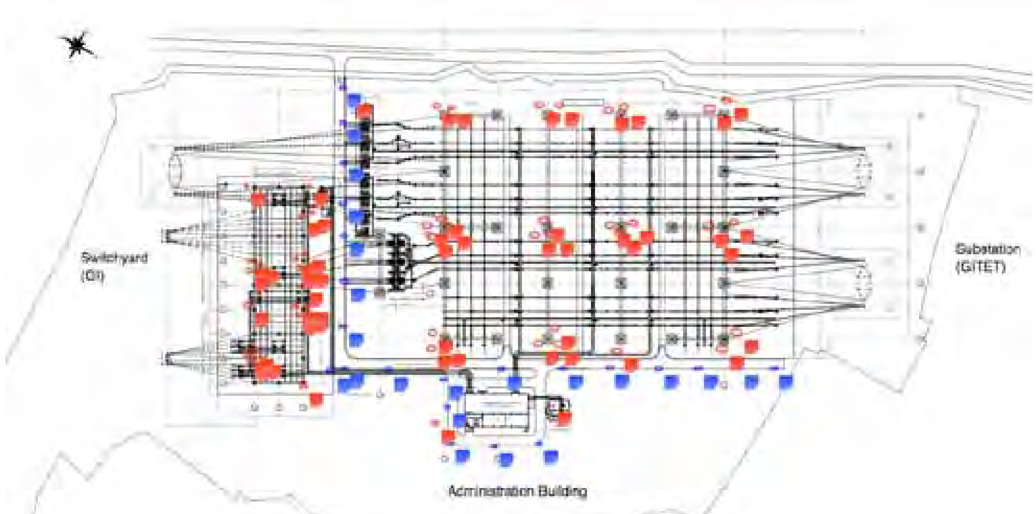
The following information is based on survey visits to a number of PLN's major power substations located in the vicinity of Jakarta (extra high voltage substations [GITET], denotes up to 500-kilovolt capacity), smaller substations and switchyards (substations [GI], denotes up to 150-kilovolt capacity), and a generation facility.

## Substation Layout

In general, the GITET and GI substations visited have similar layouts and common characteristics, and are typically located next to each other.

The typical layout is shown in Figure 3.

**Figure 3: Typical Layout of PLN Switchyard, Substation, and Administration Building**




Source: PLN.

- A typical GITET substation occupies an area of about 300 meters (m) x 500 m containing transmission towers and transformers, with support buildings located next to it. The transmission towers are 30–40 m high and are arranged in a grid (30 m x 30 m) pattern, with backup generators and large transformers grouped into an area outside of the transmission tower grid. The support and administration buildings are located outside of the transmission tower area.
- A typical GI substation occupies an area of about 200 m x 300 m, containing transmission towers and transformers. The towers are usually 25–30 m high, and also use a grid layout, with transformers in a similar grouping at one side of the grid. Usually, GIs are without any administration support buildings, or only have a small storage building and tend to be located next to larger GITET substations.
- For these locations, on–off switching was accomplished either by a photocell or manual switching via a control panel. With regard to the power generation areas, the lighting quality is quite low with minimal maintenance procedures required.

### Utility Lighting Observations from the Pilot LED Project

During visits to the pilot project substations, it was noted that the installed outdoor lighting also has similar types and conditions.

- Illumination for the tower areas at the substations is provided by 400-watt (W) spotlight-type HPS luminaires mounted in groups of four at about the 20 m level on 30 m transmission towers.
- The substations' entrance drives and support buildings have pole-mounted mercury vapor or HPS luminaires. There are also some pole-mounted metal halide spotlights for the work yards and linear fluorescent lamps for the generator areas.
- Substations have about 60 high-mounted spot luminaires, and about 20–25 street and outdoor area luminaires for the rest of the locations. Switchyards have about 30 spot luminaires and a smaller number of area and streetlights.
- Experience based on the HPS spot luminaires' quantity, mounting height, and angle indicates that the light levels available at the ground level of these substations are quite low or nonexistent. All station managers interviewed indicated that more illumination would be desirable.
- The substation managers interviewed also stated that some repair work is done in the transmission tower areas, but light is needed for security and nighttime emergency repairs.

## Financing

Several financing options are currently available to municipalities to fund street lighting retrofit programs. A number of new financing options are also being developed that may be appropriate for street lighting programs. A discussion of these options follows.

### Government Budgets

One of the most common and simplest mechanisms for local governments to fund projects, including street lighting, is through the existing local budget. This mechanism is theoretically available to all municipalities, but, in many cases, it is not sufficient for larger-scale retrofits, nor does it address the internal capacity challenges and procurement complexities of large programs, especially when the programs involve a relatively unknown LED technology.

Another challenge using local budgets is that they are based on prior-year expenditures. Therefore, if a municipality reduces its energy costs from more efficient streetlights, the following years' budget may be reduced, rather than allowing the municipality to realize the savings as payback for the investment or as funding for additional street lighting improvements.

In addition to using funds from local revenues, there are two other primary government budget mechanisms currently available for municipalities:

**General allocation fund (DAU).** A DAU is a national government budget allocation for provinces, districts, or cities to fund various types of programs, including operational purposes. DAUs represent a block grant, allowing regional and local governments to make use of the funds without use-of-proceeds interference from the central government. Approximately 80% of regionally managed DAUs are used for routine expenditures such as wages of public servants.

Some municipalities are using DAUs to finance relatively small street lighting projects, replacing around 100–500 streetlights. Since this accounts for less than 10% of streetlights in many municipalities, it will take around 10 years to retrofit all streetlights.

Further, using a DAU requires local governments to use the business-as-usual procurement methodology which often requires vendor selection based on the lowest up-front cost approach as opposed to one that uses designated specifications (such as efficiency or payback) as the primary basis for selection. The result is low-cost, low-quality, substandard technologies and limited savings, which does not serve the intended purpose of improving energy efficiency.

**Specific allocation fund (DAK).** DAKs are allocations from the national budget used to fund specific development activities implemented in and by regional governments. Since 2007, DAKs have been prioritized for seven key areas: education, health, infrastructure, regional governance infrastructure, maritime affairs and fisheries, agriculture, and the environment. Although DAKs become part of a provincial or district government's (regional) budget, the acquisition and use of DAK funding must follow the guidelines determined by the central government, such as providing at least 10% of the total DAK received in matching funds.

The DAK is the main regional funding source for large infrastructure construction (i.e., roads, hospitals, and markets). The size of street lighting programs often is not large enough to qualify for DAK funds. Additionally, many municipalities prioritize DAK funds for basic necessities and livelihoods of the community rather than energy efficiency. For these reasons, there is currently no example of a DAK-funded street lighting program.

### *National Budget*

Operational improvement programs such as street lighting are often part of regular programs within the provincial or municipal work plan, which means that the expenditure will be budgeted and noted as DAU or DAK for the relevant province, district, or municipality. If the program is implemented at a larger scale, it can also receive grants from line ministries in the central government.

There is a budget allocation for low-carbon development, including allocations to local governments for municipal street lighting programs, in the government's National Medium Term Development Plan. However, as with local budget funding, municipalities must follow procurement guidelines that favor a least up-front cost approach when utilizing funds from the national budget.

**Public–private partnerships (PPPs).** Indonesia has implemented a number of PPPs; however, a major barrier to expanding private sector participation in street lighting programs has been the government's inability to legally commit to meeting multiyear payment obligations. Presidential Regulation No. 38/2015 has begun to remedy this barrier by allowing payments to the private sector through a tariff or "availability payment" mechanism during the period of agreement (implying the approval of multiyear payments). An overview of relevant sections of the regulation is in Appendix 2.

**Loans.** There are several primary loan options for local governments to secure debt for funding a street lighting retrofit. However, a major challenge for local governments in accessing loans is the inability to use their local assets as collateral. Another challenge is the requirement that any long-term financial commitment from a local government must be approved by its local parliament through the issuance of local bylaws. Local bylaws are required to guarantee repayment beyond the political tenure of the elected officials and the approval process can be quite arduous and lengthy, often more than 2 years.

The former Indonesia Investment Agency was able to provide financing to municipal governments without any collateral and with an interest rate below the market rate. In June 2015, the agency merged with the Indonesia Infrastructure Finance, which is also committed to providing loan financing to local governments. However, any financing term greater than 1 year requires approval by its local parliament through the issuance of local bylaws, which is a major deterrent to most municipalities.

Commercial and provincial banks also require collateral for long-term debt financing. While commercial banks are not likely to be sources of financing for municipal street lighting, provincial banks may provide indirect financing through the local contractor or provincially owned enterprise that would manage the project.

**Energy services company (ESCO) financing.** An ESCO is a company that provides the turnkey development, implementation, and capital funding of energy efficiency projects, including street lighting, that are repaid from the project's long-term savings stream. The ESCO model offers a "no risk, no investment" proposition: the municipality is only responsible for paying the ESCO with actual realized savings. Despite the issuance of a new ESCO regulation (ESDM No. 14 of 2016) on 8 June 2016, a new national regulation is still required to modify any existing regulation that precludes governments from accessing ESCO services on a paid-from-savings basis.

**Vendor financing.** This option is typically limited to the specific product(s) manufactured by a vendor, which may create a risk to the government of receiving inadequate products, quality, or price. There are few vendors in Indonesia who are willing to assume the credit risk of a municipality which cannot provide any collateral. Vendors also face similar barriers as ESCOs related to the inability of municipalities to legally commit to making long-term payments.

**Utility financing.** Financing of street lighting programs by the national utility, PLN, could be a viable option to overcome the collateral and long-term payment challenges faced by municipalities. An example of this model is currently being implemented on a large scale in Thailand by the government-owned Provincial Electricity Authority (PEA). As a government-owned entity, PEA is making long-term installment payments to vendors who retrofit and maintain LED streetlights. The repayment commitment from PEA is similar to that of a power purchase agreement from a national utility. It virtually eliminates any credit risk for any vendor or ESCO providing long-term financing of a municipal street lighting program (MSLP).

It seems possible that a PEA-type of model could be implemented in Indonesia under a slightly different scheme by PLN. Such a program would require a funding commitment to PLN from the national government for providing long-term financing to vendors or ESCOs who would implement MSLPs for local governments based on an installment payment commitment from PLN. More importantly, it would require "buy-in" from PLN, which is currently inundated with processing a huge backlog of renewable energy power purchase agreements and securing funding commitments from the national government to cover the huge deficits from the related feed-in tariffs. Therefore, it is very unlikely that PLN would consider pursuing an energy-efficient street lighting program in the foreseeable future.

**Energy Resilience Fund.** The Minister of Finance is currently developing the concept for the Energy Resilience Fund, which is expected to finance renewable energy and energy efficiency project development (with an emphasis on municipal street lighting), and to also deliver innovative financing mechanisms that can further unlock the market potential. The Energy Resilience Fund is designed to be flexible, enabling it to tap financing from various sources such as reallocation of the diesel fuel subsidy, bilateral loans or grants, multilateral funding (i.e., Green Climate Fund and Clean Technology Fund), and private financing. The use of several delivery mechanisms (i.e., grants, loans, equity, and credit enhancement) offers additional flexibility.

**Green Bonds.** Indonesia has historically implemented a number of national impact bonds, opening the door for "Green Bonds" to be a promising alternative source of domestic private finance for filling the financing gap for municipal LED street lighting. It is a way to increase the ratio of green finance supply to gross domestic product. However, such a mechanism will need to have a relatively large pipeline of projects developed for financing in order to initiate any bond issuance.

**Incentives.** Indonesia aims to increase public funding to catalyze private investments in climate finance. In 2015, the Ministry of Finance issued a new regulation (Minister of Finance Regulation No. 89/PMK.10/2015) providing guidance on tax incentives for private sector investments in the low-carbon sector. Nonetheless, there has been a lack of harmonized actions between the private and public sectors to source funding needed for large-scale low-carbon projects, including forestry projects, green infrastructure projects, clean energy power generation, and adaptation projects.

# Pilot LED Project Implementation

Table 2 contains a summary of the total number of LED luminaires procured and installed as part of the Pilot LED Project in each of the pilot municipalities and PLN facilities.

### Table 2: LED Luminaire Installation Locations and Quantities

| Installation Locations - LED Luminaires | Quantity |
|---|---|
| Batang | 257 |
| Semarang | 259 |
| **Total Municipalities** | **516** |
| PLN substation and power-generating facilities | 923 |
| **Total LED Pilot Project** | **1,439** |

LED = light-emitting diode.

Source: Authors' calculations.

Since the current SNI was not directly applicable to the LEDs, new specifications for LED luminaires had to be developed as well as a new procurement process focusing on luminaire performance, quality of delivered illumination, and vendor qualifications. The new specifications were based on international best practices and were used for the procurement and installation of the LEDs that occurred in multiple stages and with different approaches.

## Developing Standards

For the development of the lighting specifications, both luminaire specifications and illumination requirements were addressed. The objective was to develop a reasonable set of specifications that can provide suitable lighting services for urban and suburban streets and areas in Indonesia. The full specifications are provided in Appendix 3.1 for municipalities and Appendix 3.2 for PLN's power stations.

The luminaire specifications used in the Pilot LED Project procurement process were developed based on a number of existing national and international standards, as well as discussions with manufacturers, PLN, and the municipalities. For LED luminaires, their performance (useful life) was the highest concern. A summary of the key product performance characteristics and mechanical and electrical requirements follows:

**Product Performance Characteristics**

- Efficacy: Minimum of 95 lumens per watt
- Lumen maintenance: Minimum of 90% of initial output at 36,000 hours of operation
- Nominal color temperature: Rated correlated color temperature 4,100 ± 200 Kelvin (K)
- Color rendering index (CRI): Minimum of CRI 70

- Backlight–up-light–glare (BUG) rating: Maximum nominal BUG rating of B1-U2-G1
- Luminaires must be designed to meet IESNA lighting standards per Recommended Practice for Roadway Lighting RP-8-00.
- Distribution: Types II and III distribution pattern should be readily available.
- Cutoff: Fixture must be classified as cutoff, or equivalent per IES Luminaire Classification System for Outdoor Luminaires TM-15-2007
- There should be no significant glare, when compared with commercially available high-pressure sodium counterparts.
- Luminaire dirt depreciation (LDD) = 0.90

**Mechanical and Electrical Requirements**

- Overall luminaire ingress protection (IP) requirement: Minimum of IP 65
- The fixture must not have any fans or moving parts.
- All components shall be approved by Underwriters Laboratories (UL).
- The fixture must have transient protection.
- Power factor > .90
- Total harmonic distortion (THD) < 20%
- LED light source(s) and driver(s) shall be compliant with the Restriction of Hazardous Substances (RoHS).

In addition to the required specification levels summarized, manufacturers and bidders were required to submit proof of testing as part of the product documentation. Specifically, proof of photometric testing (following the IESNA LM-79 or IEC 025 methods) and lifetime and/or lumen depreciation testing (following the IESNA LM-80 method) from accredited laboratories were required.

## LED Lifetime and Lumen Maintenance

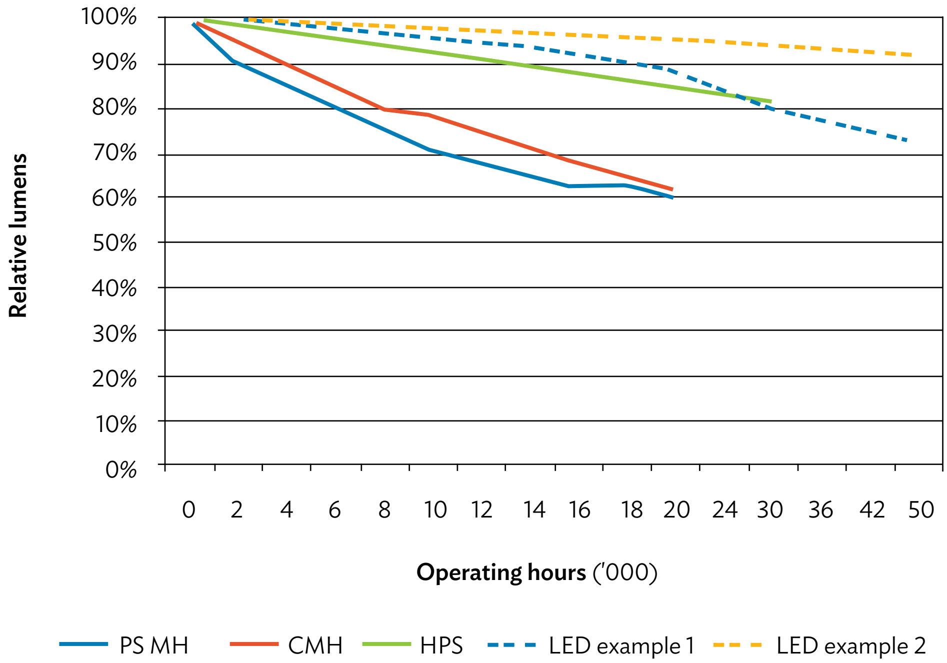
According to the United States Department of Energy, estimating LED life is problematic because the long projected lifetimes of LED chips make full life testing impractical and because the technology continues to evolve quickly, rendering past test results obsolete. Most LED manufacturers define useful life based on the estimated time at which LED light output will depreciate to 70% of its initial rating. As illustrated in Figure 4, LEDs tend to dim over time rather than catastrophically failing, like other technologies.[6] Generally, the design life target is 50,000 hours for most LED luminaire applications, but some outdoor luminaires are now designed for much longer useful lives of 100,000 hours. Well-designed LED luminaires are likely to depreciate slowly over time, so it may be difficult for a utility or maintenance crew to identify when to replace the luminaire. The requirement for LM-80 testing ensures that the LEDs used in the luminaires can maintain their rated output over time, with minimal loss of light output.

## Light Distribution and Glare

LED luminaires use different optics than HPS lamps. Effective LED luminaire designs exploit the directional nature of LED light resulting in lower optical losses, higher luminaire efficacy (the ratio of generated lumens of the light source compared with the delivered lumens in the target zone), more precise cutoff of backlight and up-light, and more uniform distribution of light to the target area. Better surface illuminance uniformity is possible with LEDs, compared with HID luminaires. Photometric performance of LED luminaires is provided by polar plots resulting from goniophotometer testing, which depict the pattern of light emitted through the horizontal and vertical planes (see Figure 5). The specifications require a cutoff rating and all light to be below a 15-degree angle to the horizontal plane, the angle which contributes most seriously to glare and sky glow (footnote 6).

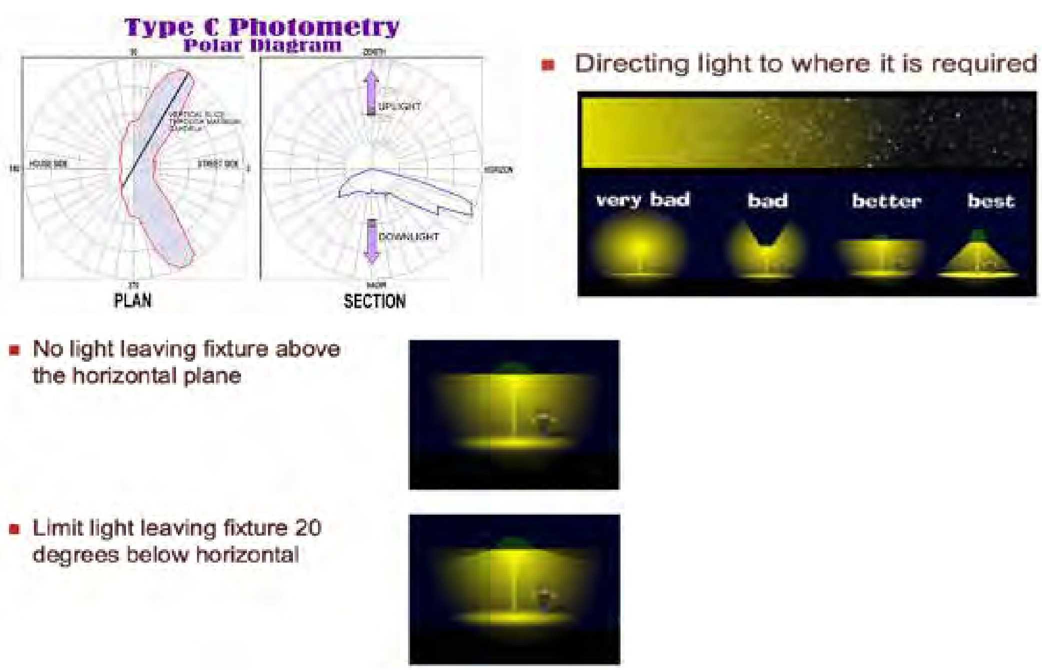
[6] United States Department of Energy. 2008. *LED Application Series: Outdoor Area Lighting.* Washington, DC.

## Figure 4: Lumen Depreciation Rate for Different Lighting Technologies




CMH = ceramic metal halide, HPS = high-pressure sodium, LED = light-emitting diode, PS MH = pulse-start metal halide.
Source: United States Department of Energy. 2008. *LED Application Series: Outdoor Area Lighting.* Washington, DC.

## Figure 5: Examples of Photometric Performance of LED Luminaires




Source: Government of Australia, Department of Industry, Innovation and Science presentation, 2014.

Illumination specifications were developed in the Pilot LED Project based on applicable municipality requirements and internationally accepted practices. As there is very limited knowledge of LED technology in Indonesia, a major challenge was overcoming the current perception held by municipal officials that higher illumination levels, higher lamp wattage, and higher initial lumens will produce better-quality light. Many decision makers were surprised by the lower peak illumination levels produced by LED luminaires, compared with other light sources such as HPS. In addition, users may not be aware that properly designed LEDs can produce higher-quality illumination at lower wattages and more useful lumens, even though they are rated 40%–50% below HPS lamps. This was apparent in Semarang where officials requested higher illumination levels for commercial areas.

For substations, there are no specific internationally accepted standards or available SNI requirements regarding illumination, so the minimum illumination levels recommended in the Pilot LED Project were based on the requirements for outdoor workspaces and public areas.

## Procurement of LED Lighting

There were two separate LED procurement processes: one for the municipalities and one for the PLN power substation facilities. Both were administered by ADB and followed ADB's Procurement Guidelines (2015, as amended from time to time). The procurement process for power substation facilities was also carried out in accordance with PLN's procurement department. Two rounds of each of these procurement processes were conducted due to the availability of additional resources.

## Bidding and Evaluation

Both procurement processes utilized limited international bidding, as per ADB guidelines, due to the estimated value of the contracts and the assessed performance of suppliers in the market. Invitations were sent to six manufacturers that were deemed to have the ability to supply the specified LED lighting technology in the market.

For both procurements, bidders were required to meet certain technical, financial, and administrative criteria. In applying international bidding practices for the Pilot LED Project, a number of new key requirements were applied. This is because, while LED technologies have advanced quite quickly, there remain challenges with the proper design and application of this new light source, as well as quality and longevity issues. To ensure that quality products were procured and properly installed and verified, bidding requirements included:

- **Lighting design proposal.** Bidders had to provide proof that the luminaires can meet the illumination requirements, as determined by computer simulations using standard lighting design programs and actual site conditions.
- **Proof of testing.** Bidders had to provide results from luminaire testing by an accredited, independent laboratory. As LEDs require specialized testing with new test methods, it was necessary to require accreditation and actual test results.
- **Installation experience.** Bidders were required to show a track record of installation and commissioning of LED products so that they can either install or train customer personnel.
- **Knowledge and measurement equipment.** As minimal MRV knowledge is available from previous LED street lighting installations, it was critical that the performance and illumination characteristics of products could be measured and verified for pre- and post-retrofit.

For municipalities, a *two-stage* procurement process was selected for the first round of procurement, due to the pilot-project nature of this procurement, as it allows for refinements of technical specifications based on discussions with the invited bidders after submission of the first technical proposal. The objective of the discussions was to ensure that all technical proposals conformed to the same acceptable technical standard required in the bidding document, while refining the specifications based on technical inputs from the bidders. After the discussion, bidders submitted a revised technical proposal with a proposed lighting design and price proposal.

The *single-stage one-envelope* procurement is more suitable for situations where bidders are provided with all of the information necessary to submit final bids, and no technical changes are anticipated. For the PLN power substation facilities, this procurement process was used since all technical issues, including design requirements, were addressed prior to bidding. In this process, both technical and financial information had to be submitted at the same time. The *single-stage one-envelope* bidding procedure was also used in the second round of procurement for the municipalities since technical specifications were previously defined.

Philips Lighting was the selected vendor for the municipalities and GE Lighting was the selected vendor for the PLN substations.

## Constraints

There were a number of institutional and market constraints experienced during the implementation of the procurement process. For one, due to national regulations, international manufacturers can only sell their products in Indonesia if they are sold through a 100% locally owned company (local distributor), or if the manufacturer has formed a local limited liability company with a trading license for product sales and not manufacturing. Because of this regulation, bidding invitations were limited to qualified LED manufacturers with local representation. Unfortunately, a number of internationally known manufacturers who are leaders in LED luminaire products were not invited because they had no Indonesian representation.

Other constraints experienced during the bidding process were due to the lack of knowledge and limited availability of products in Indonesia. With respect to the lack of knowledge, most local company representatives were not equipped to provide relevant technical information on the products that they represent, as evidenced by the insufficient technical documentation provided by each bidder in the first round. In addition, it is typical for product procurement processes to require bidders to make available samples of products. However, this was not possible because most of the local bidders represented international manufacturers, who had neither locally available samples nor in-stock inventory at their plants, and thus had to manufacture products after an order was placed. Consequently, this hampered the implementation stage of the Pilot LED Project, due to the fact that a 10–12-week delivery period was needed by the international manufacturers after the bids were awarded.

## Installation

As stated earlier, there were two separate LED procurement processes—one for the municipalities and one for the PLN power substation facilities—as well as two rounds of each of these processes. For the municipalities, the installation of luminaires was completed after the first round of procurement in September 2015 and after the second round of procurement in December 2015. For the power-generation facilities, the installation of LEDs from the first round of procurement was completed in December 2015, while the second-round LEDs were installed after June 2016.

Two separate installation approaches were utilized: the Batang and Semarang municipalities self-installed their LED luminaires through their own maintenance personnel, while the LEDs for PLN's substations were installed by the selected LED vendor.

## Self-Installation Approach

For self-installation, similar processes were used for both municipalities:

- Luminaires were received, and quantities and type confirmed by the municipality.
- Municipalities received on-site installation training from the vendor with the vendor demonstrating the installation of one LED, followed by the installation of several LEDs by each municipality's maintenance staff, observed by the vendor and project team members.
- Municipalities installed luminaires in the designated locations, ideally over the next 1–2 weeks (see challenges regarding scheduling).
- Municipalities received control equipment and software (as applicable) from the vendor after installations were completed.
- The process was repeated with luminaires from the subsequent order stages.

The luminaires in Table 3 were installed under a self-installation approach by both municipalities.

### Table 3: LED Retrofits by Procurement in Each Municipality

| | Location | Supplier | Quantity | Notes |
|---|---|---|---|---|
| **Procurement No. 1** | | | | |
| | Batang | Philips | 106 | No CityTouch controls |
| | Semarang | Philips | 108 | With CityTouch controls |
| **Procurement No. 1 Repeat Order** | | | | |
| | Batang | Philips | 32 | No CityTouch |
| | Semarang | Philips | 32 | With CityTouch controls |
| **Procurement No. 2** | | | | |
| | Batang | Philips | 119 | No CityTouch controls |
| | Semarang | Philips | 119 | With CityTouch controls |
| **All Procurements** | | | | |
| Total | Batang | Philips | 257 | No CityTouch controls |
| Total | Semarang | Philips | 259 | With CityTouch controls |
| **Total** | | | **516** | |

LED = light-emitting diode.

Note: CityTouch refers to Philips' lighting management system software.

Source: Authors' calculations.

## Vendor Installation Approach

PLN followed this process for its vendor-installed LEDs:

- Each substation location received an installation briefing from the project team and vendor on installation locations and energy-efficient lighting.
- The vendor installed luminaires in designated locations.
- Each substation and project team confirmed installation amount, type, and proper operation of the new luminaires.
- The process was repeated with luminaires from the subsequent order stages.

GE Lighting installed 423 LED luminaires at PLN's substation and power plant locations and is scheduled to install another 500, for a total of 923, all of which have manual controls.

## Opportunities and Challenges

Both processes resulted in old inefficient luminaires being replaced with new energy-efficient LED luminaires, providing better light distribution and illumination levels and, where installed with the optional digital control system, new control and operational flexibility for the municipality. Each process presented its own opportunities and challenges.

The self-installation approach gave the municipalities a vested interest in the success of the Pilot LED Project (selection of the pilot cities was based on their commitment to allocate installation resources). Municipalities were able to reduce costs by using their own existing resources for the installation, which also allowed for knowledge transfer of LEDs to the municipality staff so that they are better prepared to deal with future maintenance issues. Additionally, municipalities were able to install the luminaires on a schedule that minimizes traffic disruptions and other related issues.

The key challenges with self-installation were scheduling, commitment and locations, and controls and commissioning.

**Scheduling.** Because the municipalities' installation teams were responsible for their own installation schedules, the installation work competed with other government priorities, and last-minute changes often took place, which caused delays in installation, commissioning, and MRV-related activities. Installations should have a more defined installation schedule with realistic allocation of resources, and a risk and schedule management plan to ensure on-time installation.

**Commitment and locations.** The lack of definitive installation schedules and plans meant that municipalities could make unilateral changes to the proposed installation locations, which resulted in confusion by the MRV team and loss of baseline data. Future self-installations should require firmer political and resource commitments in order for them to happen correctly.

**Controls and commissioning.** As the municipalities conducted their own installation, it was not possible to schedule a definitive commissioning date nor to fully verify the functionality of the control system. Future installations should take this fact into account and should only make plans for full control integration after all the luminaires are installed.

The vendor installation approach ensured that the installations happened on a set, agreed-upon schedule. Installation and commissioning by the vendor also provided an independently verified and more consistent process. However, additional costs were required for installation and commissioning, and, as PLN's staff were not involved in these processes, they were not part of the knowledge transfer and may not be prepared to deal with future maintenance issues.

With respect to LED installations at utility substations and power plants, the challenges were on scheduling and safety.

**Scheduling.** The challenges with scheduling were due to the fact that power must be shut off prior to installation, as installation involves removing and replacing luminaires, or mounting new luminaires and hardware mounted on transmission towers or near high-voltage transmission lines.

**Safety.** Power decoupling must be scheduled to fit the needs of each system in order not to disrupt electricity delivery and services. This is particularly true in cases where installations of luminaires are done at a significant height, requiring extensive use of ladders or other equipment to reach the locations.

### *Measurement, Reporting, and Verification Process and Measured Savings*

The MRV process applied in the Pilot LED Project was adapted to fit the various procurement and installation situations. Pre-retrofit (baseline) actual measurements of the kilovolt-ampere (kVA) and lighting levels on lamps retrofitted with LEDs were performed in September 2015 at the municipalities and in December 2015 at the PLN facilities (under Procurement No. 1). All post-retrofit measurements were completed in April and May 2016.

The measured post-retrofit kVA energy reductions (savings) from the LED retrofits at both municipalities were determined by comparing actual measured post-retrofit kVA meter readings with the baseline measurements for 10 circuits, representing a 26% sample size of the total 516 municipal streetlights retrofitted in the Pilot LED Project.

The actual kVA readings of the sample are presented in Table 4 and show an average savings for both municipalities of 50%, with Batang realizing a higher 59% savings versus Semarang's 44%. The reason for Semarang's lower savings is that city officials specified higher illumination level requirements for certain locations serving local merchants and street commerce activities (such as night markets), rather than just vehicular traffic. As a result, higher output and higher-cost LED street lamps were procured and installed at a number of Semarang locations, which reduced the city's overall savings percentages and increased the payback period (the number of years required to recover the LED retrofit cost from savings).

Using the municipalities' normal 12 hours a day operating schedule, the above sample of measured kVA reductions was extrapolated to estimate an annual savings of $12,415 for Batang and $11,846 for Semarang, reflecting a 5- and 10-year investment payback for Batang and Semarang, respectively (see Table 5). The significantly longer payback period for Semarang is due to the much higher cost of the LED lamps to meet the city's required higher levels of illumination, plus the additional control technology included in the lamps.

In addition to pure energy savings, LEDs currently possess a significantly longer lifetime of 10–12 years compared with 3–4 years for the most commonly replaced HPS lamps. This longer lifetime eliminates the need for at least two HPS lamp replacements over the next 10 years and results in maintenance cost savings that improve the payback periods to 3.6 years for Batang and 7.0 years for Semarang.

The same process to measure post-retrofit kVA savings was used to determine an average kVA savings of over 44% at PLN's Cilegon generation station and Gardu Induk substations. No financial savings were able to be calculated due to the fact that PLN does not meter or bill itself for the electricity consumed by its own facilities.

## Table 4: Measured Kilovolt-Ampere Savings at 10 Circuits in Batang and Semarang

| | Baseline | Measured | |
|---|---|---|---|
| | kVA | kVA | Savings |
| **Batang** | 4.236 | 1.749 | 59% |
| | 2.898 | 1.303 | 55% |
| | 3.160 | 0.952 | 70% |
| | 1.651 | 0.803 | 51% |
| | 1.678 | 0.733 | 56% |
| **Total Batang** | **13.623** | **5.540** | **59%** |
| | | | |
| **Semarang** | 2.678 | 1.496 | 44% |
| | 4.274 | 2.207 | 48% |
| | 7.029 | 3.386 | 52% |
| | 2.204 | 1.673 | 24% |
| | 3.582 | 2.280 | 36% |
| **Total Semarang** | **19.765** | **11.042** | **44%** |
| **Total Municipalities** | **33.388** | **16.582** | **50%** |

kVA = kilovolt-ampere.

Source: Authors' calculations.

## Table 5: Estimated "Measured" Savings and Payback for Batang and Semarang

| | | | Annual Savings | | | | Total Pilot LEDs Purchased | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rp kWh Rate | kWh Sample | Rp Sample | $ - Sample | Total Pilot kWh | Total Pilot $ | # | $ Unit | $ | Payback Years |
| Batang | 1,395 | 35,403 | 49,389,603 | $3,799 | 115,685 | $12,415 | 257 | $243 | $62,538 | 5.0 |
| **$ kWh Rate $ 0.11** | | | | | | | | | | |
| Semarang | 1,398 | 38,208 | 53,415,472 | $4,109 | 110,160 | $11,846 | 259 | $459 | $118,976 | 10.0 |
| **Total Municipalities** | **1,397** | **73,612** | **102,805,075** | **7,908** | **225,846** | **$24,261** | **516** | **$352** | **$181,514** | **7.5** |

kWh = kilowatt-hour, LED = light-emitting diode.

Source: Authors' calculations

### *Realized PLN Savings*

There are differences in the amount of street lighting electricity billed to municipalities by PLN under its lump sum and metered methods, and the amount the municipality feels it should be billed based on actual kilowatt-hours (kWh) consumed. In analyzing the pre- and post-retrofit kWh consumption billed by PLN to the municipalities, the measured kVA savings were not consistently reflected in their invoices.

For Batang, most of the 20 circuits retrofitted with LED lamps showed a significant drop in kWh consumption starting in September 2015, after the Procurement No. 1 retrofits began. However, when extrapolating the average monthly kWh consumption from incomplete PLN billing data, only a 51% reduction appears to have been realized versus the estimated 59% measured kVA savings that should have been realized.

In contrast, for Semarang, only a few of the 19 circuits retrofitted with LED lamps showed a reduction in kWh consumption from September 2015. In fact, a relatively small reduction of only 18% appears to have been realized through PLN invoices, reflecting less than half of the estimated 44% measured kVA savings that should have been realized.

### *Post-Retrofit Measured Lighting Performance*

Baseline and post-retrofit MRV measurements of illumination values and calculated uniformity ratios (how evenly an area is lit) are shown in Tables 6 and 7 for a number of locations at Batang and Semarang.

**Table 6: Baseline and Post-Retrofit Lighting Levels and Uniformity Ratios for Batang**

| | Max Illuminance (lux) | | Min Illuminance (lux) | | Ave Illuminance (lux) | | Uniformity (Min/Ave) | |
|---|---|---|---|---|---|---|---|---|
| **Batang Location** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| Gabus/Tugu Batas Kota Barat | 45.3 | 39.8 | 7.5 | 5.2 | 25.0 | 19.9 | 0.3 | 0.3 |
| In front of Family Fun | 42.3 | 26.1 | 5.5 | 9.5 | 25.0 | 17.9 | 0.2 | 0.5 |
| APP.8 (West Kodim) | 42.3 | 26.1 | 11.8 | 9.5 | 22.1 | 17.9 | 0.5 | 0.5 |
| BT.APP.JL.DR.CIPTO, Batang | 46.3 | 53.8 | 4.0 | 6.4 | 26.9 | 24.6 | 0.1 | 0.3 |
| BT.APP.JL. Gadjahmada, Batang | 9.3 | 30.0 | 1.6 | 4.6 | 5.4 | 13.3 | 0.3 | 0.3 |
| BT.APP.JL. A. YANI | 19.3 | 31.4 | 2.5 | 19.9 | 10.6 | 24.4 | 0.2 | 0.8 |

Source: Authors' calculations.

As can be seen in Tables 6 and 7, by the higher post-retrofit (After) minimum illuminance, most LED retrofits provided similar or improved average illumination levels and delivered more light to previously dark areas. More importantly, the new LEDs provided the same or better evenly distributed light, as evidenced by the improved uniformity ratios.

Similar improvements were observed at PLN, as illustrated in the pre- and post-LED retrofit pictures at Cilegon Substation (Figure 6).

## Table 7: Baseline and Post-Retrofit Lighting Levels and Uniformity Ratios for Semarang

| | Max Illuminance (lux) | | Min Illuminance (lux) | | Ave Illuminance (lux) | | Uniformity (min/ave) | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| Jl. Soegiyopranoto (in front of Mazda) | 83.0 | 76.8 | 6.0 | 4.0 | 37.3 | 29.3 | 0.2 | 0.1 |
| Jl. Pandanaran (in front of Hana Bank) | 89.4 | 61.7 | 2.9 | 2.0 | 34.1 | 30.0 | 0.1 | 0.1 |
| Jl. Pandanaran (Position 3) - in Front of BNI | 156.0 | 142.2 | 4.2 | 10.1 | 43.9 | 63.2 | 0.1 | 0.2 |
| Jl. Pandanaran (in front of Santika Hotel) | 108.0 | 112.4 | 1.3 | 7.8 | 27.0 | 44.1 | 0.0 | 0.2 |
| SM.APP.A.YANI (in front of INDOMARET) | 33.4 | 38.8 | 4.9 | 6.2 | 13.7 | 21.5 | 0.4 | 0.3 |
| SM.APP.Kompol Maksum | 51.5 | 57.6 | 0 | 8.3 | 14.2 | 27.3 | 0.0 | 0.3 |
| SM.APP.JENSUD | 12.9 | 33.5 | 1.1 | 1.4 | 7.1 | 17.8 | 0.2 | 0.1 |

ave = average, min = minimum.

Source: Authors' calculations.

## Figure 6: Lighting Conditions at Cilegon Substation Before and After the LED Retrofit


Source: Author's photographs.

# Lessons Learned

For both municipalities and PLN's power substations, the Pilot LED Project provided an opportunity to see firsthand the potential benefits and challenges of implementing the new LED technology, as well as key lessons learned in the following major areas:

## Benefits of Municipal Street Lighting LED Retrofits

- Retrofitting municipal street lighting with LED lamps of equivalent lighting level and higher lighting quality should generate electricity savings of over 50%.
- The payback period for retrofitting municipal street lighting with LED lamps should be less than 4 years when considering the maintenance savings from the significantly longer life of LEDs.
- A significant portion of the electricity savings generated from LEDs may not be realized by municipalities due to
  - PLN billing on a flat fee (lump sum) basis or not consistently charging municipalities based on actual electricity consumed, even where PLN meters are in place; or
  - operating staff of municipalities wanting to install new LED lamps with the same wattage as the lamps being replaced because they are not aware (or do not believe) that the new LED technology provides the same lumen levels with significantly less wattage.

## Luminaire and Illumination Specifications

- There is limited institutional knowledge in municipal governments regarding the design and practice of good street lighting, or limited awareness of the characteristics of LED technologies, which provide higher-quality illumination with much lower lighting wattage levels and lower peak illumination levels than older lighting technologies.
- Municipalities currently do not have the necessary equipment (e.g., light and power meters) or training to be able to verify the performance of their own systems or conformance to standards.

## Procurement of Products

- Institutional and market constraints excluded a number of international manufacturers with qualified products from participating in the Pilot LED Project.
- LED products meeting requirements are not yet available in Indonesia, and local manufacturers have limited experience with the required product-testing and reporting of technical requirements.
- Local manufacturers have limited experience in international bidding processes and need assistance in understanding the documentation requirements.

## Installation

- By using existing staff and resources for the installation, motivated municipalities were able to reduce costs and gain knowledge of LED street lighting technologies. Self-installation also allowed municipalities to conduct the installation on their own schedule.
- Disadvantages of self-installation included inconsistent installation and commissioning, as well as significant delays that created issues with subsequent MRV.

## Measurement, Reporting, and Verification

- Data loggers should be used in LED street lighting retrofits, and installed at each PLN meter to be able to directly measure the pre- and post-retrofit kWh consumed and document the savings.
- It will be difficult for municipalities to verify LED retrofit savings where PLN does not provide kWh data for street lighting.
- There is a lack of existing institutional knowledge, proper measuring equipment, and available utility data needed to accurately measure light levels and energy consumption.
- Understanding of the importance of MRV is quite low and needs to be addressed before future LED projects are implemented since savings cannot be accurately measured after the retrofit if a baseline is not established.

## PLN Metering and Billing

To have a secure savings-based project type of financing for retrofitting municipalities with new LED street lighting, it is important for PLN to have and use a clear metering system that provides transparent consumption data, which can be verified by the municipalities and reconciled with their street lighting inventory. This will require municipalities to eliminate illegal street lighting and reconcile its street lighting inventory with the streetlights that are registered and metered by PLN. This will be very challenging in locations where PLN does not provide kWh data in its invoices and does not charge on actual electricity consumed, even where meters are installed.

# Gaps and Recommendations for LED Retrofit Scale-Up

The major gaps that need to be overcome for the scaling up of LED retrofits by municipalities throughout Indonesia are listed, along with the concomitant recommended solution:

## Electricity Costs Based on Actual Consumption

In many cases, the amount billed by PLN to municipalities for their street lighting electricity is not based on actual electricity (kWh) consumption and, even when streetlights are metered, the kWh consumption is not provided to municipalities. This is a nationwide gap that is critical to overcome so that municipalities are able to realize the energy cost reductions needed to finance citywide LED retrofits with debt or with ESCOs on a paid-from-savings basis. It is particularly important for PLN to provide actual kWh consumption in a transparent manner that is verifiable in order to overcome the current perception by many municipalities that they are paying much more than what they should for the actual electricity they consume for street lighting.

The recommended short-term solution is for PLN to have meters on all municipal streetlights that are read monthly and can be verified by the municipalities, and then bill the municipality based on actual kWh consumed. The long-term solution is for PLN to install smart metering with open access to all municipalities.

## Increase Technical Knowledge and Capacity

There is very limited LED knowledge and capacity in most municipalities which not only creates an unwillingness to retrofit city streetlights, but also increases the chance that completed LED retrofits will include inferior products or a design that delivers far less savings than possible due to more wattage or light levels than needed.

The primary solutions are to

- develop and publish a national standard that incorporates the best practices and lessons learned in this report and other donor-funded street lighting programs,[7]
- implement multiple demonstration LED projects with different retrofit and financing structures, and
- provide a nationwide capacity-building program to all municipalities.

## Project-Based Financing

Municipalities do not have the sufficient budget or access to financing for citywide LED retrofit programs. Project-based financing is needed to enable financial institutions and ESCOs to finance retrofit programs for municipalities from long-term realized savings. One of the barriers for

[7] At the time of writing, the Ministry of Transportation was developing a regulation on street lighting.

municipalities is the difficulty to make multiyear payments, which has already been addressed in Presidential Regulation No. 38/2015 by specifying that energy conservation is deemed an infrastructure project under the PPP model, which means municipalities can use the availability payment scheme to fund LED retrofits with the private sector (i.e., ESCOs or vendors).

New financial products need to be developed that allow banks and third-party entities like ESCOs to provide the needed long-term financing such as a national credit guarantee to back up payments by municipalities for a MSLP and an energy savings insurance product to guarantee the savings on MSLPs to finance the capital cost.

In addition, a national energy efficiency finance team needs to be established, trained with experienced experts, and made available to municipalities to develop LED savings-based projects and related loan structures, perform risk assessments, and manage and/or evaluate the technical analyses that include investment-grade audits.

## Access to ESCO Services

ESCOs can be major contributors to scaling up the implementation of LED retrofits in municipalities by funding up-front costs and being repaid by the savings. However, municipalities and other government agencies in Indonesia experience the following barriers to accessing ESCO services:

- **Multiyear contracts.** Presidential Regulation No. 38/2015 has introduced the capability for governments to enter into contracts over multiple years. However, this needs to be formalized into new regulations that specifically apply to ESCOs.
- **Procurement procedures.** The government's procurement procedures are designed to purchase equipment and services on a low-cost, competitive basis, which requires detailed specifications of the equipment and services being purchased to be identified upfront to ensure all bids are evaluated on the same basis. However, this approach is not viable for acquiring energy efficiency projects from ESCOs under long-term paid-from-savings contracts.
- **Budget disincentive.** The energy budget for government-owned facilities is typically allocated from a "general fund" specific for the government agency responsible to operate the applicable facility. The annual budgeted amount is usually based on the previous year's actual costs and is, therefore, reduced when an energy efficiency project (like a LED retrofit) creates savings, thus leaving no funding available to finance the project.

The solution is currently under way with draft regulations being developed under ADB technical assistance funding that will modify existing regulations, as needed, to facilitate the delivery of energy efficiency services in government facilities by ESCOs. This will follow the new ESCO regulation (ESDM No. 14 of 2016) published on 8 June 2016, which provided definitions and guidelines for ESCO services and was under development from 2015 onward with funding from ADB and the United States Agency for International Development.

# References

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United States Department of Energy. 2008. *LED Application Series: Outdoor Area Lighting*. Washington, DC.

New York City Global Partners. 2009. *Best Practice: LED Street Lighting Energy and Efficiency Program*. Los Angeles.

United States Agency for International Development India and Government of India, Bureau of Energy Efficiency. 2010. *Energy Efficient Street Lighting Guidelines*. Delhi.

# Appendix 1: Current Street Lighting Standards in Indonesia

**Standard of street lighting in Indonesia.** The street lighting standard in Indonesia is referred to as Standar Nasional Indonesia (SNI), which covers several laws related to the design and implementation of street lighting in Indonesia:

(i) Regulation of Ministry of Transportation No. PM.81 of 2011: Standard of Minimum Service for Local Transportation – Provincial and Municipality/District. In the appendix of the regulation, it is mentioned that, for road transportation (*angkutan jalan*), point c. "Fasilitas Perlengkapan Jalan": The indicator for the Minimum Service Standard is the availability of road equipment (road signs, road markings, and guardrails) and streetlights for a provincial road.
(ii) Regulation of President Republic of Indonesia No. 8 of 2011: Electricity Tariff Provided by PT PLN. In article 2.e, Basic Tariff for Public Office Building and Streetlight, streetlights are included in the low voltage group (P-3/TR).
(iii) Regulation of Ministry of Public Works No. 19/PRT/M/2011: Road Technical Requirement and Road Technical Planning Criteria. Chapter II, Article 33: Streetlights are not mandatory, except for the following places:
   a. cross-section place with a lot of pedestrians,
   b. parking area,
   c. area with limited visibility distance, and
   d. street lighting poles are mounted on the outer side of the road and/or in the middle of the road's median.
(iv) SNI 7391:2008: Specification of Street Lighting for Urban Area. Consists of lighting for street lane, cross-section on one-lane and multilane, bridge, and tunnel in an urban area, which are functionally classified as arterial, collector, and local roads. The specification covers function, type, dimension, installation, location, and arrangement of streetlights.
(v) SNI No. 04-6262-2000: Recommendation on Lighting for Vehicles and Pedestrians Identical to CIE TC 12:1997: The Lighting of Roads and Motorized Traffic.

Some of the functions of streetlights include

(i) providing contrast between objects and road surface;
(ii) helping to navigate people that use the road;
(iii) increasing safety and comfort for people that use the road, especially at night;
(iv) ensuring a more secure environment; and
(v) providing aesthetics for the road.

A unit of streetlight consists of

(i) lamp/luminaire;
(ii) optical elements (reflector, refractor, and diffuser);
(iii) electronic elements (connector to power supply, etc.); and
(iv) supporting elements consisting of the arms, vertical pole, and foundation of the pole.

Based on the SNI regulation, the use of street lighting is differentiated based on the following street classes:

(i) **Main/primary road.** A road that accommodates the local and regional activities. It is usually very busy and, thus, needs optimum lighting. Referring to SNI 2000, the street lighting required is 50 lux.
(ii) **Arterial road.** A road that supports the activity of the main road. Congestion is quite heavy and, thus, the road requires the same street lighting specification as the main road. According to SNI 2000, the streetlight requirement is 50 lux.
(iii) **Main/primary collector.** A road that accommodates traffic from the surrounding area that will end up in the main or secondary road. According to SNI 2000, the street lighting required is 30 lux.
(iv) **Arterial collector.** A road that serves as a collector from the surrounding area that will end up in the primary collector, primary road, or secondary road. This requires a street lighting specification that is equal to a primary collector. According to SNI 2000, the street lighting required is 30 lux.
(v) **Neighborhood street.** A road in a housing complex, village, or residential area in general. This requires 15 lux.

In accordance with Regulation No. 12/BNKT/1991, streetlights can be assessed from their characteristics and usage shown in Table A1.

## Table A1: Characteristics and Usage of Streetlight Lamps

| Type of Streetlight Lamp | Average Efficiency (lumen/watt ) | Average Lifespan (hours) | Power Needed (watt) | Visual Quality | Details |
|---|---|---|---|---|---|
| Low-pressure fluorescent lamp (LF or CF) | 65 | 10,000 | 20; 40 | Good | For collector road. Sufficient efficiency, short lifespan, price is average. This type of lamp is adequate for a very limited usage. |
| High-pressure mercury vapor lamp (MV) | 55 | 14,000 | 125; 250 400; 700 | Good | For collector road, local, and intersection. This type of lamp has low efficiency, thus not very economical. Long lifespan, small size so it is easier to control the light produced, price is average. |
| Low-pressure sodium vapor lamp (LPS or LPSV) | 140 | 15,000 | 90; 180 | Very poor | For local collector road, intersection, and rest area. High efficiency, long lifespan, big size, and a bit hard to control the light and reduce glare, but produces a bad yellow light. |
| High-pressure sodium vapor lamp (HPS or HPSV) | 100 | 21,000 – 27,000 | 150; 250; 400 | Good | For toll road, arterial, collector, big intersection, and interchange. High efficiency, long lifespan, and small size make it easy to control. Although expensive, it is the current recommended choice. |

HPS or HPSV = High-pressure sodium vapor lamp, LF or CF = Low-pressure fluorescent lamp, LPS or LPSV = Low-pressure sodium vapor lamp, MV = High-pressure mercury vapor lamp.

Source: Regulation No. 12/BNKT/1991: Streetlight Specification for Municipal Roads.

# Appendix 2: Overview of Regulations for Public–Private Partnerships

## Presidential Regulation No. 38/2015

The recently adopted Presidential Regulation No. 38/2015[1] is expected to accomplish the following five objectives:

(i) Emphasize the authority of the parties involved in public–private partnerships (PPPs).
(ii) Expand the scope in the implementation of PPP.
(iii) Accelerate the business process from preparation to transaction.
(iv) Increase the bankability and sustainability of projects, including the possibility of alternative financing.
(v) Provide legal certainty in the PPP processes (e.g., the success fee mechanism, land acquisition, and environmental impact assessments).

The following are several noteworthy points that will likely impact energy efficiency and energy services company work:

### Energy Conservation and Types of Projects Covered

(Chapter 5) There are 14 infrastructure development types of works identified in the regulation. One type is "infrastructure on energy conservation."

(Chapter 21) The identification of an infrastructure project needs to be in line with the long- and medium-term national and regional plans.

### Stakeholders

(Chapter 6) The government agencies or entities who can establish PPPs are ministries, government institutions, and local governments (provincial and municipalities).

### Project Structure

This new Presidential Regulation provides a basis for several PPP projects to be bundled and carried out under a single procurement process. The relevant authority for each PPP project that is bundled with another PPP project must act jointly as the government contracting agency. It also allows for the scope of PPP projects to include commercial activities, which can serve as a basis for business entities to develop commercial areas to support the project revenue streams.

[1] This overview is adopted from I. Hermawan and J. Bahar. 2016. New PPP Regulations: PR No. 38/2015. *Mondaq*. 3 February.

## Payment and Government Support

(Chapter 10) The government can lend land or facilities for the purpose of project implementation.

(Chapter 12) Allows payment to be made by the government to the private sector through a tariff or a new alternative "availability payment" mechanism. Through this mechanism, the business entity will be compensated directly by the government so long as the infrastructure is available for use, thereby providing limited revenue risk for the business entity. However, the public sector will retain revenue risk, and, thus, the business entity will not be entitled to any revenue upside.

The exact types of infrastructure projects that may use the availability payment mechanism for investment return are not specified in Presidential Regulation No. 38/2015, given that further implementation of this mechanism will be addressed in the Ministry of Finance regulations (see below regarding Regulation No. 190/PMK.08/2015). The Ministry of Finance will also regulate the mechanisms for budgeting and the criteria to make the payment available for the private entity that develops the infrastructure.

(Chapter 13) The government can allocate funds for making tariff payments during the period of agreement (which implies that it allows multiyear payments). Further details on the fund allocation and payment conditions will be provided through the issuance of a ministerial decree.

(Chapter 16) The government can give incentives to support PPP projects, which will be described in detail in the ministerial decree.

(Chapter 17) The government can give a guarantee on PPP, which will be described in detail in the ministerial decree.

(Chapter 29) The government can use a retainer fee, lump sum, and success fee payment schemes.

## Procurement

(Chapter 14) In the case that the project is initiated by the private sector, by providing a feasibility study and a proposal to the government, the proposing private sector entity can get additional compensation and a "right to match" in the bidding process or it can secure the intellectual copyright of the work methodology. This is particularly relevant to an energy services company initiating a project proposed to the government.

(Chapter 28) There has to be a process in selecting the partner institution. It is open to local and international institutions and organizations, which will be described in detail in the ministerial decree.

Presidential Regulation No. 38/2015 also introduces a new transaction scheme for business entity procurement. Specifically, it not only bases the categorization of PPP projects on how they were initiated (solicited versus unsolicited projects), but also on specific conditions: (i) the project is an expansion of an existing infrastructure project, (ii) only one provider has the technology or the intellectual property required, or (iii) the business entity owns a part or all of the land required for the PPP project. These new additions are provided to accelerate the PPP project process. Direct appointment may also be conducted by a government contracting agency if the result of the prequalification of public tender is only one bidder. This mechanism is provided to avoid the process of re-tender, which was often done under the previous PPP regulations.

### Asset Management Transfer

(Chapter 33) The government can transfer asset management to the private sector with clear stipulation of conduct in the agreement. Nonetheless, the asset cannot be used as collateral for the private sector to secure financing.

### Contracts

The general criteria for PPP contracts are provided in this new Presidential Regulation. The criteria are generally similar to those in the previous regulation, with a few modifications. Some important changes include the requirement to use Bahasa Indonesia as the prevailing language (English language can be used for official translations only) and the capping of the performance bond at 5% of the investment costs.

## Ministry of Finance Regulation No. 190/PMK.08/2015

Regulation No. 190/PMK.08/2015 was recently issued by the Minister of Finance in order to implement the provisions of Article 13 paragraph (5) of Presidential Regulation 38/2015. It includes two key elements.

(i) Chapter II, Article 2 defines the availability payment of a state expenditure or a regional government expenditure aimed at
   a. ensuring the availability of quality services to the public on an ongoing basis, resulting from the provision of infrastructure conducted through PPPs;
   b. optimizing the use value of the national and local budgets (value for money); and
   c. providing a return on investment schemes that attract business entities to cooperate with the government in the context of providing services to the community through PPPs as referred to in paragraph a.

(ii) Chapter IV, Article 6 states that the budgeting of the service availability payment funding shall be made periodically at each fiscal year as long as the enactment of the service availability payment obligation is under the PPP agreement.

# Appendix 3: LED Specifications

## A3.1 Municipalities: Evaluation and Qualification Criteria

### Evaluation Criteria

*Scope*

In accordance with the Asian Development Bank (ADB) Efficient Street Lighting Project, ADB is looking for qualified bidders to provide replacement lamps and luminaires with more energy-efficient units. The replacement luminaires will use existing poles, mounting arms, and circuits. Only new luminaires will be required.

(i) For streets in Batang Regency: A total of 119 replacement lamps and luminaires need to be provided, meeting the minimum average illumination levels and uniformity ratios as specified by SNI (Standar Nasional Indonesia) for street lighting.
(ii) For streets in Semarang City: A total of 119 replacement lamps and luminaires need to be provided, meeting the minimum average illumination levels and uniformity ratios specified by SNI for street lighting.

*Technical Criteria (mandatory, subject to rejection for any noncompliance)*

*Luminaires*

Luminaires shall be selected for their photometrics, durability, and quality, using optics that minimize spill light on adjacent properties and which significantly limit up-light.

*Documentation*

The fixture must be marked with a full production catalog number that matches manufacturer documentation. A full sheet of product specifications must be submitted. Warranty information must be included.

*Testing of Products*

Stated fixture performance characteristics must be from tested results by an independent laboratory, and accredited through an accreditation program, such as Asia Pacific Laboratory Accreditation Cooperation (APLAC).

Testing must be performed in accordance with all Illuminating Engineering Society of North America (IES) LM-79 and LM-80 or International Electrotechnical Commission (IEC) 025 guidelines.

Luminaire photometric report(s) compliant with IES LM-79 or IEC 025 from the test laboratory must be provided as part of the documentation.

Reports must contain the following information:

(i) name of test laboratory;
(ii) report number;
(iii) date;
(iv) complete luminaire catalog number;
(v) description of luminaire, LED light source(s), and LED driver(s);
(vi) goniophotometry;
(vii) IES TM-15 backlight–up-light–glare (BUG) ratings shall be for initial (worst case) values, i.e., light loss factor (LLF) = 1.0;
(viii) lumen maintenance calculations and supporting test data must be in accordance with international guidelines, such as LED Lighting Facts; and
(ix) computer-generated point-by-point photometric analysis of maintained light levels.

Stated fixture electrical, mechanical, and physical characteristics must be from tested results by accredited laboratory(ies), through an accreditation program, such as APLAC.

## *Product Performance Characteristics*

- Efficacy: Minimum of 95 lumens per watt
- Lumen maintenance: Minimum of 90% of initial output at 36,000 hours of operation
- Nominal color temperature: Rated correlated color temperature 4,100 ± 200 Kelvin (K)
- Color rendering index (CRI): Minimum of CRI 70
- BUG rating: Maximum nominal BUG rating of B1-U2-G1
- Luminaire dirt depreciation (LDD) = 0.90

## *Mechanical and Electrical Requirements*

- Overall luminaire ingress protection (IP) requirement: Minimum of IP 65
- The fixture must not have any fans or moving parts.
- All components shall be approved by Underwriters Laboratories (UL).
- The fixture must have transient protection.
- Power factor > .90
- Total harmonic distortion (THD) < 20%
- LED light source(s) and driver(s) shall be compliant with the Restriction of Hazardous Substances (RoHS).

## *Thermal Management*

- Luminaire shall start and operate in the ambient temperature range specified (10–50 degrees Celsius).

## *Electrical Safety Testing*

- Luminaire shall be listed for wet locations.
- Luminaire shall meet the performance requirements specified in American National Standards Institute (ANSI) C136.2 or equivalent SNI standards for dielectric withstand and for electrical immunity.

### *Warranty*

The minimum acceptable luminaire warranty period is 3 years. Reasonable warranty periods longer than 5 years will be taken into consideration during the bid evaluation process.

### *Maximum Delivery Time*

Delivery of goods to both Batang Regency and Semarang City should be done at maximum 16 weeks after the contract is signed.

### *Reference for Bid Winner*

The bid winner will be responsible for the lighting audit and lighting design by actual surveys and measurements that will meet the minimum requirements appropriate for each area designated for lighting upgrade. The bid winner will also be responsible for the installation plan and commissioning/acceptance plan upon notification of award.

### *Lighting Audit Report*

The winner of the bid process will be responsible for conducting a detailed lighting audit within 1 week of contract award to finalize the lighting design (ensuring that the designs meet required illumination levels and power requirements) for the designated areas in Batang Regency and Semarang City, including the following:

(i) Arrange with ADB and Batang Regency and Semarang City for an audit of the location and areas designated for lighting upgrade.
(ii) Follow measurement methodologies outlined in the ADB manual.
(iii) Submit a measurement plan and equipment to be used for measurements for each location.
(iv) Conduct a minimum of two lighting assessments for each area designated for upgrade (one measurement is acceptable for areas smaller than 10 square meters or illuminated with less than four luminaires).
(v) For each lighting assessment, collect sufficient data for each survey area to determine
   a. actual luminaire wattage,
   b. actual luminaire current (for power, THD, and phase calculations),
   c. color temperature,
   d. maximum illumination level, and
   e. minimum illumination level and uniformity ratio.
(vi) The above measurement should be sufficient to represent the baseline lighting service for each area designated for upgrade to be compared with the upgraded lighting service.
(vii) Provide a list of equipment used.

### *Lighting Design*

**Design.** Provide final lighting design for each area to be upgraded using the maps, luminaire inventories, pole height, and distance information provided by Batang Regency and Semarang City. The preliminary lighting design proposal must be conducted using an industry-recognized design software, such as AGI-32, Visual Pro, LightPro, or equivalent.

**Illumination.** The lighting design illumination levels for each proposed area of design or upgrade must meet the minimum illumination levels and uniformity ratios specified by SNI for street lighting.

Where there is no guidance, specifications for local roads and medium conflict areas (see Table A3) can be used.

### Table A3: Illuminance and Uniformity Ratio for Roadways and Sidewalks

| Road | Pedestrians | Roadway | | Sidewalk | |
|---|---|---|---|---|---|
| Classification | Conflict Area | Illuminance (fc) | Uniformity Ratio ($E_{avg}/E_{min}$) | Illuminance (fc) | Uniformity Ratio ($E_{avg}/E_{min}$) |
| **Major** | High | 1.7 | 3 | 1.0 | 4 |
| | Medium | 1.3 | 3 | 0.5 | 4 |
| | Low | 0.9 | 3 | 0.4 | 4 |
| **Collector** | High | 1.2 | 4 | 1.0 | 4 |
| | Medium | 0.9 | 4 | 0.5 | 4 |
| | Low | 0.6 | 4 | 0.3 | 6 |
| **Local** | High | 0.9 | 6 | 1.0 | 4 |
| | Medium | 0.7 | 6 | 0.5 | 4 |
| | Low | 0.4 | 6 | 0.3 | 6 |

fc =footcandle, a measure of illuminance.

Note: The required street illumination for bidding is based on lighting levels and uniformity ratios set forth in Illuminating Engineering Society of North America (IESNA)-RP-8-2000, which is the technical reference being used, in addition to relevant SNI and the Ministry of Energy and Mineral Resources technical documents.

Source: IESNA.

**Luminaires.** The specifications of the proposed replacement luminaires and lamps in the preliminary lighting design must meet or exceed the specification requirements in the Technical Criteria section, with total wattage of proposed replacement products, showing (i) that the proposed design will not exceed the total existing operating wattage, and (ii) the projected energy savings from design or upgrade.

**Photometric.** The IES photometric data files of each proposed luminaire and/or lamp type.

**Safety.** Evidence of product safety (certification that products meet SNI safety standards)

### *Testing, Training, and Commissioning and/or Acceptance*

The municipalities will install and maintain the luminaires. Therefore, within 14 days of bid acceptance, the winning bidder must be prepared to provide the following:

(i) An installation plan for the municipality specific to the luminaires proposed, noting any special details such as nonstandard connections, wiring, or control interface.

(ii) A training program for municipality personnel, who will be responsible for installation of the luminaires and lamps. The training program must address both installation procedure (wiring and securing of luminaires to mounting arms, etc.), proper aiming and alignment of new luminaires, as well as commissioning and operating procedures.

(iii) Emergency procedure

(iv) Completion and cleanup procedures

(v) Any exception or exclusion of product warranties due to the fact that the luminaires will be installed by the municipalities.

(vi) The required conditions (installation, commissioning, and operation and maintenance) that the municipalities must maintain in order to not void the product warranties.

## Qualification Criteria

### *Financial Criteria*

**Financial ability to provide warranty services:** Letter(s) of support from manufacturers represented, or letters of support from clients who have received warranty services in the past 24 months, or number of clients currently covered by product warranty in the past 36 months.

### *Experience Criteria*

- **Lighting audits:** (Specify) A list of the past four audit locations, number of actual measured locations, and equipment used.
- **Specific experience with LED technology:** A list of past five client installations involved LED luminaires in the past 3 years.
- **Follow-up services:** A reference letter stating satisfactory performance of at least 1 year (or more) of follow-up services (maintenance, training, warranty replacements, etc.) for the past five clients or past three installations.

### *Litigation History*

Not applicable

# A3.2 Power Stations: Evaluation and Qualification Criteria

## Evaluation Criteria

### *Scope*

In accordance with the Asian Development Bank (ADB) Efficient Street Lighting Project, PLN is looking for qualified bidders to provide replacement lamps and luminaires (with controls) for PLN substations ([extra high-voltage substation] GITET and [substation] GI).

The bidder has to submit the following documents: company profile, preliminary lighting upgrade proposal, warranty proposal (section 2), and price proposal. Technical documents for proposed luminaires as required are listed below.

## Technical Criteria

### *Luminaires*

Luminaires shall be selected for their photometrics, durability, and quality, using optics that minimize spill light on adjacent properties and which significantly limit up-light.

### *Documentation*

The fixture must be marked with a full production catalog number that matches manufacturer documentation. A full sheet of product specifications must be submitted.

## *Testing of Products*

Stated fixture performance characteristics must be from tested results by an independent laboratory, and accredited through an accreditation program, such as Asia Pacific Laboratory Accreditation Cooperation (APLAC).

Testing must be performed in accordance with all Illuminating Engineering Society of North America (IES) LM-79 and LM-80, International Electrotechnical Commission (IEC) 025, or equivalent guidelines.

Luminaire photometric report(s) from the test laboratory must be provided as part of the documentation.

Test reports must be compliant with the requirements of LM-79, LM-80, or IEC 025.

Reports must contain the following information:

(i) name of test laboratory;
(ii) report number;
(iii) date;
(iv) complete luminaire catalog number;
(v) description of luminaire, LED light source(s), and LED driver(s);
(vi) goniophotometry;
(vii) IES TM-15 backlight–up-light–glare (BUG) ratings shall be for initial (worst case) values, i.e., light loss factor (LLF) = 1.0;
(viii) lumen maintenance calculations and supporting test data must be in accordance with international guidelines, such as LED Lighting Facts; and
(ix) computer-generated point-by-point photometric analysis of maintained light levels

## *Product Performance Characteristics*

- Efficacy: Minimum of 95 lumens per watt
- Lumen maintenance: Minimum of 90% of initial output at 36,000 hours of operation
- Nominal color temperature: Rated correlated color temperature 4,100 ± 200 Kelvin (K)
- Color rendering index (CRI): Minimum of CRI 70
- BUG rating: Maximum nominal BUG rating of B1-U2-G1
- Luminaires must be designed to meet IESNA lighting standards per Recommended Practice for Roadway Lighting RP-8-00.
- Distribution: Types II and III distribution pattern should be readily available.
- Cutoff: Fixture must be classified as cutoff, or equivalent per IES Luminaire Classification System for Outdoor Luminaires TM-15-2007
- Glare: There should be no significant glare, when compared with commercially available high-pressure sodium counterparts.
- Luminaire dirt depreciation (LDD) = 0.90

## *Mechanical and Electrical Requirements*

- The fixture must meet the following ingress protection requirements: IEC standard IP 65.

- The fixture must easily connect to a standard mounting arm.
- The fixture must not have any fans or moving parts.
- Neither housing nor lens shall be constructed of polycarbonate or plastic that will discolor over time.
- All components shall be UL-approved or equivalent.
- The fixture must have transient protection.
- Power factor > .90
- THD < 20%
- LED light source(s) and driver(s) shall be RoHS-compliant.

### *Thermal Management*

- Luminaire shall start and operate in the ambient temperature range specified (10–50 degrees Celsius).
- Liquids or other moving parts shall be clearly indicated in the submissions, shall be consistent with product testing, and shall be subject to review.

### *Electrical Safety Testing*

- Luminaire shall be listed for wet locations.
- Luminaire shall meet the performance requirements specified in ANSI C136.2 or equivalent SNI standards for dielectric withstand, using the DC test level and configuration.
- Luminaire shall meet the performance requirements specified in ANSI C136.2 or equivalent SNI standards for electrical immunity, using the combination wave test level indicated in section 4.1.
- Luminaire shall comply with FCC 47 CFR part 15 or SNI equivalent for interference criteria for Class A (nonresidential) digital devices.

### *Energy Savings*

The total wattage for the replacement luminaires and lamps must not exceed the baseline of the total wattage of the substations currently.

### *Warranty*

The minimum luminaire warranty period is 3 years. Reasonable warranty periods longer than 5 years will be taken into consideration during the bid evaluation process.

### *Economic Criteria*

Margin of preference: Not applicable

## Qualification Criteria

### *Financial Criteria*

**Financial ability to provide warranty services:** E.g., letter(s) of support from manufacturers represented, or letters of support from clients who have received warranty services in the past 24 months, or number of clients currently covered by product warranty in the past 36 months.

## *Experience Criteria*

- **Lighting audits:** (Specify) A list of the past four audit locations, number of actual measured locations, and equipment used.
- **Specific experience with LED technology:** Whether or not the past five clients or past three installations involved LED luminaires in the past 5 years.
- **Project experience with LED (supply and installation).**

## *Supply Capacity*

Not applicable

## *Litigation History*

Not applicable

## LED Street Lighting Best Practices

*Lessons Learned from the Pilot LED Municipal Streetlight and PLN Substation Retrofit Project (Pilot LED Project) in Indonesia*

Energy-efficient light-emitting diode (LED) street lighting technologies and designs can cut energy costs and reduce greenhouse gas emissions. The Asian Development Bank, the Ministry of Energy and Mineral Resources of Indonesia, and the country's state-owned electric utility have collaborated on the implementation of a pilot LED retrofit project. This report describes the applied methodologies, measured results, and lessons learned from the project, which demonstrated average savings of 50% in street lighting electricity costs for two municipalities. It also identifies barriers to scaling up LED street lighting retrofits in Indonesian municipalities, along with technical and policy recommendations that can be implemented to overcome these barriers.

### About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

**ASIAN DEVELOPMENT BANK**
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org