Energy Efficient Urban Street Lighting Project – India

Preparation of Monitoring & Verification Protocols for Street Lighting

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Alliance for an Energy Efficient Economy

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Abbreviations

BEE	Bureau of Energy Efficiency
BMC	Bhubaneswar Municipal Corporation
CESU	Central Electricity Supply Utility, Orissa
DISCOMs	Distribution Companies
ECM	Energy Conservation Measure
EE	Energy Efficiency
EESL	Energy Efficiency Services Limited
EOI	Expression of Interest
EPC	Energy Performance Contract
ESCO	Energy Service Company
ESPC	Energy Savings Performance Contract
FIs	Financial Institutions
GVMC	Greater Visakhapatnam Municipal Corporation
HVAC	Heating, Ventilation and Air-Conditioning
IGA	Investment Grade Audit
IPMVP	International Performance Measurement & Verification Protocol
IS	Indian Standard
M&V	Measurement & Verification
PAT	Perform Achieve & Trade
ULB	Urban Local Body

1 Executive Summary

This *M&V Application Guide for Street Lighting Projects* has been developed to aid urban local bodies and project developers in implementing energy efficiency projects for street lighting. It was developed while taking into account the current street lighting scenario in India, and more specifically, the gaps in M&V for energy efficiency projects in street lighting. Additionally, inputs from case studies of street lighting projects in Visakhapatnam, Andhra Pradesh and Bhubaneshwar, Orissa were used.

Street lighting in most parts of India is in need of upgrades and suffers from inefficient operation and maintenance. In an effort to improve the street lighting situation, some urban local bodies have embarked on energy efficiency projects in street lighting. In addition to fiscal, policy and technical challenges for EE projects, roles of key stakeholders, significant gaps in understanding core Measurement and Verification (M&V) concepts are discussed to provide a context for this effort.

Measurement and Verification (M&V) is the process of using measurement to reliably determine actual energy savings created within an individual facility or system by an energy efficiency (EE) programme. A well designed M&V strategy increases the confidence of EE project financiers and decision makers, while also enabling the project team to successfully implement the project.

Any energy saving project performance can be measured in two ways 1) deemed savings approach 2) measured savings approach.

For programs targeting simpler efficiency measures with well-known and consistent performance characteristics, a deemed savings approach may be appropriate. This method involves multiplying the number of installed measures by an estimated (or deemed) savings per measure, which is derived from historical evaluations. Deemed savings approaches may be complemented by on-site inspections.

For larger and multiple efficiency measures and more complex program strategies – including those expected to result in significant savings or those with a high degree of uncertainty – a measured savings approach that follows established protocols may be appropriate. Estimates of energy (and/or demand) savings are calculated using the measured and analysed value for each projects.

The Guide lays out the M&V process for EE projects in street lighting in a comprehensive manner. it begins with an overview of the M&V options identified in the International Performance Measurement and Verification Protocol (IPMVP) from Efficiency Valuation

Organisation (EVO), considered an international best practice document in M&V. This section also presents three M&V options specific to street lighting projects, as listed below:

- **specification-based or deemed savings approach**, which can be used in projects where there is no baseline or it is difficult to establish a baseline, or in cases where the M&V plan would be too expensive or complex to implement
- **retrofit isolation (partial measurement or full measurement)**, which can be used in projects requiring a balance between reducing the uncertainty in determining energy savings and the cost of a rigorous M&V process
- **feeder level metering**, which can be used in projects with multiple energy conservation measures (ECM)

It then discusses the process for developing a project M&V strategy. This section includes guidelines on balancing M&V cost and uncertainty, project risk management and the M&V tasks to be performed during each phase of the project life cycle, namely bidding and tendering, baseline establishment, Energy Performance Contract (EPC) signing, EE implementation and EE performance phases. It then lays out the detailed process for project baseline determination which is a critical step in taking the EE project forward. Project baseline determination involves formally recording the pre-implementation electricity use conditions, namely energy consumption, operating environment and project boundary. The established project baseline needs to be agreed upon by the customer (e.g. a city or a municipality) and the project implementing entity (e.g. an ESCO). It is crucial in estimating potential energy savings from the EE project and in determining the actual savings post-implementation. This section also provides sampling guidelines and an overview of baseline adjustments in case the post-implementation conditions change relative to those in the pre-implementation baseline. Templates for switching point baseline summary data and baseline detailed data are given in Annexure 3. The challenges in baseline determination and the recommendations to address the challenges are subsequently discussed followed by a discussion of the broad categories of street lighting energy conservation measures (ECM), the corresponding energy savings methodology and the applicable M&V options.

Once the M&V strategy has been developed, based on the guidelines in this section, the project implementation team can develop the M&V plan to be used during the project implementation and performance phases.

The *M&V Application Guide for Street Lighting Projects* has case studies of street lighting projects in Visakhapatnam, Andhra Pradesh and Bhubaneshwar, Orissa to make it useful and relevant for the intended audience.

EESL proposes to include GHG emission reduction goals as part of its EE projects in street lighting. A Clean Development Mechanism (CDM) project example has been included as a Greenhouse Gag monitoring methodology that can be used to quantify GHG emissions reductions from energy efficient street lighting projects.

This application guide was developed primarily for street lighting energy efficiency projects in India. However, it can be customised for use by municipalities in other countries.

2 Introduction

Street lighting services present immense opportunities for energy savings due to their scale and visibility in the public domain. Public-private partnership (PPP) based models such as energy savings performance contracting (ESPC) models – offered by energy service companies (ESCOs) or other energy service providers – have become common tools to enhance the sustainable use of energy through energy efficiency measures. The performance contracting structure has proved successful with municipal authorities in many developed markets such as France, Germany, UK and USA, as well as emerging economies as Chile, Thailand, Brazil and Mexico.

However, actual implementation of large scale efficient street lighting through market-based mechanisms such as ESCOs, remains limited in developing countries due to a wide range of barriers, such as those related to the development of reasonable and robust baseline conditions, measurement and verification (M&V) of energy savings, and terms and conditions of the contract (such as long payback periods and duration of contracts). Limited awareness about Measurement and Verification fundamentals, practical knowledge of its application, and the absence of reliable and cost effective monitoring plans, have been cited as barriers. Both municipalities and ESCOs lack confidence in the assessment of project risks and payment mechanisms required to repay loans for projects implemented under PPP model. An often ill-addressed risk is the evaluation of the energy savings generated by a given project.

In India, Energy Efficiency Services Limited (EESL) has identified this as a priority sector and efforts are underway to develop sustainable execution models that can be replicated across Indian cities

The purpose of this *M&V Application Guide for Street Lighting Projects is* to aid project developers, urban local bodies, implementers, financiers, ESCOs and third-party M&V service providers in implementing ESPC projects for street lighting by providing general and specific M&V guidance in energy-efficient street lighting projects.

3 Street Lighting in India

3.1 Status of Street Lighting

Street lighting infrastructure in most parts of India is out-dated and its inefficient operation places a heavy burden not only on municipal budgets but also on utility grid capacity and reliability. Street lighting in India consumed about 8,478 GWh of electricity in FY13, about 1.5% of total electricity consumption. That figure can be reduced by 40-60% through use of energy efficient LED technologies for street lighting, while also leading to a potential GHG reduction of 4 million tonnes of CO_2.

3.2 Key Stakeholders for Energy Efficient Street Lighting Projects

The success of a street lighting programme depends on strong collaboration across multiple stakeholders who need to understand their roles and responsibilities well. Once the programmatic framework is in place, execution of street lighting projects will become easier. The table below provides an illustrative framework of major organisations belonging to different sectors, their major roles in energy efficient street lighting programme or project development and implementation.

Table 1. Key Stakeholders for EE Street Lighting Projects

Sector	Major Role	Examples in Indian Context
Public Sector		
Energy Department	Overall policies and regulation including the use and applicability of M&V protocols in street lighting projects; should collaborate with urban department	Bureau of Energy Efficiency (BEE)
Urban Department	Responsible for developing policies related to urban infrastructure, smart cities, etc.; should collaborate with energy department	Urban Development Department
Municipal Department	Responsible for O&M of city street lighting including payment of energy bills; identifying, designing and implementing retrofit projects; approver of M&V plan; provider of payment security guarantees to implementing organisation or ESCOs	Municipal Corporation; Urban and Local Bodies

Sector	Major Role	Examples in Indian Context
Implementation Organisation	Government supported project implementers and market enabler for energy services sector	Energy Efficiency Services Limited (EESL), National Building Construction Corporation (NBCC)
Private Sector		
Lighting systems vendors and suppliers	Responsible for supplying hardware and equipment; provide energy performance and savings guarantees on hardware and equipment per M&V plan	Various lighting equipment manufacturers
ESCOs and Energy Auditing Firms	Responsible for conducting energy audits, project design, development and implementation, guaranteeing energy savings based on M&V plan	ESCOs certified by BEE
M&V agency	Responsible for providing third party M&V services	CMVPs, Certified M&V firms
Advisory Sector		
Multilateral organisations or national development banks	Provide project financing, partial risk guarantee fund to reduce risks associated with EE projects; provide technical assistance to help develop M&V application guides and tools, contractual and legal due diligence on EPCs	The World Bank, Asian Development Bank, KfW, USAID, DFID
Foundations, Technical advisory, EE consulting organizations	Advisory services to support design and development of EE street lighting programs, training and capacity building, project facilitation and other technical support	Shakti Foundation, IFC, AEEE, ASE, IIEC
Financial Sector		
Public or private sector banks	Commercial banks investing in street lighting project on the basis of projected cash flows resulting from energy savings	IREDA, Power Trading Corporation, Retail Banks

3.3 Challenges in Street Lighting EE Projects

Provision of municipal street lighting in India faces multiple challenges of growing population, rapid urban expansion and increasing power tariffs. In addition, the existing street lighting infrastructure is often out-dated and its inefficient operation places a hefty burden on municipal budgets. Most of the energy supply distribution lines for street lights are very old and were expanded over a period of time in un-planned manner, resulting in increased technical losses and frequent maintenance. The current procurement practices are primarily governed by the initial cost of equipment and do not consider the equipment's operating costs and energy performance over time.

A significant challenge in street lighting EE projects is the absence of a comprehensive Measurement and Verification (M&V) strategy. This leads to challenges for ESCO's trying to implement EE projects for municipalities. Other challenges include policy, institutional, financial and technical challenges.

3.3.1 M&V Challenges

Table 2 lists the main gaps in M&V for energy efficiency projects in street lighting and suggests recommendations to overcome these.

Table 2. M&V Gaps and Recommendations

#	Gaps in M&V	Recommendations
1	Lack of understanding on the importance of reliable and accurate data for the project baseline	Create awareness and facilitate understanding of energy efficient street lighting projects in municipalities and ULBs through certified training providers.
2	Lack of knowledge on M&V concepts and methods for EE projects	Create awareness or provide technical support to understand the basic M&V concepts explained in IPMVP.
3	Unreliable and/or incomplete data on baseline infrastructure and usage (e.g. non-functioning meters, non-metered loads, billing discrepancy, operating hours, burned out lamps, etc.)	Develop an informed baseline situation based on the project needs and requirements and by understanding risk implications.
4	Absence of a Roles and Responsibility framework to allocate and manage risks	Understand the key factors that will affect energy savings and agree on the allocation of responsibilities between municipalities and project implementing

		entity (e.g ESCO).
5	Absence of a robust M&V plan and report agreed upon between project stakeholders	Both M&V Plan and Annual Report should be part of the contract document with appropriate quality assurance and checks built into the project development.

3.3.2 ESCO Implementation Challenges and Strategy

The concept of energy efficiency project implementation through Energy Performance Contracting (EPC) as practiced by ESCOs is not new in India. Many pilot projects have been carried out and efforts are underway to develop national and state-level programmes based on this concept. However, there are a number of challenges to the widespread implementation of ESCO projects in India and developing countries. Some of the key challenges that are linked with M&V are described in the Table 3 below, along with suggested strategies for overcoming them.

Table 3. ESCO Challenges and Mitigating Strategies

Challenges to ESCO Implementation in India	Strategies for Overcoming Challenges
Distrust and complexity of the EPC process Both municipalities and ESCOs lack confidence in the assessment of project risks and payment mechanisms required to repay loans under EPCs.	Design a robust M&V plan to reduce uncertainty and provide a tool to measure programme effectiveness. Set up an ESCROW account through which funds can be utilised for payments, based on priorities determined by a high-level project steering committee, to increase success of the performance contract. Provide continuous communication and technical assistance (“handholding”) for the various stakeholders to build confidence in the ESCO mechanism.

Challenges to ESCO Implementation in India	Strategies for Overcoming Challenges
Long project development cycle Partly as a result of high turnover among government officials and staff, long project development cycles have been cited as one of the biggest barriers that ESCOs face in the public sector. Long delays in concluding EPC negotiations mean that the total cost of doing projects is much higher than the cost initially estimated by the ESCOs.	Develop and promote a standardized approach with fixed milestones, such as, project kick-off meeting, site visits by ESCOs, pre-bid meeting, submission of the initial proposal, letter of intent to award the project, investment grade audit, final proposal, signing of the contract. When systematically adhered to, these reduce project development time. Create a mechanism to compensate ESCOs for their time and effort, in case the project contract is not signed within a stipulated timeframe. Institutionalize efforts by establishing an energy management centre responsible for the performance of all energy consuming entities under municipal management.
Difficulty of securing third party financing Most lenders and investors have a limited understanding of municipal business models and technical issues (including in the street lighting sector). Appraisals of EE projects require techniques and tools different from those of appraisals of projects designed to add to productive capacity.	Ensure that the M&V plan equitably apportions the risks to the two parties and provides a framework for managing these risks. Significant work has been done by EVO, developer of the International Performance Measurement and Verification Protocol (IPMVP), among others, and resources have been made available to create awareness and develop cost-effective M&V strategies to mitigate the risk associated with projects.

3.3.3 Policy Challenges

Municipal street lighting EE projects face a number of common challenges, such as inflexible procurement systems and the lack of policy support. In the absence of relevant policies and incentives for energy conservation measures, many municipalities are hesitant to face the technical and financial burdens of efficiency improvements without an established precedent or guarantee of payback. Government procurement procedures tend to favour lowest-cost technology replacements and investments that achieve rapid service improvements but often result in inefficient structures and equipment systems. When municipalities implement major EE projects, their capacity to retain energy cost savings is limited by variable methodologies for determining municipal (versus state) yearly budgets. While the methodology currently in use for estimating municipal yearly budgets takes into account population, area, and the services provided, it does not factor in energy expenditure and savings. Since the current year expenses are used as the basis for determining the next year's budget, reductions in operating costs can result in reduced future budget allocations—a disincentive to reducing energy costs.

3.3.4 Institutional Challenges

Many assessment studies and pilot projects have demonstrated the tremendous gains available to municipalities and their rapid returns on investment. However, very few projects have been successfully completed or scaled up in a structured manner. In most Indian states, municipal budgets are locked in a cycle of high energy costs and deferred service improvements. As in most countries, one of the greatest barriers to street lighting energy-saving initiatives in India is the lack of adequate technical and managerial capacity within municipal bodies to design and implement efficiency measures. Without specific knowledge or experience in managing energy efficiency projects, it is difficult for municipal officials to champion such projects. The key barriers are competition for resources with other social or public programmes with higher perceived value to society, public procurement policies that focus on the lowest-priced technologies rather than the lifecycle cost of the investment and the lack of financing packages designed to take advantage of the unique opportunity for reduction of operational expenditure and reaping the co-benefits offered by such projects.

3.3.5 Financial Challenges

Lack of well-structured financing packages for energy-efficient projects is often a key barrier to their implementation and to the widespread adoption of energy efficient technologies. Given the constraints on municipal budgets, financing for municipal projects must often come from other sources. These are often constrained by the conditions imposed by the grantors, lenders, or co-investors for contributing their resources to municipal projects, especially if they are based on performance contracts. Grantors need assurance that the money they provide to municipal projects will be used for its intended purpose. Lenders and co-investors need a guarantee of repayment and receiving their agreed-upon share of a project's payback.

Local financial institutions and banks lack the technical knowledge to evaluate energy efficiency projects, based on their energy and cost-saving potential, especially where it is cash-flow based financing, rather than the traditional assets or collateral-based financing. Lack of access to financing for such projects is often perceived to be a key barrier to their implementation.

Access to financing also depends on the credit worthiness of the borrower, the cash flow to be generated by a project, and available mechanisms for credit enhancement (such as collateral and loan guarantees).

Recent successes of green municipal bonds in some countries, and raising equity through green renewable bonds by some private sector banks in India, offer renewed hope that innovative financing instruments can be used to generate better financial packages to implement energy-efficient street lighting projects. In addition, the potential market value of energy efficiency retrofits is distorted by cross-subsidies and energy tariffs that are below cost-recovery levels.

3.3.6 Technical Challenges

While designing or making changes to street lighting, it is important to first understand the lighting requirements of the roads. The most common reasons for inefficient street lighting systems in municipalities include: (a) Inadequate understanding and analysis of required service levels; (b) Need for a more rigorous approach to selecting appropriate luminaires; (c) Poor lighting system design and installation; (d) Poor or inconsistent power quality; and e) Poor operation and maintenance. Another key challenge is the baseline data and its quality which is very important for establishing a credible baseline of the project. Many projects in the past have not be able to deliver the expected outputs and benefits, and have resulted in dispute over quantification of savings primarily due to issues related to baseline establishment.

3.4 Standards for Street Lighting in India

Standards applicable for street lighting in India are briefly described in this section. This is being done to develop a complete application guide for M&V of street lighting projects. A short description of contents in each standard is explained to enable the user to refer the required standard in detail as necessary.

IS-1944 (1981) Code of Practice for Lighting of Public Thoroughfares

This is an omnibus standard developed by Bureau of Indian Standards and is commonly used in cities and towns for street lighting practice. It includes general principles, lighting for main roads, secondary roads and other urban roads. It covers design and choice of equipment, siting and appearance, lighting criteria for various urban areas. Developed in 1981, this standard has not incorporated the current developments in the field of street lighting.

BEE Guidelines for Energy Efficient Street Lighting

The purpose of these guidelines is to increase the awareness about the Bureau of Indian Standards (BIS) Code of Practice for lighting of public thoroughfares and to provide practical guidance on energy-efficient street lighting best practices. In 2010, Bureau of Energy Efficiency (BEE) developed these guidelines for energy efficient street lighting to fill the existing need for projects, which were envisaged. Drawing upon BIS code, these guidelines have classified and tabulated the type of roads in urban areas, specifications of street lighting poles and their mounting arrangement. These guidelines have extensively covered current energy efficiency practices in street lighting including dimming and recommended levels of illumination for types of roads. Measurement and Verification (M&V) for street lighting projects based on IPMVP has also been narrated in these guidelines.

National Lighting Code SP 72 (2010) – BIS

National Lighting Code (NLC) published by the Bureau of Indian Standards has been formulated for the purpose of setting out in a convenient form the requirements for responsible social, commercial and engineering conduct for the designers, manufacturers and suppliers of lighting as lighting technology plays a significant role in achieving basic social safety and environmental objectives.

In a single document, the code contains good regulatory practices, which can be immediately adopted or enacted for use by various departments and public bodies. It lays down a set of minimum provisions necessary to protect the interest of the public with regard to lighting levels and quantity, safety parameters among others. For the choice of lighting products and method of lighting design for the lighting professional, detailed guidelines have been provided in the code while leaving enough scope for the integrity of the user, designer, architects and consultants.

The National Lighting Code includes the following:

a) Guidance on illumination engineering practices to be followed by various types of occupancy
b) Guidance on good engineering practices to be followed for design, selection, installation and maintenance of lighting system for indoor and outdoor areas
c) Matters related to the science of illumination such as physics of life, electric light sources, luminaires and photometry
d) Coordination aspects to be considered while designing the lighting system such as day lighting
e) Aspects relating to energy management and energy conservation in lighting installation including guidelines for design and good practices to be adopted for effective and efficient use of light sources

As of today there is no M&V standard for energy efficient street lighting projects in India. This is a gap that needs to be addressed for the successful execution of energy efficiency projects for street lighting.

3.5 Measurement and Verification Framework

Measurement & Verification (M&V) Protocol

An M&V Protocol provides a high level and flexible technical framework for assessing and quantifying energy and cost savings at a project level[1] and has very broad applicability at a national and global level. The Protocol uses key concepts related to project baseline scenario, implemented project boundaries, engineering and statistical concepts and principles, measured data from meters, sensors, and other devices, simulation to create a physical world situation that does not exist, and reasonable assumptions and stipulations. Efficiency Valuation Organisation (developer and maintainer of IPMVP), ASHRAE, ISO are some of the international organisations that have supported the development of M&V protocols. The M&V protocol deliberately provides very high level approach to energy savings calculation that is based on universal and rigorous scientific, engineering and statistical concepts and hence can be adapted for a range of sectors (e.g. buildings, industry, municipal SME, etc.) or applications (PAT[2] programme, street lighting, indoor lighting, water supply, data centre, commercial building lighting or HVAC retrofits, among others).

Measurement & Verification (M&V) Application Guide

The application guide is a technical document that enables the application of the M&V Protocol for a specific sector or segment, such as new construction or street lighting project. The application guide uses the broad technical framework developed in the M&V Protocol and adapts it for the specific application, thus facilitating its applicability to a specific sector or segment. The scientific underpinning of the different M&V options is derived from the M&V Protocol ensuring that they are also rooted in the engineering, physics and metering concepts that is largely accepted and understood by the global energy engineering community and professionals. An excellent M&V Application Guide will provide practical tips on how to develop cost-effective M&V approaches taking into account the ground realities of a specific sector or region by ensuring the understanding of baseline scenario. This document is most useful at the time of planning, designing, tendering a large street lighting retrofit programme before one moves into implementation.

Measurement & Verification (M&V) Plan

While M&V Protocol and Application Guide is probably more important and relevant during the project planning, development and tendering stage, the M&V plan is a key part of any energy performance contract and is of critical significance during the implementation and performance period of the project. An M&V Plan is specific to a project or site and is a result of the

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[1] Project level includes all kind of EE measures included as part of implementation

[2] Government of India's Perform Achieve and Trade Program

deliberations and negotiations between the project stakeholders (implementer, owner, investor or the regulator). This enhances its applicability to the specific project for which it has been developed. It must capture the project and individual energy conservation measure boundary, assumptions, engineering calculations, equations and metering infrastructure to be deployed, the parameters to be monitored and measured or stipulated along with their frequency or basis, and agreed upon by the two parties. The M&V Protocol and the Application Guide helps in developing a good M&V plan, provided both the parties understand and appreciate the constraints and limitations of the site. The M&V plan helps to develop a robust and technically sound baseline that is acceptable to key stakeholders, identifies situations and conditions where an adjustment[3] to the baseline condition may be needed, so any energy savings and associated payments risks are identified and addressed explicitly, based on the M&V plan details in case any savings discrepancy arises.

Annual Measurement and Verification (M&V) Report

The Annual (or any other frequency agreed upon by the stakeholders) M&V Report is typically developed by the energy services company or organisation responsible for implementing a performance contract where energy savings has to be validated before making the payment to the ESCOs. The document typically provides a validation of energy savings that is the basis of the performance contract. This would be based on the methodology specified in the mutually agreed M&V plan, and its applicability is limited to a specific project. The Annual M&V Report must adhere to the project-specific M&V plan agreed upon and signed off by project stakeholders. Any deviation from the agreed M&V plan must be explained and supported by signed documentation, and any discrepancy in the savings estimate or baseline conditions that can have a material bearing on the energy savings must be highlighted and explained.

[3]Adjustment in M&V parlance mean the process through which the project stakeholders address the unforeseen/unexpected changes in facilities, equipment, operating conditions, weather conditions etc. that will require a change in agreed upon baseline or energy savings calculation methodology

4 Measurement and Verification (M&V) for Street Lighting

The decision on whether to embark on an EE project is usually taken after a detailed assessment on the need for such a project. The assessment process is beyond the scope of this application guide. However, a sample needs assessment process is given in Annexure 1.

Once a municipality has decided to embark on an EE project, it needs to develop an M&V strategy for the project. The two key strategy to quantify savings are a deemed savings approach and a measured savings approach.

For programs targeting simpler efficiency measures with well-known and consistent performance characteristics, a deemed savings approach may be appropriate. This method involves multiplying the number of installed measures by an estimated (or deemed) savings per measure, which is derived from historical evaluations. Deemed savings approaches may be complemented by on-site inspections. Those using this approach should update their deemed savings values periodically to incorporate changes in operating scenario. The use of deemed values in a savings calculation is an agreement to accept a pre-determined value, irrespective of what actually "happens".

For larger and multiple efficiency measures and program strategies – including those expected to result in significant savings or those with a high degree of uncertainty – a measured savings approach that follows established protocols may be appropriate. Estimates of energy (and/or demand) savings are calculated using the measured and analysed value for each projects based on agreed M&V protocol.

Measurement and Verification (M&V) is the process of using measurement to reliably determine actual saving created within an individual facility or system by an energy management programme. Savings cannot be directly measured, since they represent the absence of energy use. Instead, savings are determined by comparing measured use before and after implementation of a project, making appropriate adjustments for changes in operating conditions.

4.1 M&V Overview

The main objective of M&V is to provide a credible, transparent and replicable process that can be used to quantify and assess the impacts and sustainability of implemented EE projects. The basic principle in M&V is comparing the measured electricity consumption and demand before and after implementation to determine the electricity savings. A well-designed M&V plan reduces uncertainty and provides a process that can be followed to measure the effectiveness of the energy management and programme success, thus increasing lenders' and decision makers' confidence in the projects.

Project M&V activities consist of some or all of the following:

- Data gathering and screening
- Development of a computation method and acceptable estimates
- Computations with measured data
- Reporting, quality assurance and third party verification of reports
- Meter installation calibration and maintenance

A good M&V plan increases the transparency and credibility of reports on the outcome of efficiency investments. It also increases the credibility of projections for the outcome of efficiency investments. This credibility can increase the confidence that investors and sponsors have in energy efficiency projects, enhancing their chances of being financed. By improving the credibility of energy management projects, M&V increases public acceptance of the related emission reduction. Such public acceptance encourages investment in energy efficiency projects or the emission credits they may create. By enhancing savings, good M&V practice highlights the public benefits provided by good energy management, such as improved community health, reduced environmental degradation, and increased employment.

It is recommended that the project developer use M&V protocols such as those available from Efficiency Valuation Organization's International Performance Measurement and Verification Protocol (IPMVP) which provides international best M&V practices using robust engineering and statistical techniques.

Under IPMVP there are four identified options for M&V

- **Retrofit Isolation**
  Savings are determined by field measurement of the energy use of the project switching points to which efficiency measures were applied separate from the energy use of the rest of the street lighting systems. The savings are determined by engineering calculations using short term or continuous measurements taken throughout the post-implementation period.

- **Partially Measured Retrofit Isolation**
  This option differs from the regular retrofit isolation method in that savings are determined by field measurements on only some of the energy use parameters of the system(s) to which energy saving measures were applied, rather than on all measures. Partial measurement may be used if the total impact of doing only certain measurements does not introduce significant error into the resulting savings calculation. Careful review of project design and installation will ensure that those measures that are monitored fairly represent the probable actual total savings. Measures omitted from M&V must be shown in the M&V plans along with an analysis of the significance of the error their omission may introduce. The savings are determined by engineering calculations using short term or continuous measurements taken throughout the post-implementation period.

- **Whole System/ facility**
  Savings are determined by measuring energy use at the whole system level such as large feeder or distribution transformer level, which cater many switching points. Short term or continuous measurements are taken throughout the post-implementation period. The data for the savings calculations are obtained from the analysis of the whole utility energy meter or sub-meter using whatever technique is appropriate, from simple comparison to regression analysis.

- **Calibrated Simulation**
  Such option is used for a single ECM or multiple ECMs within a whole facility/network where no base year data or historical data are available, either because no records exist or, more commonly, because it is a new installation. Post-retrofit measurements are used to calibrate the simulation model, and base year energy use and demand are generated by the simulation model. Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility.

Table 4 provides guidelines on choosing the most suitable M&V approach for specific Energy Conservation Measures (ECM) for an energy-efficient street lighting project, considering the actual site condition and availability of metering infrastructure.

Table 4. Applicability of Different M&V Approaches

M&V Approach	Street Lighting Applications	Implications and Key Considerations
Specifications or Stipulations-based or Deemed Savings Approach (No comparable IPMVP Option)	• Suitable for project-level M&V where a high degree of trust exist between the key stakeholders and once agreed, the stipulated clause used in the M&V plan won't be questioned (refer to Table 7 in Section 4.5 for more guidance) • Difficult to establish baseline or baseline does not exist; • Any M&V plan will be too complex and cost-prohibitive.	• This option should only be looked at if the metering and sensor infrastructure in the baseline scenario is either absent or largely broken or highly unreliable; • Uncertainty in energy savings must be mitigated through project design and rigorous contractual clauses; • Use street lighting standards and sample measurements to develop a reliable and reasonable deemed savings approach.

Retrofit Isolation (similar to Partial- or Full-Measurement Retrofit Isolation of IPMVP)	• Suitable for projects requiring a balance between engineering rigor leading to reduction in uncertainty in energy savings determination and cost; • Can be used for all three categories of ECMs typically found in street lighting projects (refer to Table 7 in Section 4.5 for more guidance).	• M&V cost will rise depending on the number of different lamp technologies being replaced, number of parameters being measured and sample size for measurement; • Use the opportunity to install an appropriate metering and sensing infrastructure to monitor the state of lamps and illuminance level.
Feeder Level Metering (similar to Whole Facility Metering of IPMVP)	• Most suitable for project-level M&V involving multiple ECMs with interactive effects; • Can also be adapted for the two broad categories of ECMs - efficiency improvements in lamp technology or improved controls (refer to Table 7 in Section 4.5 for more guidance).	• Little or no parasitic/unaccounted load; • Entire street lighting load is connected and accurately reflected the feeder level meter; • Needs to be complemented with burned-out lamps inventory and illuminance level measurements; • If prior, functional sub-metering infrastructure exists at different lamp technology cluster level, M&V cost can be brought down significantly by feeder-level metering.

4.2 Developing an M&V Strategy for Street Lighting EE Projects

Upon finalising the M&V approach for an EE street lighting project, the project team has to develop the M&V strategy for the project. When developing the strategy it is important to always keep in mind the M&V cost and risks applicable to EPC projects.

4.2.1 Balancing M&V Cost and Uncertainty

An objective of M&V planning is to design the process to incur no more cost than needed to provide adequate certainty and verifiability in the reported savings. The issue is: “how much certainty is enough, and what is a reasonable cost?” The value of savings for a specific project places limits on the expenditure that can be justified for M&V. Conversely, the number, type and complexity of ECMs in the project increases the M&V effort and expenditure for a given level of savings certainty. Clearly a project with constant load and operating hours is easier to deal with and hence cheaper (street lighting projects with fixed operating hrs) than one with variable load, variable operating hours, and with non-ECM factors, (such as weather, occupancy or production levels) that influence the energy usage over time.

It is difficult to generalise about costs for the different M&V Options. However, typically the cost ranges from 3% to 5% of annual savings[4], depending on the project and ECM objectives and constraints. The acceptable level of uncertainty in a savings calculation is a function of the value of expected savings and the cost effectiveness of decreasing uncertainty through additional time, effort and cost

4.2.2 Project Risk Management

Energy Performance Contracting (EPC) is an arrangement where an external party (ESCO) takes on a certain amount of risks in order to facilitate the implementation of EE projects. Designing a robust M&V plan is therefore a core aspect of a well-structured risk mitigation strategy for any EPC projects. A well designed M&V Plan lays out how the baseline will be developed, how the project's performance will be monitored and verified to ensure that savings are quantified accurately and within the bounds of uncertainty determined by both the parties. It is good practice to also assign responsibilities to the two parties and to provide a framework on how those risks will be managed.

Table 8 in Annexure 2 provides the M&V related Risk and Responsibility (R&R) Matrix.

4.2.3 Linking M&V with the Project Life Cycle

A primary barrier to the implementation of energy efficiency projects in the municipal sector has been the lack of ability by project implementers to ensure the delivery of desired savings. Many projects in the past have not be able to meet the expected results due the lack of proper M&V plan. A well-designed M&V plan specifies procedures that, when implemented, would allow the municipality to quantify the performance and savings resulting from the implementation of the energy efficiency project. By using an M&V plan, the municipality will be able to allocate various risks associated with achieving energy cost savings, facilitating project financing, and allowing risk reduction and better risk management.

The table below provides an outline on how the various M&V aspects need to be included during various stages of the project life cycle.

Table 5. M&V in the Project Life Cycle

Project Phase	M&V Tasks
Bidding or Tendering The client should emphasise the requirement of credible M&V plan for the project performance measurement. A guideline can be provided to the bidder on the minimum requirements for quality	The bid document should include the following: • M&V approach and methodology (deemed saving approach or measured saving approach) • Status of the current metering and data

[4] As per IPMVP Guidelines

response from the perspective bidders.	recording practices • Bid Evaluation criteria linked with M&V understanding and methodology • Guideline on annual M&V reporting requirements
Baseline Establishment The baseline establishment exercise is expected to set the stage for possible metering and monitoring plan that are required to measure the project results. The baseline report should clearly describe how the agency is planning to use the existing metering and data monitoring system for their post M&V exercise. Any additional metering or data recording requirement needs to be assessed during baseline assessment exercise to get the concurrence and acceptance of the client.	The implementing agency should propose M&V plan and its operational requirements for each energy saving measures after conducting the baseline assessment and same should be discussed and agreed upon by both the parties. At this stage both the party should agree on the accepted M&V plan, metering requirements, M&V frequency, Roles and responsibility of both the parties as part of risk mitigation strategy.
EPC Signing The operationalisation of the M&V plan is crucial and many times overlooked by the stakeholders. The leading causes of litigation in EPC are mainly based on a lack of common understanding on how savings should be evaluated before the actual evaluation period.	The agreed and signed EPC should have the following: • Measure specific M&V Plan • Entire project specific M&V plan • Meter to be used for M&V • Data source to be used for M&V • Calculation method for arriving the energy and cost savings • Approach to be adopted to compute savings in case of baseline adjustments
EE Implementation & Performance	During this phase the main tasks are measuring and monitoring energy performance according to the agreed M&V Plan

4.3 Project Baseline Determination

4.3.1 Baseline Determination

Establishing project baseline is the first and most important step of any street lighting energy efficiency project that requires demonstration of results in terms of quantification energy and cost savings. The pre-implementation electricity use conditions (energy consumption, operating conditions and project boundary) are described as the establishment of project baseline and needs to be agreed upon by both the parties. The energy baseline represents the electricity use linked to a set of conditions under which the street lighting system was operating prior to implementation. Establishment of the energy baseline is crucial for estimating the energy savings realized after implementation of any energy savings measures. During the establishment of the baseline, at least following parameters should be considered: Power failure as recorded by the electricity board or DISCOMs (hours per month), Inventory of different types of lamps to be replaced, street light operation (hours per day), average illumination levels in each street of the municipality (in lux).

Care should be taken to identify any major loads that are introduced or deleted during the period under consideration. If these factors remain unchanged, the post-implementation electricity use can be directly compared without any adjustments to the baseline. However, if any of the pre-implementation conditions change, baseline adjustments are necessary to bring the two time periods under the same set of operating conditions. In order to determine the savings, it is essential to establish a post-implementation energy usage scenario as if the EE intervention had not taken place. The baseline documentation typically requires well-documented audits, surveys, inspections and/or short-term metering activities. The extent of this information is determined by the measurement boundary chosen for the projects. For example, a typical switching point can be considered as one of the measurement boundary which includes a dedicated energy meter for the switching point for the fixed number of street lights.

An Overview of the typical switching point *baseline summary template* and *baseline detailed template* are attached in Annexure 3.

4.3.2 Baseline Adjustments

Adjustments to the baseline are made when post-implementation conditions in energy use changes relative to the original baseline conditions documented in the M&V plan. It is important to have a method of tracking and reporting changes to the baseline conditions. Many factors affect the performance of the street lighting project (e.g. addition and/or deletion of lights, seasonal operating hours etc.) over time and thereby the achievement of savings over the course of the project. Parameters that are predictable and measurable can be used for routine adjustments. Such adjustments reduce the variability in reported savings and provide a greater degree of certainty in reported savings. At times unpredictable changes to the parameters, such as unexpected changes in use, voltage variations may require non-routine adjustments to the baseline in the future.

Therefore the agreed M&V plan must take into account predictable changes to the baseline, such as addition of poles or lights within the project boundary, the ability of changes to be monitored and measured, and the likely impact of changes. The ESCO and the project host must agree on how such changes will be factored into baseline adjustments over the course of the project. The decision of whether to expend time, effort and money on more extensive adjustments depends on the purpose, required accuracy, required confidence level and the cost or benefit of taking such an action and is unique to every project.

4.3.3 Sampling Guidelines

A simple random sampling method is recommended to be used for the street lighting project. Each element of the sample will be drawn randomly from the total population of switching points involved in the project activity.

For the hours of operation, a simple random sampling method is used. The switching points represent the sample frame. As a group of fittings are connected to the same switching point and the ON-OFF operation is at switching point, this method is the most appropriate to measure the operating hours. The operating hours will be determined ex-post and used for both baseline and project energy calculations.

The percentage of functioning fittings is determined using a simple random sampling method. Each element of the sample will be drawn randomly from the total population of various types of fittings covered in the project

Basic calculation of sample size is as given below:

$$n = \frac{z^2 \times cv^2}{e^2}$$

where,

n is the sample size
cv is the coefficient of variation
e is the desired precision
z is the standard normal distribution value

4.4 Baseline Determination - Challenges & Recommendation

Implementation of street lighting projects through performance-based contract involves addressing challenges that are important for ensuring the demonstration of its results over a period of time. Some of these issues start surfacing when the project undergoes the baseline assessment or energy audit exercise. The table below provides an overview on some of the critical baseline related issues those are relevant to the project M&V in real terms and needs attention in view of minimizing the project risks and uncertainty that may occur during the performance period of the project.

Table 6. Baseline Challenges and Recommendation

Baseline Issues	Description	Recommendations
Baseline data source and quality	Source of data and its quality is very important for establishing a credible project baseline as well as preparing the post implementation M&V plan and metering infrastructure.	All the baseline data sources (historical and measured) should be assessed adequately to ensure its relevance, quality and reliability. Based on the existence of the data source, a plan can be formulated for measuring and recording data for post project results verification. Both the parties should agree upon on the type and source of the data that will be considered for analysis and computation during the course of the project.
Past historical energy consumption from energy bills	Can be used to get an indicative monthly energy consumption pattern. It is very difficult to arrive at the actual monthly lamp operating hours (total monthly lamp burning %) of any switching point in the absence of actual lamp operating hours which generally does not match with the utility energy bills.	The actual lamp operating hours can be monitored and recorded by installing additional meters as part of EE initiatives.

Baseline Issues	Description	Recommendations
Spot measurement	It provides real time energy consumption of particular switching point for actual numbers of the lights in operation.	It is suggested to monitor the actual operating hours of the each lamp of the particular switching points for better analysis of the actual operating load in a day or during the baseline measuring period.
Data logging	Data logging for 1-3 days can be designed to capture trend of the operating practice or any other variations.	It is suggested to monitor all the operating parameters such as current voltage, on-off schedules, and actual operating hours of each lamp with the project boundary for the better analysis of the actual operating load.
Light operating hours	Actual light operating hours depend upon two factors; A) Availability of power supply B) Total functional lamp in the switching point. The actual operating load could be different from the connected load due to the failure or non-working of few lamps in the particular switching point.	The baseline study needs to monitor actual light operating hours and accordingly the specific energy consumption needs to be established for the operating load. Advance monitoring system has the capability of capturing this accurately.
Supply voltage	In most cases, supply voltage level are not constant during the operational hours which affects the total energy consumption as well as illuminance level.	It is recommended to conduct the baseline and post-implementation measurement within the acceptable range of voltage as agreed upon by both the parties. Suggested voltage range for the measurement could be: 200V-230V

Baseline Issues	Description	Recommendations
Service level (Lux) – Existing (baseline) – To be maintained	If the project results are linked with the lux level, the baseline condition lux level needs to be measured for each type of lamps and roads covered under the project.	It is recommended to clearly define the required lux level for all categories of the road in the bid document and what credit, an ESCO may receive, for substantially improving the lux levels from the baseline. To deliver the enhanced lux level, the baseline energy consumption needs to be adjusted accordingly and agreed upon by both the parties prior to the implementation.
Uniformity of pole height and pole spacing	In some cases, the height and spacing of the poles may not be uniform and such roads and stretches needs to be identified as part of baseline study and clearly mentioned in the report.	These can be described as non-standard road and accordingly the required lux level and uniformity level can be agreed upon by both the parties prior to the implementation.
Project boundary	Very important for street lighting project and all the details such as total number of lights at a particular switching point, feeders' details, meter functioning etc. should be recorded.	Both parties should agree upon the details of the project boundary. Any change in the project boundary during the performance period requires baseline adjustment to be done for fair quantification of energy savings.
Electricity meter	Baseline assessment should include checking of functioning of the utility meter, i.e. working, erratic reading, billing, calibration etc.	As in most cases, this utility meter is expected to be considered for energy billing, any issues with the functioning of the meters needs to be reported clearly for its rectification prior to the implementation.

4.5 M&V Plan Framework for Energy Conservation Measures (ECM) Categories

The energy and cost savings are computed by comparing the pre and post condition energy consumption with utility/or ESCO energy meter (as agreed upon) as the reference meter.

$KWh_{Savings}$ = Baseline Energy Consumption ($kWh_{baseline}$) – Actual Energy Consumption (kWh_{post}) ± Adjustment

Table 7. Best Application of M&V Options in Typical Street Lighting Energy Conservation Measures[5]

EEM Category	Energy Savings Calculation Methodology	Best M&V Option
Efficiency Improvements Only (Load reduction measures)	$kWh_{savings} = (kW_{pre} - kW_{post}) \times hrs \pm adjustment$[6] Energy savings by reducing lighting load through measures such as installing more efficient lamps or ballasts. Key Parameters: kW_{pre}- from baseline report or stipulated[7] kW_{post}- from utility meter/or ESCO meter or stipulated (mutual agreement) hrs – same before and after Meter requirement: 1. Utility meter/ESCO provided meter 2. Run-hour meter	• Deemed Savings • Retrofit Isolation

[5]All three M&V Options discussed in Table 4, earlier have been considered keeping in mind the technical requirements, capacity at the municipalities, prevailing conditions on the ground.

[6]Adjustments can have a significant impact on the variability of energy savings calculations. It is in the interest of both the parties to document any deviations from baseline conditions or stipulations (e.g. connected load, energy consumption, run-time, illuminance levels, etc.) that can have a material impact on agreed energy savings calculations methodology.

[7]To arrive at a consensus on the stipulated energy use parameters, both parties could consider using manufacture published data OR accredited Test lab measurement data for the sampled lamps OR measuring power consumption of lamps on a pilot basis

EEM Category	Energy Savings Calculation Methodology	Best M&V Option
Control Improvements only (Optimize operating hours through better controls)	$kWh_{savings} = kW (hrs_{pre} – hrs_{post}) \pm$ adjustment Operating hours are reduced by using a control device on lighting circuit. <u>Key Parameters:</u> hrs_{pre}- from baseline report or stipulated[8] hrs_{post} – from Run-hour meters or stipulated kW – same before and after <u>Meter requirement</u>: 1. Run-hour meter	• Deemed Savings • Retrofit Isolation
Efficiency and Control Improvements (Capture the interactive effects)	$kWh_{savings} = (kW_{pre} \times hrs_{pre} - kW_{post} \times hrs_{post}) \pm$ adjustment This combines efficiency and control improvements <u>Data source</u>: kW_{pre}- from Baseline report or stipulated kW_{post}- from utility meter/or ESCO meter or stipulated (mutual agreement) hrs_{pre}- from baseline report or stipulated hrs_{post} – from Run-hour meter or stipulated <u>Meter requirement</u>: A. Utility meter/ESCO provided meter B. Run-hour meter	• Deemed Savings • Feeder-level Metering

Depending upon the project stakeholder's agreement on the M&V approach to be taken, the above table mention parameter(s) can be identified for assumption and for to be measured for the purpose of calculating the energy savings after the implementation of the project. Although the technical and financial benefits of implementing energy-efficient street lighting projects are increasingly understood, many of the players who need develop performance based projects are not familiar with the right approach to align with the best M&V practices for doing so. The above sections/chapters of the application guide aims to serves as a practical tool for anyone interested in being a part of the development and implementation of street lighting energy efficiency project using a performance based contract. The illustration of the M&V approaches and how that can be applied to typical ECMs has been shown through examples and with the background of street lighting operating practices in India in the current context. Although the information contained in the application guide can be readily adapted around the world, it will be most relevant for the Indian context.

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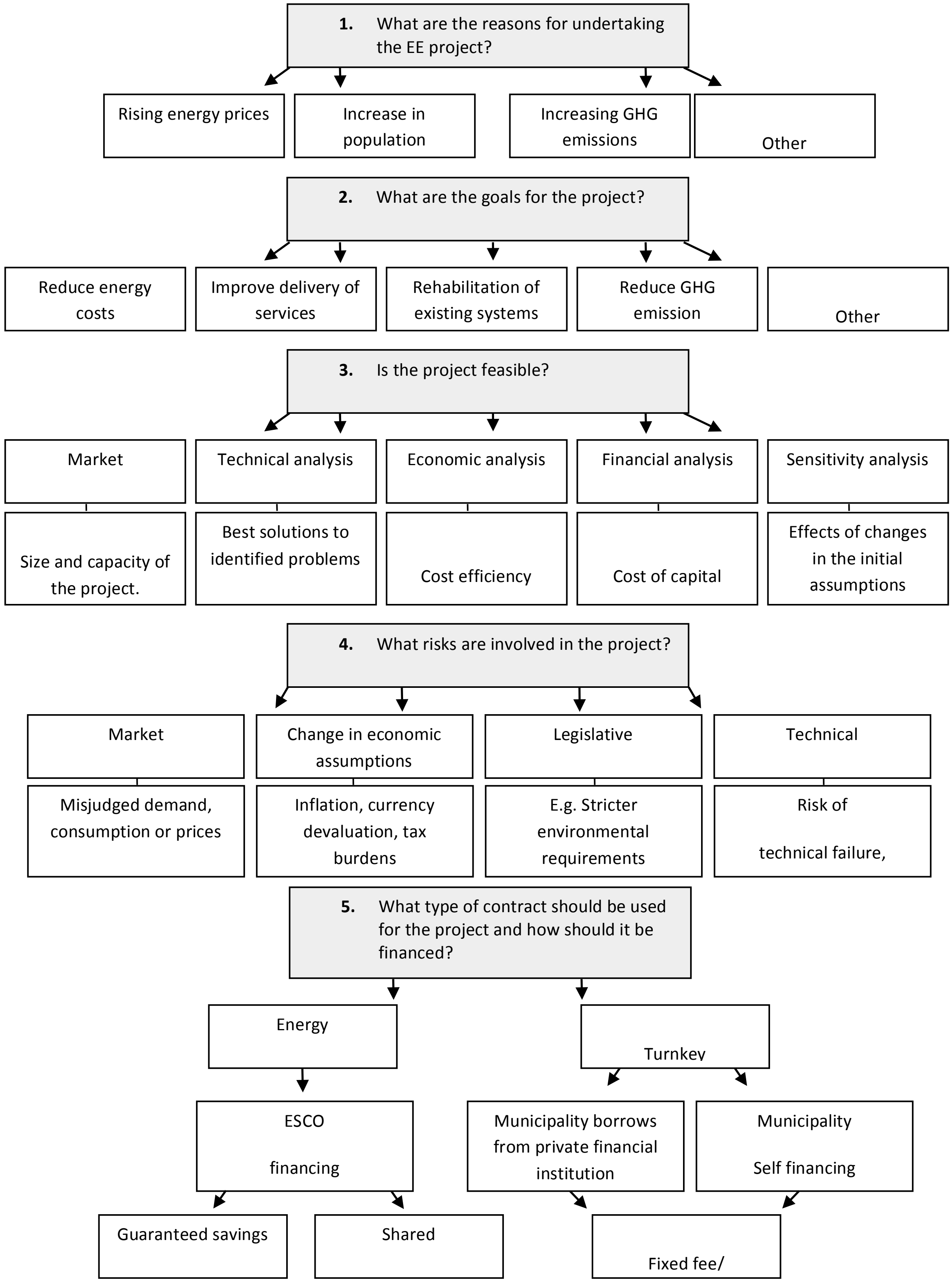
[8] To arrive at a consensus on the stipulated operating hours, both the party could consider measuring run-time hours on a pilot basis or use historical run-time hours information.

Annexure 1: EE Project Assessment Flow Chart



Annexure 2: Project Risk Management Template

Table 8. M&V Risk Management Template

Responsibility/Description	ESCO/Implementer Proposed Approach	Municipality Assessment
Operational		
<u>Lamp Operating hours</u>: The municipalities generally has control over operating hours. Increases and decreases in operating hours can show up as increases or decreases in "savings" depending on the M&V method (e.g., operating hours multiplied by improved efficiency of equipment). **Clarify whether operating hours are to be measured or stipulated and what the impact will be if they change.** If the operating hours are stipulated, the baseline should be carefully documented and agreed to by both parties.		
<u>Lighting Load</u>: Equipment loads (addition and deletion of lights) can change over time. The municipalities generally have control over hours of operation, intensity of use (e.g., temporary addition of loads during festive seasons). Changes in load can show up as increases or decreases in "savings" depending on the M&V method. **Clarify whether equipment loads are to be measured or stipulated and what the impact will be if they change**. If the equipment loads are stipulated, the baseline should be carefully documented and agreed to by both parties.		
<u>User participation</u>: Many energy conservation measures require user participation to generate savings (e.g., control settings such as light dimming during off-peak hours). **Clarify what degree of user participation is needed and utilize monitoring of such activities.** If performance is stipulated, document and review assumptions carefully and consider M&V to confirm the capacity to save (e.g., confirm that the controls are functioning properly).		

Responsibility/Description	ESCO/Implementer Proposed Approach	Municipality Assessment
Performance:		
Equipment performance: In most cases the Contractor has control over the selection of equipment and is responsible for its proper installation, commissioning, and performance. Generally the Contractor has responsibility to demonstrate that the new improvements meet expected performance levels including specified equipment capacity, standards of service, and efficiency. **Clarify who is responsible for initial and long-term performance, how it will be verified, and what will be done if performance does not meet expectations.**		
Operations: Responsibility for operations is negotiable, and it can impact performance. **Clarify responsibility for operations, the implications of equipment control, how changes in operating procedures will be handled (e.g on-off of the street lights, public complain logging etc), and how proper operations will be assured.**		
Maintenance: Responsibility for maintenance is negotiable, and it can impact performance. Clarify how long-term preventive maintenance (e.g., control panel, meter calibrationetc) will be assured, especially if the party responsible for long-term performance is not responsible for maintenance (e.g., Contractor provides maintenance checklist and reporting frequency). **Clarify who is responsible for long-term preventive maintenance to maintain operational performance throughout the Contract term. Clarify what will be done if inadequate preventive maintenance impacts service level and public inconvenience**		

Responsibility/Description	ESCO/Implementer Proposed Approach	Municipality Assessment
Light, Control Panel Repair and Replacement: Responsibility for repair and replacement of Contractor-installed equipment is negotiable, however it is often tied to project performance. **Clarify who is responsible for replacement of failed components and repair time throughout the term of the Contract.** Specifically address potential impacts on performance due to lights failure. Specify expected equipment life and warranties for all installed equipment. Discuss replacement responsibility when equipment life is shorter than the term of the Contract.		

Annexure 3: Baseline Data Measurement and Analysis

Summary Template

<u>Overview of Switching Point</u>

The Switching Point Boundary

<table>
<tr><td>Switching Point Code:</td><td colspan="6"></td></tr>
<tr><td>Switching Point Location:</td><td colspan="6"></td></tr>
<tr><td>Utilty Meter No:</td><td colspan="6"></td></tr>
<tr><td>Type of Meter (Single/ Three Phase)</td><td colspan="6"></td></tr>
<tr><td>Distribution Transformer (DT) Code or No.</td><td colspan="6"></td></tr>
<tr><td>Type of Road(s) covered under the Switching Point (A1, A2, B1 etc)</td><td colspan="6"></td></tr>
<tr><td rowspan="2">Total No. of Poles and Fixtures (ideal condition)</td><td colspan="3">Total No. of Poles</td><td colspan="3">Total No. of Fixtures</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td rowspan="3">Type of fixtures (ideal condition)

SV, MH, FTL,250W/150W/70W/40W</td><td colspan="2">Type of Lights</td><td colspan="2">Wattage</td><td colspan="2">Quantity</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

The above mentioned detail serves the purpose of defining each switching point boundary conditions.

<u>Observation and Analysis:</u>

Baseline Street Lighting Load (KW Baseline) (With 100 % load in operation) :	
Baseline Energy Consumption (KWh Baseline) (With 100 % load in operation and 10** hours of operation) :	
Lux level to be maintained based on Road Category Note: *In Case of Non Standard Road, the Lux level is established as per bid conditions*	

*** Or agreed operating hrs*

<u>Signed by</u>: Municipal Corporation Project Implementer/ ESCO Third Party Agency (if any)

Detailed Template

Overview of Switching Point

The Switching Point Boundary

Switching Point Code:				
Switching Point Location and Connected Street Address				
Utility Meter No:				
Type of Meter (Single/ Three Phase)				
Distribution Transformer (DT) Code or No.				
Type of Road(s) covered under the Switching Point (A1, A2, B1 etc)				
Approximate length of the road connected with the switching point (km)				
Widths of Street Illuminated				
Approx. height of the poles* **Indicate the street with mixed height poles*				
Distribution Transformer(DT) Capacity (kVA)				
DT owned and managed by				
Total No. of Poles and Fixtures (ideal condition)	Poles		Fixtures	
Type of fixtures(ideal condition) SV, MH, FTL, 250W/150W/70W/40W	Type of Lights	Wattage	Quantity	Ballast
On Off Operational Practices (Manual, Timer etc.				
Application of Dimmers(Yes/No)				

Measurements

1-3 day measurement details -Filed Study Date:

Date	Total no of Poles	Type of Fixtures					Total No of Fiixt ures	Utility start meter reading (kWh)	Utility end meter reading (kWh)	Switc hing on Time	Switc hing off time	Supply Power outage (hrs)	Non-functio nal lamp hours (hrs)	Conn ected load (kW)	Meas ured Energ y Consu mptio n (kWh)	Measu red appare nt energy (kVAh)
		HPSV -250	HPSV -150	FTL T-12	MH-250	LED-70										

Data Review and Analysis (Summary of three day data monitoring)

Total Operational Load (KW)	
Total Operational Hrs	
Total KWh recorded for Operational Load	
Utilty Meter recorded KWh (start and end meter during three day study)	
Any Difference in Recorded and CESU meter KWh Reading (unit and % deviation)	
Light burning % (based on spot measurement during three day)	
Average Power Factor Observed	
Measured Lux level (only applicable for non-standard roads)	
Energy Bill Analysis	
Observation on total energy consumption as per the energy bills Vs extrapolated three day measured data	
Any penalties	
Assessment of average billing -for faulty and non-working meters (if the average billing is based on reasonable assumption on connected load and operating hrs.)	

- Voltage profile (Add graph) – Highlight Max, Min and Mean value
- Single line diagram of switching point (to be gathered from ESCO and validated by TPEA)
- The SLD includes following;
- Lighting installation layout
- Distribution Transformer code
- Switching point code and location
- Total No. and type of lights
- Type of road category
- Type of distribution --- Single/Median etc. No of fixtures on poles
- Approx. length of street covered by switching point
- Assets details (Pole numbers from –to)
- Any special remarks

Annexure 4: Visakhapatnam Street Lighting Project - Case Study

The devastating cyclone Hudhud, which landed on the eastern coast of India on 12th October 2014, caused massive damage to infrastructure in several parts of Andhra Pradesh (AP) particularly, in Visakhapatnam (popularly known as Vizag). In Vizag city, out of around 90,000 street lights, only 10,000 remained functional. This was causing major concerns of public safety and security in an already ravaged city. Restoration of street lights expeditiously was a top priority for the AP Government, and Energy Efficiency Services Ltd (EESL) was requested to install new LED street lights to rebuild the infrastructure and also to ensure that energy efficient options are used. Greater Visakhapatnam Municipal Corporation (GVMC) requested EESL on 1.11.2014 to install 90,000 street lights on top priority. This was followed by a request by Secretary (Energy), Government of Andhra Pradesh to Secretary, Ministry of Power to issue necessary directions to EESL to take expedite the same.

Uniqueness of the Project

Conventionally, M&V plan should be prepared and agreed upon by all concerned stake holders before implementing any energy efficiency project including street lighting. This would ensure that all the existing conditions of the project are known to stakeholders and the baseline conditions can be monitored and measurements taken before the commencement of implementation. However, in this situation, as most of the street lights were severely damaged, the priority of the project was to restore it without delay.

Baseline Scenario

The baseline is taken as prior to implementation of the project, as well as prior to the cyclone Hudhud destruction. The entire street lighting in Vizag is divided into 8 zones, of which zones 7 and 8 (Anakapalli and Bimli), were more recently created. Around 4,000 switching points existed but these were not metered. For unmetered switching points, the utility was billing in an *ad-hoc* manner, based on the understanding reached with GVMC. The amount was dependent on the number and type of light fittings on each unmetered switching point. All switching points were manually operated, and on an average each operator switched ON and OFF around 25 to 30 locations. This process would take around one hour in the evening, as well as in the morning, to cover all points allotted to the operator. There was already a system of receiving and monitoring complaints about non-functioning street lights and this system was reported to be functioning well. On an average, around 2,000 complaints (2.22%) were pending at any point of time prior to this project.

Details of the type and number of light fittings derived from lights actually replaced are as under (total being 91,775) and agreed by GVMC to be considered for base line purposes.

Sl. No.	1	2	3	4	5	6	7
Type of fitting	40W TFL	70 W HPSV	150W HPSV	250W HPSV-1	250W HPSV-2	250W HPSV-3	400W HPSV
No of fittings	60,395	4,084	18,392	4,578	3,000	1,200	126

Implementation

The foremost objective in implementing the street lighting project at Visakhapatnam was to restore street lights devastated by the cyclone. The number of operational lights had come down from 90,000 to merely 10,000. The secondary objective was also to bring down the overall energy consumption through adoption of LED lighting, conforming to required *lux* levels as per norms of the National Lighting Code (NLC). Provision of automated controls through Centralized Control and Monitoring System (CCMS) would also ensure timely switching ON and OFF of the lighting and enable continuous monitoring.

These objectives were to be achieved in the following manner:

a. Retrofitting all light fittings with energy efficient LED lights and fixtures and thereby saving on power consumption.
b. Selection of wattages of LED lighting in such a way that NLC (National Lighting Code) norms are met with and at some road locations, higher wattages lamps to be used for beautification purposes (like on Beach Road and some VIP areas of the city).
c. Controlling hours of use by having automation for switching ON & OFF through CCMS. This was done to ensure timely switching ON & OFF of lights as per need.
d. Selecting a lighting scheme, which will not only be energy efficient but will also require less maintenance and last longer thereby saving on operations and maintenance (O&M) costs.
e. CCMS would also ensure close monitoring, measurement, immediate reporting of complaints.
f. For the present, dimming of lights in off-peak hours is not being attempted. However, all three vendors are required to keep a provision for three step voltage reduction. This energy saving measure can also be implemented at a later stage.

Assumptions

a. Since, baseline measurements are not feasible, power consumption by old light fittings for baseline period is assumed on the basis of manufacturers ratings and prevailing norms as given below:

Sl. No.	1	2	3	4	5	6	7
Type of fitting	40W TFL	70 W HPSV	150W HPSV	250W HPSV-1	250W HPSV-2	250W HPSV-3	400W HPSV
Estimated power consumption in watts	53.5*	85	170	280	280	280	450

* Assuming that most of the lights were having 40W tubes and average consumption of chokes varied from 12 to 15 Watts.

b. As switching ON and OFF of street lights was being done manually and no records exist about the exact timing, the operating hours have to be assumed for baseline period. For reporting period, operating hours will be available from CCMS for all the 4,000 switching points. Based on experience, there is a saving of energy due to automation leading to operating hours reduction in actual practice, by about 30 to 60 minutes. This can be an agreed upon between GVMC and EESL.

c. Between the scheduled switching ON and OFF, there might be frequent and long power cuts. However, for simplification, un-interrupted power supply could be assumed during entire ON period for baseline, as well as reporting period, and energy consumption could be computed accordingly.

d. As no *lux* measurements were available for different types of fittings, based on NLC and prevailing norms fixture replacements have been arrived at for equivalent *lux* levels as under:

Sl. No.	1	2	3	4	5	6	7
Type of fitting	40W TFL	70 W HPSV	150W HPSV	250W HPSV-1	250W HPSV-2	250W HPSV-3	400W HPSV
Corresponding LED fitting having equivalent lux levels	20W	40W	70W	120W	120W	120W	210W

Methodology and Approach

Energy savings from the implementation of the project form the basis for arriving at the *annuity* amount. This methodology is simplest to use. The Annuity-based methodology, is based on savings determined by extrapolation of limited measurements, to the entire area of the street lighting project, as actual metering is not feasible. Payments are determined from these measurements without linking to bills or on actual or metered savings.

Projects based on this methodology can consider complete life-cycle cost which is inclusive of capital cost as well as costs of energy, maintenance and replacement for arriving at most appropriate lighting. This methodology has lesser M&V cost as measurements are required to be taken only one-time basis, or as per pre-determined intervals.

Measurement Boundary and Measurement

'Measurement boundary' can be based on individual light fittings for each type. It is also possible to consider switching point as measurement boundary but these switching points have more than one type of fitting. Operating hours for each switching point can be taken from CCMS based on actual logged data.

All points related to metering, and meter specifications used for taking measurements, should be specified in advance and recorded as these will affect accuracy of measurements and ultimately final results. Other details such as type of meters to be used, meter commissioning, calibration process should be defined before commencement of project activities.

Measurement Process

For Baseline

As there was an urgency of putting street lights into operation, measurement could not be taken for baseline period before commencing the retrofit project. Number and type of fittings for baseline period have been finalized based on replacement made with energy efficient fittings. These have been agreed between EESL and GVMC.

Conventionally, retrofitting the lights or for implementing any energy conservation measure or project of this nature, voltage, current, harmonics, power are measured. For this purpose, sample size for the baseline period for all categories of fittings has been determined and operating hours. It should also include the following:

a. Measurement of *lux* levels as per 9-point method for the sample size determined as per prescribed procedure mentioned at **Form-III** and recorded in format placed at **Form-I**.
b. If reduction of operating hours is aimed at, it is important to know the period for which lights remain ON in base line conditions in case it is not automated. Baseline conditions can be ascertained from the Municipal Corporation.

During retrofitting

In Vizag project, due to urgency of restoring the street lighting, recommended measurements have not been carried out. In normal conditions, following points should have been considered:

a. Retrofitting of lights is jointly verified by authorized persons from both sides in prescribed format, to record type and number of old, as well as retrofit fittings, along with date when it was done. This data will be used in two ways. Firstly, to know exact numbers of fittings retrofitted and particularly when inventory data is unavailable. Secondly, to know the date on which the lights were retrofitted on a feeder/switching point for determining energy savings.

b. Keep a separate record of fittings which are upgraded for making improvement in *lux* levels so that adjustments could be made on this account.

<u>For Post retrofit period</u>

In Vizag project, this is the period for which measurements are possible and these can be carried out as under:

a. After retrofitting the lights; voltage, current, harmonics, power should be instantly measured for the determined sample size as per format placed at **Form-I** for all categories of retrofitted fittings.
b. It is required to know the exact period for which lights remain ON in reporting period. In this case, time can be considered from CCMS where, these details will be readily available.
c. Measure lux levels as per 9-point method for the number of samples determined as per prescribed procedure mentioned at **Form-III** and recorded in format placed at **Form-II**

Baseline Period - Energy and Conditions

Considering the urgency of installing street light in operation, measurements for baseline were given lower priority. Baseline period energy will be calculated as laid down in the *Analysis Procedure*, given further below.

Post retrofit - Energy and Conditions

Measurement period would be as small as few seconds since measurements of a light can be taken instantaneously. Retrofit period energy will also be calculated as laid down in *Analysis Procedure*, given further below.

Replacements have been made as under:

Sl. No.	1	2	3	4	5	6	7
Type of fitting	40W TFL	70 W HPSV	150W HPSV	250W HPSV-1	250W HPSV-2	250W HPSV-3	400W HPSV
No. of fittings	60,395	4,084	18,392	4,578	3,000	1,200	126
Corresponding LED fitting having equivalent lux levels	20W	40W	70W	120W	150W	160W	210W

Variables

Voltage keeps on varying with time and season of the year and has a considerable impact on power consumption of a light fitting. However, the effect of voltage on power consumption and *lux* levels is comparatively less in case of LED lightings. It is to be considered that voltage levels for base line period could not be known. Thus, voltage may not be considered as one of the variables.

Other variable is operating hours for street lighting after retrofit. This is recorded by CCMS for each switching point and would be considered for computing energy savings.

Sampling Plan

Sample size is found out for each group separately for base line and reporting period using following formula (for getting 80% confidence level with 10% accuracy):

$$\text{Sample Size } n = \frac{41 \times N}{41 + N}$$

Based on the above formula, sampling size for various type of fittings is worked out as mentioned below.

Sl. No.	1	2	3	4	5	6	7
Type of fitting before retrofitting	40W TFL	70 W HPSV	150W HPSV	250W HPSV-1	250W HPSV-2	250W HPSV-3	400W HPSV
Wattage of LED fitting after Retrofitting	20	40	70	120	150	160	210
No. of fittings	60,395	4,084	18,392	4,578	3,000	1,200	126
Sample size as per formula	41	41	41	41	40	40	31

NOTE: a. Sample size cannot be in fraction and therefore has been rounded off to nearest whole number.

b. Formula mentioned above is based on a value of 0.5 for coefficient of variance (Cv) which will be calculated continuously while measurement are being taken and sample size will change based on actual Cv, which is the *standard deviation / mean*

Analysis Procedure

a. Inventory of lights for base line period as well as after retrofit has been agreed by GVMC and EESL.
b. Sample size determined at 2.10 for each category of lights will be used.
c. For knowing power consumption and other parameters for each group of light fitting, measurements will be taken for the sample size as shown at **Form-II** in such a way that it covers almost all area and whole night.
d. As no automation for switching ON and OFF existed in the GVMC, operating hours can be found out based on the system followed by GVMC for base line period.
e. Base line energy consumption will be computed using power consumption and number of lights shown as given in the *Assumptions* earlier, for the base line period considered at point mentioned above.
f. After retrofitting, energy consumption can be found out from average power consumption calculated from measurements taken for sample size for each type of fittings and considering time of use from CCMS. For easy calculations and ideal situation, same time for ON and OFF should be set for all switching points.

Energy Prices and Financial Savings

Energy price is reported to remain same (fixed) for entire length of project for seven years.

Monitoring Responsibilities

Reporting period of seven years can give rise to several changes. There could be increase in number of switching/metering points, increase in number and/or type of light fittings. Any of these changes will affect energy consumption. However, maintaining retrofitted lights and its operation is in the scope of EESL. Monitoring these will be the as per the agreement signed. CCMS data can be taken in monitoring most of the conditions, as both sides will have access to the system.

Form I
Determining average Lux levels
(After retrofit)

- **Date-**

S. No.	Switching point/Locality/Zone	Pole identification	Lux measurements									Average Lux*	Remarks
			A1	A2	B1	B2	C1	C2	C3	C4	D		

*Average lux = (A1+A2+B1+B2)/16 + (C1+C2+C3+C4)/8 + D/4
Please refer Appendix E for more details

Name and Signature of ULB authorized person **Name and Signature of EESL authorized person**

Form II

Measuring Electrical Parameters
(After Retrofitting)

Date-

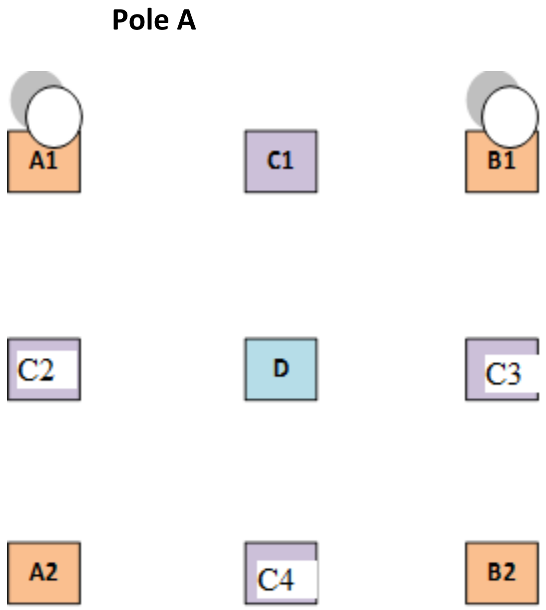
S. No.	Switching point/Locality/Zone	Pole identification	Type of fitting	Measurements						Time of Measurement	Remarks
				Voltage (Volts)	Current (Amp)	PF	Power (W)	THDv (%)	THDi (%)		

Name and Signature of ULB authorized person Name and Signature of EESL authorized person

Form III

Nine Point Method for Determining Lux Levels in Street Lighting

In some of the situations, ECM might be retrofitting light fittings for maintaining a given *lux* level or ULB may ask ESCO/service provider for maintaining recommended *lux* levels as per type of road (details given at Appendix F). In such a situation, it will be necessary to measure *lux* level in base line period and/or in reporting period. A standard and worldwide most accepted method for determining *lux* level is mentioned below.



Average Lux =

(A1 + A2 + B1 + B2)/16 +

(C1 + C2 + C3 + C4)/8 + D/4

Notes:

1) Any ward/locality/zone may contain multiple switching/metering points and each switching points may give supply to one or more street light feeders.
2) A minimum of 1 span per feeder, and minimum 3 spans per switching/metering point should be taken for lux measurements.
3) In case of Poles located at centre of road, measurements for each span to be repeated on either side of the centrally located poles
4) In case of varying Span between poles, Avg. Lux measurements should be made for at least three Spans – viz. Minimum span, Maximum Span, & Average Span per feeder

Actual savings in Vishakhapatnam Street Lighting project can be determined after carrying out M&V activities as per agreed M&V plan. In order to have an estimate of savings, energy savings are being calculated as under:

1. Annual consumption of energy prior to retrofit based on the inventory of fittings existing before Hudud cyclone are as follows:
   [53.5 X 60,395 + 85 X 4084 + 170 X 18392 + 280 X 4,578 + 280 X 3,000 + 280 X 1,200 + 450 X 126] X 11 X 365/1000 = 3,67,88,448 units
2. Annual savings due to reduced wattages of retrofitted LED lamps assuming 11 hours of operational use of street lights for baseline as well as reporting period for all 365 days of a year

   = {(53.5- 20) X 60,395 + (85-40) X 4,084 + (170-70) X 18,392 + (280-120) X 4,578 + (280-150) X 3,000 + (280-160) X 1,200 + (450-210) X 126} X 11 X 365/1000

   = {20,23,232.5 + 1,83,780 + 18,39,200 + 7,32,480 + 3,90,000 + 1,44,000 + 30,240} X 11 X 365 /1,000

   = 2,21,89,751 units ie 60.31 %
3. Annual savings due to increased wattages of retrofitted LED lamps for Sr. no. 5 & 6 fittings installed in order to meet NLC lux norms/beautification purpose assuming 11 hours of operational use of street lights for reporting period for all 365 days of a year

   = ((150-120) X 3,000 + (160-120) X 1,200} X 11 X 365/1000

   = (90,000 + 48,000) X 11 X 365/1000

   = 5,54,070 units
4. Annual estimated savings due to reduced operational hours of street lighting by 45 minutes (as normally varies between 30 min to 60 minutes)

   = {(53.5- 20) X 60,395 + (85-40) X 4,084 + (170-70) X 18,392 + (280-120) X 4,578 + (280-150) X 3,000 + (280-160) X 1,200 + (450-210) X 126} X 0.45 X 365/1000

   = {20,23,232.5 + 1,83,780 + 18,39,200 + 7,32,480 + 3,90,000 + 1,44,000 + 30,240} X 0.45 X 365 /1,000

   = 9,07,763 units

Total annual energy savings at Visakhapatnam street lighting project = 2,36,51,584 units i.e., 64.29 %.

Thus, it can be seen that total energy savings at Visakhapatnam street lighting project comes to more or less same as of guaranteed savings of 24 m units. However, actual savings will be determined only after carrying out M&V activities at the project.

Annexure 5: Bhubaneshwar Case Study

Bhubaneswar Municipal Corporation (BMC) Street Lighting Energy Efficiency Project

The objective of the ongoing project is to upgrade BMC's street lighting systems through design and procurement of advance lighting technology measures in order to enhance the service delivery level by reducing expenditures (energy and Operation & Maintenance cost).

Project Design and Implementation Model

Performance Based Contract – PPP Model

Selection of EE Technology: LED, Dimming, Voltage conditioning

Project Duration: 10 Years, extendable on mutual agreement

Energy savings guaranteed: 80.02%

Shared saving model: 90% to ESCO, 10% retained by BMC

O&M Annuity payment: Rs 300 per fixture to ESCO escalated at 5.5% on yearly basis

Tariff Escalation: At 2.5% per annum

Repayment mechanism: ESCROW Account (three month estimated energy cost savings deposited by BMC as buffer amount)

ESCO is eligible for claim on CDM benefits (90% to ESCO and 10% to BMC)

Letter of comfort to ESCO from Housing and Urban Development, Government Odisha

Key Stakeholders and Roles & Responsibility

Agency	*Roles and Responsibility*
Ministry of Housing and urban Development (MOHUD)	Confidence support to ESCO in repayment Overall monitoring of project Scaling up of project
BMC	Overall project management Coordination among key stakeholders

CESU	Metering and other infra related support Key project committee member
Shah Investment- ESCO	Project Implementation O&M of project during project period
Third Party Energy Auditor	Energy baseline establishment Measurement & verification activity
IFC	Advisory services in project preparation and execution Overall monitoring of project
ASE	Project management and advisory support Capacity building of key stakeholders

Project Scope:

Total No. of street lights: 19,873

Switching Points: 1,043

Connected Load: 3.965 MW

Project Implementation will cover at-least 70% of the fixtures (approx. 13900 lights)

Establishing Project Baseline:

Baseline energy audit was carried out by third part energy audit agency. Energy baseline for each switching point has been agreed upon by both the parties. The finalization of baselines includes the anticipated energy consumption for 100% burning of the lights while maintaining the agreed lux level in each feeder.

Challenges encountered- Billing inaccuracies, non-functioning of the utility meters, drop points, no data on actual burning hours of the lamps in the typical circuit, poor voltage quality, etc.

Definition of Baseline includes:

Project boundary to be defined for each switching point (number of poles, fixture, length and type of road etc)

Each switching point to refer as reference point with asset marking on each pole

Establishment of baseline data based on 3 day of continuous data logging and analysis of the data

Baseline report reflects the LUX level to be maintained at different category of road after the implementation

Project Measurement & Verification (M&V)

Key Highlights:

The M&V section included in the bid document and linked appropriately with the baseline establishment exercise.

Issues related to utility meter functioning and reliability has been brought under the notice of key project stakeholders from day one and step to replace all the project meters has been initiated by BMC.

Maintaining the lux level as per the road category has been freezed and linked with one of the M&V parameters.

Agreed M&V Plan and template for each switching point.

Provisions for additions and deletion of loads has been made and accordingly formula has been suggested to adjust the baseline to quantify the savings.

Separate strategy has been made to regularize the DROP point’s connection prior to the implementation.

Pre Scenario (before implementation of project)

Detailed survey and Asset marking by ESCO

Metering of all switching points by CESU

Establishment of baseline by TPEA

Post Scenario (Commissioning and Implementation)

Implementation of dedicated programmable metering system at each switching point by ESCO

Establishment of control center by ESCO in BMC premises

Reporting to BMC on Daily, Monthly and Annually, Linked with BMC website

Lux level performance monitoring (periodical)

Reporting

The ESCO is expected to maintain daily basis record and report to BMC on – energy consumption, power outage, voltage dimming hours, hour wise number of estimated functional lamps etc. as per the formats provided , also include the

Daily non- functional lamp report

Daily report for switching point

Daily overall report for entire project

The ESCO will submit monthly reports to BMC, about the:

Update on the assets

Operation and maintenance services;

Energy saving report

Lamp failure report etc.

Project Repayment Mechanism

BMC and ESCO has opened ECROW account.

Initial Deposit by BMC in ESCROW/TRA account:

Estimated 3 months electricity bill before execution of EPC as buffer amount

3 month O&M charges – as per agreed rate

ESCO send invoice to Escrow agent, with a copy to BMC Pursuant review of supporting documents

Escrow agent pay 75% invoice amount to ESCO within 5 business days of invoice

Remaining 25% of invoice paid by Escrow agent, upon submission by ESCO on written approval of invoice by BMC. (BMC need to approve/dis approve invoice within 30 days of receipt) –

Training and Capacity Building:

The IFC and Alliance organized series of working sessions and workshop for project management committee and key project stakeholders. The aim of the capacity building working sessions was to raise awareness about the ESCO-based Street lighting project implementation and requirements of the projects design among public and private stakeholders and to provide an overview of the ongoing project as per the real time project progress.

Annexure 7: GHG Emissions Monitoring Methodology

Project Description

The purpose of the project is to reduce the energy required for the Street Lighting network in the typical Municipal Corporations in India. The Greenhouse Gas (GHG) emission reduction project is designed as a component of EESL LED Street Lighting project through performance-based contracts under ESCO business model. An energy performance contract (EPC) is a contract between the municipality and an energy efficiency service provider (e.g., ESCO). In an EPC, goods and services associated with the project are paid for with the energy-cost savings accrued from it, allowing the municipality to implement improvements without incurring any upfront costs. The additional source of GHG revenue will help EESL in reducing the contracting period further, by allowing additional revenue stream for repayment of the investment borne by EESL. A certain portion of the revenue generated from GHG reduction is expected to be shared with the municipalities as an incentive, in addition to the energy cost savings. Reasonably accurate quantification of the GHG benefits, will raise the profile of the energy conservation efforts and achievements made by EESL.

The project could be developed as a single Clean Development Mechanism (CDM) project activity using CDM incentives, and also the EPC model to deploy efficient street lighting technologies in the municipality. EESL is expected to replace baseline fluorescent T12 and mercury or sodium vapor lamps and fixtures, with energy efficient LED lamps with electronic ballast.

This is expected to deliver annual electricity savings, which will reduce GHG emissions from the electricity grid by a proportionate value in terms of tonnes of CO_2 equivalent (tCO_2e) per year.

Under the *business-as-usual* scenario, energy efficient lighting is not a priority as the needed investment competes with more urgent social needs such as water supply, sanitation, development of common spaces, education and healthcare, among others. The basic tasks of maintenance, replacement of burnt-out lamps which were part of the existing scenario included as part of baseline technology, is often given low priority due to municipalities financial constraints.

The project has a large replication potential in other municipalities for further substantial energy savings and reduction in carbon dioxide (CO_2) emissions, provided that CDM revenues are available to overcome the very significant barriers to implementation.

Project Institutional and Implementation Arrangements

The project is implemented by EESL through the ESCO model. EESL has entered into energy services and CDM agreements with the municipalities to finance and implement the project on their behalf, and to receive and distribute the resulting CDM revenues or CERs (Certified Emission Reductions).

EESL will implement both the technical (energy efficiency) and the GHG emission reduction strategies of the project. EESL signs a performance contract with its customers (the municipalities) and guarantees the energy savings which includes design and structuring of the projects, and providing the technology, entire funding for implementation of the project, maintenance support and Measurement and Verification (M&V) after the installation of the project light fittings. Additionally EESL also substantiates the GHG quantification methodology with the M&V process, during the performance contracting period. Furthermore, EESL, through its contract with lamp manufacturers or suppliers, will also be responsible for the maintenance of the street lighting, supply of spare parts and for all replacements during the contract period.

Municipalities: The Municipal Corporations are public entities, and are the clients of EESL. During the reimbursement period, the Municipal Corporations will make regular payments to EESL, in accordance with the Energy contract period. The payment mechanism consists of a secured *escrow account* that will cover the monthly reimbursable amounts to EESL, or direct repayment from municipality account, along with the GHG reduction benefits through CERs, which EESL will share with the municipalities. This would provide the Municipalities an additional incentive for maintaining, and sustaining the project activities.

Project contribution to Sustainable Development

The Street Lighting Project also delivers sustainable development benefits for the host country, such as[9], social, economic, environmental and technology benefits.

Social well-being: The financing scheme proposed under the project activity will allow municipalities to use energy and maintenance budgets effectively to respond to the population's needs for social services and infrastructure development. The project itself creates new jobs during the implementation phase, and then during the O&M and monitoring phase, and improves the quality of life by offering better lighting and electricity to the population.

Economic well-being: The investment to upgrade the street lighting, provides better services and reduce municipalities' energy expenditures is brought by the private sector (EESL) with no financial risk and debt for the Municipal Councils. As such the project brings in additional

[9]Government of India interim approval criteria can be found at: http://envfor.nic.in/cc/cdm/criteria.htm

investment and reduces the current energy costs municipalities are paying. The monetary savings could help municipalities direct the resources towards the needs of the people. For EESL, the sale of emission reduction credits or CERs, will allow the company to implement the energy efficient lighting projects by providing an additional revenue stream which will provide increased comfort to EESL in financing the projects upfront. The project is also expected to promote a sustainable financing model for scaling-up street lighting projects.

Environmental well-being: Reduction in electricity consumption will lead to a reduced use of coal and other fossil fuels for electricity generation, thus reducing greenhouse gas emissions from the burning of these fuels. It is assumed that the LED lamp is environmentally much less harmful that the conventional lamps it is expected to replace.

Technological well-being: The technology involved in the project activity is composed of LED lamps from leading Indian and international manufactures, and appropriate state-of-the-art switching control and monitoring systems. The success of the project will promote best practice in street lighting technology and management by using efficient lighting equipment. Training and education of the municipal employees will create awareness on the efficient use of electricity and proper energy management's positive effect on the environment.

Project type and category

From the CDM perspective, the project activity is an *energy savings initiative at the demand-side* under UNFCCC CDM methodology. It falls under:

- Sectoral Scope 3: *Energy demand*
- Type II: *Energy efficiency improvement projects*
- Category II.C *Demand-side energy efficiency activities for specific technologies*

The project activity is a small-scale project activity under type II (Energy efficiency improvement projects), category II.C (Demand-side energy efficiency activities for specific technologies) as defined in the Appendix B of the Simplified Modalities and Procedures for Small-scale CDM Project Activities because of the following:

- the proposed project aims at replacing baseline inefficient street lights with efficient LED lamps in 9 municipalities
- The aggregate energy savings of the project activity is expected to be less than 60 GWh per year allowed in AMS II-C
- The lumen output is improved compared to the baseline, and depends on the type of street and roads

Technology and Measures

The measures include replacement of Baseline lamps with energy efficient LED Lamps of various capacity depending upon light requirements on the various categories of the road.

The combination of the technology change, and reduced line losses effectively reduces or eliminates system saturation without requiring a complete rewiring of the system. The project technology has a positive impact on the global environment by reducing the GHG emissions and limiting local environmental impacts. Locally, there is a minimal risk of contamination of soils and groundwater resources, when compared with the conventional fluorescent tubular lamps (FTL) and mercury lamps which contain small quantities of mercury.

Outputs comparison

The project is expected to follow the para 2 of AMS-II.C, Version L. *Demand-side activities for efficient outdoor and street lighting technologies*, for each replaced appliance, equipment, system the rated capacity or output or level of service (e.g., light output, water output, room temperature and comfort, the rated output capacity of air-conditioners etc.) is not significantly smaller (maximum - 10%) than the baseline or significantly larger (maximum + 50%) than the baseline.

The *lux* level is the output used by EESL and municipality to assess if the project fittings are delivering the same or improved output compared to the baseline situation. This is also in accordance with Indian Standard, *Code of Practice for Lighting of Public Thoroughfares*, IS 1944-7:1981 which provides street lighting output in *lux*[10].

Application of a Baseline and Monitoring Methodology

The project activity is a Type II *Energy efficiency improvement projects* and Category C, Version (latest available) *Demand-side energy efficiency activities for specific technologies*, there are updated version of the same currently) because it meets the following applicability criteria:

1. The eligibility criteria for small-scale CDM project activities:

   (b) Type II project activities or those relating to improvements in energy efficiency and reduce energy consumption, on the supply and/or demand-side. These shall be limited to a maximum output of 60 GWh per year (or an appropriate equivalent).

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[10]Bureau of Energy Efficiency. 2010. Guidelines for energy efficient street lighting. Page 8.

The project activity includes installation of new and efficient lamps to reduce the energy consumption on the demand-side. The annual electrical energy reduction is estimated to be less than 60 GWh per year in individual municipalities, which is well within the limits required for a small scale CDM project.

The project participant confirms that the project will remain under the limits of small-scale project activity as per AMS-II.C (as per the latest versions).

Description of the project boundary

According to the methodology AMS–II.C, "The project boundary is the physical, geographical location of each measure (each piece of equipment) installed."

All the proposed efficient technologies will be implemented in the physical and geographical location of each baseline fixture, within each municipality. For this purpose, a complete list of all fixtures to be replaced and their location is prepared and a corresponding list of new fixtures and their location is available with EESL, for each municipality.

The electricity is supplied by the grid. Therefore, the GHG emissions (CO_2) from grid-connected power plants are reduced. Other sources or gases are deemed negligible.

	Source	**Gas**	**Included?**	**Justification/Explanation**
Baseline	Power plants serving the electricity grid	CO_2	Included	Main Emission Source.
		CH_4	Excluded	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	Excluded	Excluded for simplification. This emission source is assumed to be very small.
Project Activity	Power plants serving the electricity grid	CO_2	Included	Main Emission Source.
		CH_4	Excluded	Excluded for simplification. This emission source is assumed to be very small.
		N_2O	Excluded	Excluded for simplification. This emission source is assumed to be very small.

Description of baseline and its development

In order to determine baseline energy consumption, baseline equipment has been identified in the *business-as-usual* case where the municipalities maintain and operate the street lighting systems to provide lighting with the minimum investment costs. The *business-as-usual* situation is characterized by the use of baseline technologies including T12 fluorescent tubular lamps, high pressure sodium vapour lamps and mercury vapour lamps.

The baseline energy consumption is the sum of the weighted average power of each type of fittings (lamps + ballasts) times the number of fittings multiplied by the number of operating hours. In accordance with AMS-II.C, version 13 "*nameplate data can be used, and metering can be done of a sample of the units for their operating hours using run time meters*".

Nameplate data and the number of each type of fittings and a sample runtime meter readings will therefore be used to estimate the emission reduction. A baseline survey is to be conducted. This consists of listing the devices to be replaced and the associated switching points. The listing includes records of power, type, number and location.

Parameters used for baseline emissions calculation

Parameters / Variables	**Justification**	**Source of data**
Ni	Number of baseline fittings removed in the baseline. The number is established for each type of devices and in each city and aggregated for baseline emissions calculations. For ex-ante calculation, the number agreed in ESCO contracts will be used. The ex-post verification will indicate the actual number of fittings replaced.	Municipalities and EESL from ESCO agreements. Installation reports
Pi	Weighted average rated power of each type of fittings.	Lamps nameplate
Oi	Average annual operating hours determined ex-post through runtime meters to be installed on sample units in each city. For ex-ante calculation, the number of operating hours agreed in the ESCO contracts is used. The actual operating hours will be measured in the project.	EESL sample runtime meters
Ly	Average annual technical grid losses (transmission and distribution) during year y for the grid serving the locations where the devices are installed. A default value of 0.1 is used	AMS-II.C, version --

	as no recent data are available or the data cannot be regarded as accurate and reliable.	
$EF_{CO2,ELEC}$	CO2 grid emission factor of the project electricity system. The ex-ante grid emission factor value will be used. The emission factor used is the Combined Margin (incl. Imports) published by the Central Electricity Authority (CEA), Version 5.0. NEWNE Grid	Central Electricity Authority

Emission reductions

The project activity is the replacement of baseline inefficient lamps, with efficient LED lamps in India. As per AMS-II.C, version 13 or later versions, there are two options for the emission baseline determination. These two options are analyzed as follows:

Baseline alternatives as per AMS II.C, version 13	Project baseline Identification
i) If the energy displaced is fossil-fuel based, the energy baseline is the existing level of fuel consumption or the amount of fuel that would be used by the technology that would have been implemented otherwise. The emissions baseline is the energy baseline multiplied by an emission factor for the fossil fuel displaced. Reliable local or national data for the emission factor shall be used; IPCC default values should be used only when country or project specific data are not available or difficult to obtain.	Devices involved in this project are electrical driven. Therefore, this situation does not constitute the baseline for the proposed project.

Baseline alternatives as per AMS II.C, version 13		Project baseline Identification
ii) If the energy displaced is electricity, the emission baseline is determined using two of the following options:	Option 1: The product of the baseline energy consumption of equipment/appliances and the emission factor for the electricity displaced	The lamps are energized with electricity from the regional electricity grid. The baseline energy consumption is the sum of the weighted average power of each type of fittings (lamps + ballasts) times the number of fittings multiplied by the number of operating hours. Therefore, Option 1 is used for the emission baseline determination.
	Option 2: The specific energy consumption of the system in the baseline times the output in project year y times the emission factor for the electricity displaced. This option can only be used where comparable conditions for the output in the baseline and project can be established.	Option 2 is not found appropriate for the baseline emission calculation. The baseline energy is calculated based on power of each piece of equipment to be replaced and operating hours. The system option is not suitable for the proposed project as there are multiple pieces of equipment to be replaced in the entire city with separate meters and switching points.

The project activity meets the applicability conditions of the AMS-II.C, version 13 (or later version). Accordingly, the emission baseline is determined as the product of the baseline energy consumption of baseline lamps and the emission factor of the regional grid for the electricity displaced (option 1 as per AMS-II.C, version 13 or later versions). The methodological steps to evaluate the emission reductions are based on AMS-II.C, version 13 or later versions and described as follows.

The baseline and project energy and emissions calculations are applied to each city and aggregated for the project activity.

(1) Baseline

The EESL's ESCO approach is related to the determination of the baseline boundary (making the list of devices and switching points) as well as the determination of the real devices' consumption.

Baseline Energy

According to methodology AMS-II.C (version 13 or later versions), the baseline electricity consumption is calculated as follows:

$E_{BL,y} = \sum_i (n_i * p_i * o_i)/(1 - l_y)$

Where:

$E_{BL,y}$	Energy consumption in the baseline in year y (MWh)
Σ_i	Sum over the group of "i" devices replaced, for which the project energy efficient equipment is operating during the year, implemented as part of the project activity n_i Number of devices of the group of "i" devices replaced, for which the project energy efficient equipment is operating during the year. The aggregated results on number of fixtures can be found in Annex 3.
*n*i	Number of devices of the group of *"i"* devices replaced, for which the project energy efficient equipment is operating during the year. The number and the power of devices are established during the baseline measurement campaign (see B.5). The number of fixtures can be found in Annex 3.
p_i	Power of the devices of the group of "i" baseline devices (e.g. 40W incandescent bulb, 5hp motor). In the case of a retrofit activity, "power" is the weighted average of the devices replaced. In the case of new installations, "power" is the weighted average of devices on the market. Nameplate data are used and total power is type-wise calculated and aggregated for each city and the project.
o_i	Average annual operating hours of the devices of the group of "i" baseline devices. Ex-ante calculations used the number of days in a year (365 days) and daily average operating hours as per ESCO contract to arrive at the annual operating hours. Ex-post value will be monitored on sample switching points using run-time meters.
l_y	Average annual technical grid losses (transmission and distribution) during year y for the grid serving the locations where the devices are installed, expressed as a

fraction. This value shall not include non-technical losses such as commercial losses (e.g., theft/pilferage). The average annual technical grid losses shall be determined using recent, accurate and reliable data available for the host country. This value can be determined from recent data published either by a national utility or an official governmental body. Reliability of the data used (e.g. appropriateness, accuracy/uncertainty, especially exclusion of non-technical grid losses) shall be established and documented by the project participant. A default value of 0.1 shall be used for average annual technical grid losses, if no recent data are available or the data cannot be regarded accurate and reliable.

Technical losses

There is no systematic breakdown of T&D losses in terms of technical and non-technical losses in India. Initiatives have been launched by central and state governments and utilities to differentiate technical losses and commercial losses. The T&D losses level is submitted by utilities to the Electricity Regulatory Commission for approval. As no accurate value was found during the PDD preparation, the default value of 10% is used as average annual technical grid losses in accordance with AMS-II.C, version 13.

Emission Baseline

The emission baseline is determined as the product of the baseline energy consumption of equipment/appliances and the emission factor for the electricity displaced:

$BE_y = E_{BL,y} * EF_{CO2ELEC,y}$

Where:

BE_y	Baseline emissions in year y (tCO_2 e)
$EF_{CO2,ELEC,y}$	Emission factor in year y calculated in accordance with the provisions in AMS I.D, version 17 (tCO_2e/MWh). The Central Electricity Authority of India has established the emission coefficients for the five regional grids.

Grid Emission Factor

(a) A combined margin (CM), consisting of the combination of the operating margin (OM) and build margin (BM) according to the procedures prescribed in ‘Tool to calculate the emission factor for an electricity system’. OR

(b) The weighted average emissions (in kg CO_2e/kWh) of the current generation mix. The data of the year in which project generation occurs must be used.

The option ‘a’ approach has been selected for the PE by the project proponent, i.e. the combined margin emission factor with the *ex-ante* approach.

Data and parameters that are available at validation

Data / Parameter:	Ni
Data unit:	No,s
Description:	Number of each type of baseline fittings removed
Source of data used:	Joint survey by EESL and Municipal corporations
Value applied:	As per respective installed data from respective project (Annex 3).
Justification of the choice of data or description of measurement methods and procedures actually applied :	Initial quantity is provided by cities in the agreement for each type of baseline fitting and confirmed during removal of baseline fittings.
Any comment:	The actual number is confirmed after actual replacement with project fittings.

Data / Parameter:	*O*i
Data unit:	Hour
Description:	Average annual operating hours of the devices of the group of *"i"* baseline devices.
Source of data used:	As per ESCO agreement between EESL and municipalities
Value applied:	As per city situation
Justification of the choice of data or description of measurement methods and procedures actually applied:	For ex-ante calculation purpose, the annual operating hours of 3,650 hours (10 hours per day) or 4,015 hours (11 hours per day) are used depending on operating hours in the ESCO agreement in each city. Operating hours are determined on the basis of the change in streetlights turning ON time and OFF time depending on the sunrise and sunset times of the city through the year.
Any comment:	For purpose, runtime meters will be installed at a sample of switching points in the project. The average project value from the meters will be

	used to calculate the actual operating hours and calculate baseline and project energy.

Data / Parameter:	Pi
Data unit:	Watt
Description:	Rated power of baseline fitting
Source of data used:	as per nameplate data
Justification of the choice of data or description of measurement methods and procedures actually applied :	The nameplate information is used to establish rated power of baseline fittings including lamps and ballasts. The rated power is taken for each type of fitting (group "i") and total power for group "i" is the rated power of unit (including ballast) multiplied by the total number of fitting of the same type. For each city, the total power is the aggregated total of total power of all groups "i".
Any comment:	Data are available at MCs and EESL

Data / Parameter:	Simple Operating Margin emission factor of the NEWNE Grid
Data unit:	tCO_2e/MWh.
Description:	Emission factor that is calculated as indicated in the relevant OM baseline method for the NEWNE Grid as city are located in Rajasthan, Madhya Pradesh and Maharashtra states.
Source of data used:	Central Electricity Authority of India, CO2 Baseline Database for the Indian Power Sector. Version 5.0, 2009
Value applied:	1.00
Justification of the choice of data or description of measure ment methods and procedures actually	This value is used to calculate the combined margin emission factor with 50% weight.

applied:	
Any comment:	Calculated as per “Tool to calculate the emission factor for an electricity system”.

Data / Parameter:	Build Margin emission factor of the NEWNE Grid
Data unit:	tCO_2e/MWh.
Description:	Emission factor that is calculated over recently built power plants defined in the baseline methodology for the NEWNE Grid for the required city.
Source of data used:	Central Electricity Authority of India, CO2 Baseline Database for the Indian Power Sector. Version 5.0, 2009
Value applied:	TBD
Justification of the choice of data or des criptio of measurem ent methods and procedures actually applied:	This value is used to calculate the combined margin emission factor with 50% weight.
Any comment:	Calculated as per “Tool to calculate the emission factor for an electricity system”

Ex-ante **calculation of emission reductions:**

<u>**A typical case of Municipal Corporation**</u> is used here to show the step-wise calculations.

Baseline Energy

According to methodology AMS-II.C, version --, the energy baseline on year “y” during crediting period is calculated as per equation (1):

$E_{BL,y} = \sum_i (n_i * p_i * o_i)/(1 - l_y)$

Municipal Corporation				
Type of baseline fittings	Power Rating (W)	Number of pieces	Annual Operating hours (ex-ante)	Baseline Energy (MWh)
	p_i	n_i	o_i	$E_{BL,y} = p_i * n_i * o_i * / (1-10\%)$
FTL T12 40W – 1.2m	50	9,273	3,650	1,880
HPSVL 70	82	183	3,650	61
MVL 125	145	97	3,650	57
HPSVL/MVL 150	175	1,485	3,650	1,054
HPSVL/MVL 250	285	1,965	3,650	2,271
Sum		**13,303**		**5,323**

Baseline emission

The baseline emission in year "y" is given by:

$BE_y = E_{B,y} * EF_{CO2,ELEC,y}$[11]

Applied to the typical case, the baseline emission is:

$BE_y = 5{,}323\ MWh/year * 0.84\ tCO2/MWh = 4{,}471\ tCO2/year$

Project emission

The project energy on year "y" during crediting period is calculated as:

$E_{P,y} = \sum_i (n_i * p_i * o_i)/(1 - l_y)$

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11 https://cdm.unfccc.int/filestorage/x/m/47LNIYMZACBSDQ6FJ85RTH1UVE0XG3.pdf/PDD_AEL.pdf?t=OUh8bnFkenFyfDCFss7l08f4CDJZGb4_t3XN – for typical example case formulae used from one of the UNFCCC registered CDM project, refer page 36 (project emission) and page 39.

Typical Municipal Corporation				
Type of new fittings	Rated Power including ballast (W)	Number of pieces	Annual Operating hours (ex-ante)	Project Energy (MWh)
	p_i	n_i	o_i	$E_{P,y}=p_i*n_i*o_i*/(1-10\%)$
FTL T5 4' 28W	28	9,273	3,650	1,053
FTL 2x14W 2' T5	28	183	3,650	21
FTL 2x24W 2' T5	48	97	3,650	19
FTL 4x14W 2' T5	56	1,485	3,650	337
FTL 4x24W 2' T5	96	1,965	3,650	765
Sum		**13,303**		**2,195**

The project emission in year "y" is calculated as:

$PE_y = E_{Pj,y} * EF_{CO2,ELEC,y}$
For typical municipality, it gives:

$PE_y = 2{,}195\ MWh/year * 0.84\ tCO2/MWh = 1{,}844\ tCO2/year$

Leakage

The leakage emission in year "y" is calculated using equation

$LE_y = E_{Ly} * EF_{CO2,ELEC,y} = 0$

Emission Reduction

The emission reduction of the project (ER_y) activity, for year “y” of the activity, is calculated for all groups of “i” devices replaced and considering the data gathered during baseline measurement campaign. The emission reduction achieved by the project activity is determined as the difference between the baseline emissions and the project emissions and leakage:

$$ER_y = (BE_y – PE_y) - LE_y$$

Therefore, the emission reduction is:

$$ER_y = (4{,}471 – 1{,}844) – 0 = 2{,}627\ tCO_2/year$$

Application of a Monitoring Methodology and description of the Monitoring Plan:

Data and Parameters monitored

Data / Parameter:	Ni
Data unit:	Nos
Description:	Number of energy saving fittings installed in the project for group “i” of devices
Source of data to be used:	Actually installed quantity of each type of fitting after installation phase
Value of data	As per the respective installed data from respective city.
Description of measure ment methods and pro cedures to be applied:	The number of new fittings installed is as per work orders approved by the municipalities. The total number is witnessed by the cities.
QA/QC procedures to be applied:	The actual number of installed fittings is compared to the number of fittings removed. Any discrepancy is justified and documented. Data reviewed jointly by EESL and MCs.
Any comment:	The actual number of installed fittings is used for energy savings and emission reductions calculations..

Data / Parameter:	pi
Data unit:	Watts

Description:	Rated power of the project streetlight fittings
Source of data to be used:	Nameplate data
Value of data	As per nameplate data of project devices.
Description of measure ment methods and pro cedures to be applied:	The rated power of all type of fittings is recorded from the nameplate data. The value include ballast power
QA/QC procedures to be applied:	Data are reviewed by EESL and MCs. Reports signed by both parties. Data storage on paper and electronic for 2 years after the end of the crediting period.
Any comment:	This data will be used to determine energy consumption in the project and energy savings. Each city case is treated separately and the results are aggregated for the project activity.

Data / Parameter:	*O*i
Data unit:	Hour
Description:	Average annual operating hours of the fixtures for project energy and baseline energy consumption calculation in each city
Source of data to be used:	Run time meters installed by EESL on a sample of switching points in each city
Value of data	As per annual records
Description of measurement methods and procedures to be applied:	Operating hours are on the basis of the change in streetlights turning ON time and OFF time depending on the sunrise and sunset times of the city through the year. A sample of switching points is continuously metered for the run-time in each city. The sample size is determined for a $\pm$10% precision with a 90% confidence level and a variability of 0.2. The data recorded will be downloaded annually (see Annex 4 for the size of sample).
QA/QC procedures to	While the runtime meters will totalize the number of hours on annual

be applied:	basis, monthly records will be carried out to cross-check discrepancy in data and take corrective actions. Data reviewed jointly by EESL and MCs. Reports signed by both parties. If there is any failure in the meters, the lowest historic data of similar period will be used.
Any comment:	The number of hours will be established for each city for emission reduction calculations. The total ER will be the aggregated result of all cities.

Description of the monitoring plan:

The project participants applied the monitoring plan as required by the simplified baseline and monitoring methodology for small-scale CDM project activity AMS-II.C. This monitoring is used as part of the ESCO project monitoring and verification plan.

As per AMS-II.C, version 13 requirements, the monitoring should cover the following points:

- The emission reduction achieved by the project activity shall be determined as the difference between the baseline emissions and the project emissions and leakage. If the devices installed replace existing devices, the number and "power" of a representative sample of the replaced devices shall be recorded in a way to allow for a physical verification by DOE. If the devices installed have a constant current (ampere) characteristic, monitoring shall consist of monitoring either the "power" and "operating hours" or the "energy use" of the devices installed using an appropriate method. Appropriate methods include:

  (a) Recording the "power" of the device installed (e.g., lamp or refrigerator) using nameplate data or bench tests of a sample of the units installed and metering a sample of the units installed for their operating hours using run time meters;

  OR

  (b) Metering the "energy use" of an appropriate sample of the devices installed".

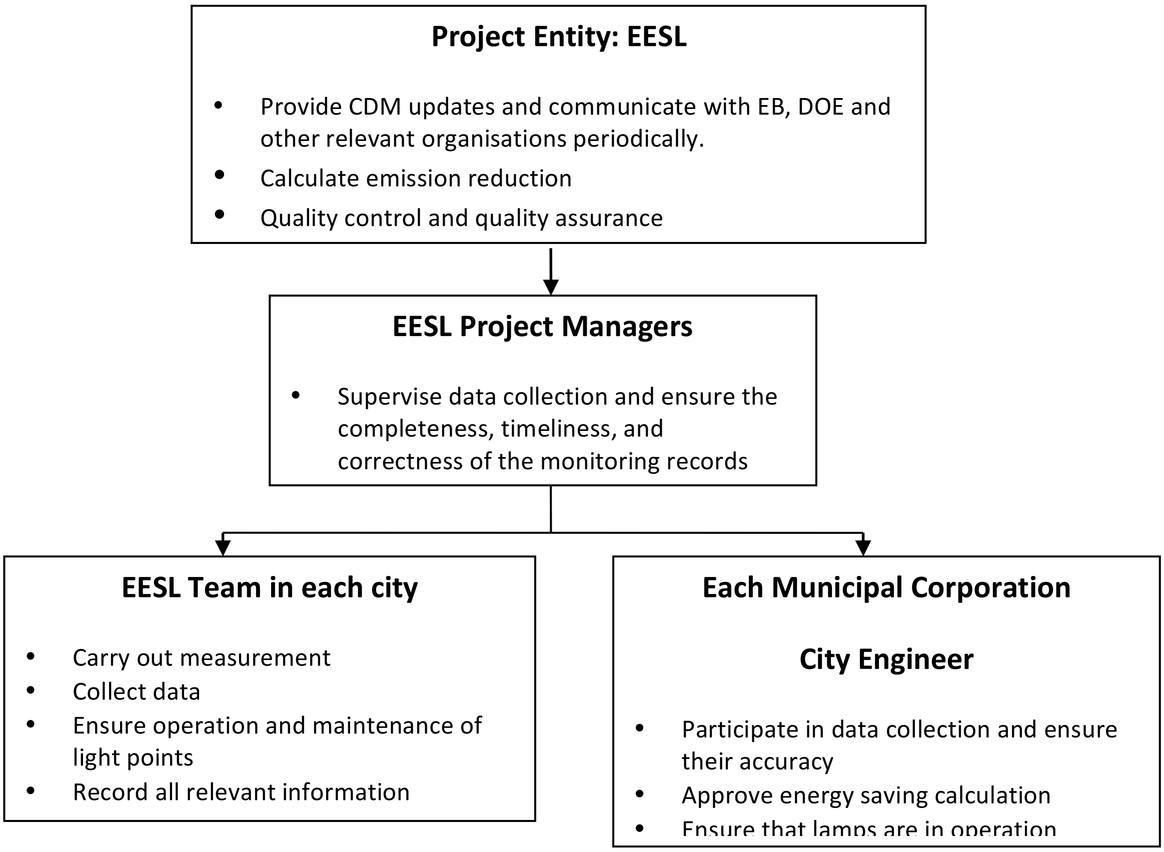
As per Option (a) in this project, nameplate data of all type of fittings are recorded. EESL will install run-time meters on a sample of switching points to calculate the average annual operating hours.

As required by the methodology, monitoring shall include annual checks of a sample of non-metered systems to ensure that they are still operating.

The sample will is designed to a 90% confidence level and 10% error margin in accordance with the “Standard for Sampling and Survey for CDM project activities and programme of activities”, Version 02, EB 65.

Monitoring and QA/QC responsibilities

The project monitoring organization chart is shown below.



The data collection and management directives are issued from EESL Delhi Office. The data is maintained by the project managers. All staff involved in the project are trained on the field for data collection and records keeping.

Recording of the number of devices

The following procedure, which is the verification measurement campaign, is immediately applied after the starting date of the project crediting period.

(a) The precise number of fixtures categorized by types as defined. The table and location of switching points and fittings are available for each Municipality. The final number is jointly approved by EESL and each municipality.
(b) Nameplate data are used to record the rated power of new fittings (lamps + ballasts) and the number of fittings.

The data will be kept and maintained in the project database centrally and separately for each city for at least two years after the end of the crediting period or last issuance of the CERs whichever is later.

Metering Sample Units

In the current street lighting configuration, several units (lamps/poles) are powered from switching points (SP), where a groups of fittings are connected to the same SP and the ON-OFF operation is at the switching point. Therefore, a cluster sampling method is used for estimating the annual operating hours. The SPs (group of lamps), define the population from which the sample is drawn. This method is the most appropriate to measure the operating hours which is supposed to be the same in the entire city. The sample size is calculated for the total switching points in each city. A runtime meter will be installed on the sample of switching points selected randomly in respect of the geographical spread in each city.

Based on the installed sample meters, the annual operating hours is continuously metered for a sample of switching points in each city. The average value of all meter readings is used to calculate the electricity consumption and savings from devices installed in each city. All calculated energy consumption and savings for individual cities will be aggregated to derive the project activity electricity consumption and savings. The annual operating hours will also be used to calculate the baseline energy and baseline emissions.

Calibration

EESL will be responsible for the calibration of run-time meters. EESL will ensure that the meters are working and calibrated. The results of the calibration will be included in the monitoring report. If there are any anomalies in the readings of the runtime meters, they will be recalibrated and the measurement reinitiated. For the period in which anomalies were noted, lowest value recorded in the past, ex-ante and metered will be used to calculate energy savings and emission reductions.

Data management

All electronic and hard copy records of the metering devices, electricity monitoring records, relevant documentation and the results of calibration will be collated by the project manager of EESL and the Municipality.

While the runtime meters will totalize the number of hours on annual basis, monthly records will be carried out to cross-check discrepancy in data and take corrective actions. The data will be reviewed jointly by EESL and MCs. Reports signed by both parties.

All monitoring data will be archived and will be kept for a minimum of two years after the end of the crediting period or last issuance of the CERs whichever is later.

Damages to monitoring equipment

In case monitoring equipment are damaged and no reliable readings can be recorded, the project entity will use the lowest historic data of similar period will be used and the meter will be replaced/repaired.

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