ESMAP
Energy Sector Management Assistance Program

Knowledge Series 026/16

PROVEN DELIVERY MODELS FOR LED PUBLIC LIGHTING

Synthesis of Six Case Studies

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ACKNOWLEDGEMENTS

This report was written by Pedzi Makumbe, Debbie K. Weyl, Andrew Eil, and Jie Li, with funding from the World Bank's Energy Sector Management Assistance Program (ESMAP) and the Community Development Carbon Fund (CDCF), both of which are multi-donor technical assistance trust funds administered by the World Bank. ESMAP published the work in close collaboration with the Social, Urban, Rural, and Resilience Global Practice (GSURR) and the Environment and Natural Resources Global Practice (GENDR) of the World Bank Group.

The authors benefitted tremendously from discussions with key professionals who shared their time, experience, and resources, and would like to thank the following:

- **Asian Electronics Ltd. in Central and Northwestern Central India**: Naman Shah, AEL Managing Director; Manoj Panchakshari, Super Wealth Financial Enterprises Pvt. Ltd., V. Baraneedharan, Consultant; Aditya Dhar, International Finance Cooperation; Neeraj Gupta, Principal Investment Officer, International Finance Corporation; and W. Nick Bowden, Carbon Finance Specialist, World Bank
- **Energy Efficiency Services, Limited in Visakhapatnam (Vizag), India**: Mr. Saurabh Kumar, Managing Director, EESL; Mr. Tarun Tayal, Deputy General Manager, Business Development, EESL; Mr. Rajneesh Rana, Deputy General Manager, Contracts, EESL; Mr. Mohit Khatri, Deputy General Manager, Finance, EESL; and Mr. Adesh Saxena, Project Manager, EESL
- **Ontario, Canada**: Kerry Wilson, RealTerm Energy; Phil Jessup, LightSavers Canada; Scott Vokey, Local Authority Services, Ontario; George Shaparew, InnPower (Innisfil, Ontario); and Brian Aaltonen, Municipality of Greenstone, Ontario
- **Birmingham, United Kingdom**: Anne Shaw, Acting Assistant Director, Transportation, Connectivity, and Economy Directorate, Birmingham City Council; and Paul Laythorpe, Highways Electrical Asset Manager, Street Services Division, Birmingham City Council
- **Guadalajara, Mexico**: Ing. Héctor Ledezma Aguirre, Director of States and Municipalities, CONUEE, Government of Mexico; Lic. Francisco Castillo, Secretary of Public Services, Municipality of Guadalajara; Ing. Alberto Arreola, Director of Street Lighting, Municipality of Guadalajara; and Ing. Sergio González Cota, Advisor to the Municipality of Guadalajara and Member of the Association of Electrical Engineers from the State of Jalisco
- **Quezon City, Philippines**: Ricky Aureo, Engineer and Head of the Task Force on Streetlights; Frederika Rentoy, Head of the Environmental Protection and Waste Management Department; and Andrea Andres-Po, Assistant Department Head III in the Environmental Protection and Waste Management Department of the Quezon City government

Finally, the report benefited tremendously from support by Rohit Khanna, ESMAP Practice Manager, World Bank. It also significantly benefited from comments by Wendy Hughes, Lead Energy Economist; Ivan Jaques, Senior Energy Economist; Martina Bosi, Senior Energy Economist (ESMAP); Ashok Sarkar, Senior Energy Specialist (World Bank); and Luiz Maurer, Principal Industry Specialist (International Finance Corporation).

EXECUTIVE SUMMARY

Many cities around the world are implementing public lighting programs for two main reasons. First, public lighting promotes community safety: studies have shown that public lighting can reduce crime by up to 20 percent,[1] and can reduce the number of fatal traffic accidents by 35 percent.[2] Second, public lighting supports economic growth by increasing the amount of time that people can spend on economic activities such as "entertainment and meals away from home at night." [3]

Within these public lighting programs, light-emitting diode (LED) technology is becoming increasingly popular because it has several advantages over alternative forms of public lighting. For instance, LED electricity consumption tends to be 40 to 60 percent lower. Also, operation and maintenance costs tend to be lower because LED luminaires last at least four times longer than traditional bulbs. Thus, despite higher initial cost, the lifetime costs for LED can be lower than for less efficient lighting options. Additionally, LED lighting is generally perceived as of better quality than traditional lighting because it has a higher color rendering index.

However, there are several challenges associated with LED public lighting. For instance, although the capital cost is falling by 10 to 15 percent per year, it is still much higher[4] than that of contemporary options. City governments and other responsible authorities often struggle to raise financing for the investment. Moreover, because LED lighting is fairly new (the oldest large-scale[5] implementation was completed in 2013 in Los Angeles, United States), it is still perceived as risky. Risk-averse city governments are often hesitant to adopt this relatively new technology. Finally, when they decide to invest in LED lighting, city governments often struggle with both a lack of capacity and a lack of supportive national institutional and regulatory frameworks.

Several delivery models have been found to successfully address these challenges, and the delivery model option used to address barriers depends on several factors such as the city's[6] objectives, the existence of appropriate legal frameworks, the city's size, the willingness of cities to work together, the stability of the city's leadership, and the technical capacity of city staff. This report summarizes six such models in the form of case studies: **energy service company** (ESCO), **super-ESCO**, **joint procurement**, **public-private partnership** (PPP), **lease-to-own**, and **municipal financing**. The case studies highlight the key themes of risk allocation and mitigation, government (beyond the municipality level) roles, private sector roles, stakeholder engagement, and experience with mid-stream adjustments, as follows:

Risk allocation and mitigation. Municipal governments have used a mix of strategies to mitigate technical, performance and financial risks. To minimize technical risk, many have obtained product warranties from manufacturers, and some have even arranged for third-party, independent tests of the LED luminaires or completely outsourced public lighting infrastructure. To minimize performance risk, some conducted extensive pilots and/or used energy performance contracts. And to minimize financial risk, financiers obtained guarantees from the state or commercial banks.

Government roles (national and state). Some governments developed and implemented supportive policies, laws, regulations and technical standards; some provided incentives; some provided technical assistance; and one set up a super-ESCO. At a minimum, national governments provided public lighting standards that served as useful guidelines for the programs.

Private sector roles. In most cases, the private sector provided financing—as debt and/or equity. In all cases, the private sector provided technical expertise in an

advisory role or as contracted engineering service providers. The private sector also provided operational efficiency in cases where the municipalities relinquished ownership and operations of the public lighting infrastructure.

Stakeholder engagement. Some cities engaged local utilities that provided incentives and/or technical expertise. In one case study, the local utility installed LED luminaires in areas under its jurisdiction. Some municipalities engaged local activist groups that supported LED investments because of their climate change mitigation benefits. Some engaged international partners, such as the World Bank and KfW, which provided financing and technical expertise. Still, other municipalities engaged partners that helped with program branding.

Experience with midstream adjustments. Several municipalities had to make adjustments as the programs advanced. For example, two cities had to revise and reissue their procurement bidding documents in order to attract qualified candidates—one had to loosen its local manufacturing requirements and the other had to indicate its desired levels of efficiency gains.

The detailed case studies are available on the ESMAP website.[7] Each case study discusses the motivation of the municipality to launch a LED program, the context in which the decisions were made, and the model selected. The discussion of the model includes program development, financing, risk allocation, procurement, implementation, and lessons learned. These case studies present real-life examples of cities managing to attract private sector participants to provide necessary financing and technical expertise; examples of programs implemented in municipalities that are not creditworthy and have limited policy and institutional support; examples involving small municipalities of about 2,500 residents, as well as cities with several million residents; examples of cities managing the perceived risk; and finally, examples of cities effectively handling the measurement and verification of electricity savings accruing from the implementation of more efficient LED lighting.

Brief overviews of the six case studies:

1 | The **energy service company** (ESCO) [8] model was applied in Central and Northwestern India by Asian Electronics Limited (AEL). The main challenges facing the cities were poor public lighting quality and high public lighting electricity costs. The ESCO model was appealing because the cities could not raise the upfront investment. A private ESCO was selected because there were neither government-owned ESCOs nor significant government programs aimed at helping cities install LED lighting. AEL financed the investment using its balance sheet along with carbon finance. The municipalities are repaying the ESCO out of the electricity savings.

As one of the first ESCOs in India to provide efficient-lighting programs, AEL had to overcome several challenges using the ESCO model without a national ESCO framework:

- It was difficult to define electricity consumption baselines in contracts. Electricity consumption increased as the number of functioning lights increased and as cities expanded public lighting coverage. The resulting increase in electricity use due to increasing number of lighting points, in some cases, exceeded the reduction in electricity use per lighting point due to efficiency gains, with the result that the overall electricity bill went up. This created a problem because the cities anticipated making payments based on “saved electricity.”
- There were no provisions in the contracts for factors beyond the ESCO’s control, such as irregular voltage and poor infrastructure, which affected

the performance of the public lighting system. Again, this caused difficulties because payments were based on system performance levels.

- In some cases, ESCO and carbon financing contracts had different measurement and verification (M&E) methodologies. This increased M&E costs and made the M&E process more difficult.

Despite these challenges, AEL managed to come up with innovative solutions and was able to replace baseline fixtures with more-efficient lighting.

2 | The **super-ESCO**[9] model was used in Visakhapatnam (Vizag), India. The Vizag context was different from the AEL context. Cyclone Hudhud had destroyed infrastructure in the city, and there was no public lighting. A few years prior, in 2010, the government of India, through the Ministry of Power, had set up a super-ESCO called Energy Efficiency Services Limited (EESL) that was transforming the LED market in India by lowering LED costs and setting standards for ESCO procurement. As a result, Vizag chose EESL to lead a program for the replacement of its 92,000 lights. Due to the emergency nature of the situation, the program was stripped down to three steps: (i) the signing of an implementation agreement between EESL, Vizag, and the state (Andhra Pradesh) government; (ii) definition of a payment mechanism; and (iii) the selection of an implementation partner. The entire replacement was accomplished in six weeks, illustrating that LED programs can be implemented quickly when necessary. EESL provided the upfront investment, and Vizag is repaying the loan from the electricity savings. Lessons from this case study are particularly relevant for stakeholders interested in super-ESCOs and cities interested in quick program implementation.

3 | The **joint procurement** model was used in Ontario, Canada, where municipalities were both driven by the need to lower public lighting electricity costs, and encouraged by the generous incentives for LED programs provided by the provincial and national governments. Unlike Indian cities, Ontario's cities generally have significant financial resources and can easily raise low-cost capital—as low as 3 percent compared to rates of 12 to 15 percent in India. Additionally, the Canadian municipalities had a history of working together with the Local Authorities Services (LAS), a nonprofit company wholly owned by the Association of Municipalities of Ontario (AMO). As the exclusive procurement arm of the Association of Municipalities of Ontario, Local Authorities Services initiated the joint procurement in Ontario. The company competitively procured both the operator (the special purpose vehicle that implemented the programs) and the firm that supplied LEDs to all municipalities. This removed the burden on each municipality of having to procure its own operator and LED supplier, thus, significantly cutting transaction costs. Local Authorities Services also developed a framework agreement between the operator, the LED luminaire manufacturer, and the municipalities. The agreement covered elements of the program common to all municipalities, such as technical lighting standards derived from the national lighting standards. The detailed photometric designs were unique to each city, and the municipalities had to negotiate specifics with the operator and manufacturer on their own. The municipalities also individually negotiated the financing mechanism details, depending on their access to capital and creditworthiness. Many obtained incentives and used their own capital. The model is particularly relevant for cities that can benefit from increased economies of scale by jointly procuring their LED public lighting programs. Unlike centralized procurement, the joint procurement had some flexibility, which allowed cites to craft tailored solutions.

4 | The **public-private partnership** (PPP) model was used in Birmingham, United Kingdom. The case study is particularly interesting as it describes the combining of

several infrastructure investments under one PPP contract; as such, it serves as a model for cities and governments that wish to bundle investments in order to lower individual transaction costs. In this case, the PPP's scope included maintenance of roads, streets, and bridges in addition to lighting. The city was motivated to embark on the program by the need to revitalize its infrastructure and carry out deferred maintenance. The PPP option was particularly appealing because it meant that the city could access technical and financial support from the government under the Private Finance Initiative (PFI). The PFI—an established PPP legal and institutional framework—was vital for the success of this PPP model. The framework provided contracting guidelines among the different stakeholders, an environment familiar enough for private investors to provide financing at reasonable cost and technical assistance to parties to the PPP. Under the PPP model, Birmingham signed a 25-year contract with Amey Plc. Financing was provided by both the government and private sector (banks, funds, and Amey Plc itself), a special purpose vehicle (SPV) majority-owned by Amey Plc installed the LED lights, and Amey Plc assumed ownership and maintenance of the lights for the duration of the contract.

5 | The **lease-to-own** model was applied in Guadalajara, Mexico. The Guadalajara municipality had two goals: lowering crime rates and improving safety in parts of the city, and lowering public lighting electricity and maintenance costs. The program was implemented in the context of a national lighting program initiated by the national government. The program provided substantial technical assistance, a private company provided financing with a payment guarantee from the state government (using federal resources), another private company installed the LED luminaires (and assumed the technology and performance risks), and the municipality has responsibility for the maintenance. The national program initially had five key signatories—the Federal Electricity Commission (*Comisión Federal de Electricidad* or CFE), the National Commission for the Efficient Use of Energy (*Comisión Nacional para el Uso Eficiente de la Energía* or CONUEE), the National Bank of Public Works and Services (*Banco Nacional de Obras y Servicios Publicos* or Banobras), the Ministry of Finance, and the Ministry of Energy—and this presented significant bureaucratic challenges. The national program had to be restructured and simplified in order to improve implementation. This model is particularly relevant for cities involved in national programs and governments developing national programs.

6 | The **municipal financing** model was used in Quezon City, Philippines. The city was driven to embark on an efficient street lighting program by the need to lower street lighting electricity costs, which constituted 65 percent of the city's electricity costs and 5 percent of its overall budget while the city's rapidly growing population was putting additional pressure on the city budget. The program was designed and implemented in the context of a stable city government with enough resources to launch the program on its own and many partners interested in helping the city given its track record in making environmentally friendly investments. The municipality used its own capital to finance the investment. A special purpose vehicle oversaw the LED installations, and the luminaire supplier assumed the technology risk by providing an eight-year product warranty. The main advantage of the municipal financing model is that financing costs can be lower than for the other models described here, but the programs can take a long time depending on available municipal resources.

This report is divided into three chapters. Chapter 1 discusses the benefits of public lighting using LED technology. Chapter 2 provides summaries of each case study. Finally, Chapter 3 discusses key cross-cutting findings that address financial barriers, a variety of risk mitigation strategies, the role of the government and the private sector, mid-stream adjustments, and other themes.

1 | LED FOR PUBLIC LIGHTING: BENEFITS AND CHALLENGES

Access to public lighting is an important element of development, and LED public lighting provides additional benefits beyond those typically provided by traditional forms of lighting. As a result, entities responsible for public lighting—such as city governments,[10] national government departments, and local utilities—have expressed interest in implementing LED public lighting using delivery models suitable for their respective political, institutional, and market environments as well as their financial capacity. This report is one in a series of publications the Energy Sector Management Assistance Program (ESMAP) has produced to share experience and lessons learned about various approaches to undertaking LED public lighting interventions. This report includes summaries of six case studies:

1 | **ESCO Delivery Model** as was implemented by Asian Electronics, Limited in Central and Northwestern India

2 | **Super-ESCO Model** as was implemented by Energy Efficiency Services Limited (EESL) in Vizag, India

3 | **Joint Procurement Model** as was implemented in Ontario, Canada

4 | **Public-Private Partnership Model** as was implemented in Birmingham, United Kingdom

5 | **Lease-to-Own Model** as was implemented in Guadalajara, Mexico

6 | **Municipal Financing Model** as was implemented in Quezon City, Philippines

In addition to the case study summaries (the full case studies are available on ESMAP's website[11]), this report highlights cross-cutting findings, and discusses the overall benefits of public lighting, factors motivating municipalities to embark on LED programs, and lessons learned from the programs.

PUBLIC LIGHTING

Societies around the world consume varying amounts of lighting, depending partly on environment, lifestyle, and level of development. For example, the average North American consumes 101 megalumen-hours of lighting per year, the average European 42, and the average developing-country citizen 8.[12] As countries develop, the level of consumption is bound to increase, though the level of efficiency and culture will have a significant impact on the rate of increase. Another driver of demand growth is the rural-urban migration—5 billion people (comprising 60 percent of the world population) are expected to live in cities by 2050. The International Energy Agency (IEA) estimates that overall demand for lighting will grow by 3.6 percent per year under current economic and energy efficiency trends, and will be 80 percent higher by 2030. Most of this growth will happen in developing countries.

Public lighting is one category of lighting and it is particularly important from the public sector perspective. While lighting as a whole represents over 15 percent of global electricity consumption, public lighting represents 4 percent—which is equivalent to the amount of electricity consumed by Germany, the fourth largest economy in the world. Most public lighting is concentrated in cities, where it sometimes constitutes up to 40 percent of municipal electricity budgets.[13]

Public lighting has three key benefits: (i) it fosters economic growth, (ii) it improves safety by reducing crime and traffic accidents, and (iii) it enhances city aesthetics by accenting monuments, fountains, and landmarks. The first two benefits—fostering growth and improving safety—are particularly important for development and are discussed further below.

Fostering Economic Growth

Stanford University researchers at Resources for the Future, a Washington-based research group, found that improved lighting can lead to increased economic growth, particularly in areas where there was no public lighting or poor lighting before.[14] At its simplest, this is because people can participate in economic activities after sunset. For example, after the Serbian city of Kllokot installed better public lighting, it observed increased business activity as citizens stayed out later. When the businesses recognized the value provided by the municipality, they started paying municipal taxes more regularly and that, in turn, enabled the municipality to provide more services.[15] The contribution of such economic activity to the gross domestic product (GDP) is important. According to the U.S. Bureau of Labor Statics, 10 percent of a typical American family's annual expenditures goes to "entertainment and meals away from home," usually at night.[16] The percentage is higher in cities with young professionals. Thus, the increase in economic growth due to night-time economic activities can be substantial.

Improving Safety

Better public lighting also reduces crime and traffic accidents, thereby improving the safety and livability of cities. A meta-study by the UK Home Office—based on a systematic review

of 13 studies conducted in the United States and the United Kingdom—found that improved lighting reduced crime by 21 percent compared with control areas. The decrease in crime was greater where existing lighting was poor and the lighting improvement considerable.[17]

Similarly, several researchers have concluded that improved lighting reduces the number of fatal traffic accidents. While only 25 percent of all travel occurs between 7 p.m. and 8 a.m., accidents between these times account for 40 percent of fatal road traffic accidents. One study showed that nighttime accidents declined by 65 percent following the installation of better lighting.[18] The New Zealand Transport Authority (NZTA), when evaluating a recent 35 percent reduction in fatal crashes, attributed a large role to improved lighting.[19]

It is important to note that smart dimming of lights to reduce excessive electricity consumption does not necessarily reduce the benefits of improved lighting. *Smart dimming* is the selective reduction of public lighting illumination and typically uses a centralized control system. The dimming is done when the streets are largely deserted—say, between 2 and 5 a.m.—in such a way that the level of dimming is not easily noticeable to the naked eye. Researchers at the London School of Hygiene and Tropical Medicine analyzed data from 62 municipalities across England and Wales and found that smart dimming did not lead to increased fatal accidents.[20]

LED LIGHTING

In 2014, the Royal Swedish Academy of Sciences awarded the Nobel Prize in Physics to three researchers whose work contributed to the development of LEDs.[21] LED lighting is a type of solid-state lighting that has three main advantages over traditional lighting technologies:

- 40 to 60 percent less electricity consumption, depending on the mix of public lighting technologies replaced—typically high-pressure sodium (HPS), mercury vapor (MV), and metal halide (MH);
- Longer lifetimes—over 50,000 hours, compared to HPS (32,000 hours) and MV lighting (12,000 hours); and
- Better color rendering, meaning that the human eye sees more of the colors it sees during daylight under LED light than under HPS light.

The remainder of this section discusses these advantages and the challenges associated with LED lighting in the context of public lighting programs.

The Benefits

In places with inefficient public lighting, investing in more efficient LED lighting infrastructure can potentially lower costs over the lifetime of the investment. LED lighting consumes less electricity and lasts longer, requiring fewer luminaire replacements and less maintenance. In the United States alone, reducing lighting electricity consumption by 40 percent by investing in LED lighting would save US$53 billion in annual electricity costs and reduce electricity demand by the equivalent of 198 mid-size power stations.[22] The reduction in electricity consumption translates into a reduction in greenhouse gas emissions.[23] With regard to outdoor lighting, the United States would save US$6 billion annually and reduce carbon emissions by the equivalent of taking 8.5 million cars off the roads for a year.[24]

However, the reduction in lifetime and system costs is not universal due to the high capital costs of LEDs. LED lighting tends to be economically and financially viable where

the cost of electricity is high, the price of LED luminaires is not inflated by exchange rates and taxes, and/or the maintenance cost is high due to high labor costs or older existing lighting technologies.

In many local contexts, the cost reductions can be important in no small part because savings can be allocated to other needs. For example, the Nairobi City County Government paid US$0.23 per kilowatt hour of electricity for public lighting in 2014. Across its 29,000 public lighting points, Nairobi could have saved about 60 percent on its electricity operations and maintenance costs, and the investment would have paid for itself in seven years. The savings could have been used to expand public lighting coverage, which is needed to improve security in the city.[25] In cities where public lighting costs are paid using earmarked taxes, LED lighting could help lower those taxes. For instance, in Brazil, electricity bills include a public lighting tax. In Rio de Janeiro, lower electricity bills could help regularize service provision for the 1.3 million people living in *favelas* by improving electricity affordability. This would encourage safe electricity consumption while providing a strong incentive for utilities to invest in efficient public lighting.

LED public lighting improves safety as well. It has a color rendering index of 80, far superior to HPS lighting's index of 23. This means that under LED lighting, the human eye sees 80 percent of the colors that it would typically see in daylight, compared to only 23 percent of the colors that it would see under HPS light. This not only increases safety for those out at night, but also makes it easier for police to identify suspects, especially when paired with security camera systems.

The Challenges

Although LED public lighting capital costs are falling by 10 to 15 percent per year,[26] they are still higher than those of traditional technologies such as HPS and MV lighting. Unsubsidized LED luminaires can cost two to four times more than HPS luminaires, depending on taxes, exchange rates, the absence or presence of local manufacturing, and the size of the LED program.[27]

In addition, the payback period of LED investments depends on local electricity prices. The higher the cost of electricity, the shorter the LED investment payback period will be. Existing LED public lighting programs tend to have payback periods of between five and seven years, though some programs designed for specific uses, such as bus stations and warehouses, tend to have shorter payback periods of around three years. In general, the payback periods are decreasing as LED prices continue to drop and electricity prices continue to rise.

Lastly, although LED public lighting technology is often *perceived* to be riskier than older technologies—municipalities contemplating investing in LED lighting often cite the limited global experience with LED public lighting as a key barrier—this perception is slowly changing as more programs are implemented, more success stories are told, and manufacturers provide long-term warranty periods to mitigate risk for municipalities. Moreover, some municipalities are transferring this risk to special purpose vehicles that oversee the LED public lighting programs.

Looking Forward

Overall, there is significant appetite for LED public lighting programs where they make sense economically, financially, and politically. The institutional setup of the public lighting sector tends to make it a "low-hanging fruit" for energy efficiency investments: it generally falls under the jurisdiction of one or two entities in the city, it is politically visible, and the investments can be large enough to lower per-luminaire transaction costs and attract large investors.

2 | DELIVERY MODEL CASE STUDY SUMMARIES

Municipalities that are interested in the benefits of LED public lighting often face significant challenges such as lack of capital, high perception of risk associated with LEDs, lack of a supportive regulatory environment, and unfamiliarity with the delivery models that would best serve their needs. This chapter aims to assist these municipalities by summarizing how six cities across the globe—featuring different institutional, political, and financial contexts—have used distinct delivery models to implement LED programs. The models are energy service company (ESCO), super-ESCO, joint procurement, public-private partnership (PPP), lease-to-own, and municipal financing. Each summary begins by discussing the particular challenges and opportunities that motivated the municipality to adopt LED public lighting programs. This is followed by a description of the program's implementation that covers program development, financing, procurement, and installation. The summaries then end with a short commentary on the model.[28]

1. ESCO DELIVERY MODEL: ASIAN ELECTRONICS, LIMITED IN CENTRAL AND NORTHWESTERN INDIA

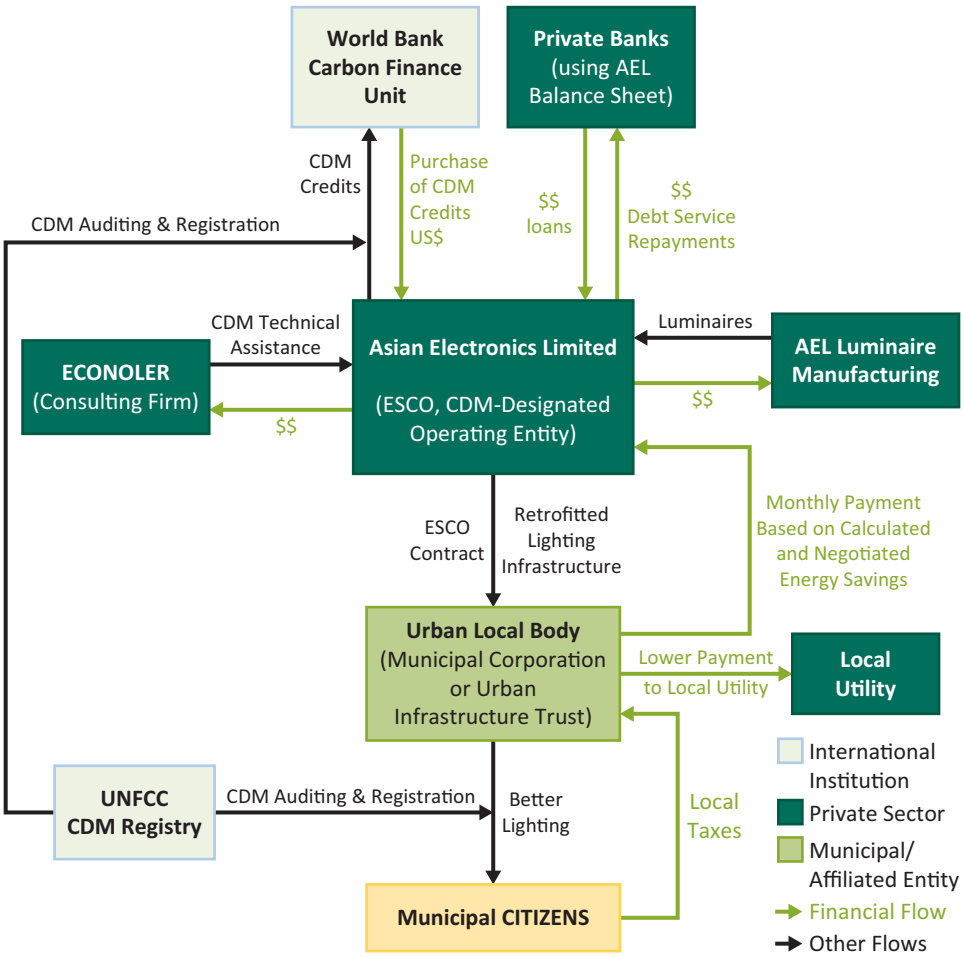
In India, street lighting electricity and maintenance costs can consume 5 to 10 percent of municipal budgets in large cities and up to 20 percent in smaller cities. The cost of electricity has been rising—accounting for over 80 percent of all expenditure on street lighting—and municipalities are struggling to make the payments. Moreover, 5 to 10 percent of the lights are either over- or under-designed, resulting in inefficient and/or inadequate street lighting. The need to find cost-effective solutions that provide better street lighting is acute.

Around 2005, Asian Electronics Limited (AEL) emerged as one of the first few **energy service companies** (ESCOs) in India to offer fully financed shared savings energy performance contracts (EPCs) for public lighting. There were no government-owned ESCOs at the time, and there were only a few national public lighting energy efficiency programs that were struggling to take off. This case study discusses AEL's efficient lighting program in India, which covers seven municipalities: Latur, Akola, Pune, Ajmer (via the Ajmer Municipal Corporation [MC] and Ajmer Urban Improvement Trust [UIT]), Bikaner, Alwar (via Alwar UIT and MC), and Indore.

While India now has a famous ESCO market and well-known framework, neither existed when AEL started developing its program with the cities in 2005. AEL had to convince cities of the potential to achieve savings without the cities needing to make upfront capital investment. This often marked the beginning of its program in a given city. Once the cities expressed interest, the program development process would continue with the city providing input (by defining geographic scope, desired service and infrastructure upgrades, and technology requirements based on national standards) and the ESCO would then help the city to develop the program scope and conduct an energy audit.

Financing for the projects was challenging. Municipalities in India are greatly restricted in terms of access to debt capital. Many are not creditworthy and often require state-level approvals (which can be difficult to obtain) in order to borrow. Thus, AEL had to raise financing for all upfront costs. As a division of a large-scale lighting manufacturer, AEL was able to use its AAA credit rating and its balance sheet to secure corporate bank loans at 12 to 15 percent interest per year. Additionally, the ESCO obtained carbon financing from the World Bank Community Development Carbon Fund (CDCF). The cities

Figure 1: Notional Flows for the ESCO Model | LED Street Lighting Retrofit by AEL Project in Central and Northwestern India



are repaying EESL out of both the electricity savings and a portion of the funds from the sale of certified CO_2 emission reductions to CDCF. Figure 1 summarizes the notional flows in the AEL ESCO model in India. This model evolved as AEL improved its operations—as explained briefly later in this section.

Procurement under the program was not uniform due to the absence of a national framework for ESCO contracts. The cities in the case study procured AEL's services independently using different procedures and contracts. This made the process challenging and expensive. However, AEL standardized its contracts as the program progressed and provided later cities with bidding templates from other cities, bringing some uniformity to the procurement process.

Installation was typically lead by AEL as the ESCO usually signed Design, Supply and Install (DSI) contracts with the cities. AEL would often start by demonstrating the savings using a small pilot project, and then proceed with full-scale designs and complete installations.

The case study is particularly informative as AEL was one of the first ESCOs in India. It documents the challenges the new ESCO encountered and how it addressed them.

For example, AEL started with the shared savings model—AEL would get about 80 percent of the energy savings (i.e., the city paid them 80 percent of the avoided cost due to energy savings) and the city would get the remaining 20 percent (the percentages varied by city)—but switched to a deemed savings model as the ESCO struggled with delayed payments and verifying energy savings. In the deemed savings model, AEL and the city would agree on expected savings based on a pilot and payments were based on the results of that pilot. The savings were crucial for both the ESCO contracts and the Clean Development Mechanism (CDM)[29] funding because payments depended on them. The cities repaid AEL from the energy savings and the CDM paid AEL based on verified energy savings. The different requirements for measurement and verification (M&E) of the two mechanisms compounded the difficulty of demonstrating results: the Emission Reduction Purchase Agreement (ERPA) with CDCF measured *luminaire* (light) performance whereas the ESCO contract measured *lighting pole* performance. Thus, a lighting pole comprising two or more luminaires (with one luminaire working) could be recorded as meeting performance under the ESCO agreement but not under the Emission Reduction Purchase Agreement.

AEL tried three solutions: (i) adjusting the baseline of record by accounting for increased consumption as broken luminaires were repaired and the city expanded public lighting coverage; (ii) advocating for frequent updating of baselines using real measurements; and (iii) making provisions for factors outside of AEL's control that would affect lighting performance, such as electricity outages, theft, and irregular voltage. This last solution included investing in load management systems with a global positioning system to locate failed fixtures, and reducing electricity theft by concealing supply points and using tamper-proof meters. These measures proved difficult and costly, and AEL gradually migrated towards the deemed savings model—where the savings were estimated on the basis of pilot programs.

In order to be certain of recouping its investment, AEL required the cities to provide bank or state government guarantees. The deemed savings model minimized M&E costs, lowering overall investment capital requirements. AEL further evolved its model to separate service and maintenance payments from capital repayment; this separation allowed AEL to withhold maintenance service if the cities failed to pay and reduced the risk of nonpayment. Finally, AEL sought the preapproval of initial payments and automated approval of payments in order to reduce delays associated with the bureaucratic process of approving payments and municipal cash flow problems.

2. SUPER-ESCO DELIVERY MODEL: ENERGY EFFICIENCY SERVICES LIMITED IN VIZAG, INDIA

Visakhapatnam (Vizag) is the largest city in the state of Andhra Pradesh and has a GDP of US$26 billion. In 2014, Cyclone Hudhud damaged much of Andrah Pradesh's infrastructure, including street lighting (81,000 of the 91,000 streetlights in Vizag were destroyed) and telephone and electrical grid systems. Total economic losses were estimated at US$11 billion. The Andrah Pradesh government and Greater Visakhapatham Municipal Corporation (GVMC) reached out to Energy Efficiency Services Limited (EESL)—a well-respected super-ESCO[30] established by the Indian government in 2010—to rebuild the entire public lighting system in Vizag.[31]

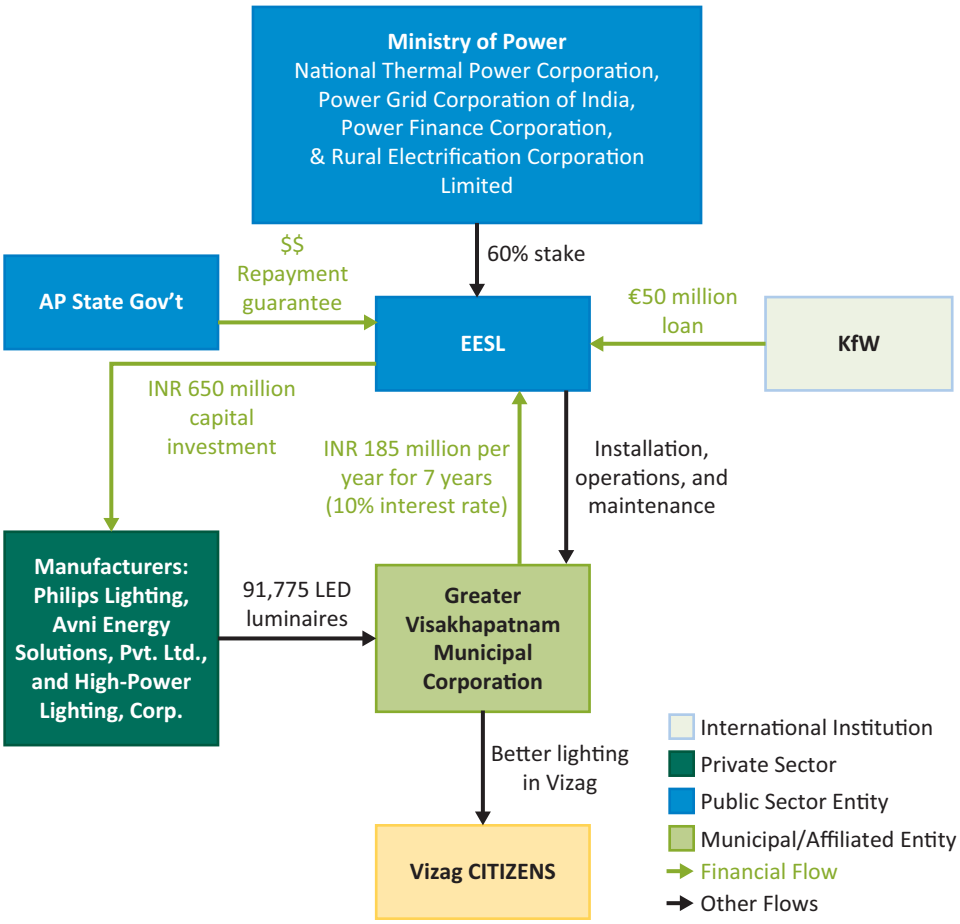
EESL took on the challenge of retrofitting the streetlights in Vizag with LEDs. As a **super-ESCO**, EESL's objectives included creating and sustaining the country's energy efficiency market; developing projects in various sectors, such as the public lighting sector; addressing specific barriers; enabling financing of energy efficiency projects at reason-

able rates; developing document templates; disseminating best practices; and providing transaction support.[32] Vizag provided an opportunity to contribute towards fulfilling some of these objectives. The broad context was conducive to EESL's success. The super-ESCO had a mandate to lead the implementation functions of the prime minister's National Mission of Enhanced Energy Efficiency (NMEEE), which sought to unlock the energy efficiency market in India. The price of LEDs was falling and many lessons had been learned (by both EESL and the Bureau of Energy Efficiency, which had led India's energy efficiency activities until 2010) from previous experience with struggling ESCOs.

In Vizag, the usual project development steps—preparing detailed energy audits, verifying the number of lights, demonstrating the technology, and so on—were skipped or compressed to accelerate the emergency installation of public lighting. Moreover, there were few streetlights to audit since most had been destroyed by the cyclone. Implementation began immediately after a tripartite implementation agreement was reached between EESL, Vizag, and the Andrah Pradesh government.

Upfront capital investment was provided by EESL, as is usual in ESCO contracts. The ESCO invested INR 650 million (US$9.8 million), and the notional flows are shown in Figure 2. A KfW loan financed 80 percent of the capital investment, EESL provided the

Figure 2: Notional Flows for the Super-ESCO Model | LED Street Lighting Retrofit by EESL in Vizag, India



remaining 20 percent as its equity in the project, and the Andrah Pradesh government provided the payment guarantee. Over the seven-year leasing contract, GVMC will pay EESL INR 185 million (US$2.8 million) every year, which reflects an annual interest rate of 10 percent. Vizag will make the annuity payments from the energy savings, which are expected to be between 50 and 55 percent of the baseline consumption. Once the leasing contract expires and all terms are met, ownership of the luminaires will revert to GVMC.

Despite being an accelerated process, procurement of the LEDs was transparent. Whereas EESL typically conducts a competitive bidding process to select the LED supplier and the installer, in Vizag the same were selected from companies that had already been vetted through a Request for Empanelment (being on a list of qualified suppliers and service providers). Three manufacturers—Philips Lighting, Avni Energy Solutions, Pvt. Ltd., and High-Power Lighting, Corp.—won the bid to supply the LEDs and a couple of smaller companies won the bids to install. EESL appointed a project team to oversee and supervise the quality of work, installation timelines, and compliance with the specified standards. It also organized daily meetings with Vizag and suppliers in order to plan the project execution phases and solve any field problems. The whole installation was completed in a record 45 days.

EESL's tremendous success depended on several key innovations that successfully addressed the challenges faced by AEL in Central and Northwestern India. Developing an annuity-based ESCO model is one such innovation and the model is now widely accepted as best-practice in India. The annuity-based model has the following features:[33]

- Payments to the super-ESCO are based on initially demonstrated and agreed upon energy performance rather than the energy bill. This removes the measurement and verification challenges that AEL encountered.
- Energy savings are demonstrated on a sampling basis during the preparation of a detailed project report (feasibility study). This accelerates project implementation as there is no need to conduct exhaustive energy audits, which require a significant amount of time and resources.
- A bank or state government guarantee is required to cover the capital costs. Ensuring that there is a repayment mechanism in case the city defaults on its payments reduces EESL's risk and lowers the cost of capital.
- There is a service-level agreement covering technical standards and free-replacement warranties. This ensures that the municipalities get good public lighting after the installations and reduces the municipality's risk.
- Repayments are based on fixed annual payments by the municipal corporation. This removes the disagreements on what the payments should be, and allows EESL to separate capital investments from operation and maintenance work. It also allows the government to better plan the use of its resources.

Additionally, being government-owned has allowed EESL to develop a widely accepted ESCO framework, whereas AEL could not do the same as a private company with a few municipal clients—particularly at the beginning. As a state-owned entity, EESL was perceived by the public sector (municipalities) as being driven by its public mandate rather than maximizing profits and that helped improve acceptance of its model.

3. JOINT PROCUREMENT DELIVERY MODEL IN ONTARIO, CANADA

The province of Ontario, in east-central Canada, consists of 444 municipalities and represents 13.6 million residents. Public lighting electricity consumption and operating costs are fairly high in Ontario due to the abundance of high-pressure sodium lighting and the remoteness of some municipalities. For instance, in Greenstone, a small town in northwestern Ontario, the nearest repair crews are at least three hours away by car, making it costly and slow to receive service when lights break. The need to reduce public lighting costs coincided with the activism of nonprofit groups such as LightSavers, which supports LED lighting because of its climate change mitigation benefits. The activists secured LED lighting support from key stakeholders such as Natural Resources Canada (the Federal Ministry of Natural Resources), the Toronto Atmospheric Fund, the Canadian Urban Institute, and the Ontario Power Authority (now merged with the Independent Electricity System Operator). These organizations provided financial incentives and political support that encouraged implementation of the LED lighting program in Ontario.

The program to retrofit public lights in Ontario was led by Local Authorities Services (LAS), a nonprofit company wholly owned by the Association of Municipalities of Ontario (AMO). Local Authorities Services chose to use the **joint procurement** model in order to: (i) leverage the municipalities' scale and buying power to secure lower prices; and (ii) relieve smaller municipalities of the burden of designing and managing a complex, two-stage procurement of energy services and luminaires. *Joint* procurement differs from *centralized* procurement in that the latter creates a single procurement contract that is divided among all the participating entities. By contrast, Local Authorities Services procured the operator and LED supplier, and negotiated a framework agreement that allowed cities to individually negotiate their specific lighting designs and financing needs. As of August 2015, 127 municipalities had participated in the program and more than 101,000 fixtures had been purchased.

Project development and procurement were each divided into two stages. The first *development* stage involved designing a framework grounded in national standards, LED studies by Local Authorities Services, and the identification of common municipal lighting needs by Local Authorities Services. This allowed Local Authorities Services to move on to the first *procurement* stage by competitively procuring RealTerm Energy (RTE) as the operating agent and Cree Inc. as the LED manufacturer. (The operating agent is responsible for handling turnkey services for municipalities such as design, installation, maintenance, financing, data management, and interfacing with local distribution companies and utilities, per preferences of the client municipalities.) Before moving on to the second development and procurement stages, RealTerm Energy focused on encouraging municipalities to join the program in order to create service contracts.

Then, in the second *procurement* stage, an interested municipality would fill out and return a questionnaire to Local Authorities Services, and RealTerm Energy would prepare a proposal and letter of intent to engage. The municipality would then present the proposed project to its town or municipal council for review in lieu of conducting its own expensive and technically demanding tendering process.

Once a municipality was onboard, the second *development* stage began with investment-grade audits and photometric designs specific to the number of lights of different

wattages, pole heights, fixture heights, setbacks, arm lengths, and so on of each municipality.

Financing mechanisms in the joint procurement model differed from city to city, depending on political needs and access to financing. RealTerm Energy offered three operational and financing models:

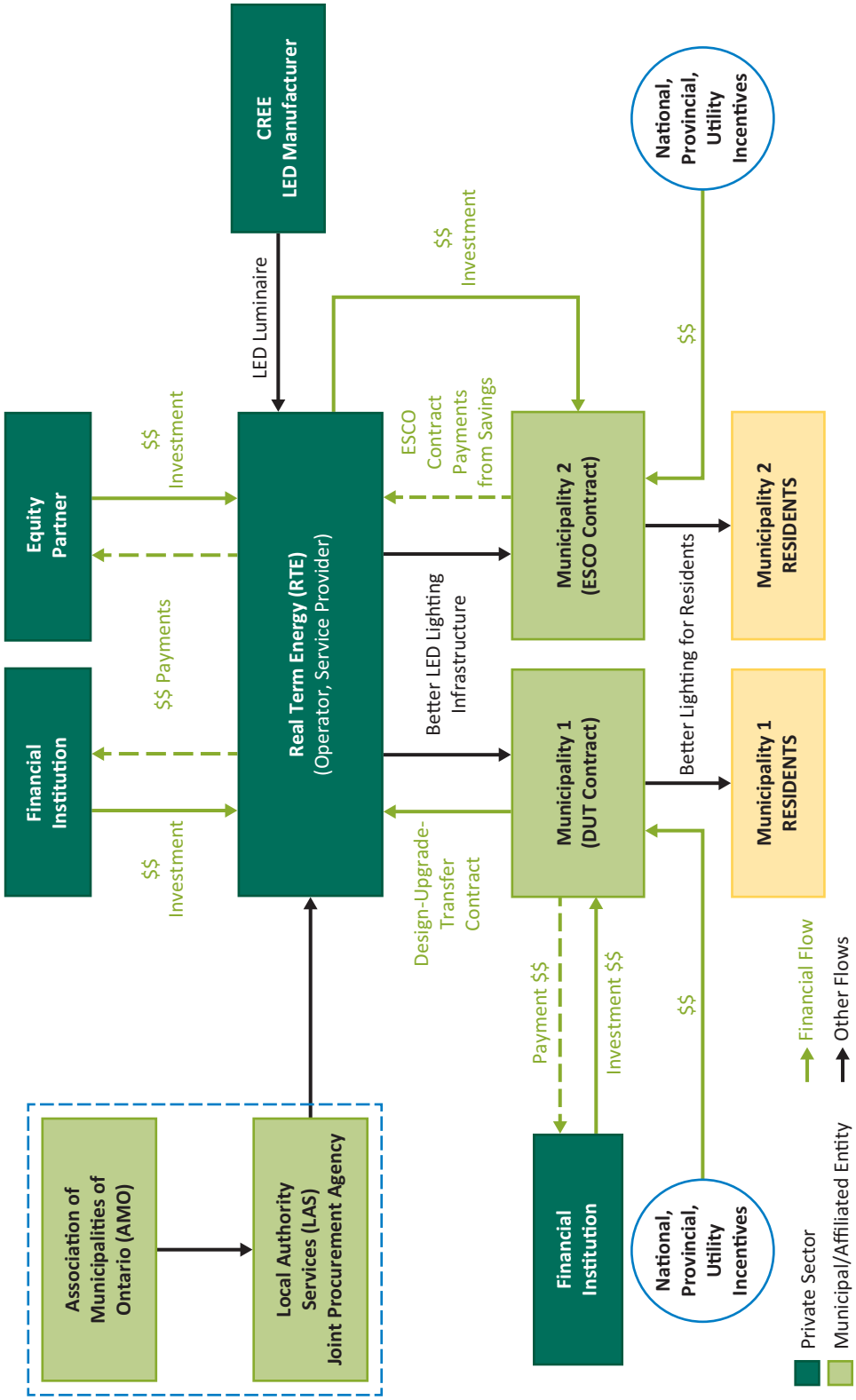
- **"Design-Upgrade-Transfer" Contract** or "design-retrofit-transfer" contract. Under this contract, the municipality supplies its own financing and hires RealTerm Energy to design and upgrade its public lighting.
- **Shared Savings ESCO contract.** Under this contract, RealTerm Energy provides the investment capital, and savings from the street lighting system are shared between RealTerm Energy and the municipality at a negotiated rate for up to 10 years.
- **Concession Contract.** In addition to providing all the services of the design-upgrade-transfer and shared savings ESCO contracts, RealTerm Energy manages the street lighting system for up to 20 years, bearing all maintenance and upkeep responsibilities. In turn, RealTerm Energy would charge operation and maintenance fees on top of the normal ESCO fees.

Most municipalities chose the design-upgrade-transfer (DUT) contract and a few chose the ESCO contract. None chose the concession contract due to the availability of capital and the creditworthiness of the municipalities in Canada: they can easily borrow at low cost (from Infrastructure Ontario or commercial banks) or issue municipal bonds. Infrastructure Ontario is a provincial financing agency raises money by issuing bonds and then offers low-interest infrastructure loans to municipalities. There were many incentives for the projects from the national and provincial governments, and the provincial utility as well. The incentives played a key role in the financing of the projects. For instance, the city of Innisfil, with 2,814 luminaires, had applied (at the time of writing) for a US$300,000 incentive on a US$1.1 million investment—a subsidy of 27 percent—from the provincial "saveONenergy" program. This subsidy more than doubled the net present value of the 10-year contract for Innisfil, from US$230,000 to US$530,000. Figure 3 shows the notional flows in the Ontario joint procurement for two generic municipalities: one choosing the DUT contract, and the other choosing the ESCO contract. Installations were done by companies hired by RealTerm Energy in both cases.

The Ontario case study illustrates an example where many small municipalities jointly procured LED public lighting with the help of a strong regional association. It allowed these municipalities to conduct competitive and transparent procurement in a cost-effective way. The flexibility of cities to choose their own contract and financing terms with the operator (while keeping luminaire costs and operator and manufacturer selection fixed) facilitated the participation of municipalities in the program.

This is a very appealing model for cities whose benefits from economies of scale outweigh the costs of collaboration. Because the cities in Ontario had worked together before, it was easy for them to do so again. It is worth noting that, because the joint procurement was led by a nonprofit association, there was limited bureaucracy often associated with joint procurement conducted through central governments.

Figure 3: Notional Flows for Joint-Procurement Model | LED Street Lighting Retrofit in the Ontario, Canada



4. PUBLIC-PRIVATE PARTNERSHIP DELIVERY MODEL IN BIRMINGHAM, UNITED KINGDOM

In the 20th century, Birmingham was the manufacturing hub of the United Kingdom and industrial taxes were a significant source of revenue for the city. As manufacturing declined in the United Kingdom, Birmingham City Council's (BCC) industrial tax revenue declined as well, and the city struggled to maintain its public infrastructure—including 97,000 streetlights—and accumulated deferred maintenance as a result. In 2000–01, the Council's conducted a Best Value Review of infrastructure maintenance, and concluded that city staff would not be able to carry out a step-wise improvement of the infrastructure and an external cash infusion would be needed to bring the infrastructure to a reasonable standard.[34]

As a result, Birmingham opted to implement a **public-private partnership** (PPP) under the Private Financing Initiative (PFI)—an established national PPP legal and institutional framework that provided contracting guidelines among the parties to the PPP—in order to implement the infrastructure improvements. PFI contracts are:

> *Long-term contracts (typically 20–35 years) where the private sector constructs the project's assets (for example a building) and raises the required funding, usually on a project finance basis (i.e. where contractual payments from the public sector represent the primary security for funders). . . By contracting in this way, the aim is to ensure that whole-life costs associated with such assets are minimized and required associated services are provided competitively. Wherever possible, contracts specify the outputs rather than the inputs associated with a particular project.*
>
> *Under PFI, a private sector firm creates and/or maintains the asset at its own cost. The public sector counterpart agrees to cover these costs over time, including the cost of capital, which is typically higher than if the public sector had funded the project itself. As long as the higher cost of capital is offset by greater efficiencies elsewhere, such projects still offer value for money for the public sector.*[35]

In the United Kingdom, the public and private sectors already had extensive experience working together under PPP policies first developed in 1974. Implementation of these policies was enhanced in 1992 when the government created the Private Financing Initiative. In 2012, the government improved the framework by creating Private Finance 2 (PF2).[36] Private Finance 2 better facilitated access to capital, had greater transparency, accelerated delivery, and had improved risk allocation mechanisms.

The PFI framework also allowed the government to provide financing (via "PFI credits") while facilitating private sector financing at reasonable costs (the framework was proven and well known within the United Kingdom that the perceived risk was low). The PPP itself allowed the city to access financing and technical expertise, benefit from private sector operational efficiency, and shift performance and technology risk to the private sector.

Through the PFI framework, Birmingham contracted Amey Plc to repair, modernize, maintain, and manage of 2,500 kilometers of roads, 4,200 kilometers of footways, 97,000 streetlights, 76,000 street trees, 1,100 traffic light signals, and over 850 bridges, tunnels, and highway structures over a 25-year period. This case study focuses on the streetlights. Decisive interest in LED lighting came from Amey Plc because the company

had assumed electricity cost risk in meeting the public lighting *output* requirements. Thus, any savings in electricity consumption would accrue to Amey Plc. The Birmingham City Council was also interested because of the benefits of LED lighting, such as reduced emissions and better lighting quality.

The total value of the contract is £2.7 billion (US$4.2 billion), of which US$117 million is for the lighting program.[37] Uberior Fund and Equitix Investment Fund provided £330 million in financing, the government provided £996 million in PFI credits, and the rest of the financing was provided by Amey Plc and its partners. The notional flows are shown in Figure 4.

Council's procurement of Amey Plc was done according to PFI guidelines. The bid for the contract was publicly advertised, 41 companies submitted expressions of interest, and the list was narrowed down to 2 finalists who were asked to produce best and final offers. In July 2009, the Council selected Amey Plc as the preferred bidder and, in May 2010, the final contract was signed.

After the Birmingham City Council awarded the contract to Amey Plc, a special purpose vehicle was created to install the LED lights. The city authorities feared losing control of city's assets and the labor unions worried about job losses. However, Amey Plc and the Council addressed these concerns. Many lighting staff joined both Amey Plc and the new special purpose vehicle. Council created a new Street Services Division (SSD) to audit Amey Plc's performance and manage the statutory functions, drainage, and emergency planning activities retained by the council. This also absorbed some of the staff.

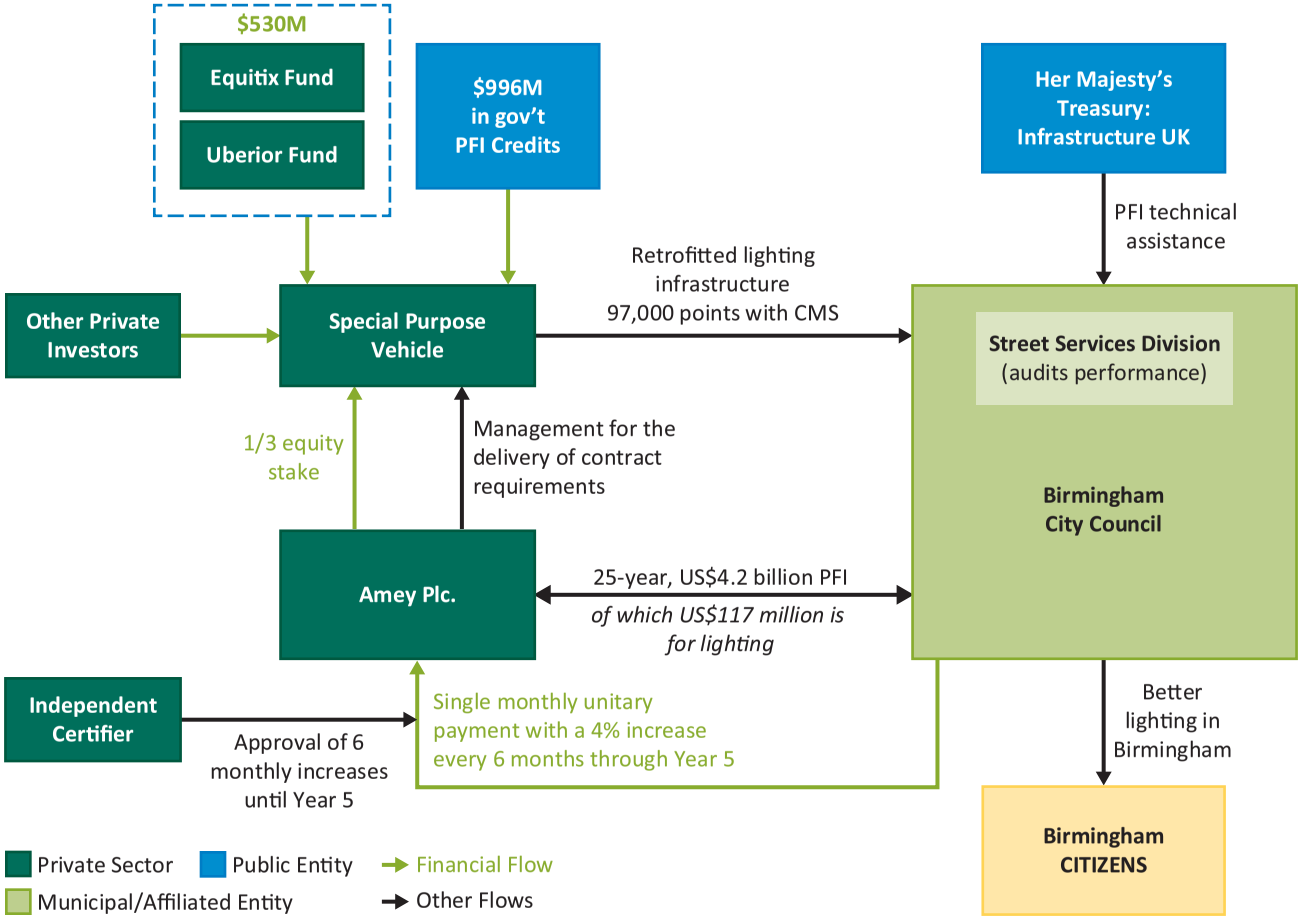
Given the financial and technical constraints facing many municipalities, the PPP model can be very appealing. However, the model has relatively high transaction costs, and small and medium cities might struggle to issue a PPP each time they need infrastructure upgrades. In this respect, the Birmingham case study is a compelling example of a broader PPP that includes several other forms of related infrastructure. Grouping similar kinds of infrastructure under one PPP contract may help cities lower their transaction costs.

The Birmingham PPP model is also informative as it has provisions for using the latest technology to meet the output requirements specified in the contract. This is because the contract defines service level criteria rather than technology. This is important because the life of the contract is 25 years and the underlying technology is bound to change over this period. Thus, the PPP contractor was free to choose LEDs as a way to meet the requirements while minimizing costs. The contractor went a step further and implemented a central management system (CMS) that allows the city to slightly dim lights at appropriate times—for example, between 2 a.m. and 5 a.m., when the streets are deserted—in order to reduce electricity costs. The central management system also allows the contractor to gradually increase the current flowing to the luminaires in order to prolong the useful life of the LEDs. The amount of light produced by an LED per unit of current (efficacy) decreases over time and the increased current compensates for the decrease in the LED's ability to produce light.

5. LEASE-TO-OWN DELIVERY MODEL IN GUADALAJARA, MEXICO

Guadalajara's street lighting infrastructure had not been renovated in over 30 years. Lighting crews could not keep up with outages reported by citizens and there were many

Figure 4: Notional Flows for Public-Private Partnership Model | LED Street Lighting Retrofit in Birmingham, UK



unlit areas around the city. These areas suffered from high crime rates. The dated infrastructure required a significant amount of spending on maintenance and electricity for street lighting represented approximately 18 percent of municipal electricity consumption—a significant component of the city's budget.[38]

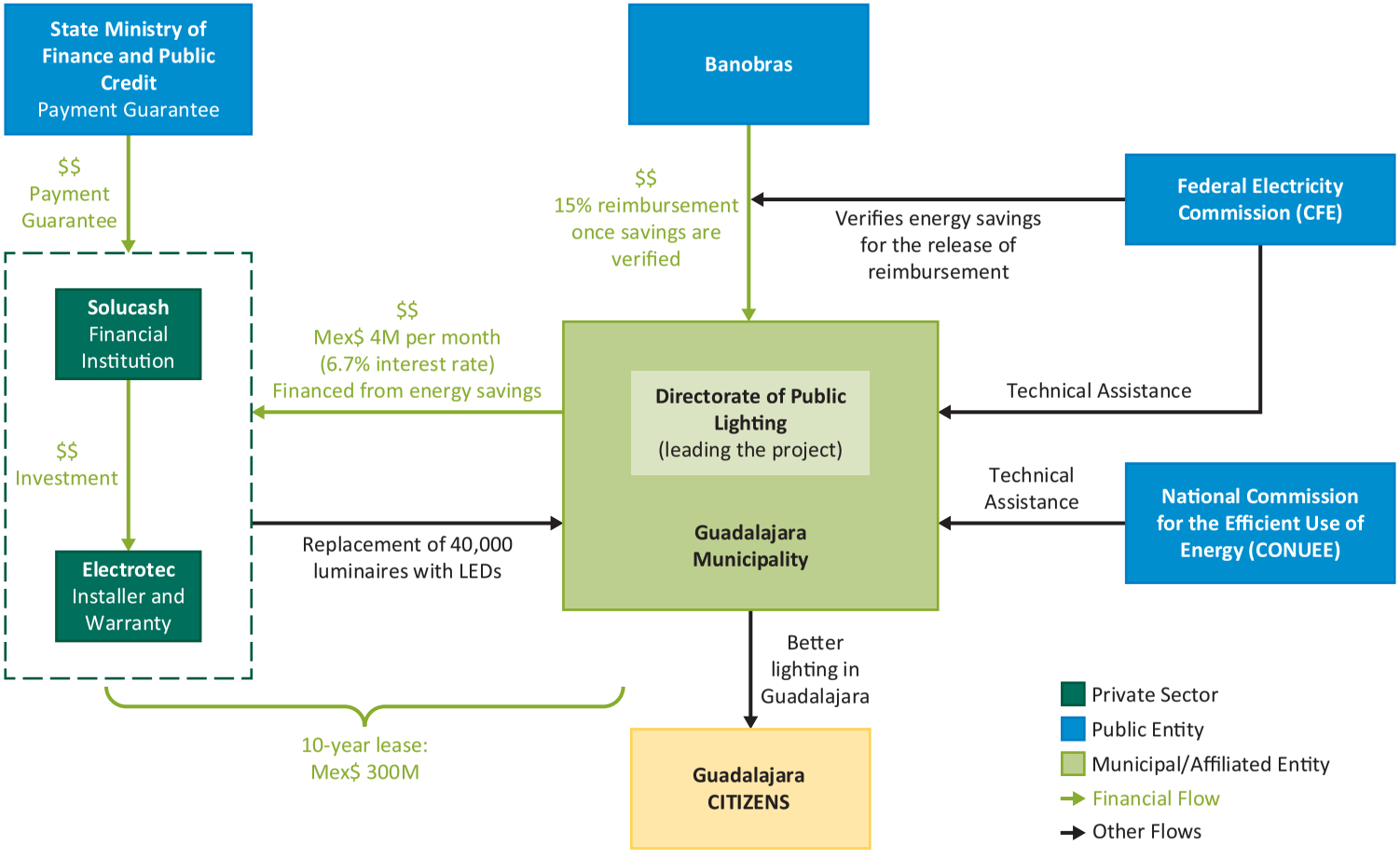
In the context of the National Public Lighting program established by the Mexican government in 2009-2012, Guadalajara initiated its LED street lighting program in 2013 with the objective of accelerating the implementation of better and energy efficient lighting. The city had approximately 80,000 streetlights in 2015, all of them sodium-vapor luminaires; of these, half were being retrofitted with LEDs in 200 districts and along 100 roads. The program also used a portion of the removed stock of still-operational sodium-vapor luminaires to replace the out-of-service luminaires in other parts of the city.

Program development began with Guadalajara authorities' preparatory assessment of the needs of the city's diverse districts (*colonias*), including the characteristics of key roads, in order to define lighting requirements. After conducting studies of public energy use in collaboration with the Federal Electricity Commission (*Comisión Federal de Electricidad* or CFE), the city then prepared and submitted a financing application, along with the technical documentation from the CFE studies, to the National Bank of Public Works and Services (*Banco Nacional de Obras y Servicios Publicos* or Banobras) and the National Commission for the Efficient Use of Energy (*Comisió Nacional para el Uso Eficiente de la Energía* or CONUEE) for financial and technical viability evaluation, respectively. These procedures (of going through CFE, Banobras, and CONUEE), which were required by the National Lighting Program, helped Guadalajara lower its perception of the risks associated with LED lighting. That being said, the procedures also made the program approval process quite bureaucratic.

Guadalajara municipality chose to use a **lease-to-own** delivery model, the notional flows for which are shown in Figure 5. In the lease-to-own model, the service provider (a partnership of private companies Solucash and Eletrotec) retrofitted the streetlights with LEDs and assumed ownership of retrofitted lights. Guadalajara then leased the retrofitted lights from the service provider and will reassume ownership at the end of the leasing contract. The financing instrument is a 10-year leasing contract valued at Mex$300 million (approximately US$19 million) for "the substitution of lighting and strengthening of lighting network infrastructure." The partnership obtained a repayment guarantee from the State Ministry of Finance, and Public Credit and Banobras will rebate 15 percent of project costs (up to Mex$10 million), if energy savings are realized. The rebate serves as an incentive. The municipality will pay an average of Mex$4 million (approximately US$250,000) per month to the Solucash and Electrotec partnership over the 10-year lease term, which reflects an interest rate of 6.7 percent.[39] After the leasing contract expires and all terms are met, ownership of the luminaires will be transferred back to the municipality.

In procurement, bidding requirements were produced by the Guadalajara municipality in collaboration with CONUEE. The municipality launched its first call for tenders in January 2015, using request for proposal (RFP) documents stipulating the installation of at least 50 percent LED luminaires, but did not receive any qualified bids. In March 2015, the municipality launched a second call for tenders requiring at least 75 percent LED luminaires. After narrowing the bids to two finalists and conducting three-day trial tests, Guadalajara municipality awarded the contract to the partnership between Electrotec and Solucash. The requirement for 75 percent LED luminaires sent a price signal that

Figure 5: Notional flows for Lease-to-Own model | LED Street Lighting Retrofit in Guadalajara, Mexico



had not been clear in the first RFP—specifically, it was clear that the city had intentions of installing LEDs and was willing to invest at LED price levels.

Following project approvals by the Ministry of Energy and Ministry of Finance, and additional delays after tendering, installations began in late 2015 and were ongoing as of April 2016. Electrotec is responsible for installations, a third-party comptroller is providing supervision, and Guadalajara is responsible for maintaining both the new and old lights.

The national program in Mexico faced two main difficulties:

1 | Cities interested in participating had to secure collaboration and approvals from CONUEE, CFE, the Ministry of Finance, the Ministry of Energy, and Banobras. This made the program bureaucratic and dissuaded cities from participating.

2 | Financing for the investments was fairly limited. Guadalajara was one of the few cities that could obtain investments from the private sector. Many cities could not and incentives from Banobras were available only after verification of savings; hence, they could not help with financing program implementation.

As result, the Mexican government has partnered with the World Bank to develop a new Municipal Energy Efficiency project[40] that addresses these constraints and provides financing for cities that need it while removing many of the bureaucratic challenges that discouraged cities from investing in efficient lighting.

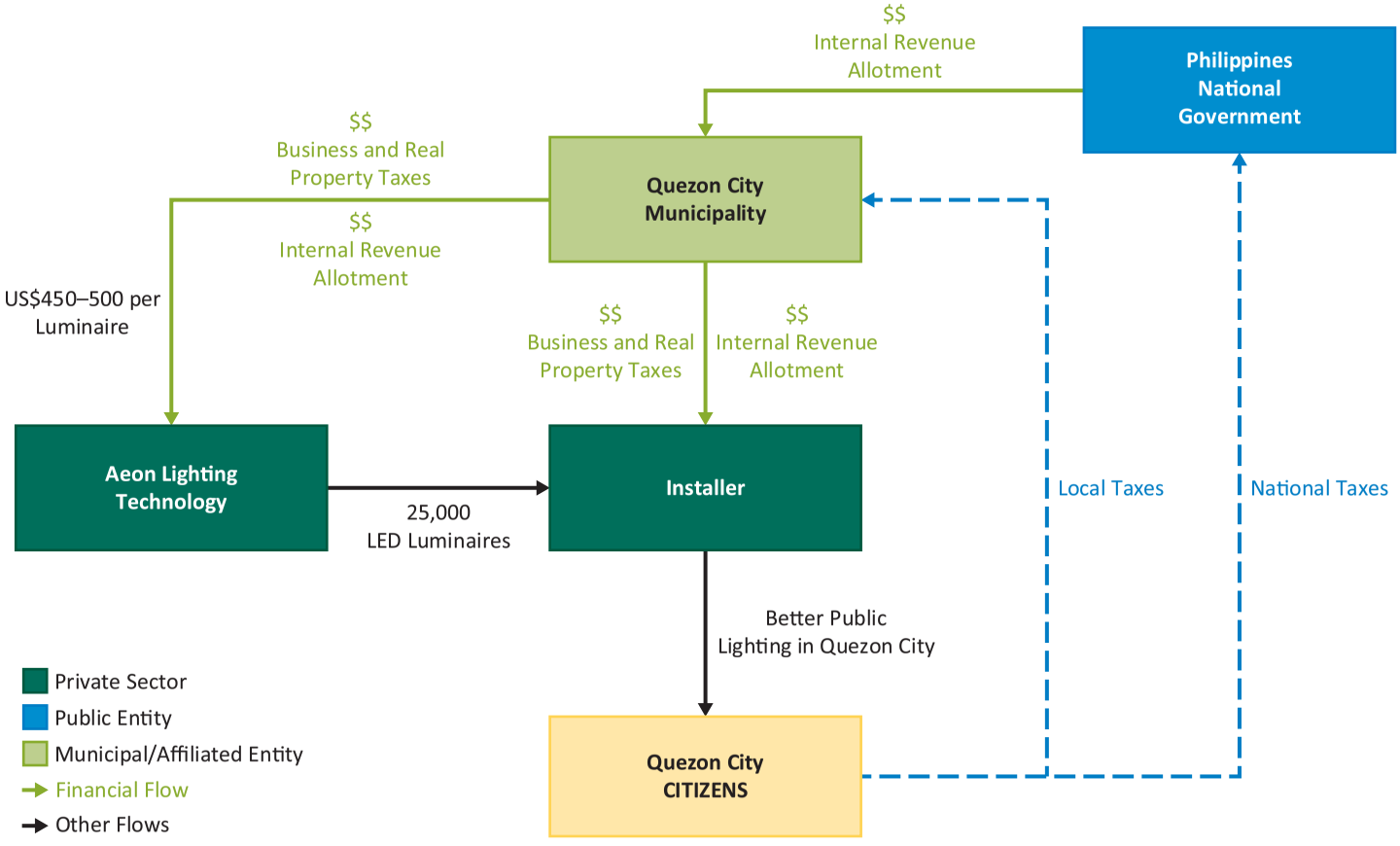
6. MUNICIPAL FINANCING DELIVERY MODEL IN QUEZON CITY, PHILIPPINES

In Quezon City, the quality of street lighting was fairly poor and citizens were concerned about crime and lack of safety at night. The poor-quality public lighting accounted for 65 percent of the city's annual expenditures on electricity, or about 5 percent of the city's overall annual budget. As a result, Quezon City has embarked on an LED public lighting program to improve lighting quality, lower its costs, and enhance tourist areas. The city is retrofitting 25,000 streetlights with LED lights and expanding street lighting to areas currently not illuminated. Five thousand luminaires were retrofitted with LEDs in 2013–14 as part of the program. Additionally, the program plans to install at least 5,000 luminaires annually from 2015 to 2018, for a minimum total of 20,000 retrofitted luminaires over four years. As of June 2015, a total of 3,856 LED luminaires had already been installed, with a further 2,678 installations underway. Under a separate program, the National Road Board funded installation of an additional 2,046 LED streetlights on major roads in Quezon City that are currently not illuminated.

The mayor initiated the program by issuing Executive Order No. 10, which created the Task Force on Installation, Repair and Maintenance of Street Lighting. The task force developed the program requirements working with The World Bank, The Climate Group, and other partners. For financing, Quezon City adopted the **municipal financing** model and the notional flows of financing and resources are shown in Figure 6. In the municipal financing model, Quezon City used its own resources to finance the investment in LED lighting. These included a contribution from the national government in the form of a percentage of the city's Internal Revenue Allotment (i.e., the money that the city traditionally gets from the national government), which is a national tax, and local business and real estate property taxes.

Procurement RFPs were issued in compliance with official Philippines Bidding Documents (PBDs).[41] Although nine bidders purchased the RFP documents for the first Quezon City

Figure 6: Notional Flows for Municipal Financing Model | LED Street Lighting Retrofit in Quezon City, Philippines



bidding conducted in October 2012, only five submitted proposals and none met the bidding criteria. For the second call for proposals in July 2013, Quezon City relaxed its local manufacturing requirement and a joint venture led by Aeon Lighting Luminaires won the bid. Aeon Lighting Technology (ALT) supplied the luminaires and assumed the technology risk by providing an eight-year warranty. Installation was conducted by a local installer in partnership with Aeon Lighting Technology.

Because the program can take a long time, depending on municipal financial resources,[42] this model tends to work for creditworthy municipalities with stable leadership. Quezon City is among the wealthiest municipalities in the Philippines, it has an A+ credit rating from Standard & Poor's, and its leadership has been stable over the last 15 years. From a technical perspective, the program's success was enhanced by the fact the city secured technical support from several international partners such as the World Bank Institute (WBI), LightSavers, the United Nations Development Programme (UNDP), the Global Environment Facility (GEF), and Cities Alliance. Additionally, because about 28 percent of the city's streetlights are metered, Quezon City could benefit directly from savings from the LED investments. The city was also able to negotiate with the local utility to change 3,000 more lighting points from a flat rate, deemed-consumption structure to a metered-consumption structure.[43]

The main advantages of this model are that financing costs tends to be lower than in other models because there are no borrowing costs and it is fairly straightforward to implement because the city can use traditional procurement procedures. One of its main disadvantages is that implementing the program may be prolonged if a city has limited resources.

3 | KEY CROSS-CUTTING FINDINGS

Though each of the case studies is unique, there are six cross-cutting observations:

1 | There are several options for addressing financial barriers.

2 | National governments can play different roles, ranging from setting policy to testing the LED lights as technical experts.

3 | A variety of risk mitigation measures may be used, depending on the specific situation.

4 | Private sector participation can bring in technical capacity, financial resources, and operational efficiency.

5 | Strategically engaging stakeholders enhances the likelihood of success.

6 | Making adjustments during program implementation may be necessary.

1 | THERE ARE SEVERAL OPTIONS FOR ADDRESSING FINANCIAL BARRIERS

The delivery model option used to address financial barriers depends on several factors, such as the city's[44] objectives, the existence of appropriate legal frameworks, the city's size, willingness of cities to work together, stability of the city's leadership, and the technical capacity of city staff. However, financing barriers tend to have a strong influence on the type of delivery model cities choose. Figure 7 highlights the different models used under different financial situations.

Figure 7: Potential Delivery Model Options for Addressing Financial Barriers to LED Public Lighting

Situation	Action	Delivery Model	Examples
Does the municipality have sufficient resources to fund the program itself?	Allocate funds by establishing budget line item for project	Municipal Financing Model	• Quezon City, Philippines • Ontario, Canada (cities opting for the Design-upgrade-transfer model)
Are there ESCOs active or planning to be active in the local market?	Negotiate an energy service performance contract with ESCOs	Private ESCO Model Public ESCO Model	• AEL, India • EESL in Vizag, India • Ontario, Canada (cities opting for shared savings EPC model)
Are leasing or private financing programs available?	Determine eligibility criteria and negotiate financing agreements	PPP Model Lease to Own Model	• Guadalajara, Mexico • Birmingham, UK

2 | NATIONAL GOVERNMENTS CAN PLAY DIFFERENT ROLES

Governments at the national, state, and local levels play important roles in the realization of investments in LED public lighting. These roles include: (a) developing supportive policies, regulatory frameworks and technical public lighting standards; (b) providing incentives (financial or otherwise) for the programs; and (c) supplying technical expertise.

a | Developing Supportive Policies, Regulatory Frameworks, and Technical Public Lighting Standards

The case studies illustrate a variety of contexts, ranging from countries with well-developed policies, institutions, regulations, and standards to those with virtually none. In the United Kingdom, the public and private sectors already had extensive experience working together under PPP policies first developed in 1974, with the 1992 establishment of the Private Financing Initiative, setting a national PPP framework and standardized PPP contracting nationally, and was updated in 2012 (Private Finance 2).[45] Likewise, Canada had an appropriate joint procurement framework in place before the Ontario case study began and the Canadian province of Ontario had extensive experience implementing joint procurement for municipalities with Local Authorities Services.

The India Asian Electronics Limited (AEL) case study illustrates a different context in which the government did not have supportive policies in place. The ESCO framework was not clearly defined at the national, state, or municipal levels when the program started. In such cases, projects are normally "managed by contract"; in other words, the contract is longer and more detailed to account for eventualities that are not covered by regulations. However, experiences with ESCOs in India were so limited that "management by contract" was challenging as well—each municipality had its own procurement process—and AEL had to adapt its contracts as it went along. As a result, the ESCO implemented measures such as precalculated payments, automatic payments, expedited government approvals to limit arrears, and standardized contracts. The improvements worked, but did not entirely eliminate delayed payments and arrears.

b | Providing Incentives

Because of the benefits of LED investments beyond the lifecycle cost benefit, such as climate change mitigation or better lighting, several governments in the case studies provided incentives for the programs. The UK government provided £620 million in PFI credits for the Birmingham PPP, which had a total contract value of £2.6 billion (covering lighting, roads, trees, and bridges). The credits were part of the government's program to "engage the private sector in the design, build, finance and operation of public infrastructure, with the aim of delivering good quality and well maintained assets that provided value for money for the taxpayer."[46]

Similarly, the Canadian government provided incentives to some municipalities from a Federal Gas Tax Fund, promulgated through its Community Projects window, designed to "provide funding for local infrastructure projects."[47] Another Canadian initiative, the "Save ONEnergy" program, provided substantial rebates because the investments reduce energy consumption. These incentives, in some cases, were substantial. For instance, the City of Innisfil in Ontario had applied for a 27 percent subsidy from such programs for its investment in LED public lighting at the time of writing.

In Mexico, Banobras (the state-owned development bank) reimburses 15 percent of the total cost of the project (up to Mex$10 million), if the energy savings targets are met. This subsidy is based on performance—unlike subsidies provided by other governments studied that did not consider the performance of the project. However, most cities need money *in order to* make investments; hence, the National Public Lighting program struggled in less creditworthy cities. This illustrates one of the differences between the provision of incentives and the provision of financing though both were monetary.

c | Supplying Technical Assistance

Governments also provided technical assistance in some of the case studies. For instance, the national laboratory in the Philippines tested the selected LED luminaires before implementation. In Mexico, CONUEE provided in-depth technical assistance from project inception through to the final stages of implementation. More specifically, CONUEE: (a) developed a *technical and economic tool* to help cities to assess the energy savings potential and financial impacts of a transition to more efficient lighting; (b) helped municipalities use the *SEAD Street Lighting Tool,*[48] which evaluates the light quality and life cycle costs of fixtures that are being considered for procurement or installation in a project; and (c) created and maintained a *certified product list*, updated monthly, comprising products that have passed 1,000 and 6,000 hours of testing.[49] CONUEE also provided technical certification needed by the Ministry of Finance to approve funding. This is notable because the vetting of the technical specifications and certification by a third party reduces the risks municipalities and financial institutions face when investing in a new technology such as LEDs.

3 | A VARIETY OF RISK MITIGATION MEASURES MAY BE USED

There is a variety of technical, financial, and performance risk mitigation measures that may be considered to address municipalities' perception of LED lighting as risky technology, and to reduce risks to lenders and implementing entities where municipalities are seen as posing a high risk of nonpayment. These are summarized in Table 1.

4 | PRIVATE SECTOR PARTICIPATION MAY BRING IN FINANCIAL RESOURCES, TECHNICAL CAPACITY, OPERATIONAL EFFICIENCY, AND MAY ASSUME TECHNICAL AND PERFORMANCE RISK

There is strong private sector participation in the implementation of LED public lighting programs. One prominent reason is municipalities' limited financial resources matched with private sector's ability to supply financing. When Birmingham needed additional resources to undertake its PPP, Uberior Fund and Equitix Investment Fund supplied £330 million in private financing. Solucash supplied the financing in Guadalajara. In India, many municipal corporations are not creditworthy and do not have full autonomy over their finances. The challenges are more acute in smaller second- and third-tier cities, which included AEL's clients. AEL was able to obtain carbon financing and use its balance sheet to finance the investments. In Ontario, many municipalities (because of good credit ratings) were able to secure low-cost credit either from private institutions or from Infrastructure Ontario.

The private sector also provided technical capacity. In all case studies, the private sector supplied the engineering know-how for implementing LED programs. In Ontario, RealTerm Energy designed and upgraded the lighting infrastructure under a build-operate-transfer contract. In Birmingham, Amey Plc's special purpose vehicle designed and

Table 1: Summary of Risk Mitigation Measures in LED Public Lighting Programs

Type of Risk	Risk Manifestation	Risk Mitigation Measure	Example
Technical Risk	Failure of LED luminaires	• Obtain product warranty from LED luminaire manufacturer	Ontario, Canada
		• Extensively test luminaires with external technical assistance	Quezon City, Philippines
		• Obtain third-party certification of luminaires	Guadalajara, Mexico
Performance Risk	Failure of installed LED system	• Conduct extensive pilots	Quezon City, Philippines
		• Outsource risk to private sector by procuring "lighting service" with performance penalties in PPP contract	Birmingham, United Kingdom
		• Outsource risk to private sector contractors by using EPC contracts	EESL in Vizag, India
		• Conduct own maintenance	Guadalajara, Mexico
		• Extensively search and procurement of a trusted operator	Ontario, Canada
Financial Risk	Failure to make payments	• Secure state government guarantees	Guadalajara, Mexico
		• Secure commercial bank guarantees	AEL, India
		• Work with private sector with substantial resources	Birmingham, United Kingdom

conducted the installations. In India, AEL implemented the programs through design, supply, and install contracts, and EESL supervised the private sector conducting the installations. Closely related is the private sector's ability to provide efficiency. EESL was able to conduct the whole installation in Vizag in six weeks partly because of its efficient implementation of the program.

Lastly, the private sector assumed technical and performance risks in the programs. LED manufacturers provided product warranties and operators often provided performance warranties. Thus, the manufacturers in these cases assumed the LED technology risk and the operators the performance risk. For example, Cree Inc. assumed the technology risk in Ontario, and Aeon Technology in Quezon City. AEL assumed the performance risk in India, and Electrotec in Mexico. Amey Plc not only assumed the performance risk, but also provided operational efficiency as it operates lighting for the duration of the PPP contract in Birmingham.

5 | ENGAGING STAKEHOLDERS ENHANCES THE LIKELIHOOD OF SUCCESS

In addition to the national government and private sector, the case studies also highlight the importance of engaging many national- and state-level stakeholders and international partners. In the Philippines, the municipality engaged national entities, the local electricity utility and international partners. Each of these stakeholders played key roles that ultimately led to the program's success. For example, the National Road Board

replaced public lights on primary roads, the Philippine Department of Energy tested the LED luminaires, the World Bank provided technical assistance, and Meralco—the local electricity utility—launched its own LED program to retrofit the luminaires under its jurisdiction in the city. Within the National Lighting Program in Mexico, National Commission for the Efficient Use of Energy (CONUEE) provided technical assistance, the Federal Electricity Commission (CFE) verified energy savings, and the state-owned development bank, Banobras, provided rebates and guidance on financing the investments.

In Canada, the Ontario Power Authority developed a "Conservation First" program that "maps out Ontario's energy conservation goals" from 2014 to 2020, "emphasizing a coordinated effort within all stages of energy planning, as well as more effective teamwork among sector partners, particularly in support of local distribution companies (LDCs)."[50] This helped galvanize support for the LED lighting programs. Likewise, activism from nonprofit organizations, such as LightSavers, galvanized support for the program in Ontario.

6 | MAKING ADJUSTMENTS DURING PROGRAM IMPLEMENTATION MAY BE NECESSARY

The case studies highlight adjustments that had to be made midstream to LED public lighting programs at both the macro and micro levels. At the macro level, governments modified policies and frameworks, as necessary. The UK government developed Private Finance 2, which improved on its initial Private Financing Initiative by facilitating access to capital markets, enabling better risk allocation, accelerating delivery, and improving transparency.[51] The government of India created EESL between the first AEL ESCO program in 2005 and the Vizag program, which was completed in 2015. EESL has developed widely accepted municipal energy performance contracting practices, such as shortlisting of ESCOs using the Expressions of Interest (EOI) process; issuing Requests for Proposals (RFPs); evaluating and selecting the most qualified ESCOs; negotiating contracts; and conducting monitoring and evaluation (M&E).[52] These developments are helping transform the implementation of LED programs in India.

At a micro level, both Quezon City and Guadalajara had to reissue RFP documents. The second Quezon City RFP relaxed some of the local manufacturing requirements that had disqualified international firms during the first round. The second Guadalajara RFP changed the LED requirements from 50 percent to 75 percent and the city received qualified bidders. The requirement for 75 percent LED luminaires sent a price signal that had not been clear in the first request.

CONCLUSIONS

LED lighting has several benefits compared to traditional forms of lighting. It consumes less electricity to produce better lighting, and has lower operation and maintenance costs. Thus, LED lifetimes costs can be lower than those of alternative forms of lighting, resulting in significant savings for the cities (or other stakeholders) that implement LED programs. Moreover, LED lighting is becoming more attractive as capital costs are falling by about 10 to 15 percent per year. While many cities are interested in LED lighting programs, they tend to struggle with the lack of financial resources; lack of supportive policy, institutional, and regulatory frameworks; lack of technical capacity; and finding appropriate delivery models suitable for their local contexts. The case studies demonstrate that options are available to address each of these challenges, and that successful LED public lighting programs are feasible across a wide range of municipal characteristics and regulatory contexts, ranging from small to large, well established to minimal regulation, and strong to quite weak financial positions.

ENDNOTES

1 David P. Farrington and Brandon C. Welsh, 2002. Home Office Research Study 251. "Effects of Improved Street Lighting on Crime: A Systematic Review." https://keysso.net/community_news/May_2003/improved_lighting_study.pdf

2 Michael Jackett and William Frith, 2013. "Quantifying the impact of road lighting on road safety—A New Zealand Study." *IATSS Research* 36 (2): 139–45.

3 U.S. Bureau of Labor Statistics, 2015. "Consumer Expenditures—2014." Economic News Release dated September 3, 2015. http://www.bls.gov/news.release/cesan.nr0.htm

4 The price of LED varies by location, but LED lights can be two to three times more expensive than traditional forms of lighting. Where electricity and labor costs are low, LED lighting might not be economical

5 141,089 street lights.

6 "City" and "municipality" are used interchangeably.

7 http://www.esmap.org/node/56868

8 An ESCO is an energy services company whose key distinguishing feature is that payments to the ESCO are made from energy savings.

9 A *super-ESCO* is different from an ESCO in that it is owned by the government, has a significant public sector mandate and clientele, and supports the capacity development and activities of other ESCOs.

10 For the purpose of this report, city governments are interchangeably referred to as *local governments*, *cities,* or *city authorities*. Additionally, given the large of number cities responsible for public lighting, we will generally use city-based terminology, but findings can also be used by regional and national government departments or utilities responsible for public lighting.

11 http://www.esmap.org/node/56868

12 IEA, 2006. *Light's Labour's Lost: Policies for Energy-efficient Lighting.* https://www.iea.org/publications/freepublications/publication/light2006.pdf

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15 Mary Larzelere, 2013. "Lighting the way to municipal prosperity." *Urban Wire: International Development.* Urban Institute. http://www.urban.org/urban-wire/lighting-way-municipal-prosperity

16 Bureau of Labor Statistics, 2014; Consumer Expenditures: http://www.bls.gov/news.release/cesan.nr0.htm

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18 Chidoka, 2008. *Effects of Street Lighting on Road Traffic Accidents*.

19 Michael Jackett and William Frith, 2013. "Quantifying the impact of road lighting on road safety—A New Zealand Study." *IATSS Research* 36 (2): 139–45.

20 Royal Society for the Prevention of Accidents, 2015. *Road Safety Information*: http://www.rospa.com/rospaweb/docs/advice-services/road-safety/roads/street-lighting.pdf

21 The Royal Swedish Academy of Sciences, press release dated 7 October 2014: http://www.nobelprize.org/nobel_prizes/physics/laureates/2014/press.html

22 Assuming two terawatt-hours of generation per year from each power station. Data from Philips Market Intelligence and IEA: Philips (2011), "The LED lighting revolution: A summary of the global energy savings potential," based on IEA analysis.

23 The reduction in greenhouse gas emission depends on the local emission factor of the electricity used to provide public lighting. The reduction is higher where the electricity is produced from dirty fossil fuels, but much lower when the electricity is generated from cleaner sources of electricity.

24 Bill Bien, 2015. "LED Street Lighting: An Untapped Opportunity in Driving Energy Efficiency," *Energy Manager Today.* http://www.energymanagertoday.com/led-street-lighting-an-untapped-opportunity-in-driving-energy-efficiency-0116174/

25 http://wbdocs.worldbank.org/wbdocs/viewer/docViewer/index1.jsp?objectId=090224b082e682fc&standalone=true&respositoryId=WBDocs

26 McKinsey and Company, 2012. *Lighting the Way: Perspective on Global Lighting Market.*

27 Larger programs benefit from economies of scale and manufacturers are often willing to negotiate prices.

28 The detailed case studies themselves are available on the ESMAP website: http://www.esmap.org/node/56868

29 The CDM was not involved in later deemed savings contracts.

30 A *super-ESCO* is an energy service company that (a) is established, and is majority-owned, by the government; (b) serves as an ESCO for the public sector; (c) supports the capacity development and activities of other ESCOs; and (d) facilitates access to project financing. Dilip Limaye, Asia ESCO Conference 2010. http://www.asiaesco.org/pdf/presentation/2-2.pdf

31 Officially the Greater Visakhapatnam Municipal Corporation.

32 Energy Efficiency Services Limited, 2013. *EESL Toolkit for Street Lighting Energy Efficiency*.

33 EESL Toolkit: http://www.eeslindia.org/writereaddata/EESL%20Toolkit%20final.pdf

34 Birmingham City Council, 2004. *Highways Management and Maintenance PFI*, Report to City Council from the coordinating Overview and Scrutiny Committee, pp. 10–11.

35 European PPP Expertise Centre, June 2012. *United Kingdom – England: PPP Units and Related Institutional Framework*. http://www.eib.org/epec/resources/publications/epec_uk_england_public_en.pdf

36 HM Treasury, 2012. "A New Approach to Public Private Partnerships: Permanent and Predictable Funding for Municipalities." http://tinyurl.com/olmplyw

37 http://www.birmingham.gov.uk/highwayspfi

38 "Mexico: Street Lighting Programme." Presentation at the World Bank International Conference on Energy Efficient Street Lighting in New Delhi, India. March 2014.

39 Including interest, payments over the 10-year lease term will total Mex$490.4 million (approximately US$29 million).

40 http://www.worldbank.org/en/news/feature/2016/04/27/scaling-up-urban-energy-efficiency-in-mexico-how-two-pilots-led-to-a-national-program-and-leveraged-investment

41 http://www.gppb.gov.ph/downloadables/PBDs.html

42 The municipality would tend to finance what it can afford, and this is usually fewer lights than when sufficient capital is raised to retrofit all public lights in the city.

43 Although not all cities have metered electricity consumption, many are able to renegotiate and lower the flat rates charged by local utilities.

44 "City" and "municipality" are used interchangeably.

45 HM Treasury, 2012. "A New Approach to Public Private Partnerships: Permanent and Predictable Funding for Municipalities." http://tinyurl.com/olmplyw

46 *Ibid.*

47 Infrastructure Canada, 2014. "The Federal Gas Tax Fund: Permanent and predictable funding for municipalities." http://www.infrastructure.gc.ca/plan/gtf-fte-eng.html

48 The SEAD Street Lighting Tool provides a quick, free, and easy way for government procurement officials to evaluate the quality, efficiency, technical compatibility, and lifetime cost of different street lighting products. More information is available at: www.superefficient.org/sltool

49 The certification process is a result of NOM-031, which establishes a series of tests and two certification processes: (1) testing for the first 1,000 hours (if light output levels are achieved, an initial certificate is given); and (2) testing for another 5,000 hours—for a total of 6,000 hours—to measure if light output levels are maintained throughout the product's lifetime (if light output levels are maintained, a final certificate is given). A list of products that have passed and failed these tests is available online and is updated regularly.

50 IESO. "Conservation First Framework," accessed August 18, 2015: http://www.ieso.ca/Pages/Conservation/Conservaton-First-Framework/default.aspx.

51 HM Treasury, 2012. "A New Approach to Public Private Partnerships," p. 13. (http://tinyurl.com/olmplyw)

52 Jas Singh, Dilip R. Limaye, Brian Henderson, and Xiaoyu Shi, 2010. *Public Procurement of Energy Efficiency Services: Lessons from International Experience.* Washington, DC: The World Bank. http://tinyurl.com/nd2undy

ACRONYMS AND ABBREVIATIONS

AEL	Asian Electronics Limited
Banobras	*Banco Nacional de Obras y Servicios Publicos* (National Bank of Public Works and Services, Mexico)
£	British pound (currency)
CDCF	Community Development Carbon Fund
CDM	Clean Development Mechanism
CFE	*Comisión Federal de Electricidad* (Federal Electricity Commission, Mexico)
CMS	Central management system
CONUEE	*Comisión Nacional para el Uso Eficiente de la Energía* (National Commission for the Efficient Use of Energy)
DUT	Design-upgrade-transfer
EESL	Energy Efficiency Services Limited
Electrotec	*Electricidad y Tecnología SA de CV*
EPC	Energy performance contract
ESCO	Energy service company
€	Euro (currency)
GDP	Gross domestic product
GVMC	Greater Visakhapatnam Municipal Corporation
HPS	High-pressure sodium
IEA	International Energy Agency
INR	Indian rupee (currency)
KfW	Kreditanstalt für Wiederaufbau (German Government Development Bank)
LED	Light-emitting diode
M&E	Monitoring and evaluation
MC	Municipal Corporation
Mex$	Mexican peso (currency)
MH	Metal halide
MV	Mercury vapor
PFI	Private Financing Initiative
PPP	Public private partnership
RFP	Request for proposals
UIT	Urban Improvement Trust
UK	United Kingdom
US$	United States dollar (currency)
Vizag	Visakhapatnam (India)
WB	World Bank

All currency in United States dollars (USD, US$, $), unless otherwise indicated.

PROVEN DELIVERY MODELS FOR LED PUBLIC LIGHTING

Proven Delivery Models for LED Public Lighting | Synthesis of Six Case Studies

CASE STUDIES

1 ESCO Delivery Model in Central and Northwestern India: Asian Electronics, Limited

2 Super-ESCO Delivery Model in Vizag, India: Energy Efficiency Services, Limited

3 Joint Procurement Delivery Model in Ontario, Canada

4 Public-Private Partnership Delivery Model in Birmingham, United Kingdom

5 Lease-to-Own Delivery Model in Guadalajara, Mexico

6 Municipal Financing Delivery Model in Quezon City, Philippines

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Typesetting | Automated Graphic Systems, Inc.

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