SAARC Energy Centre
Islamabad

Efficiency Enhancement and Solarization of Streetlights in SAARC Region

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Foreword

Dr Nawaz Ahmad
Director
SAARC Energy Centre

The urbanization and aspirations of people in SAARC region is posing both challenges and opportunities in terms of increased requirement of energy to maintain a reasonable and acceptable levels of citizen services such as street lighting. Efficiency enhancement and solarization of street lighting in SAARC Member States helps the cities to reduce energy cost, improve financial status and meet NDCs of the Member States. LED based street lighting and smart controls based on information and communication technologies are becoming standard technology approach for efficiency enhancement in street lighting. Many SAARC Member States have implemented such energy enhancement projects for street lighting.

Similarly, the solarization of street lighting has been of interest to Member States which is seen as an effective solution for areas that have limited or no grid access. The solar based street lighting has matured technologically in terms of performance of individual system components and waiting to be a viable solution with gradual reduction in capital cost as the demand increases, just as was the case with LED based street lighting a few years ago.

This research report presents the techno-financial viability of projects with key technological pathways that are presently pursued by various cities in SAARC Member States and reflects the role of SAARC Energy Center being a regional center of excellence that develops capacity and expertise for the region for the matters relating to energy efficiency and climate change.

The study is to carry out the detailed cost benefit analysis of replacing existing street lighting system with efficient LED systems/solarization. The techno-financial analysis of various technology options are made available in this study report with case studies from selected cities in each Member State to enable the Member States take informed decisions on implementing similar projects in future.

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List of Acronyms

ADB	Asian Development Bank
AEEP	Afghanistan Energy Efficiency Policy
AEPC	Alternate Energy Promotion Council
AJAY	Atal Jyoti Yojana
BAU	Business as Usual
BEE	Bureau of Energy Efficiency
CAGR	Compound Annual growth Rate
CCMS	Centralised Control and Monitoring System
CCT	Correlated Colour Temperature
CDA	Capital Development Authority
CEB	Ceylon Electricity Board
CFL	Compact Fluorescent Lamp
CIE	Commission Internationale de l'Eclairage
CMC	Colombo Municipal Council
CMS	Control and Monitoring System
CPI	Consumer Price Index
CRI	Colour Rendering Index
DCC	Dhaka Municipal Corporation
DPR	Detailed Project Report
EE	Energy Efficiency
EEI	Energy Efficiency Improvement
EESL	Energy Efficiency Services Limited
ESCO	Energy Service Company
ESPC	Energy Service Performance Contract
FTL	Fluorescent Tube Lamp
GHMC	Greater Hyderabad Municipal Corporation
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HID	High Intensity Discharge
HPMV	High Pressure Mercury Vapour
HPSV	High Pressure Sodium Vapour
IEC	International Electrotechnical Commission
INDC	Intended Nationally Determined Contributions
IoT	Internet of Things
IRR	Internal Rate of Return
KMC	Kathmandu Municipal Corporation
LED	Light Emitting Diode
LM	Lumen Maintemanace
MCI	Metropolitan Corporation of Islamabad
MH	Meta Halide
MU	Million Units

NDC	Nationally Determined Contributions
NEECA	National Energy Efficiency and Conservation Authority
NEES	National Energy Efficiency Strategy
NMEEE	National Mission on Enhanced Energy Efficiency
NPV	Net Present Value
O&M	Operation & Maintenance
OEM	Original Equipment Manufacturer
PPP	Public Private Partnership
RGoB	Royal Government of Bhutan
SAARC	South Asian Association for Regional Cooperation
SEC	SAARC Energy Centre
SLNP	Street Lighting National Programme
SREDA	Sustainable and Renewable Energy Development Authority
SSL	Solar Street Lighting
TM	Temperature Maintenance
ULB	Urban Local Body
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VAS	Value Added Services
WACC	Weighted Average Cost of Capital

Executive Summary

i. Global Overview of Street Lighting:

a) There are around 320 million street lighting poles in the world in which Asia accounts for 25% and Europe & North America accounts for 20% and South America of 10% and the rest of the world (Australia & Africa) accounts for 45% of street lighting poles (Little, 2019). The World average lighting density is about 13 people per pole (Little, 2019). The lighting density ranges from 7 people per pole in Europe to 20 people per pole in Asia Pacific (Little, 2019).

b) LED street lighting is now being considered the most energy efficient. Many cities across the world have completed replacing conventional street lighting fixtures (e.g., HPSV, HPMV, FTLs, CFL and MH) with LED fixtures. Examples of cities with 100% LED street lighting include Milan (Italy), New York (USA) and Visakhapatnam (India). The LED penetration differs widely primarily an account of financial barriers and administrative inabilities of municipalities in adopting suitable business models.

c) The overall average LED penetration (i.e., number of LED fixtures to the total number of fixtures) is still less than 15% globally with Japan and Canada showing highest LED penetration of 44 – 50%. The LED penetration in Europe is around 10% with only Germany having a penetration above the European average. The LED penetration in USA is 26% and that of South America is less than 5%. (Little, 2019).

d) Asia Pacific region leads the solarization of street lighting system followed by Africa (Intelligence, 2020). The key driver for the leadership in solarization of street lighting in Asia and Africa appears to be the resolve of the respective national governments to provide street lighting in geographically difficult areas. The solarization of street lighting is based on energy efficient LED lights which also meets the energy efficiency and sustainability aspects of street lighting service.

e) The key drivers that are promoting the energy efficient street lighting at global level are given below:

Regulatory Policies: Street lighting energy efficiency and solarization projects are one of the fast, replicable projects to meet the commitments as per NDCs under Paris Agreement of UNFCCC. All the national governments globally have taken steps to implement energy efficient street lighting both in urban areas as well as rural / county side. Regulatory requirements at global level have helped creation / availability of technical and financial resources. This has helped participation of public and private sector to innovate on implementation models, financial engineering for energy efficiency project. Thus, regulatory requirements at global level are helping local government systems to overcome the issues with the limited technical and financial resources in the implementation of EE in street lighting.

Financial Viability and Innovative Business Models: The financial viability of energy efficient street lighting itself pays for the project cost with paybacks ranging from few months to 3 – 4 years depending on the electricity tariff. Various business models such as ESCO route have been successful in many cities which enabled implementation of energy efficient and smart street lighting without any upfront cost to the municipalities.

IoT convergence: Smart city development and advanced remote-control systems drive the growth of the Value-Added Services (VAS) segment. The Internet of Things is the connection of everyday products such as cars, alarm clocks, and lights to computing devices via the internet to allow them to exchange data.

LED prices drop: The quality improvement and reduced costs are making LED the viable option for lighting

f) The poles equipped with street lights are most suitable infrastructure and can be also used for the other purposes such as video surveillance services, Weather monitoring, to host a fiber network, used EV charging points and etc.

ii. Efficiency enhancement and Solarisation of street lighting in SAARC Region:

a) The penetrations of technology and implementation status of Efficiency enhancement and solarization of street lighting in Member States is summarized in the Table ES: 1

Table ES: 1 Summary of Key Technologies in SAARC Region

S No	Country	LED lighting Fixtures	Control & Monitoring		Solarisation of Street Lighting
			Smart Control	Other Controls	
1	Afghanistan	✓	-	✓ (Manual)	✓ (pilot studies)
2	Bangladesh	✓	✓	✓ (Manual)	✓ (pilot studies)
3	Bhutan	✓	✓	✓ (Manual)	-
4	India	✓	✓	✓ (Manual)	✓
5	Maldives	✓	✓	✓ (Manual)	✓ (under planning)
6	Nepal	✓	✓	✓ (Manual)	✓ (pilot studies)
7	Pakistan	✓	✓	✓ (Manual)	✓ (pilot studies and outdoor lighting of gated communities)
8	Sri Lanka	✓ (Under implementation)	✓ (Under implementation)	✓ (Manual)	-

Source: Research by East Coast Sustainable

b) Electricity demand for street lighting in SAARC region has been estimated for the period 2021 – 2030 considering 3 scenarios as under:

Scenario-1: Business As Usual (BAU)

The electricity consumption for street lighting in base year has been projected for the period 2021 – 2030 considering CAGR based on actual data, CAGR of road length or urbanisation.

Scenario-2: Efficiency Enhancement with LED based EE fixtures with CCMS

This scenario projects the energy consumption for street lighting considering a conservative savings of 50%[1] from baseline for the fixtures converted from conventional lamps to LED based lamps with smart control and monitoring system. It is assumed that the Member States would achieve 100% of this conversion by 2027 and all new additions of street lights would be based on this technology.

Scenario-3: Solarization of street lighting with LED based lighting and CCMS

This scenario is based on assumption that the solarization will be adopted by Member States commencing from 2024 and would reach 90% by 2029. It is assumed that remaining 10% of street lights may not be amenable for solarization and would remain to be fed by the grid.

c) The energy saving potential with respect to baseline street lighting energy consumption in Scenario-2 and Scenario-3 over a period of 10 years is summarized for SAARC Member States presented in the Table ES: 2

Table ES: 2 Energy Saving Potential in Street Lighting SAARC Region

Country	Energy Saving Potential with LED and smart control (%)	Energy Saving Potential with Solarisation (%)
Afghanistan	29.14	42.29
Bangladesh	28.60	41.36
Bhutan	28.52	41.22
India	29.87	43.53
Maldives	28.77	41.66
Nepal	28.52	41.22
Pakistan	29.14	42.29
Sri Lanka	31.81	47.73

Source: Research by East Coast Sustainable

iii. Selection of municipality for Case Study

One city town / municipal area has been selected from each of the SAARC Member States for preparing case studies for each of the major technological interventions. The selection of cities for each Member State is based on ease of access of the data, impact of EE improvements. Cities which are yet to implement EE projects or where implementation is in planning/underway have been preferred over cities which have completed the LED based EE improvement projects in street lighting. Further, the cities selected for case studies are also diverse in terms of size (i.e, population, number of street lights and existing lighting technologies) that would validate the relevance and viability of EE improvement in street lighting in SAARC region. The details of cities selected are presented in the Table ES: 3.

[1] Based on presentation received from Mr Srinivasa Chari E of GHMC who verified the savings of EESL project in Hyderabad, India

Table ES: 3 Selected Municipalities for Case Study

S No	Country	City selected	Municipality Name
1	Afghanistan	Kabul	Kabul Municipality
2	Bangladesh	Chittagong	Chattogram City Corporation
3	Bhutan	Gelephu	Gelephu Thromde (Municipal Office)
4	India	Hyderabad	Greater Hyderabad Municipal Corporation
5	Maldives	Male	Male City Council
6	Nepal	Kathmandu	Kathmandu Metropolitan City
7	Pakistan	Islamabad	Metropolitan Corporation Islamabad
8	Sri Lanka	Colombo	Colombo Municipal Council

iv. Techno-financial Analysis of selected municipalities:

a) The techno-financial analysis tool based on MS-excel has been developed for each selected municipality from SAARC Member States for the following cases:

Case-1: Replacement of conventional lighting fixtures with LED based EE lighting system without CCMS.
Case-2: Replacement of conventional lighting fixtures with LED based EE lighting system with CCMS.
Case-3: Solar Based EE Lighting System with CCMS

b) The summary of techno-financial analysis for selected municipalities is presented in the Table ES: 4 and Table ES: 5.

Table ES: 4 Summary of Techno-financial Analysis-1

Country	Municipality	Case-1		Case-2	
		Payback Period (years)	IRR (%)	Payback Period (years)	IRR (%)
Afghanistan	Kabul	1.25	79	1.30	76
Bangladesh	Chittagong	2.96	34	3.29	30
Bhutan	Gelephu	4.76	16	4.99	14
India	Hyderabad	0.80	127	1.23	84
Maldives	Male	1.26	78	1.31	75
Nepal	Kathmandu	5.22	15	5.42	18
Pakistan	Islamabad	1.10	95	1.15	91
Sri Lanka	Colombo	2.68	38	2.79	36

c) In respect of solarization (under Case-3) of various cities, the financial results are summarised in the following table with the details of subsidy requirement (from government and other donors) for a reasonable IRR.

Table ES: 5 Summary of Techno-financial Analysis-2

Country	Municipality	Case-3		
		Subsidy (%)	Payback Period (years)	IRR (%)
Afghanistan	Kabul	40	6.0	7
		50	5.0	12
Bangladesh	Chittagong	80	6.1	10
		90	3.1	33
Bhutan	Gelephu	88	6.1	10
		90	5.0	16
India	Hyderabad	60	7.5	4
		70	5.7	12
Maldives	Male	70	5.4	8
		80	3.6	21
Nepal	Kathmandu	70	7.9	3
		80	5.3	14
Pakistan	Islamabad	50	7.1	10
		60	5.7	16
Sri Lanka	Colombo	70	6.4	9
		80	4.3	21

v. Conclusions:

a) LED based street lighting system with or without CCMS is being implemented in all SAARC Member States. The CCMS system for street lighting can be seen more as a productivity multiplier reducing manpower deployment for control and monitoring of street lighting systems resulting in low O&M cost besides energy saving. The productivity improvement on account of smart controls increases with the scale of operation (number of street lights connected).

b) The ROI/Payback period and internal rate of return for efficiency enhancement in street lighting are very attractive. The ROI/payback and IRR are in the range of 0.8 – 5.2 years and 15% - 127% respectively under Case-1 i.e., efficiency enhancement with LED based street lighting without smart control. The higher payback periods for Case-1 in few Member States (e.g., Bangladesh, Bhutan and Nepal) is primarily on account of lower electricity tariff and higher capital cost of equipment due to procurement in small quantity. Similarly, where the capital cost of implementation is relatively lower on account of large-scale procurement by aggregating procurement quantity of multiple municipalities (e.g., India), the project payback period is low and IRR is high.

c) In respect of efficiency enhancement under Case-2 i.e., LED based street lighting with smart control, the ROI/Payback and IRR of the project are estimated to be ranging from 0.9 to 5.42 years and 14% - 105% respectively. The additional savings from smart controls (e.g., CCMS) improve the project NPV. The biggest driver for smart control implementation is in terms of improved service level of street lighting system.

d) The most popular smart controls (e.g., CCMS) are IoT based control and monitoring system where it is possible to dynamically programme the street light operations, monitor operating status, burning hours that would enable to expedite fault/failure detection and corrective action. The smart controls are amenable for additional features such as dimming based on time or traffic detection.

e) Solarization of street lighting is under pilot studies in various Member States of SAARC region. The key driver for solarization presently is lack of or limited access to grid in few Member States especially in rural areas and remote areas. The techno-financial analysis indicates that a capital subsidy/grant ranging between 50% to 90% for a reasonable minimum IRR of 8% - 10%. This is on account of higher initial cost and replacement cost of batteries during the project life.

f) The financial viability of solar based street lighting can improve with price reduction as the adoption of the technology increases as was the case with LED based street lighting.

g) The donor agencies are required to contribute the subsidy component for few pilot projects with the aim of breaking the price barrier of the technology so that the subsequent solarization projects would become viable without any requirement of subsidy. Another well-known method of breaking the price barrier for market transformation is the bulk procurement by aggregating the demand of multiple municipalities as was done by EESL (India) for many EE technologies such as LED street lighting, LED lamps, star labelled electrical appliances.

h) SAARC Member States are at different level in respect of penetration of efficiency enhancement and solarization of street lighting. India which is largest electricity consumer of SAARC region has already replaced more than 100 million street lights with LED based street lighting with IoT based smart controls in most of the municipalities and implementing similar projects in rural areas. Other SAARC Member States are also implementing similar projects in different phases. Such efficiency enhancement is expected to be completed in 4 to 5 years and the average energy savings over 10 years period (2021 – 2030) is estimated to be between 28% - 32% for various Member States. Similarly, the solarization is estimated to bring an average energy saving of 41% to 47% over a period of 2021 – 2030 under assumption that the solarization will be viable and penetration would gradually reach 90% in 2029. Given such energy efficiency potential, the municipalities and concerned agencies are required to work towards creating an enabling environment for expedited implementation.

i) Some of the key factors for successful implementation of EE and solarization in street lighting are given below:

   i. Improve capacities of municipalities in terms of technical, financial and organizational factors that would enable them implement EE projects in street lighting with various financial mechanisms including Public-Private-Partnership (PPP) and ESCO.
   ii. Take advantage of latest Information and Communication Technologies (ICT) for objective verification of energy savings that are crucial in PPP/ESCO model to cover technical risks.
   iii. The municipalities or other project proponents may utilize risk management instruments such as Partial Risk sharing Facility (PRSF) made available in India with the support of the World Bank. PRSF provides partial credit guarantees to Participating Financial Institutions (PFIs) to cover a share of default risk faced by them in extending loans to Energy Efficiency (EE) projects implemented by the Host entity through Energy Service Companies (ESCOs)[2].
   iv. The respective governments of the Member States may designate or create nodal agencies to implement EE projects for multiple municipalities through demand aggregation. This would enable to bring in economy of scale towards reducing procurement cost. This would also enable to harmonize the technical and quality specifications of hardware, software, installation and O&M practices.

j) The cities selected for case study under this research represents diversity in terms of population, time, geographical terrain. Despite such diversity the aspiration and competitive spirit are the same when it comes to implementing efficiency enhancement and solarization in street lighting. The different penetration of such EE projects is primarily on account of issues related to availability of financial resources and governance that can be overcome with the regulatory force of NDCs, adoption of financial mechanisms / business models involving public/private owned specialized agencies such as ESCO.

[2] http://prsf.sidbi.in/user/pages/viewpage/p_brief

1 Introduction

1.1 Background and Introduction

There are around 320 million street lighting poles in the world in which Asia accounts for 25% and Europe & North America accounts for 20% and South America of 10% and the rest of the world (Australia & Africa) accounts for 45% of street lighting poles (Little, 2019). The average lighting density in terms of urban population per each lighting point is about 13% in the world (Little, 2019). The lighting density ranges from 7 people per pole in Europe to 20 people in Asia Pacific (Little, 2019)

Street Lighting is one of the major components of electricity consumption in SAARC Member States. The street lighting electricity consumption ranges between 11% to 21% of total electricity consumption of individual Member States and the average hovers around 15% (TERI, 2014) . The street lighting services are mostly provided by city administration (e.g., municipalities / local bodies). Often, these services are burden for local bodies which are financially strained with competing services such as water pumping, sanitation and roads. Streetlighting services is often a looser in the pecking order of municipalities. Hence although significant energy savings are possible with technological interventions, the street lighting function has remained a neglected area for long time.

With the concerns of climate change and reducing financial burden for the local bodies, SAARC Member States have been working to introduce suitable institutional framework and innovative financing mechanisms to fund efficiency enhancement in street lighting function of the local bodies. Various technological interventions such as replacing inefficient luminaire with efficient one (e.g., HPSV to LED), on-off control (e.g., time based, almanac based and nature switch) are becoming popular with funding from private and government owned ESCOs in SAARC Member States. For example, Energy Efficiency Services Limited (EESL), which is a Super ESCO of Government of India is running very successful energy efficiency programme for street lighting in most of Indian cities and villages as well. Under this programme, EESL is investing in LED based street lighting with timer-based control and providing O&M service which has resulted in improved service levels to the citizens (EESL Report).

Other technological developments include LED lighting with dimming facility that can be deployed with motion and infrared sensor to vary the light intensity as per requirement. Besides, grid-independent / autonomous solar LED street lighting systems are now available in the market with the potential to completely reduce electricity for street lighting consumed from the grid.

Solarization of Street Lighting, in SAARC region or globally has significant impacts in terms of reducing grid electricity consumption by 15% (TERI, 2014), reducing financial burden for municipalities and other local bodies, GHG reductions, reducing economic costs of grid extension for street lights, ability to provide street lighting service at where grid access is difficult.

Given such benefits, many SAARC Members States have piloted the feasibility studies for solarization of street lighting. The present study is aimed at providing information regarding various technology options for enhancement of efficiency and solarization of street lighting with techno-financial analysis based on the case studies from selected cities of the Member States.

1.2 Rationale and Objectives of the Study

SAARC Member States have deployed variety of luminaires as street light fittings. These include incandescent bulbs, FTLs (T12, T8 & T5), HPMV & HPSV and metal halide (MH) and LED based lighting[3]. The replacement costs and issues could be different from existing technology type to LED based street lighting system.

Further, solarization of street lights is another aspect of the present study. There are cases of both successful and failed projects of solarization of street lighting in SAARC Member States. The primary barriers to solarization of street lighting are initial cost of the system, requirement for replacement of batteries during the project period, lack of contractual clauses and enforcement in the agreements relating to battery replacement. A project financial analysis considering the life cycle costing would help to determine the project viability, extent of grant/subsidy required for the solarization projects. As of now, we are of the considered opinion that solarization of street lights would equally gain popularity and get implemented.

Given this background, the objective of the study is to carry out the detailed cost benefit analysis of replacing existing street lighting system with efficient LED systems/solarization. The techno-financial analysis of various technology options are made available in this study report with case studies from selected cities in each Member State to enable the Member States take informed decisions.

1.3 Scope of the Study

The study has been envisaged as a specific and focused study on street lighting efficiency enhancement and solarization. The study has been envisaged to use case study-based methodology to bring out cost benefit analysis of technological interventions.

Based on the above, the following scope has been considered.

a. One city town / municipal area has been selected from each of the SAARC Member States for preparing case studies for each of the major technological interventions. The selection of cities for each Member State is based on ease of access of the data, impact of EE improvements, annual energy consumed, the total number and types of streetlights in its jurisdiction etc. Cities which are yet to implement EE projects or where implementation is in planning/underway have been preferred over cities which have completed the EE improvement street lighting. Further, the cities selected for case studies are also diverse in terms of size (i.e, population, number of street lights and existing lighting technologies) that would validate the relevance and viability of EE improvement in street lighting in SAARC region.

b. Data collection and analysis of existing technologies in street lighting from primary and secondary sources. This includes the number of street lights, type of luminaire, wattage, and baseline energy consumption for at least one municipality from each Member State.

c. On the similar lines mapping of O&M practices including smart control systems for identifying and estimating energy saving opportunities.

[3] Kindly refer to List of Acronyms at the beginning of the report

d. Study of the significant aspects of solarization of street lights based on available case studies in SAARC Member States.

e. Preparation of detailed techno-financial analysis for each or combination of technology interventions providing details of energy savings and cost savings over the life of the project.

1.4 Approach and Methodology

To meet the objectives of the study, the following methodology has been adopted.

a. Task-1: Collection of data and information on street lighting in SAARC Member States:
The team has used data and information published by the governments and municipalities and other agencies related to the status of street lighting. Desktop-based research has been used with suitable communication with the agencies having such data as the case may be. Both primary and secondary data sources have been relied on. Wherever possible the concerned officers have been contacted by WhatsApp / Skype / Email / Digital meeting platforms to explain the objective of the study and requested them for providing the information in an expedited manner.

b. Task-2: Data analysis for identification of municipalities for case study:
Municipalities have been selected based on ease of access to data, impact of EE improvements and considering diversity of cities in terms of size of population/street lights.

c. Task-3: Mapping current trends in efficiency improvements and solarization of street lighting:
This task involves study of various innovative technologies that are available and proven for efficiency improvement in street lighting. Products related information have been collected from OEMs and technology vendors which includes typical product specifications and prices.

d. Task-4: Development of case study based detailed cost benefit analysis:
This task would involve development of MS-excel based cost benefit analysis tool for various technological interventions carried out at selected municipalities. The tool has been prepared separately for each of SAARC Member States incorporating respective currencies for easy understanding of the users.

e. Task-5: Report Preparation:
The report also contains country wise conclusions, barriers and hurdles faced by respective municipalities, innovative financial mechanisms to overcome barriers, case study-based cost benefit analysis, pictures of actual implementation, collation of best practices, etc.

1.5 Limitations and Assumptions

In the estimates of energy consumption and cost data, the following assumption/considerations have been made.

Assumptions:

a. The street lights are assumed to be burning for 12 hours a day (based on general practice of municipalities in India) unless the actual burning hours are indicated by the selected municipalities.

b. The energy consumption for street lighting with existing street light fixtures is based on wattage of the luminaires, number of luminaires and burning hours of the luminaires.

c. The LED failure rate has been considered at 2%[4] per year unless specific information has been provided by the selected municipalities. This is based on data from large scale EE implementation in street lighting from SAARC region

d. Recommended LED lamp rating is under assumption that the lux levels from existing conventional fixtures are sufficient / meets the minimum lux level requirement.

e. The capital cost considered are based on eihter actual cost or from OEM price list provided as Annexure:1.

f. In case of solar street lighting system, it is assumed[5] that battery requires replacement during 5th year and would cost 50% of total system cost.

g. The cost benefit analysis is prepared for existing conventional fixtures. In practice the number of fixtures would increase due to city development.

h. The electricity tariffs and maintenance cost are assumed to be increase as per Consumer Price Index (CPI)

i. Discounting factor used in estimation of Net Present Value (NPV) of the project is based on Weighted Average Cost of Capital (WACC) of respective Member State.

Limitations:

a. In cases where the installation cost, maintenance cost for conventional system and LED with smart control are not available for any Member State, then such information from neighboring countries have been used.

b. Installation cost and maintenance cost for the Maldives was considered the same as India since the project was implemented by EESL of India and there was no information received

[4] Based on telephonic discussion with officer of EESL, India

[5] Street Lighting Solarisation projects in Nepal and Bangladesh have been abandoned/discontinued after failure of battery in 4 to 5 years. The municipalities did not attend the batteries for maintenance. In Nepal the 3rd party agency responsible for O&M of batteries exited the project despite the agreement of 10 years due to poor enforcement clauses. The information is available formally and informally and accordingly the assumption is made that once in 5 years the battery needs replacement. With better O&M and technology development, this time may be extended and municipalities can revise this number in the MS excel tool when they evaluating the project

from the Maldivian Authorities. Similarly, these costs for Afghanistan were considered the same as that of Pakistan as there was no information received from Afghanistan.

c. Only direct benefits and costs have been considered and any cost of externalities have not been considered

1.6 Currency Exchange Rates

The cost data related to street lighting system and techno-financial evaluation has been prepared in respective currencies of SAARC Member States. However, for understanding of wider audience the same is also reported in USD with exchange rates in Table- 1 below:

Table- 1: Currency Exchange Rates

USD	Equivalent Currency accessed on Google (As on 16 September 2021)[6]
1 US Dollar (USD)	85 Afghan Afghani (AFN)
	85 Bangladeshi Taka (BDT)
	73 Bhutan Ngultrum (BTN)
	74 Indian Rupees (INR)
	15.4 Maldivian Rufiyaa (MVR)
	118 Nepalese Rupee (NPR)
	168 Pakistani Rupee (PKR)
	200 Sri Lankan Rupee (LKR)

[6] https://www.xe.com/

2 Technology Status of Street Lighting

2.1 Existing Technologies for Street Lighting

The street lighting technologies in municipalities have been changing over last 25 years with advent of more efficient technologies. The incandescent lamps were replaced with Fluorescent Tube lamps (FTLs). The high-ways which were lit with High Pressure Mercury Vapour (HPMV) were mostly replaced by High Pressure Sodium Vapour (HPSV) lamps. The residential areas were generally provided with FTLs and replaced with more efficient T5 FTLs and Compact Fluorescent Lamps (CFLs).

While all such upgradation in street lighting technologies had been happening till the first decade of the 21st century, the use of Light Emitting Diode (LED) based lighting system has brought in a paradigm shift in lighting technology covering domestic, commercial and street lighting segments across the world. Despite such continuous upgradation of technologies, street lighting systems in most municipalities of the developing countries including SAARC Member States have obsolete technologies and practices. Municipalities are still having vintage technologies such as HPMV, HPSV and CFLs and manual control for switching ON and OFF. Thus, it may be prudent to have a brief look at the technologies and its typical energy performance indicators which are presented as under.

2.1.1 Basic Terminology of Lighting System

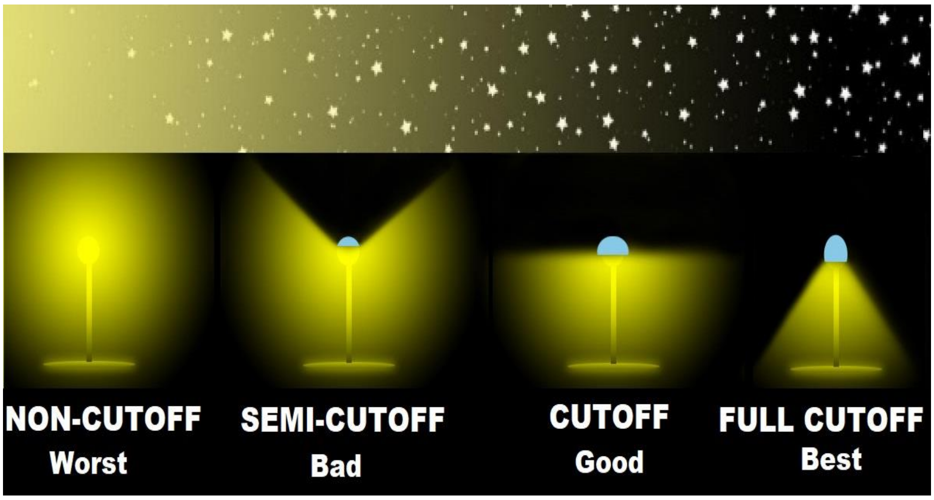
The terminology of lighting system are discussed as follows

- **Lumen output (Lm):** Amount of light emitted by the light source.
- **Candela (cd): C**andela is the unit of luminous intensity. Candela is the amount of light a light source emits in a particular direction
- **Lamp wattage (W):** Amount of electricity required by the lamp to emit the lumen output
- **Luminous efficacy (Lm/W):** Luminous or lumen efficacy measures the efficacy of the light source. It measures how much light is being emitted by the light source per unit of power and is expressed in lumen per watt of electricity used.
- **System wattage (W):** Amount of electricity required by the system to emit the lumen output.
- **System efficacy (Lm/W):** Luminaires include ballasts, drivers, heat management systems, optics, all of which can diminish the original luminous efficacy of the light source. Since the road surface is being lit up by the luminaire as a whole, system efficacy is a better metric to use than luminous efficacy when making comparisons.
- **Watts per square meter (W/m^2):** The amount of power required for each lighting appliance to illuminate a road surface to the required light level. For road lighting, this is the most appropriate way to measure the efficiency of a light source, though lumen efficacy or lumen output are often considered easier to measure.
- **Lifetime (hours):** Lifetime of LEDs is measured differently than conventional lighting technologies, which reach end of life at the point when they stop producing light entirely. However, LEDs typically do not stop producing light completely, but depreciate or dim over

time to a point where the lumen output is insufficient to meet the required light levels. For LEDs, industry defines lifetime as the point when the LEDs lumen output reaches 70% of the original (Glamox, n.d.).

- **Color Rendering Index (CRI):** An index used to measure an artificial light's ability to reproduce the colors of an object, relative to the natural light source (the sun) with CRI of 100. Higher CRI means better visibility.
- **Correlated Color Temperature (CCT):** It is a measure of light source color appearance defined by the proximity of the light source's chromaticity coordinates to the blackbody locus, as a single number rather than the two required to specify a chromaticity.
- **Full Cutoff:** With full cutoff, no light is emitted at or above an angle of 90 degrees from the nadir (horizontal plane). The intensity does not exceed 100 Candela per 1000 lamp Lumens (10 percent) at a vertical angle of 80 degrees from the nadir (Sky, 2021)
- **Cutoff:** A small amount of up lighting is permitted with cutoff light fixtures. The intensity does not exceed 25 Candela per 1000 lamp Lumens (2.5 percent) at a vertical angle of 90 degrees from the nadir. The intensity does not exceed 100 Candela per 1000 lamp Lumens (10 percent) at an angle of 80 degrees from the nadir (Sky, 2021)
- **Semi-Cutoff**: Semi-cutoff light fixtures emit more light directly into the sky and provide little control at the property line. The intensity does not exceed 50 Candela per 1000 lamp Lumens (5 percent) at an angle of 90 degrees from the nadir. The intensity does not exceed 200 Candela per 1000 lamp Lumens (20 percent) at an angle of 80 degrees above nadir (Sky, 2021)
- **Non-Cutoff:** Non-cutoff light fixtures distribute light without Candela limitation in the zone above the max Candela (Sky, 2021).

Figure- 1: Cut-off arrangements of Street Lighting



Source: https://www.blancocountynightsky.org/guidelines.php

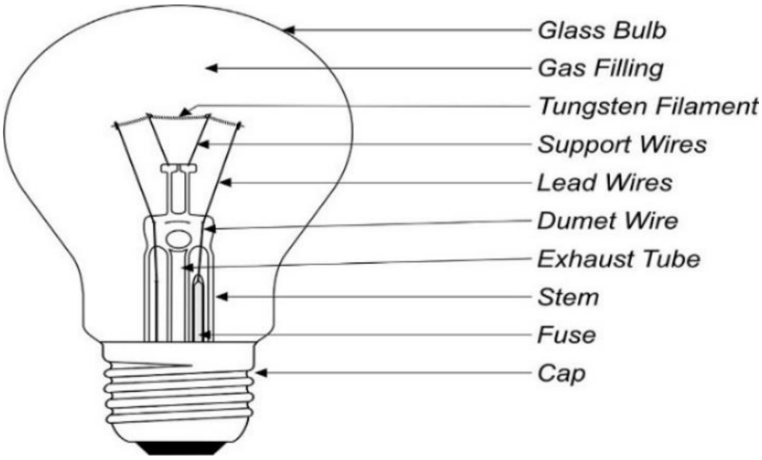
2.1.2 Lamp / Luminaire Technologies

Various types of lamp technologies are prevalent in the market today. These technologies greatly vary in their luminous efficacy, color rendering properties, and lamp life. A brief description of types of lamp technologies currently used is provided below.

i. **Incandescent Lamps:**

Incandescent lamps produce light by means of a filament heated to incandescence by the flow of electric current through it. The principal parts of an incandescent lamp, also known as GLS (General Lighting Service) lamp include the filament, the bulb, the fill gas and the cap (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015).

Figure- 2: A Typical Incandescent Lamp



Source:http://www.lamptech.co.uk/Documents/IN%20Introduction.htm

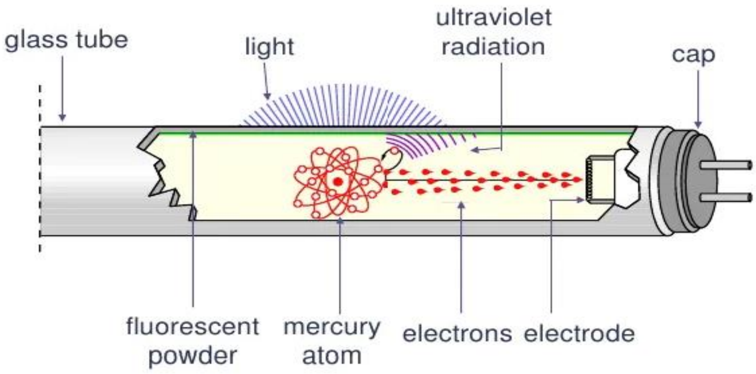
ii. **Gas Discharge Lamps:**

The light from a gas discharge lamp is produced by the excitation of gas contained in either a tubular or elliptical outer bulb. The most commonly used discharge lamps are as follows:

a) Fluorescent Tube Lamps (FTL):

A fluorescent lamp is a low weight mercury vapour lamp that uses fluorescence to deliver visible light. An electric current in the gas energizes mercury Vapour which delivers ultraviolet radiation through discharge process and the ultraviolet radiation causes the phosphor coating of the lamp inner wall to radiate visible light (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015).

Figure- 3: A Typical Fluorescent Lamp (FTL)[7]

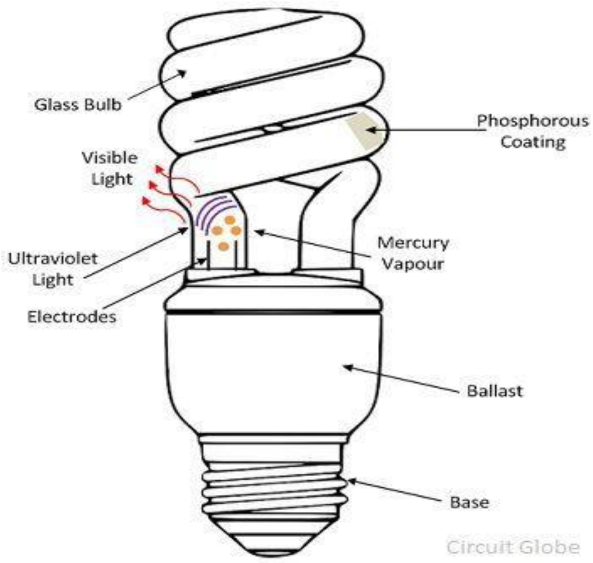


A fluorescent lamp changes electrical energy into useful light energy more efficiently than incandescent lamps. The normal luminous efficacy of fluorescent lighting is 50 to100 lumens per watt, which is few times higher the efficacy of incandescent lamps with equivalent light.

b) Compact Fluorescent Lamps (CFL):

A compact fluorescent lamp (CFL) is a lamp that combine the energy efficiency of fluorescent lighting with the convenience and popularity of incandescent fixtures. CFLs can replace incandescent that are roughly 3–4 times their wattage, saving up to 75% of the initial lighting energy. Although CFLs cost 10–20 times more than comparable incandescent bulbs, they last 10–15 times as long (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015).

Figure- 4: A Typical Compact Fluorescent Lamp (CFL)[8]



[7] Source:https://www.researchgate.net/figure/Structure-of-double-capped-linear-fluorescent-lamp-CREE-Inc-2015_fig5_330468620

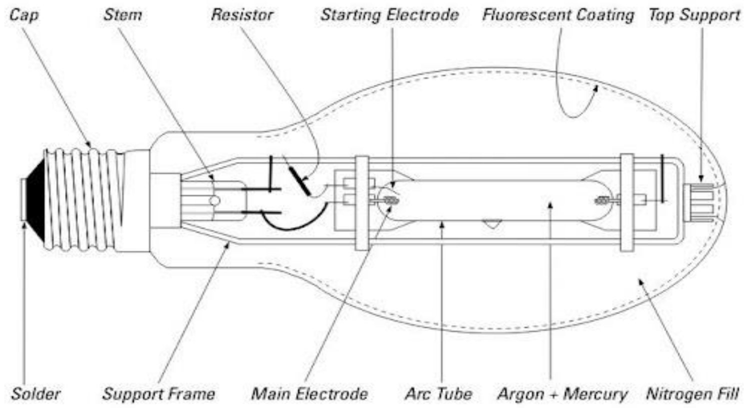
[8] Source: https://circuitglobe.com/difference-between-cfl-and-led-bulbs.html

CFLs work much like standard fluorescent lamps. They consist of two parts: a gas-filled tube, and a magnetic or electronic ballast. The gas in the tube glows with ultraviolet light when electricity from the ballast flows through it. This in turn excites a white phosphor coating on the inside of the tube, which emits visible light throughout the surface of the tube.

c) Mercury Vapour Lamps (MV):

In mercury Vapour lamp, electromagnetic radiation is created from discharge within mercury Vapour, but the regime is different than that in the normal FTLs. During operation, the pressure within the lamp is in the range of 200 – 400 kPa. It is not possible to achieve the mercury Vapour discharge in a cold lamp. For this reason, the lamp also includes Argon, and the initial arc is struck as an argon arc (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015).

Figure- 5: A Typical Mercury Vapour Lamp (MV)



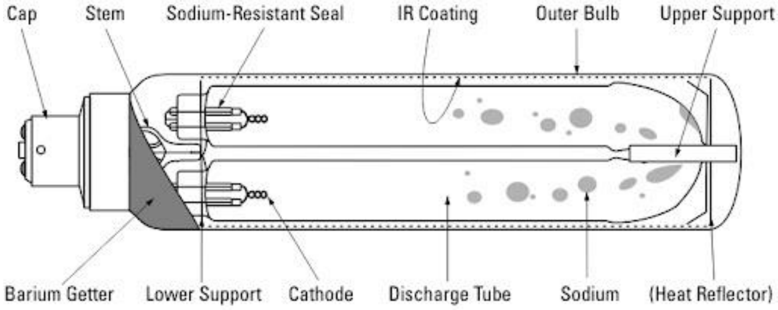
Source: http://lamptech.co.uk/Documents/M1%20Introduction.htm

The MV lamp produces a much greater proportion of visible light than FTL and gives off a bluish white light. Phosphor coating can be given to improve the color rendering index.

d) Sodium Vapour Lamps (SV):

The arc tube consists of frame and is highly pressured with sodium for better efficiency. The arc tube is made of aluminum oxide ceramic which is resistant to the corrosive effects of alkalis like sodium. The start of lighting up process begins through pulse start. High voltage energy is sent through ignitor through the arc tube. Firstly, the pulse starts an arc through the xenon gas which makes the lamp turns sky blue due to xenon lighting up. After that the arc then heats up the mercury and the mercury Vapour then lights, giving the lamp a bluish color. Sodium is the last material to Vapourize as sodium Vapour strikes an arc over 240 ^{0}C. The sodium is mixed with other impurities to create a whiter light. The mercury helps add a blue spectrum light to the pure yellow of the sodium (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015).

Figure- 6: A Typical Sodium Vapour Lamp (SV)



Source: http://www.lamptech.co.uk/Documents/SO%20Introduction.htm

For maintaining a vacuum, oxygen and other gasses can seep in over time. The getter keeps a stable vacuum by sucking out remaining oxygen and unwanted gas elements. The sodium is stored often stored in the amalgam reservoirs on the ends of the arc tube when it is cool unlike the LPS lamp where the sodium is stored in the bumps on the side of the tube

Low Pressure Sodium Vapour Lamp (LPSV): LPSV lamps are similar to that of FTLs. LPSV lamps are the most efficacious light sources, but they produce poorest quality light of all the lamp types. Being a monochromatic light source, all colours appear black, white, or shades of gray under an LPSV source. LPSV lamps are available in wattages ranging from 18 – 180.

LPSV lamps use has been generally limited to outdoor applications such as street lighting and indoor, low wattage applications where color quality is not important.

High Pressure Sodium Vapour Lamp (HPSV): The HPSV lamps are widely used for outdoor lighting and industrial applications as the light is yellowish. HPSV lamps has high efficacy and used when good color rendering is not a priority.

e) **Metal Halide Lamps (MH):** MH lamp can be considered as high-pressure mercury Vapour lamp (HPMV). In addition to mercury Vapour and argon, this lamp contains metal halide. The mercury Vapour radiation is augmented by that of the metals. A highly compact electric arc is produces in a discharge tube. A starter is needed to switch on the lamp. The use of ceramic discharge tube further improves the lamp properties (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015). Metal-halide lamps are used for general lighting purposes both indoors and outdoors, such as commercial, industrial, and public spaces, parking lots, sports arenas, factories, and retail stores.

Figure- 7: A Typical Metal Halide Lamp (MH)

Source: https://www.superiorlighting.com

MH lamps have a significantly better color rendering index than MV and can be tailored by the choice of halides.

iii. Light Emitting Diode (LED Lamps):

The fast-growing technology in the street lighting system is Light-emitting Diode (LED) with significant amount of energy savings. The energy consumption of LED s is half of the conventional lighting and lasts for about 50000 burning hours depending on quality of LED, system design, operating environment and etc (BEE, Guide Book-3 for Certified Energy Auditor/Managers, 2015).

Figure- 8: A Typical LED Street Light[9]

Advantages of LED street lighting:

- LEDs are one of the most energy efficient and environmentally friendly lighting technology
- Reduced maintenance costs due to long lifetimes

[9] Source: https://www.industricals.com/crompton-60w-cdl-nexus-street-light

- No warm up needed (no time delay to reach optimum brightness levels)
- Can be dimmed (unlike CFLs), allowing for flexibility in controlling light levels
- High colour index, providing bright, true colour during night time hours
- No glare effect, reducing visual fatigue for both drivers and pedestrians

Disadvantages of LED street lighting:

- High initial costs than the conventional lights and can lead to long paybacks
- Provision of only directional light limits usefulness to only streetlights that are hanging or facing downward
- Adequate heat-sinking is required to ensure long life with high-powered LEDs

Typical lighting performance parameters of various type of lamps are presented in Table- 2 below:

Table- 2: Performance Parameters of Various type of Lamps

Type of Lamp	Luminous Efficacy (lm/W)	Color Rendering Properties	Lamp life in hrs.	Remarks
High Pressure Mercury Vapour (MV)	35-36 lm/W	Fair	10000-15000	High energy use, poor lamp life
Metal Halide (MH)	70-130 lm/W	Excellent	8000-12000	High luminous efficacy, poor lamp life
High Pressure Sodium Vapour (HPSV)	50-150 lm/W	Fair	15000-24000	Energy-Efficient, poor color rendering
Low Pressure Sodium Vapour (LPSV)	100-190 lm/W	Very Poor	18000-24000	Energy-Efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamp (T12 & T8)	30-90 lm/W	Good	5000-10000	Poor lamp life, medium energy use, only available in low wattages
EE Fluorescent Tubular Lamp (T5)	100-120 lm/W	Very Good	15000-20000	EE, long lamp life, only available in low wattages
Compact Fluorescent Lamp (CFL)	40 - 100 lm/W	Very Good	15000-20000	EE, long lamp life, only available in low wattages
Light Emitting Diode (LED)	70-160 lm/W	Good	40000-90000	High energy savings, low O&M, long life, no mercury, high capital cost and evolving technology.

(Source: Energy Efficient Street Lighting Guidelines, BEE)

2.1.3 Street Lighting Control Systems

Besides energy efficiency improvements at device level, various control systems are also used in street lighting system to control switching of the device as per the requirement, dimming the light as per the traffic conditions. The developments in sensor and communication technologies also made their way into street lighting system that enabled real time status of individual lamp / luminaire, improving the service levels to the citizens in terms of expedited repair and maintenance.

a) Autonomous control

This type of control system, the luminaires are pre-programmed with fixed time periods for operation and does not require further control. There is no way to adjust the control often. Furthermore, internal timers may not be accurate, and any upgrade of the system requires changes in every lamp post. Alternatively, sensors might detect the ambient light at every light post and decide on whether to activate the lamps. However, this causes additional expenses (inteli, n.d.).

b) Centralized control and Monitoring system with IOT

Group Control & Monitoring System is a GSM/GPRS/2G/3G/4G/Equivalent proven technology installed in a feeder or switching point for remote monitoring and controlling group of lights. It is group wise central monitoring system. Group Controller is an Automatic light control throughout the year on the basis of precise sunrise and sunset time depending on the geographical location (EESL, 2021).

Features:

- Schedule the timing of lights (pre-programmed based on astronomical clock or on field or through central control)
- ON / OFF Switch (on field or centrally)
- CCMS System to Capture the energy usage and other parameters at predetermined interval and store data for 30 days
- Ability to connect with a communication device
- Ability to download data in field
- System protection against surges
- Ability to upgrade firmware on field using a communication device

2.1.4 Street Lighting Control Strategies

a) **Astronomical / Almanac timer**

Astronomical timers have precise information about sunrise and sunset times for any given geographical position. These can be calculated in advance with a very high level of accuracy for long time spans. However, lighting control strategies based on astronomical timers might not take specific geographic aspects into account, such as large hills or mountains blocking the sun at dawn or dusk. Furthermore, astronomical timers can make no predictions about weather conditions such as storms which might require artificial lighting even during daylight hours.

Astronomical timers might establish a simple on-/off scheme for illumination that specifies the time of activation of the lighting in the evening and the deactivation in the morning. Alternatively, it might specify periods later at night during periods when less traffic is expected during which the lighting remains active but at reduced operating intensity.

One of the main advantages of astronomical timers is that they do not require any complex ICT systems to operate (inteli, n.d.).

b) **Daylight harvesting**

In contrast to using astronomical timers, daylight harvesting strategies use photo sensors to detect the ambient light and adjust the artificial lighting if the ambient light levels fall or increase beyond certain threshold values. This approach works especially well with dimming and can adjust to extended periods of twilight as well as inclement weather. However, the photo sensors require regular cleaning in order to ensure their proper function. Furthermore, it must be decided whether a single photo sensor is controlling the lighting for a large area or whether each group of lamps or even each individual lamp has its own sensor. The first option reduces the system complexity but cannot reflect all localized conditions (such as especially shaded areas or smaller weather systems) and represents a single point of failure for the system

The second option allows for more flexibility, but also requires the purchase of a large number of additional sensors and requires more maintenance for keeping the sensors clean.

The photo sensors can be embedded into a larger ICT infrastructure, which (depending on setup) can enable real time monitoring of the road illuminance. Thereby any problems with insufficient lighting can be quickly identified and addressed (inteli, n.d.).

c) **Traffic detection**

On many roads, traffic may be consistently low, especially late at night. Thus, reducing their level of illumination in compliance with the requirements stipulated in EN 13201 offers potentially large energy savings. In order to ensure that traffic participants can still navigate these roads safely, traffic detection systems can be installed which increase the level of illumination again when needed. The most common technology for detecting traffic – whether motorized vehicles, cyclists, or pedestrians – are motion sensors. Types of motion detectors include the following (inteli, n.d.).:

Ultrasonic motion detectors detect the shift in sound waves bouncing back from a moving object. This type of sensor does not require line of sight. It is cheap, can detect objects irrespective of their materials, and is little affected by air flows of up to 10 m/s (36 km/h). However, they have a low detection range and can be affected by humidity and high temperatures.

Microwave motion detectors detect shifts in microwaves bouncing back from a moving object, similar to radar speed guns. They are able to detect even small motions and are not affected by the ambient temperature of objects. However, they are costly and may cause false detection due to movements outside the specified zone.

Infrared sensors detect the heat of an object or a person relative to their surroundings. They are purely passive sensors – thus, they do not emit sound or radiation in order to collect information. However, they might trigger false detection from warm air, rainfall, or hot objects.

Video processing uses video cameras as smart sensors, identifying moving objects via smart algorithms. They can monitor a larger area than other detection system and detect not only the motion but also the presence of objects. They also have a low probability of false responses. However, the data processing algorithms are fairly complex, resulting in both added cost for the software as well as added electricity consumption due to their processing power requirements. Furthermore they are dependent on light, though this can be compensated with infrared filters to some degree. Motion detection systems can also be combined so that the disadvantages of one type are compensated by the capabilities of another.

Once the need for added illumination is detected by the sensors, the system should ensure that the usual requirements for the relevant street lighting class are met. This means that a motion sensor attached to a particular lamp pole generally should not just be used to activate that particular lamp, but also one or more adjacent lamps so that traffic participants are not subject to glare from rapidly changing lighting conditions.

Any motion detector-based systems that are intended to cover more than pedestrian-only areas almost invariably require integration into a larger ICT setup. However, this has the added advantage of allowing traffic information data which can be useful to traffic controllers, urban planners, emergency services and other agencies.

d) **Dimming**

Depending on traffic, weather, and ambient lighting conditions it may not be necessary to operate lamps at full power throughout the night. By combining proper astronomical timers, daylight harvesting, and traffic detection schemes with dimming, huge energy savings can be attained – in some projects, up to 85 % savings were achieved (inteli, n.d.). Furthermore, gradually increasing and decreasing the illumination reduces discomfort glare for nearby residents. LEDs are especially suitable for dimming-based strategies as they can be dimmed smoothly with almost no technical complications, whereas other lamp types used in street lighting cannot be dimmed, produce drastic color shifts when dimmed (high-pressure mercury and metal halide lamps) or are limited in how far they can be dimmed (inteli, n.d.).

2.2 Global Practices in Smart Street Lighting Systems

2.2.1 Status of Global Practices in Smart Street Lighting Systems

There are around 320 million street lighting poles in the world in which Asia accounts for 25% and Europe & North America accounts for 20% and South America of 10% and the rest of the world (Australia & Africa) accounts for 45% of street lighting poles (Little, 2019). The average lighting density in terms of urban population per each lighting point is about 13 peopleper pole in the world (Little, 2019). The lighting density ranges from 7 people per pole in Europe to 20 people in Asia Pacific (Little, 2019).

LED based street lighting is now being considered the most energy efficient. Many cities across the world have completed replacing conventional street lighting fixtures (e.g., HPSV, HPMV, FTLs, CFL and MH) with LED fixtures. Examples of cities with 100% LED street lighting include Milan (Italy), New York (USA) and Visakhapatnam (India) (Little, 2019). The LED penetration differs widely primarily on account of financial barriers and administrative inabilities of municipalities in adopting suitable business models.

The overall average LED penetration (i.e., number of LED fixtures to the total number of fixtures) is still less than 15% globally with Japan and Canada showing highest LED penetration of 44 – 50%. The LED penetration in Europe is around 10% with only Germany having a penetration above the European average. The LED penetration in USA is 26% and that of South America is less than 5%. (Little, 2019).

The technology development in solar PV and energy storage/ battery have resulted in multiple end use applications including street lighting. The solar PV panel with battery storage supplying electricity to LED based street lighting system is emerging as the next ‘’big thing’’ in street lighting systems.

Asia Pacific region leads the solarization of street lighting system followed by Africa (Intelligence, 2020). The key driver for the leadership in solarization of street lighting in Asia and Africa appears to be the resolve of the respective national governments to provide street lighting in geographically difficult areas. The solarization of street lighting is based on energy efficient LED lights which also meets the energy efficiency and sustainability aspects of street lighting service. The value of worldwide solar street lighting market is estimated to be $5.7 billion. The number of solar street lighting systems sold during 2019 was 1.454 million units and the sales are expected to increase at a CAGR of 9.4% during 2020 – 2030 (Intelligence, 2020).

Most of the solar street lighting projects are for road ways and high ways in terms of application and for retrofitting existing systems in terms of installation. Various multi-lateral financing institutions such as the Asia Development Bank (ADB), The World Bank, International Finance Corporation (IFC) have been introducing subsidies/grants in Asian and Africa to promote solarization of street lighting.

2.2.2 Success Drivers for EE Street Lighting

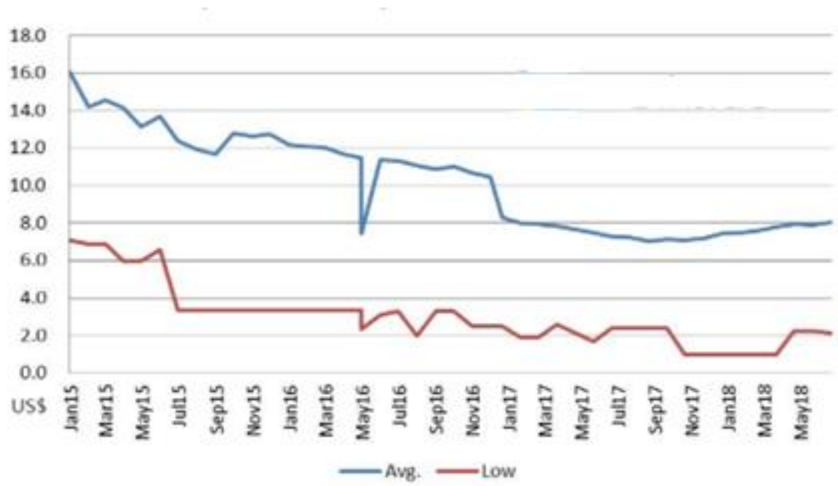
The key drivers that are promoting the energy efficient street lighting at global level are:

- **Regulatory Policies:** Street lighting energy efficiency and solarization projects are one of the fast, replicable projects to meet the commitments as per NDCs under Paris Agreement of

UNFCCC. All the national governments globally have taken steps to implement energy efficient street lighting both in urban areas as well as rural / county side. Regulatory requirements at global level have helped creation / availability of technical and financial resources. This has helped participation of public and private sector to innovate on implementation models, financial engineering for energy efficiency project. Thus, regulatory requirements at global level are helping local government systems to overcome the issues with the limited technical and financial resources in the implementation of EE in street lighting

- **Financial Viability and Innovative Business Models:** The financial viability of energy efficient street lighting itself pays for the project cost with paybacks ranging from few months to 3 – 4 years depending on the electricity tariff. Various business models such as ESCO route have been successful in many cities which enabled implementation of energy efficient and smart street lighting without any upfront cost to the municipalities.
- **IoT convergence:** Smart city development and advanced remote-control systems drive the growth of the VAS[10] segment. The Internet of Things is the connection of everyday products such as cars, alarm clocks, and lights to computing devices via the internet to allow them to exchange data. Street lighting will benefit from this, as lighting poles will become hosting infrastructure for several connected devices (e.g., sensors, video cameras, EV chargers).
- **LED prices drop**: The quality improvement and reduced costs are making LED the default option for lighting. The following Figure- 9 provides the price drop trend for a 60 W equivalent LED lamp during 2015-2018.

Figure- 9: 60W LED Lamp retail price trend 2015-2018[11]



2.2.3 Street Lighting Poles for Technology Convergence

The poles equipped with street lights are most suitable infrastructure and can be also used for the following purposes (Little, 2019).

[10] VAS – value added service

[11] Source: https://www.ledinside.com/news/2018/8/global_led_lighting_products_price_trend

- Poles' capillarity is extremely relevant for video surveillance services and autonomous driving.
- Weather monitoring (by installing suitable sensors). Figure- 10 shows the street lighting pole mounted weather monitoring in Delhi (India).
- Poles are the most convenient infrastructure on which to host a fiber network, and they can also be used for hosting small cells/antennas to meet 5G densification.
- Poles are already equipped with electricity connection, and can host EV charging points with relevant cost benefits compared to traditional low-charge EV stations. Figure- 10 shows the street lighting pole mounted EV charging station at Kozhikode (India).

Figure- 10: Street Lighting for Technology Convergence

Source: (India.com, 2018) Source: (Hindu, 2021)

2.3 Energy Efficiency Practices in SAARC Region

2.3.1 Afghanistan

The grid access in Afghanistan has improved from mere 16% (WB, 2009) circa 2010 to 44% (RISE, 2021) presently. Most of this improvement has come in urban centers whereas most of the rural population is without grid access. Even the areas with grid access face severe constraints when hydro power generation which is about 40% (WB, 2009) of total electricity generation, reduces during winter months. The operation of diesel-based power plants during winter months results in overall increase in the average tariff as well as high marginal cost.

The poor status of supply side position in terms of infrastructure, availability and reliability of network and high prices of electricity provide good opportunity for Afghanistan cities to leap-frog in improving energy efficiency in street lighting. The Afghanistan Energy Efficiency Policy (AEEP) of 2016 has mentioned energy efficiency in public lighting as one of the components for implementation of suitable actions to realize the strategy (AEEP, 2016). The argument in favor of EE in public lighting as per AEEP 2016 is that it is simple to achieve EE in public lighting that would reduce 30% - 50% (AEEP,

2016) of the cost for municipalities. Accordingly, AEEP recommended that 50% of public lighting be upgraded with EE fixtures and 50% of public lighting asset be powered by solar energy (AEEP, 2016). This would auger well for Afghanistan cities which are struggling with insufficient grid access and supply.

Figure- 11: Solar Street Lighting of Kabul City Roads

Source: https://www.zularistan.com

A number of projects, mostly based on standalone solar based LED street lighting systems have been initiated in various municipalities with the support of donor organizations. The cities where such projects were implemented include Kandahar, Kabul, Bamian, Badakhshan, Ghor, Bandi Barq, Helmand. Although Afghanistan appears to be lagging in terms of overall penetration of EE fixtures in street lighting at present, the overall policy direction and the projects implemented so far indicate that, the country has potential to take advantage of solar based street lighting (with LED fixtures) to leap-frog to a leadership level in terms of technology adoption. Since 80% of Afghanistan population lives in rural areas and AEEP requires 50% of public lighting based on EE lighting and 50% solarisation of public lighting, it may be concluded that the technology adoption, local capacity building of municipalities in Afghanistan is necessary to implement the same in rural areas.

2.3.2 Bangladesh

Bangladesh has initiated its Energy Efficiency Improvement (EEI) Projects for street lighting under City Region Development Project (CRDP) with financial support of Asian Development Bank (ADB). The energy efficient technologies chosen that time were T5 FTLs[12], LED and standalone solar street lighting. The pilot project at Tongi pourashava (municipality) was successfully completed that involved replacement of 2,745 number of conventional lights (FTLs, CFLs) to T5 and LED with voltage regulator for 10 lighting circuits, Photo-electric timer controls in 10 feeders for automatic ON/OFF, that resulted in 0.179 MU of electricity savings (ADB, Bangladesh: Energy Efficiency Improvement , 2013).

On account of the quality improvement and price drop in LED street lighting Bangladesh is now having plans to replace street lights with LED technologies. Sustainable and Renewable Energy Development Authority (SREDA) of Bangladesh has signed an MoU with India's EESL for technical cooperation to implement LED based street lighting with IoT enabled Centralized Controlling & Monitoring System (CCMS)[13]. Under this programme SREDA with the support of EESL has completed replacing 519 conventional street lights with LED based street lights connected with 24 numbers of CCMS modules in Tungipara Municipal Corporation in March 2017 (EESL, 2021).

Ever since, various municipalities in Bangladesh are taking up conversion of conventional street lighting with LED based street lighting. The Chittagong city intends to replace a total of 39950 conventional street lights comprising of Incandescent bulbs, FTLs, Halogen lamps, HPSV and Metal halide lamps (CCC, 2021) with LED lamps.

Solarization of Street Lighting in Bangladesh:

Bangladesh's tryst with solar street lighting started way back in 2009 with installation of 355 number of solar street lights in Chittagong Hill Tracts region by Bangladesh Power Development Board (BPDB) with the support of ADB. The low maturity levels of LED technology at that time, lack of maintenance have made these installations out of order well before its expected life (ADB, Energy Efficiency Improvement TA-7642-Bangladesh, 2013). In 2014, Dhaka Municipal Corporation (DCC) had installed 122 number of solar street lights under the project ''Solar Photovoltaic-Powered LED (Light Emitting Diode) Street Lighting'' launched by Government of Bangladesh with the support of ADB (IEEE, 2014). Further replication was stopped due to poor financial viability on account of high prices of system components (solar panel, battery and LED) prevailing at that time vis-a-vis the lower cost savings on account of lower electricity tariffs.

[12] EE variant of Fluorescent Tube Light. T5 with diameter of 0.625 inch

[13] Please refer to Section 2.1.3 for brief explanation

Figure- 12: Solar Street Lighting of Chirirbandar roads, Bangladesh[14]

Ministry of Disaster Management and Relief set up 120 solar street lights on 40-km roadsides under the Taka for Work and Test Relief projects during FY 2017-2018 -. Ministry has also installed 600 solar street lights in various places such as huts, bazaars, hospitals, traffic junctions, educational institutions, mosques, temples and other religious institutions of Chirirbandar upazila under the Rural Infrastructure Maintenance Programme during the 2017-2018 fiscal (Expert, 2018).

2.3.3 Bhutan

The vast areas of forestry and green supply side of primary energy (hydro power and fire wood) have helped the Bhutan remain carbon neutral on net basis. The Royal Government of Bhutan (RGoB) has also committed to remain carbon neutral since 2009. RGoB communicated its INDCs under Paris Agreement in September 2015. Bhutan has also adopted National Energy Efficiency & Conservation Policy (EE&C) and National Energy Efficiency Roadmap in 2019 (NEE&C, 2019).

Bhutan being dependent on tourism as one of its economic activities, the building sector, appliances and industrial process would be major sectors for GHG emissions in time to come and would result in increase in urbanisation. Keeping this in view, the RGoB policy and roadmap relating to energy efficiency is specifically focused on these sectors. The 12th plan of Bhutan (2018-2023) had identified 13 Low Emission Development Strategies (LEDS) of which energy efficiency in street lighting is one of the mitigation measures focusing on urban areas (RGoB, 2019). The following Table- 3 presents details of LEDS under 12th plan of Bhutan.

[14] Source: https://thefinancialexpress.com.bd/national/country/solar-power-street-lights-illuminate-chirirbandar-1531913365

Table- 3: Prioritization of mitigation measures for human settlements in Bhutan

Mitigation measure	Ranking Priority	Recommended for rural (R) or urban (U) areas
Waste composting	1	U+R
Energy efficient buildings	2	U+R
Reduce, reuse and recycle solid waste (3R)	3	U
Energy efficient Street lighting	4	U
Electric mass public Transport	4	U
Wastewater Management	4	U
Cable cars	4	U
Energy efficient appliances	5	U+R
Electric Vehicles	5	U

Source: Urban and Rural Settlements in Bhutan: A low emissions development strategy, 2017

The capital city Thimphu has commenced its energy efficiency improvement projects in street lighting way back in 2015 by replacing existing HPSV with LED lamps and Induction lamps on Thimphu-Babesa expressway (Kuensel, 2017). As of date, all 4,864 street lights in capital city of Thimphu are replaced with LED based street lighting (Authors). In 2017, Phuentsholing Thromde (which is biggest city after Thimphu) has commenced its EE initiatives in street lighting by replacing 29 HPSV lamps with LED and had plans to replace the entire city street lighting with LED based street lighting (Kuensel, 2017). The city of Gelephu is in the process of replacing its street lights based on 90W CFL with LED based street lighting (Authors).

Figure- 13: Street Lighting of Bhutan roads

Source: untoldbhutan.com

The solarization of street lighting in Bhutan is yet to start. The proposals for solar based street lighting is under preparation for budget allocation[15].

[15] *Based on telephonic discussion with Mr. Minjur, Department of Renewable Energy, Ministry of Economic Affairs RGoB*

2.3.4 India

The energy efficiency improvements in street lighting is a continues activity wherein municipalities and Urban Local Bodies (ULBs) in India have been replacing inefficient lighting fixtures with efficient ones. However, with signing of Paris Agreement and communication of INDC / NDCs, India commenced National Mission on Enhanced Energy Efficiency (NMEEE). Street Lighting National Programme (SLNP) is one of the flagship programme under NMEEE wherein the government owned Super ESCO (EESL) has been implementing LED based energy efficiency upgradation. The SLNP programme is being implemented by EESL without any burden of upfront cost on municipalities. The EESL has also put in place IoT based Central Control and Monitoring System (CCMS) to connect the street lights using GIS based group controllers. The EESL also made public a GPS based Dashboard with city wise and area wise details / status of street lights, energy savings presented in **Figure- 14**. The indexing of the group controller and poles also helps in identification of failed street lights and remedial action within 24 – 48 hours. This has improved the quality of services for the citizens.

EESL has covered more than 95% of cities in India under SLNP programme and installed about 10.1 million LED based street lighting system with CCMS during the period of 2016 – 2020. The total energy savings estimated from SLNP programme by EESL has been 6841 MU (BEE, Impact of Energy Efficiency Measures, 2019-20) of electricity over the 4-year period. The total investment has been funded by EESL as ESCO with O&M responsibility for 7 years. The state wise LED installations and Energy saving from SLNP programme is presented in the Table- 4.

Table- 4: Details of LED street lights installed in India

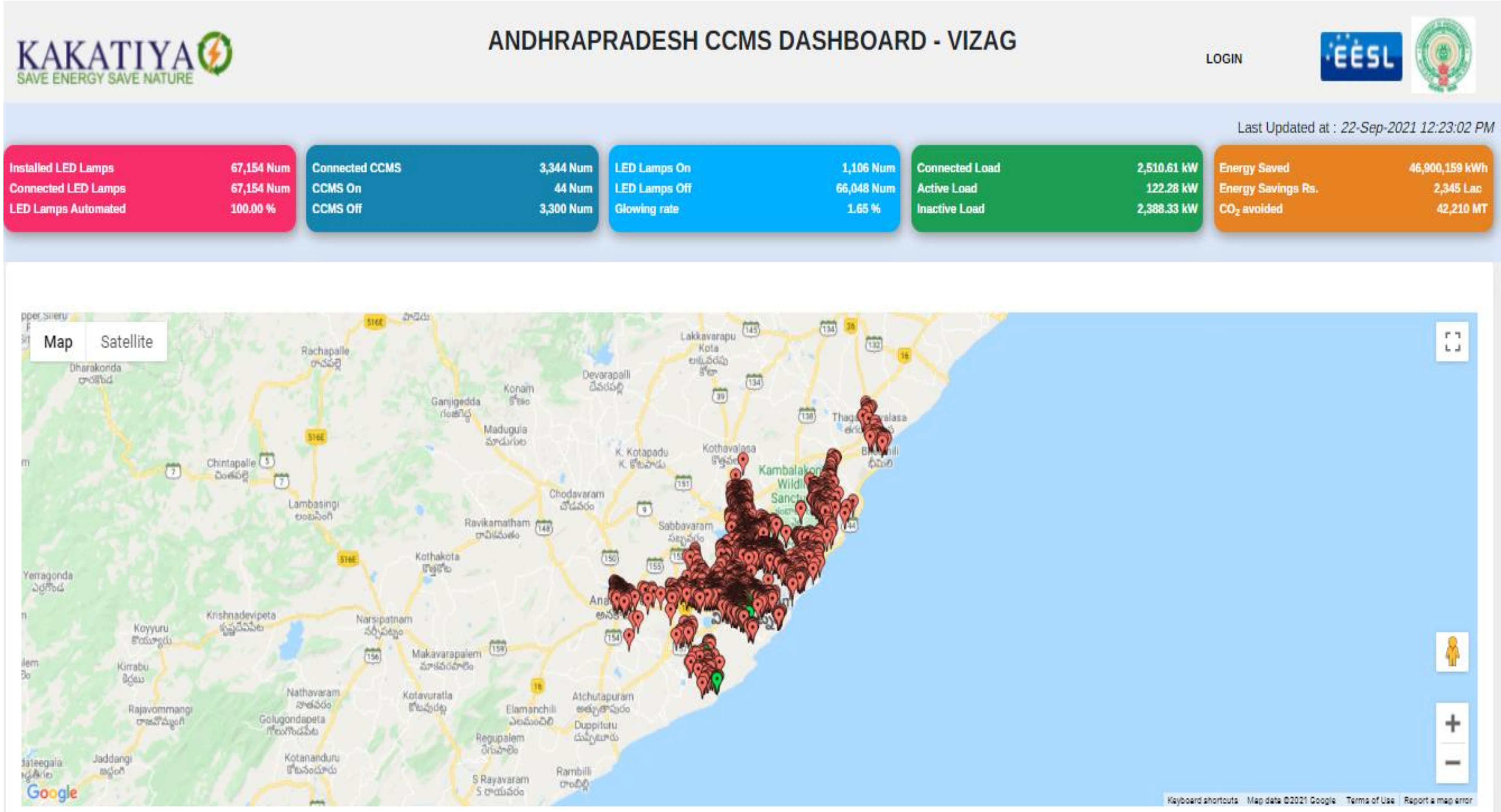
States/Union Territories	No. of LED street lights installed in FY-2016-20	Energy Savings in FY 2016-20 (MU)
Andaman & Nicobar Islands	14,737	9.89
Andhra Pradesh	2,666,836	1789.45
Assam	40,737	27.33
Bihar	443,991	297.92
Chandigarh	43,476	29.17
Chhattisgarh	405,947	272.39
Delhi	211,161	141.69
Goa	209,657	140.68
Gujarat	888,579	596.24
Haryana	80,341	53.91
Himachal Pradesh	56,209	37.72
Jammu & Kashmir	86,719	58.19
Jharkhand	484,352	325
Karnataka	12,310	8.26
Kerala	88,020	59.06
Lakshadweep	1,000	0.67
Madhya Pradesh	117,438	78.8
Maharashtra	818,225	549.03

States/Union Territories	No. of LED street lights installed in FY-2016-20	Energy Savings in FY 2016-20 (MU)
Odisha	335,226	224.94
Puducherry	150	0.1
Punjab	107,306	72
Rajasthan	869,725	583.59
Sikkim	868	0.58
Tamil Nadu	7,699	5.17
Telangana	996,471	668.63
Tripura	41,551	27.88
Uttar Pradesh	1038,629	696.92
Uttarakhand	47,683	32
West Bengal	80,229	53.83
Total	**10,195,272**	**6841.03**

Source: Impact of Energy Efficiency Measures, BEE 2019-20

Centralized Control & monitoring System (CCMS) dashboard is presented in the **Figure- 14**

Figure- 14: CCMS Dashboard of Visakhapatnam city of India



Source: http://dashboard.CCMS.tech/andhrapradesh?cname=Vizag

LED Equivalents (for same lumen output) of Typical Conventional lighting fixtures used in SLNP is presented in the Table- 5.

Table- 5: LED Equivalents of Typical Conventional lighting fixtures used in SLNP

Conventional Fixtures	LED Fixtures
FTL 40W	LED 18W
HPSV 70W	LED 35W
HPSV/HPMV 150W	LED 62W
HPSV/HPMV 250W	LED 110W
HPSV (High Mast) 400W	LED 200W

Source: East Coast Research

Solarization of Street Lighting in India:

EESL is implementing Atal Jyoti Yojana (AJAY), a sub-scheme under Off- Grid and Decentralized Solar Application Scheme of MNRE. Under AJAY, Solar LED Lights are being installed in rural, semi-urban and urban areas which don't enjoy adequate coverage of power. Under AJAY phase-I and II, EESL has installed around 200,000 Solar LED Street lights in rural areas of Uttar Pradesh, Assam, Bihar, Odisha, Jharkhand, Madhya Pradesh, Uttarakhand, Rajasthan and Gujarat. (EESL, 2021)

The dashboard of ATAL JYOTI YOJANA can be accessed at Source: http://ajay.eeslindia.org/

Maldives

The Maldives have joined en.lighten initiative of UNEP in 2013 and commenced its journey of energy efficiency improvements in street lighting by replacing existing HPSV and T12 FTLs with LED based lamps and T5 FTLs (IEA, 2010).

Maldives being a chain of islands with about 40% of population living in capital city of Male. The street lighting in Male city which primarily consist of 40W FTLs has been upgraded to 24W LED based street lighting with the support of government of India in 2017. EESL of India has successfully implemented the energy efficiency street lighting project in the Male city (EESL, 2021).

Figure- 15: Street Lighting of Male city of Maldives

Source:https://en.sun.mv/65357

For other island, the Maldives is planning to install 25,000 solar based street lighting with the support of EESL of India (EESL, 2021).

2.3.5 Nepal

Nepal has adopted its National Energy Efficiency Strategy (NEES) in 2013, in which lighting was one of the focus areas along with other sectors such as power generation & distribution, industries, building, transportation. With regard to street lighting Alternate Energy Promotion Council (AEPC) of Nepal has developed Project Management, Technical & Procurement Guidelines for Municipalities for solar street lighting in 2014. AEPC has also developed Technical Guidelines for solar steer lighting in 2016. Kathmandu Metropolitan City (KMC) has implemented solar street lighting project by replacing 1600 street lights with solar street lighting in 2014 with the support of ADB. It also installed 1,285 solar based street lights in 2016 with Public-Private Partnership (PPP) model (Post, 2021). Other cities like Lalitpur and Pokhara had also installed solar street lighting during 2014 to 2016. However, many of these street lights are dis-functional due to lack of maintenance especially with respect to battery replacement. At present solar street lighting is pursued by AEPC in rural municipalities such as Phikkal in 2019 (RERL, 2019).

Figure- 16: Solar Street Lighting of Kathmandu city of Nepal [16]

The apparent failure of solar street lighting projects in Nepal cities appear to be more on account of lack of suitable contractual frame work and enforcement to maintain the solar street lighting assets and replacement of batteries during the agreed project period of 10 years in PPP model. It is not clear as to whether the ADB supported street lighting project of 2014 had provisions for battery replacement. The crucial lessons from Nepal's solar street lighting projects are in respect of contractual and budgetary provisions for O&M of system components and replacement of batteries during the project period. Such requirements had been clearly documented in AEPCs Project Management, Technical & Procurement Guidelines for Municipalities for solar street lighting of 2014. The municipalities could have taken enough steps based on the advice of AEPCs document.

Presently, the major cities of Kathmandu, Lalitpur, Barthpur, Pokhara have been perusing EE street lights with smart controls. The existing metal halide and HPSV lamps are replaced with LED lamps.

[16] Source: https://kathmandupost.com/national/2020/07/29/lalitpur-to-install-669-smart-electric-street-lamps-on-three-routes

Solar street lighting can still be pursued given the technology development and price drops in LED lamps and solar panels and battery. The suitable enforcement mechanisms and budget in contracts for end-of-life replacement of batteries could ensure that project would be operated for the agreed time period (10 years) after which fresh contracts can be executed based on the best available technology and prices at that point.

2.3.6 Pakistan

In 2021, Pakistan communicated its INDCs and mentioned that it intends to reduce up to 50% of its 2030 projected GHG emissions. The INDC communication mentioned replacement of incandescent bulbs with energy efficient LED lamps as one of the mitigation measures from Energy Sector to meet the target towards its INDCs.

National Energy Efficiency and Conservation Authority (NEECA) has conducted Market Assessment for Lighting Sector in Pakistan in 2018. As per the market-based survey of NEECA, only 1.2% of LED components imported are for street lighting and the balance is for other sectors such as domestic and commercial buildings. The street lights imported are mostly from China (83%). Pakistan also imports LED lights from other countries such as Finland, Germany, Thailand, Japan, UAE and Korea. The data indicates that Pakistan has already initiated energy efficiency projects in street lighting.

Capital Development Authority (CDA) has replaced 339 number of conventional street lights with modern LED Road lights in the areas of Islamabad (Today, 2017). CDA also installed 516 number of LED street lights on different roads of Islamabad city in 2017 (Today, 2017). CDA also intends to replace the conventional lamps with energy efficient LED lights throughout the city of Islamabad in different phases. Presently CDA is considering replacement of about 38,000 conventional street lights with LED based lamps (with smart controls) under ESCO model (NEECA, 2020).

Figure- 17: Road Lighting of Islamabad city of Pakistan[17]

[17] Source: http://www.cbc.gov.pk/en/street-light

Source: http://www.cbc.gov.pk/en/street-light

The government of Pakistan had installed 563 number of LED based street lights of 180W each along the Peshawar Karachi Motorway (PKM) expressway in 2019 built by 7th Bureau of Hydropower (iFLUX, 2021). Cantonment Board of Clifton, Karachi has 12,990 number of street lights in which 876 numbers are replaced with LED (CBC, 2021). Similarly, Cantonment Board of Lahore has also replaced 260 number out of 11750 number of conventional street lights with LED street lights.

In 2015, 14 W solar street lights were installed at commn places of village Shafi Muhammad and village Hashim Mir Bahar, UC Gharo, Tehsil Mir Pur Sakro, District Thatta under Sindh Coastal Development Programme (SCAD) funded by The World Bank. In 2020, Government of Khyber Pakktunkhwa initiated the project to install 105 solar street lighting systems in merged districts of Khyber Pakktunkhwa (KPK, 2020). Government of Balochistan has also plan to install solar street lighting systems in the main cities of province (Business Recoder, 2021).

2.3.7 Sri Lanka

Sri Lanka has formed its National Energy Policy & Strategy (NEP&S) in 2008, which specified the energy efficiency in street lighting as one of the focus areas for energy efficiency besides household, industries and commercial sectors. A strategic plan for street lighting was intended to form to ensure proper management of street lighting that will contribute to energy conservation.

The Ceylon Electricity Board (CEB) has conducted a street lighting lamps survey in 2010, which releals that there are 390,000 street lights (IEI, 2015). The details of lamp fixtures in Sri Lanka as per the street lighting survey are presented in Table- 6

Table- 6: Details of Lamp Fixtures used in Sri-Lanka Street lighting survey[18]

Type of fixture	Incandescent Bulbs	FTL	CFL	MV	SV
Number	33,024	84,825	120,567	133,044	16,635
Wattage	100	40	23	150	250

From the street lighting survey, CEB identified three options which helps to reduce the street lighting energy consumption, such as

- Replacement of all existing street lamps by equivalent LED fixtures;
- Replacement of all existing street lamps by solar powered LED lighting system;
- Introduction of proper street lighting control system.

As per NEP&S of 2019, the government of Sri Lanka intends to introduce and enforce standard for street lighting, in rural, urban and major roads and public spaces on a mandatory basis by 2020[19] (MoPEBD, 2019).

Energy Sector Assessment, Strategy, and Road Map of 2019 mentions the key issues relating to street lighting in Sri Lanka which are as under:

- The majority of street lighting equipment are of poor quality and badly maintained resulting in very high energy wastage;
- Use of incandescent lamps with very poor efficacy;
- A high portion of lamps are fitted in very poor-quality luminaires with a very low coefficient of utilization;
- There is no consistency in types of lamps, luminaire, overhang arms, and height of luminaires;
- Poor quality and use of manual control and quite often indoor-quality control equipment exposed to rain, for controlling the street lighting result not only in creating life hazard situations, but also wasting energy by leaving the lights on during the daytime;

[18] Source: Analysis on Energy Efficiency and Optimality of LED and Photovoltaic Based Street Lighting System (IEI, 2015)
19 At the time of preparation of report, the said enforcement standard has not been prepared.

- Very high uniformity ratio level;
- Very low lamp life and very high lumen depreciation factor;
- Absence of separate feeders for street lighting which make it difficult to control and meter;
- Majority of street lighting lamps are controlled individually either through daylight sensors or by manually controlled switches;
- Manually controlled lights operated by either local government staff or volunteers, are usually turned on early and turned off later than necessary.

On account of poor financial situation of municipalities, the cost of electricity supplied for street lighting was not recovered by electricity utility (CEB). Instead CEB recovers cost of energy supplied for street lighting from other consumer categories. Thus, the municipalities do not feel the heat of higher cost of operation of street lighting due to inefficient fixtures. However, the concerns of climate change, mandate of lighting standards for street lighting and pressure from consumer groups are driving cities in Sri Lanka to implement EE in street lighting.

In 2020 Colombo Municipal Council (CMC) initiated project to upgrade 12,000 conventional street lighting system to LED based street lighting system with IoT based smart controls under PPP model (Morning, 2021).

Figure- 18: Road Lighting Galle Road in Colombo City of Sri Lanka[20]

[20]Source: https://www.ft.lk/propertyconstruction/CMC-s-energy-efficient-Smart-LED-street-lighting-drive-progressing/10516-707809

Presently, there have been no major initiatives in respect of solarization of street lighting in Sri Lanka. However, the PPP model of CMC can pave way for similar initiatives in solar based street lighting projects in Sri Lanka.

2.3.8 Implementation Status of Technologies in SAARC Member States

Efficiency enhancement and solarisation of street lighting in Member States in terms of guiding policies, penetration of technology and implementation status has been discussed in previous sections. The Table- 7 summarises the overall status of key technologies under implementation in various SAARC Member States.

Table- 7: Key technologies under implementation in various SAARC Member States

and	Country	LED lighting Fixtures	Control & Monitoring		Solarisation of Street Lighting
			Smart Control	Other Controls	
1	Afghanistan	✓	-	✓ (Manual)	✓ (pilot studies)
2	Bangladesh	✓	✓	✓ (Manual)	✓ (pilot studies)
3	Bhutan	✓	✓	✓ (Manual)	-
4	India	✓	✓	✓ (Manual)	✓
5	Maldives	✓	✓	✓ (Manual)	✓ (under planning)
6	Nepal	✓	✓	✓ (Manual)	✓ (pilot studies)
7	Pakistan	✓	✓	✓ (Manual)	✓ (pilot studies and outdoor lighting of gated communities)
8	Sri Lanka	✓ (Under implementation)	✓ (Under implementation)	✓ (Manual)	-

Source: Research by East Coast Sustainable

2.3.9 Electricity Demand and Energy Saving Potential of Street Lighting in SAARC Region

Electricity demand for street lighting in SAARC region has been estimated for the period 2021 – 2030 considering 3 scenarios as under:

- **Scenario-1: Business As Usual (BAU)**
  The electricity consumption for street lighting in base year has been projected for the period 2021 – 2030 considering CAGR based on actual data, CAGR of road length or urbanisation.
- **Scenario-2: Efficiency Enhancement with LED based EE fixtures with smart controls**
  This scenario projects the energy consumption for street lighting considering a conservative savings of 50%[21] from baseline for the fixtures converted from conventional lamps to LED based lamps with smart control and monitoring system. It is assumed that the Member States would achieve 100% of this conversion by 2027 and all new additions of street lights would be based on this technology.
- **Scenario-3: Solarisation of street lighting with LED based lighting and smart controls**
  This scenario is based on assumption that the solarisation will be adopted by Member States commencing from 2024 and would reach 90% by 2029. It is assumed that above 10% of street lights may not be amenable for solarisation and would remain to be fed by the grid.

Based on assumptions in above scenarios, the energy saving potential with respect to baseline street lighting energy consumption in Scenario-2 and Scenario-3 over a period of 10 years is summarised for SAARC Member States and presented in the Table- 8 and the detailed energy demand projection and saving potential is presented as Annexure:2.

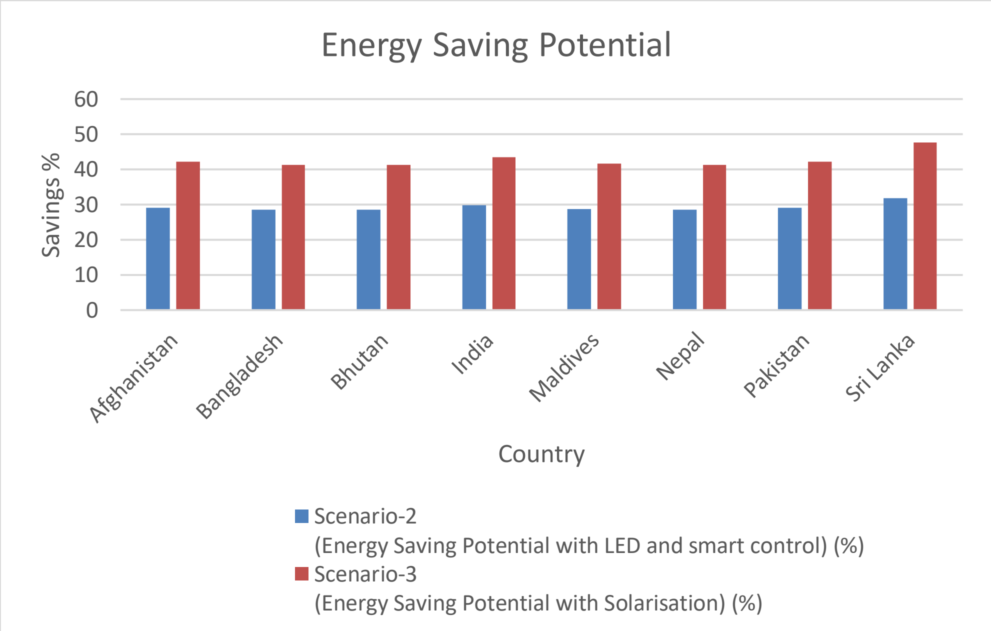
Table- 8: Energy saving potential with respect to BAU street lighting energy consumption

Country	Scenario-2 (Energy Saving Potential with LED and smart control) (%)	Scenario-3 (Energy Saving Potential with Solarisation) (%)
Afghanistan	29.14	42.29
Bangladesh	28.60	41.36
Bhutan	28.52	41.22
India	29.87	43.53
Maldives	28.77	41.66
Nepal	28.52	41.22
Pakistan	29.14	42.29
Sri Lanka	31.81	47.73

Source: Research by East Coast Sustainable

[21] Based on presentation received from Mr Srinivasa Chari E of GHMC who verified the savings of EESL project in Hyderabad, India

Figure- 19: Energy saving potential with respect to BAU street lighting energy consumption



2.4 Implementation Models for EE in Street Lighting Projects

Despite good potential for EE improvements, municipalities face significant challenges in the implementation. These challenges primarily related to project funding/financing, contractual enforcement to cover technical performance risks, ownership of the project throughout the project life. Various implementation models have been in use for EE improvements in street lighting and the same are discussed briefly in this section.

The implementation models for the EE street lighting projects largely vary by the type of financing models chosen. The primary financing options available for cities to finance EE projects are via internal funding through capital budgets, debt financing (mostly loans and lease) and via energy performance contracts (shared and guaranteed savings). The Municipal EE Street lighting project implementation can be financed in three ways

- The municipality uses its internal funds such as O&M budget and capital budget
- The municipality borrows from financial institutions
- The Energy Saving Company (ESCO) brings the finance and implements agreed upon energy saving measures

This section focuses on two implementation models as under (Bank W. , Energy-Efficient Street Lighting—Implementation and Financing Solutions, 2015)

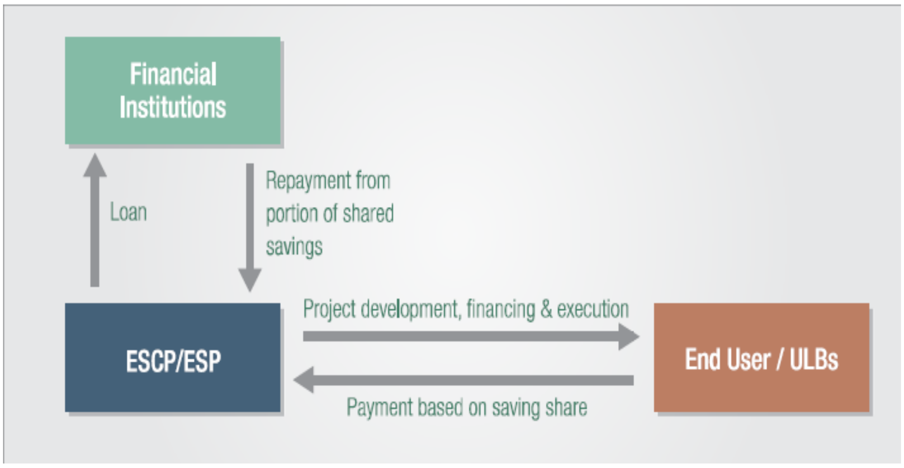
a. **Model-1**: Municipality procuring finance from a financial institution to contract with an ESCO/OEM to implement the Energy Efficiency Project on a turnkey basis.

b. **Model-2**: Public-Private Partnership–based Models- ESPC[22] approach (ESCO financing the Energy Efficiency Project implementation under an Energy Performance Contract). Under this the following models are used for implementation

   i. **ESPC Shared Saving Model:** The ESCO takes on the risk of third-party financing from a lender, putting the loan on ESCO's balance sheet. The savings are shared between the municipality and ESCO with the pre-defined and agreed contract stipulating that the municipality will receive a certain percentage of savings, but it does not guarantee the magnitude of those savings.

[22] Energy Service Performance Contract

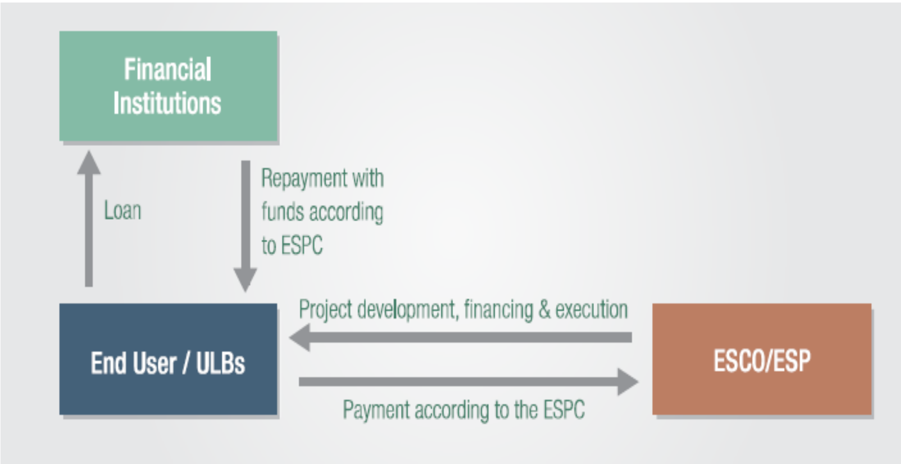
Figure- 20: ESPC Shared Saving Model



Source: (Bank W. , Energy-Efficient Street Lighting—Implementation and Financing Solutions, 2015)

ii. **ESPC Guaranteed Saving Model:** The ULBs takes on the third party financing from a lender, putting the loan on its own balance sheet. The ESCO guarantees that savings will be sufficient to cover the investment cost, and if they are not the ESCO pays the difference between the realized savings and project payments. Excess savings can be shared between municipality and ESCO.

Figure- 21: ESPC Guaranteed Saving Model



Source: (Bank W. , Energy-Efficient Street Lighting—Implementation and Financing Solutions, 2015)

iii. **Annuity-Based Deemed Saving Model:** Under this model it can be ensured that the best available technology is retrofitted with an overall cost saving to the Municipal Corporations (MCs)/ ULBs. This model does not require periodic demonstration of energy and cost savings. The cost saving is recovered from the combined expenditure of MC/ULB on electricity bill and O&M charges. This model is used by EESL of India, which is successfully implementing SLNP programme for all cities in India and also rural areas in India (Bank W. , 2015). The key steps involved in EESL's implementation model is presented as Annexure:3.

2.5 Life Cycle Costs of Street Lighting Systems in SAARC Region

Evaluation of EE improvement project in street lighting system would require cost information related for LED luminaires with fixtures, Control & Monitoring system and solar based street lighting package. The operating cost would involve cost of electricity, replacement cost of conventional lighting fixture with LED fixtures, O&M cost for man power and spares to attend repairs and maintenance.

2.5.1 Capital Cost

The capital cost information for various wattage of LED based street lighting fixtures, CCMS and solar based street lighting have been collected from OEMs, municipalities and other government agencies working, bidding results of EESL (India) and presented in the Table- 9

Table- 9: Capital costs of LED Fixtures and CCMS

Item	Units	Price range[23]
18 W LED	USD	12 - 25
20 W LED	USD	13 - 28
32 W LED	USD	14 - 43
35 W LED	USD	16 - 46
40 W LED	USD	17 - 58
45 W LED	USD	17 - 62
60 W LED	USD	25 - 88
70 W LED	USD	26 - 96
90 W LED	USD	33 - 125
110 W LED	USD	37 - 145
190 W LED	USD	65 - 300
200 W LED	USD	66 - 305
Control & Monitoring System 1-phase	USD	237
Control & Monitoring System 3-phase	USD	272

It is observed that the price of LED based street lighting varies widely with price dependent on quantity purchased. The lower price of the band is mostly from EESL procurement of large quantities. The pricing of CCMS varies with quantity and warranty required. For example, CCMS with 10 years warranty may cost 15 to 20% more compared to that with warranty of 7 years[24].

The capital cost of solar PV based standalone system with 2 days battery backup has been collected from OEMs. The prices may drop depending on the order quantity.

[23] OEMs, municipalities and other government agencies
[24] East Coast Research

Table- 10: Rating of Module size and Battery storages for different lamp sizes[25]

Lamp Size (Watt)	Minimum Solar PV Module Size (Wp)	Minimum Battery Size for Lead Acid (AH)	Minimum Battery Size for Lithium Ion (AH)	Minimum Charge Controller Size (A)	Height of pole in meter	Price Range (USD) approx.
10	50	40	30	5	7	475
20	100	60	45	10	7	665
30	150	80	60	12	7	926
40	200	100	75	15	8 or 9	959
60	300	150	115	25	8 or 9	1048
80	400	200	150	30	10	1088
100	500	250	180	40	10	1288

Source: (AEPC, 2016) *and OEMs*

2.5.2 Operating & Maintenance Cost

Electricity is one of the major costs in operation of street lighting system and often the reason for financial hot-ship of municipalities and one of the major drivers for EE projects in municipal sector. The electricity tariff for street lighting in SAARC Member States is presented in the Table- 11.

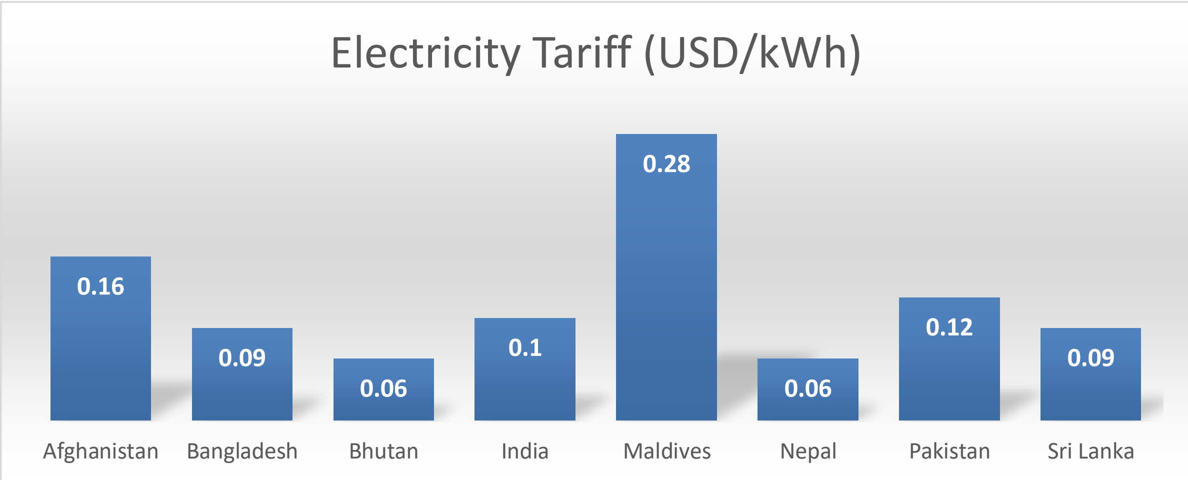
Table- 11: Electricity tariff for street lighting in SAARC Member States

Country	Electricity Tariff[26]	
Afghanistan	13.8 AFN/kWh	0.16 USD/kWh
Bangladesh	7.7 BDT/kWh	0.09 USD/kWh
Bhutan	4.1 BTN/kWh	0.06 USD/kWh
India	7.5 INR/kWh	0.1 USD/kWh
Maldives	4.4 MVR/kWh	0.28 USD/kWh
Nepal	7.3 NPR/kWh	0.06 USD/kWh
Pakistan	20.6 PKR/kWh	0.12 USD/kWh
Sri Lanka	17 LKR/kWh	0.09 USD/kWh

[25] Battery capacities are estimated based on 80% DOD for Li Ion and 50% for Lead Acid batteries respectively and 2 day autonomy with 12 hours/day operation

[26] Afghanistan: https://main.dabs.af/KabulElectricitytariff
Bangladesh: https://dpdc.org.bd/article/view/52/Tariff
Bhutan: https://www.bpc.bt/electricity-tariff/
India: GHMC officials' data
Maldives: https://www.stelco.com.mv/tariff-rates#tariff-rates-government-institutes
Nepal: Nepal Electricity Authority Annual Report 2020-21
Pakistan: https://iesco.com.pk/index.php/customer-services/tariff-guide
Sri Lanka: https://ceb.lk/tariff_catergory/en

Figure- 22: Electricity tariff pattern of street lighting in SAARC Member States



Source: Research by East Coast Sustainable

The variation in electricity tariff among SAARC Member States is the single most reason that would dictate the financial viability of EE / solarization projects.

The EE / solarization in street lighting would involve replacement of old conventional fixture with LED fixtures that would be part of O&M cost. The longer life of LEDs and CCMS would ensure a cost-efficient maintenance for LED based street lighting visa-vi the conventional lamps with manual control. The typical cost for replacement is around 4 USD per fixture. This may increase when number of fixtures to be replaced reduces. Similarly, the O&M cost for repairs and maintenance for conventional lighting fixtures with manual control is ranges between 10 - 25 USD per fixture and that for LED with smart control ranges between 2 – 15 USD[27].

The experience with large scale LED street lighting with smart control projects reveal that the O&M cost for repairs and maintenance can reduce by 5 times on account of longer life of LED and the productivity improvement with IoT based CCMS. The benefit of CCMS increases as the scale of operation increases. This is an additional benefit of CCMS / smart controls in addition to incremental energy savings.

2.6 Quality Control and Standards

Quality and performance standards are of importance for EE projects in street lighting whether they are implemented through funding of municipalities, through support of external agencies or through ESCO / PPP model. The quality and performance standards have been developed to ensure safety of motorized and pedestrian traffic, improving comfort to drivers in terms of lighting and glare reduction and energy efficiency.

[27] Refer Chapter-3

2.6.1 International Standards Relating to Street Lighting

International standards and guidelines applicable for street and outdoor lighting and traffic lighting are listed in the Table- 12 (PWC, 2017):

Table- 12: International standards and guidelines applicable for street and outdoor lighting

Description	Standard
Glare and Uniformity in Road Lightings Installations	CIE 31-1976
Depreciation of Installation and their Maintenance (in Road Lighting)	CIE 22-1977
Road Lighting for Wet Conditions	CIE 47-1979
Light Signals for Road Traffic Control	CIE 48-1980
Road Surfaces and Lighting (Joint Technical Report CIE/PIARC)	CIE 66-1984
Road Lighting as an Accident Countermeasure	CIE 93-1992
Design Methods for Lighting of Roads	CIE 132-1999
Road Lighting Calculations	CIE 140-2000
Guide to the Lighting of Urban Areas	CIE 136-2000
Road Surface and Road Marking Reflection Characteristics	CIE 144-2001
Recommendations for the Lighting of Motorized Traffic (updated)	CIE 115-2007
Technical Report: Road Transport Lighting for Developing Countries	CIE 180-2007
Lighting of Roads for Motor and Pedestrian Traffic	CIE 115-2010
Recommended System for Mesopic Photometry Based on Visual Performance	CIE 119-2010
Road Lighting—Part 1: Selection of Lighting Classes	CEN/TR 13201-1
Road: Lighting—Part 2: Performance Requirements	EN 13201-2
American National Standard Practice for Roadway	ANSI/IESNA RP-8-00
Road Lighting—Vehicular Traffic Lighting	AS/NZS 1158.1/1-1997
Standards Association of Australia (SSA) Public Lighting Code—Lighting of Minor Streets	AS 1158.2-1971
Australian Standard Rules for Street Lighting	AS CA19-1939
Crystalline silicon terrestrial photovoltaic (PV) modules - Design Qualification and type approval	IEC 61215 (2nd Edition)
PV module safety qualification	IEC 61730

Source (PWC, 2017)

2.6.2 Illuminating Engineering Society of North America (IESNA) Standards for LED testing

- **LM 79-08 and CIE S025/E:2015:**

Illuminating Engineering Society of North America (IESNA) has developed a global test standard of LM 79-08 for photometric and electrical properties of LED.

Many of the national standards could not opt the IESNA LM79-08. Hence CIE has published CIE S 205/E:2015 based on global representation and covers more measurement instruments and has greater depth.

- **LM 79-08:** It is used to measure lumen maintenance of LED light sources. The report provides luminous flux for a given current over a 6000-hour period. It is conducted for 3 different LED case temperatures: 55°C, 85°C and a 3rd temperature selected by the manufacturer.
- **TM 21-11:** It is the approved method by IESNA for taking LM-80 data and make useful lifetime projections for LED luminaires

In Situ Temperature Measurement Test (ISTMT): It is the measure of the LED source temperature within the LED system. It is used to check whether the temperature of the luminaire is within the temperature of the LM 80-08 report and it forms the basis for determination of LED lifetime based on TM 21-11 or any other method.

2.6.3 Standards for LED based Lighting:

Some of the specific standards for LED lighting for safety and performance of LED luminaire listed in the Table- 13. These standards have been adopted by SAARC Member States such as India for their SLNP programme by EESL.

Table- 13: General Lighting Standards

Sr No	Standards Title	International Standards
1	Terms and Definition	IEC 62504 TS
2	Self-ballasted LED lamps for general lighting services Part 1, Safety Requirements	IEC 62560
3	Self-ballasted LED lamps for general lighting services Part 2, Performance Requirements	IEC 62612
4	LED modules for general lighting— Safety Specifications	IEC 62031
5	LED modules for general lighting Part 2, Performance Requirements	IS 16103(Part2)
6	DC- or AC-supplied electronic control gear for LED modules—Performance Requirements	IEC 62384
7	Method of measurement of lumen maintenance of solid-state light (LED) sources	LM 80
8	Electrical and Photometric Measurements of Solid-State Lighting Products	LM 79
9	LED luminaires for general lighting purpose's part 1, safety requirements	34D/950/NP
10	LED luminaires for general lighting Part 2, Performance requirements	34D/977/DC
11	Photo biological Safety of LED and LED systems	IEC 62471

Source: BIS 1981 (PWC, 2017)

2.6.4 Road Classification, Recommended Lux levels and Luminaire Mounting Height

Based on various international standards, the SAARC Member States have adopted standards for pole height and lux level for various types of roads. The following Table- 14, Table- 15, Table- 16 provide details of road classification, specification for street lighting poles and recommended lux level with mounting height of luminaire adopted in India. Most of SAARC Member States also follow the same standards and specifications as they have been adopted from international standards.

Table- 14: Classification of the Roads

Group	Description
A1	For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of drivers
A2	For main roads with considerable mixed traffic like main city streets, arterial roads, and thoroughfares
B1	For secondary roads with considerable traffic such as local traffic routes, and shopping streets
B2	For secondary roads with light traffic
C	For residential and unclassified roads not included in the previous groups
D	For bridges and flyovers
E	For towns and city centres
F	For roads with special requirements such as roads near airports, and railways

Source: BIS 1981 (PWC, 2017)

Table- 15: Specifications for Street Lighting Poles

Section	Overall length 11 m + 25 mm (base plate)			Overall length 9.5 m +25 mm (base plate)		
	Outside Diameter (mm)	Thickness (mm)	Length (mm) Outside D	Outside Diameter (mm)	Thickness (mm)	Length (mm) Outside D
Bottom section	139.7	4.85	5600	165.1	4.85	5000
Middle section	114.3	4.5	2700	139.7	4.5	2250
Top section	88.9	3.25	2700	114.3	3.65	2250
Planting depth	1800 mm			1800 mm		
Nominal weight of the pole	160 kg			147 kg		
Tolerance on mean weight for bulk supply is 7.5 %						
Tolerance for single pole weight is 10%						

Source: BIS 1981 (PWC, 2017)

Table- 16: Recommended Levels of Illumination and Mounting Height of Luminaires

Type of Road	Road Characteristics	Average Level of Illumination on Road Surface (Lux)	Ratio of Minimum /Average Illumination	Type of Luminaire Preferred	Min: Max (%)	Type of Luminaire Preferred (m)
A1	Important traffic routes carrying fast traffic	30	0.4	Cut-off	33	9 to 10
A2	Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cut-off	33	9 to 10
B1	Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cut-off or semi-cut-off	20	7.5 to 9 meters
B2	Secondary roads with light traffic	4	0.3	Cut-off or semi-cut-off	20	7.5 to 9

Source: BIS 1981 (PWC, 2017)

2.6.5 Typical Specifications of Street Lighting System

This section provides typical specifications of street lighting system components such as LED, Control & Monitoring System (CCMS) and Solar panel and Battery (in case of solar based street lighting system) that are being used in few SAARC Member States such as India and Nepal. The specifications for LED based street lighting, IoT based Centralized Control and Monitoring System (CCMS) have been derived from the international competitive bidding documents of EESL (of India) which has successfully implemented EE in street lighting in India and other SAARC countries by installing more than 100 million street lights and more than 3 million CCMS units to connect and control the street lights with IoT based systems. Similarly, Nepal has taken lead in development of specifications and system configuration for solar based street lighting which have been used in the bidding process. The SAARC Member States can take advantage of such specification as a ready reckoner. Such specifications would help to emulate in improving the EE in street lighting based on learning from other Member States. The detailed technical specifications for LED, CCMS and SSL is presented as Annexure:4.

2.7 Selection of Municipality and SWOT Analysis

One city town / municipal area has been selected from each of the SAARC Member States for preparing case studies for each of the major technological interventions under Case-1 (LED based EE lighting fixtures), Case-2 (LED based EE lighting fixtures with smart controls) and Case-3 (Solarization of street lighting with LED and smart control). The selection of cities for each Member State is based on ease of access of the data, impact of EE improvements. Cities which are yet to implement EE projects or where implementation is in planning/underway have been preferred over cities which have completed the LED based EE improvement projects in street lighting. Further, the cities selected for case studies are also diverse in terms of size (i.e, population, number of street lights and existing lighting technologies) that would validate the relevance and viability of EE improvement in street lighting in SAARC region. The details of cities selected with their respective strengths and weakness are presented in the following Table- 17.

Table- 17: SWOT Analysis of Selected Municipalities

S No	Country	City /municipality selected	Selection Criteria	SWOT
1	Afghanistan	Kabul	Ease of Access of Data	**Strengths:** Capital and largest city of Afghanistan and municipality in Kabul province. **Weakness:** The primary weakness of the city may be the poor availability of Grid electricity and poor availability of funds **Opportunities:** EE improvements in street lighting not only improves the financial status of the municipality but also provides a positive image of the Capital city besides GHG reduction. The energy savings from street lighting project also mean that the saved energy can be distributed to other consumers improving the access to electricity. The energy savings in municipality also would improve ability of the municipality to extend and improve street lighting services in the city. **Threats:** Afghanistan also indicated that implementation of its INDCs/NDCs is conditional on receiving external funding for such climate change related projects.
2	Bangladesh	Chittagong	Ease of Access of Data and Second largest city after Capital city of Dhaka	**Strengths:** Chittagong is the largest port city in Bangladesh and second largest city after the Capital city of Dhaka. Chittagong thrives on the business and industry houses. **Weakness:** The low electricity tariff may be the only impediment that may come in the way for EE improvement projects in Bangladesh especially for solar street lighting. **Opportunities:** Partnership with ESCOs and private sector companies from SAARC Member States funding for large scale replication from international organisations. **Threats:** High subsidy/grant required for viability especially for solarization projects.
3	Bhutan	Gelephu	Small City with less than 2000 street lights. EE in street lighting is under implementation	**Strengths:** Gelephu municipality is one of the few urban centres in Bhutan. It represents small town aspirations of SAARC Member States wherein it is competing with other bigger towns and cities in terms of EE improvements in street lighting. Despite low electricity tariffs and funding issues, Gelephu is on its way in implementing EE projects in street lighting in a phased manner. **Weakness:** Limited financial resources forcing the implementation in phases despite size of the municipality is small in comparison to other cities. Difficult geographical terrine that may come in the way of solarization. **Opportunities:** The success of Gelephu in EE street lighting projects is vindicates that the barriers to EE (such as lower scale of operation, funding issues, difficult geographical terrain) can be overcome by the determination of municipal administrators. **Threats:** Difficult weather conditions especially in winter that may effect solarization.

S No	Country	City /municipality selected	Selection Criteria	SWOT
4	India	Hyderabad	One of the projects of EESL	**Strengths:** Hyderabad is one of the largest metro cities in India and Capital of a State/Provence of Telangana. The large scale of operation of municipal systems of Hyderabad has been beneficial in breaking the price barriers of LED lighting and helped EESL to replicate the success in other cities. **Weakness:** The key issues faced by the city were lack of accurate data about fixture wattage and number and lack of energy meters for bill payments. The city was paying electricity bills based on estimates by Distribution company/electrical utility. This is overcome by the energy meters and validation by fixture data and operating hours data from CCMS. **Opportunities:** Development of innovate indigenous control and monitoring system based on IoT technology for street lighting that has helped to automate the controlling functions required for street lighting and as productivity multiplier resulting in reduction in O&M cost. **Threats:** Inadequate and improper baseline. Mixed load feeders resulting in voltage surges effecting the lighting and control system.
5	Maldives	Male	Ease of Access of Data	**Strengths:** Male is the Capital city and also tourist city where the 40% of the total population lives. **Weakness:** Maldives needs financial assistance to upgrade its street lighting infrastructure. The other major barrier/weakness is the number of islands with limited access to electricity which the Maldives may turn into an opportunity for solar based street lighting systems. **Opportunities:** Tourism being one of the key economic activities of the Maldives, the street lighting is a key and strategic infrastructure in providing safe, secure environment for the city. The upgradation of street lighting infrastructure is also key to reducing energy consumption which is mostly generated by Diesel Engines. **Threats:** Poor financial status. Prone to cyclones/typhoons that may effect the street lighting infrastructure especially with respect to solar PV panel of street lighting. Poor internet connectivity that may effect operation of smart controls.
6	Nepal	Kathmandu	Ease of Access of Data and Capital City	**Strengths:** Kathmandu is the Capital city of Nepal and represents aspirations of people of Nepal. Nepal has hands on experience both EE projects and solarisation projects. It has been very progressive by implementing pilot projects on solar street lighting system and now perusing EE projects based on LED lamps with smart controls. **Weakness:** Poor financial status of municipality.

				Opportunities: The lessons from Kathmandu in respect of solar street lighting are relevant for all SAARC Member States in respect of consideration of costs for battery replacement, contractual enforcement of conditions on partners in PPP model. Despite initial setbacks of solar street lighting projects, Nepal can still pursue such projects by learning lessons from its own failures. **Threats:** No established ESCOs in government and private sector.
7	Pakistan	Islamabad	Ease of Access of Data and Capital City and EE in street lighting is under active consideration by CDA	**Strengths:** The Federal Capital of Pakistan represents one of the largest cities of Pakistan. **Weakness:** Lack of sufficient funds for large scale implementation of EE/solarization of street lighting. **Opportunities:** EE projects in street lighting can be implemented both with the funds of CDA and private sector ESCOs. **Threats:** Dependent on few ESCOs in private sector.
8	Sri Lanka	Colombo	Ease of Access of Data and Capital City and EE in street lighting is in the initial state	**Strengths:** Colombo is the Capital and largest city of the Island Nation and key to the economy of the country. **Weakness**: The electricity charges of street lighting are not paid by the municipality but by electricity consumers through the retail tariff. Thus, the municipalities do not have financial driving force to make the system energy efficient. But the pressures of climate change and consumer group are driving EE projects in street lighting in Colombo and other cities of Sri Lanka. **Opportunities:** EE implementation through ESCO/PPP model that is expected to bring in latest technologies such as IoT based smart controls to the street lighting sector. **Threats:** There is no financial driver or force on municipalities to enhance EE in street lighting as cost is born by other electricity consumers.

Source: Research by East Coast Sustainable

2.8 Street Lighting Electricity Consumption of Selected Municipalities

The existing electricity consumption of street lighting in municipalities selected for case study is estimated from lighting fixtures data (wattage and number) and average burning hours and presented in the following Table- 18.

Table- 18: Existing Energy Consumption of Street lights in SAARC Member State[28].

S No	Country	City/municipality selected	Number of Street Lights (approximate Number)	Energy Consumption for Street Lighting (MU/year)
1	Afghanistan	Kabul	16,500	10.84
2	Bangladesh	Chittagong	33,950	8.85
3	Bhutan	Gelephu	1,652	0.54
4	India	Hyderabad	420,927	245.00
5	Maldives	Male	2,500	0.33
6	Nepal	Kathmandu	16,100	7.29
7	Pakistan	Islamabad	38,000	10.95
8	Sri Lanka	Colombo	23,238	13.21

Source: Research by East Coast Sustainable

The detailed breakup of lighting fixtures for different types of luminaires is presented as part of case study in Chapter-3.

[28] Refer Chapter-3 for detailed sources of data and calculations

3 Techno-Financial Assessment of Street Lighting Project

The techno-financial analysis has been carried out for the following cases:

Case-1: Replacement of conventional lighting fixtures with LED based EE lighting system without CCMS: Under this case, the conventional lamps would be replaced with LED based lamps. It is assumed that the existing lux levels delivered by conventional lamps are sufficient and the rating of LED is chosen to maintain the same lux level. The energy savings would accrue from difference in wattage of the lamps. No separate smart control system has been considered under this case. The control of the individual lamps after implementation would be same as it was in the baseline case which may be manual switch ON/OFF.

The energy savings and cost savings are estimated for project period of 10 years. With regard to investment, we need to consider investment towards replacement of failed lamps as well as investment for end-of-life replacement besides the original investment. In this case it has been assumed that the failure rate of LED lamps is 2%. There is no investment required for replacement at end-of-life as the life of LED (in terms of burning hours) is more than project life of 10 years.

Case-2: Replacement of conventional lighting fixtures with LED based EE lighting system with CCMS: Under this case, the conventional lamps would be replaced with LED based lamps. It is assumed that the existing lux levels delivered by conventional lamps are sufficient and the rating of LED is chosen to maintain the same lux level. The system would also consist of an IoT based group controller connecting 40 to 50 lamps for controlling and monitoring. The energy savings would accrue from difference in wattage of the lamps as well as from automated and accurate switching ON and OFF based on the time, resulting in additional energy savings. Based on the experience of implementing IoT based control system for street lighting, energy savings on account of avoidance of unnecessary burning of lamps for about 30 – 60 minutes can be achieved. This is due to the fact that manual switching ON/OFF would take some time as well as there are chances of missing switching OFF of few lights due to manual errors or inclement weather conditions or negligence. The additional savings from implementation of control and monitoring system, are estimated at a conservative value of energy corresponding to 30 minutes avoided additional burning per day vis-a-vis the manual switch ON/OFF.

The energy savings, cost savings are estimated for project period of 10 years. With regard to investment, we need to consider investment towards replacement of failed lamps as well as investment for end-of-life replacement besides the original investment of LED. In this case it has been assumed that the failure rate of LED lamps is 2% and the failure rate of CCMS units is 2%. There is no investment required for replacement at end-of-life as the life of LED (in terms of burning hours) is more than project life of 10 years.

Case-3: Solar Based EE Lighting System with CCMS: Standalone retrofit solution based on LED lamps powered by solar PV panel with 3 days power autonomy[29] / backup with 11 hours per day operation is considered under this case. Li-Ion based battery with 80% Depth of Discharge (DoD) The system components of LED lamp and solar panel would outleap the project period of 10 years considered for techno-financial evaluation. Hence no investment has been considered towards end-of-life replacement for these components (except for failed LEDs). However, battery is required to be changed one time during the project life. The system would also consist of an IoT based group controller connecting 40 to 50 lamps for controlling and monitoring of solar based street lights.

[29] Solarization of street lighting is considered with autonomy from grid since poor/low is the main driving force for solarization. There is a viability gap that needs to be funded through subsidy by the governments or grant from the donors. Net metering based solar street lighting system is another technical option where grid is available and reliable. However, the regulatory issues pertaining to energy accounting (i.e., generation in day time and consumption in night time) may not permit net metering for street lighting. Also, the mammoth task of meter installation, meter reading, processing of bills for individual street lights makes net metering based solar street lighting an unpractical option. With net metering, each street light would become a consumer of electricity utility and transaction costs related to meter reading and energy accounting makes this option unviable. However, some municipalities (e.g., Visakhapatnam, India) have installed centralised solar PV power plants to offset part of their electricity consumption (including consumption for street lighting) from the grid. Such option, a supply-side solution, is not specific to street lighting.

3.1 Case Study on Kabul City, Afghanistan

Kabul is the capital city of Afghanistan. The city is spread over 1028.24 sq. km. Kabul is located high up in a narrow valley between the Hindu Kush mountains and bounded by the Kabul River, with an elevation of 1,790 metres (5,873 ft) making it one of the highest capitals in the world.

Figure- 23: Kabul City Roads

Source: https://www.unops.org/afghanistan

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of HPSV/HPMV lamps with LED based efficient street lighting. The techno-financial analysis for Kabul Municipality is based on following macro data and assumptions.

Table- 19: Street Lighting Commercial Data for Kabul Municipality, Afghanistan

Parameter	Units	Value
Exchange rate (1USD)	AFN	85
Electricity Tariff[30]	AFN/kWh	13.8
	USD/kWh	0.16
CAGR of CPI for maintenance cost increase[31]	%	2.3
LED Cost Information		
Cost of 70 W LED[32]	AFN	8,265
	USD	97.24
Cost of CCMS Unit[33] (5 kW)	AFN	23,277
	USD	273.85
Installation Cost of LED[34]	AFN/LED	300
	USD/Unit	4
Installation Cost of Solar Street Lighting Unit[35]	AFN/Unit	600
	USD/Unit	7
Cost of 70W Solar Street Lighting Unit[36]	AFN/Unit	91,066
	USD/Unit	1,071
Failure rate of LEDs[37]	%	2
Failure rate of CCMS Unit[38]	%	2
Weighted average cost of capital (WACC) for the Country[39]	%	2.95%
Discounting Factor[40]	%	2.95%

The techno-financial analysis has been carried out for the following cases:

[30] https://main.dabs.af/KabulElectricitytariff
[31] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD-AF
[32] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[33] EESL (India)
[34] Based on Market trend in SAARC region
[35] Based on Market trend in SAARC region
[36] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[37] Assumption based on general Trend of LED failure
[38] Assumption based on general Trend of CCMS failure
[39] https://www.adb.org/sites/default/files/linked-documents/44444-013-fa.pdf
[40] Considered same as WACC

3.1.1 Case:1 Replacement with LED based EE Lighting System without CCMS

The details of existing and proposed luminaires for the case are presented under Table- 20.

Table- 20: Details of Existing and proposed luminaires in Kabul Municipality

Existing/Baseline/BAU Luminaires		
Type	-	HPSV
Number	Nos	16,500[41]
Wattage	W	150
Proposed Luminaires		
Type	-	LED
Number	Nos	16,500
Wattage	W	70

Source: Research by East Coast Sustainable

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 21 and Table- 22.

Table- 21: Details of Energy Consumption & Savings of Case-1 for Kabul Municipality

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	10,840.50
Average Operating Cost	AFN (Million)/year	209.56 (USD 2.47 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	5,058.90
Average Operating Cost	AFN (Million)/year	83.66 (USD 0.98 Million)
Savings		
Average Annual Energy Savings	MWh/year	5,782
Total Cost Savings	AFN (Million)/year	125.90 (USD 1.48 Million)

Source: Research by East Coast Sustainable

[41] There is no authentic data available on number of street lights in Kabul city. Authors depended on population of Kabul city of 30 – 33 million and people to street lighting pole ration of 200 (typical in medium sized cities of SAARC region)

Table- 22: Results of Case-1 techno financial analysis for Kabul Municipality

Parameter	Units	Value
Total Investment Required	AFN (Million)	171.32 (USD 1.96 Million)
Simple Payback Period	Years	1.25
Internal Rate of Return	%	79%
Net Present Value	AFN (Million)	1,050.64 (USD 12.36 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:5 to this report

3.1.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 23.

Table- 23: Details of Luminaires and CCMS units in Case-2 for Kabul Municipality

Existing/Baseline/BAU Luminaires		
Type	-	HPSV
Number	Nos	16,500
Wattage	W	150
Proposed Luminaires		
Type	-	LED
Number	Nos	16,500
Wattage	W	70
No of CCMS Units	Nos	231[42]

Source: Research by East Coast Sustainable

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 24and Table- 25.

Table- 24: Details of Energy Consumption & Savings of Case-2 for Kabul Municipality

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	10,840.50
Average Operating Cost	AFN (Million)/year	209.56 (USD 2.47 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	5,057.55
Average Operating Cost[43]	AFN (Million)/year	83.66 (USD 0.98 Million)
Savings		
Average Annual Energy Savings	MWh/year	5,782.95
Total Cost Savings	AFN (Million)/year	125.92 (USD 1.48 Million)

Source: Research by East Coast Sustainable

[42] CCMS are rated for 5 kW or 10 kW. Authors considered 5 kW CCMS to estimate number of CCMS units required

[43] The cost of CCMS includes the cost of hardware, software, data and storage. Hence Operating cost under Case-1 and Case-2 are the same. However, the investment required under Case- 1 and Case-2 would be different.

Table- 25: Results of Case-2 techno financial analysis for Kabul Municipality

Parameter	Units	Value
Total Investment Required	AFN (Million)	178.14 (USD 2.10 Million)
Simple Payback Period	Years	1.30
Internal Rate of Return	%	76%
Net Present Value	AFN (Million)	1,049.68 (USD 12.35 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:5 to this report

3.1.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 26.

Table- 26: Details of Luminaires and CCMS units of SSL[44] in Case-3 for Kabul Municipality

Existing/Baseline/BAU Luminaires		
Type	-	HPSV
Number	Nos	16,500
Wattage	W	150
Proposed Luminaires		
Type	-	LED
Number	Nos	16,500
Wattage	W	70
Rating of Solar PV module	Wp	300
Rating of battery for storage	Ah	240
System Voltage	V	24
No of CCMS Units	Nos	231

Source: Research by East Coast Sustainable

[44] Solar Street Lighting

Details of energy consumption and cost savings for Case-3 is presented in the following Table- 27.

Table- 27: Details Case-3 Energy savings, Cost savings for Kabul Municipality

BAU case	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	10,841
Average Operating Cost	AFN (Million)/year	209.56 (USD 2.47 Million)
Savings		
Average Annual Energy Savings	MWh/year	10,841
Total Cost Savings	AFN (Million)/year	169.28 (USD 1.99 Million)

Source: Research by East Coast Sustainable

The Table- 28 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 28: Results of Case-3 techno financial analysis for Kabul Municipality

Results of Case-3 Techno Financial Analysis for Kabul Municipality											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period	Years	9.95	8.96	7.96	6.96	5.97	4.97	3.98	2.98	1.99	0.99
Internal Rate of Return	%	-5%	-3%	0%	3%	7%	12%	19%	30%	49%	101%
Net Present Value	AFN (Million)	922.30	974.45	1,026.59	1,078.74	1,130.88	1,183.03	1,235.17	1,287.32	1,339.46	1,391.61
	USD (Million)	10.85	11.46	12.08	12.69	13.30	13.92	14.53	15.14	15.76	16.37
Total investment by end user	AFN (Million)	2,121.21	1,909.09	1,696.97	1,484.84	1,272.72	1,060.60	848.48	636.36	424.24	212.12
	USD (Million)	24.96	22.46	19.96	17.47	14.97	12.48	9.98	7.49	4.99	2.50
Total programme/Project cost	AFN (Million)	2,121.21	2,121.21	2,121.21	2,121.21	2,121.21	2,121.21	2,121.21	2,121.21	2,121.21	2,121.21
	USD (Million)	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96

Source: Research by East Coast Sustainable

The IRR becomes positive at around 30% of subsidy/grant. Thus, a minimum of 30% subsidy/grant is required to make the project viable. Further 40% - 50% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR. The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:5 to this report

3.2 Case Study on Chittagong City of Bangladesh

Chittagong is large port city on the southeastern coast of Bangladesh. The city is spread over 168 sq. km.

Figure- 24: SSL of Chittagong City Corporation roads[45]

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of Incandescent bulbs, FTLs, HPSV/HPMV and Metal Halide lamps with LED based efficient street lighting.

The techno-financial analysis for Chittagong city is based on following macro data and assumptions.

[45] https://www.daily-sun.com/printversion/details/325380/2018/07/28/Chittagong-City-Corporation

Table- 29: Street Lighting Commercial Data for Chittagong City, Bangladesh

Parameter	Units	Value
Exchange rate (1USD)	BDT	85
Electricity Tariff[46]	BDT/kWh	7.7
	USD/kWh	0.09
CIGR of CPI for maintenance cost increase[47]	%	5.7
LED Cost Information[48]		
Cost of 20 W LED	BDT	2,533
	USD	29.8
Cost of 50 W LED	BDT	5,758
	USD	68
Cost of 70 W LED	BDT	8,177
	USD	96
Parameter	**Units**	**Value**
Cost of 120 W LED	BDT	14,960
	USD	176
Cost of CCMS Unit[49]	BDT	23,034
	USD	271
Installation Cost of LED[50]	BDT/LED	300
	USD/LED	4
Installation Cost of Solar Street Lighting Unit[51]	BDT/Unit	600
	USD/Unit	7
Solar Street Lighting Cost Information[52]		
Cost of 20W Solar Street Lighting Unit	BDT/Unit	56,160
	USD/Unit	661
Cost of 60W Solar Street Lighting Unit	BDT/Unit	89,803
	USD/Unit	1,057
Cost of 70W Solar Street Lighting Unit	BDT/Unit	90,836
	USD/Unit	1,069
Failure rate of LEDs[53]	%	2
Failure rate of CCMS Unit[54]	%	2
Weighted average cost of capital (WACC) for the Country [55]	%	2.1%
Discounting Factor (same as WACC)	%	2.1%

[46] https://dpdc.org.bd/article/view/52/Tariff
[47] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD
[48] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[49] EESL (India)
[50] Based on Market trend in SAARC region
[51] Based on Market trend in SAARC region
[52] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[53] Assumption based on general Trend of LED failure
[54] Assumption based on general Trend of CCMS failure
[55] https://www.adb.org/sites/default/files/linked-documents/44192-016-fa.pdf

3.2.1 Case:1 Replacement with LED based EE Lighting System without CCMS

The details of existing and proposed luminaires for the case are presented under Table- 30

Table- 30: Details of Existing and proposed luminaires in Chittagong City[56]

Existing/Baseline/BAU Luminaires					
Type	Incandescent Bulbs	FTL	Halogen	HPSV/HPMV	Metal Halide
Number	3,500	23,250	3,500	3,500	200
Wattage	100	40	150	100	250
Proposed Luminaires					
Type	LED	LED	LED	LED	LED
Number	3,500	23,250	3,500	3,500	200
Wattage	20	20	70	50	100

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 31 and Table- 32.

Table- 31: Details Energy Consumption & Savings of Case-1 for Chittagong City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	8,853
Average Operating Cost	BDT (Million)/year	101.76 (USD 1.20 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	3,930.69
Average Operating Cost	BDT (Million)/year	46.05 (USD 0.54 Million)
Savings		
Average Annual Energy Savings	MWh/year	4,922.39
Total Cost Savings	BDT (Million)/year	55.71 (USD 0.66 Million)

Source: Research by East Coast Sustainable

[56] *Source: http://ccc.org.bd/street_lighting*

Table- 32: Results of Case-1 techno financial analysis for Chittagong City

Parameter	Units	Value
Total Investment Required	BDT (Million)	156 (USD 1.84 Million)
Simple Payback Period	Years	2.96
Internal Rate of Return	%	34%
Net Present Value	BDT (Million)	473.07 (USD 5.57 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:6 to this report

3.2.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 33.

Table- 33: Details of Luminaires and CCMS units in Case-2 for Chittagong City

Existing/Baseline/BAU Luminaires					
Type	Incandescent Bulbs	FTL	Halogen	HPSV	Metal Halide
Number	3,500	23,250	3,500	3,500	200
Wattage	100	40	150	100	250
Proposed system					
Type	LED	LED	LED	LED	LED
Number	3,500	2,3250	3,500	3,500	200
Wattage	20	20	70	50	120
Number of CCMS units (nos)	196				

Source: http://ccc.org.bd/street_lighting

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 34 and Table- 35.

Table- 34: Details Case-2 Energy savings, Cost savings for Chittagong City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	8,853.08
Average Operating Cost	BDT (Million)/year	101.76 (USD 1.20 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	3,929.58
Average Operating Cost	BDT (Million)/year	46.05 (USD 0.54 Million)
Savings		
Average Annual Energy Savings	MWh/year	4,923.49
Total Cost Savings	BDT (Million)/year	55.72 (USD 0.66 Million)

Source: Research by East Coast Sustainable

Table- 35: Results of Case-2 techno financial analysis for Chittagong City

Parameter	Units	Value
Total Investment Required	BDT (Million)	171.95 (USD 2.02 Million)
Simple Payback Period	Years	3.29
Internal Rate of Return	%	30%
Net Present Value	BDT (Million)	472.13 (USD 5.55 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:6 to this report

3.2.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 36

Table- 36: Details Luminaires and CCMS units in Case-3 for Chittagong City

Existing/Baseline/BAU Luminaires						
Type	-	Incandescent Bulbs	FTL	Halogen	HPSV	Metal Halide
Number	Nos	3,500	23,250	3,500	3,500	200
Wattage	W	100	40	150	100	250
Proposed system						
Type	-	LED		LED	LED	
Number	Nos	26750		3500	3900	
Wattage	W	20		70	60	
Rating of Solar PV module	Wp	30		300	240	
Rating of battery for storage	Ah	150		240	200	
Number of CCMS units	Nos	196				
Source: Research by East Coast Sustainable						

Details of energy consumption and cost of operation for Case-3 is presented in the Table- 37

Table- 37: Details Case-3 Energy savings, Cost savings for Chittagong City

BAU case	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	10,841
Average Operating Cost	BDT (Million)/year	209.56 (USD 2.47 Million)
Savings		
Average Annual Energy Savings	MWh/year	10,841
Total Cost Savings	BDT (Million)/year	93.65 (USD 93.10 Million)

Source: Research by East Coast Sustainable

The Table- 38 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 38: Results of Case-3 techno financial analysis for Chittagong city

Results of Case-3 Techno Financial Analysis for Chittagong City, Bangladesh											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period	Years	30.57	27.51	24.45	21.40	18.34	15.28	12.23	9.17	6.11	3.06
Internal Rate of Return	%	-23%	-21%	-19%	-17%	-14%	-10%	-6%	0%	10%	33%
Net Present Value	BDT (Million)	44.62	123.24	201.87	280.49	359.11	437.74	516.36	594.99	673.61	752.24
	USD (Million)	0.52	1.45	2.37	3.30	4.22	5.15	6.07	7.00	7.92	8.85
Total investment by end user	BDT (Million)	3,074.83	2,767.35	2,459.87	2,152.38	1,844.90	1,537.42	1,229.93	922.45	614.97	307.48
	USD (Million)	36.17	32.56	28.94	25.32	21.70	18.09	14.47	10.85	7.23	3.62
Total programme/Project cost	BDT (Million)	3,054.34	3,054.34	3,054.34	3,054.34	3,054.34	3,054.34	3,054.34	3,054.34	3,054.34	3,054.34
	USD (Million)	35.93	35.93	35.93	35.93	35.93	35.93	35.93	35.93	35.93	35.93

Source: Research by East Coast Sustainable

The IRR becomes positive at around 70% - 80% of subsidy/grant. Thus, a minimum of 70% - 80% subsidy/grant is required to make the project viable. Further 80% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR. The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:6 to this report

3.3 Case Study on Gelephu City of Bhutan

Gelephu, is a town or Thromde in Sarpang District in Bhutan. The city is spread over 11.5 sq. km. The Gelephu city has an elevation of 221 metres (725 ft).

Figure- 25: Street Lighting in Gelephu City

Source: https://mapio.net/pic/p-77663150/

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of CFL lamps with LED based efficient street lighting.

The techno-financial analysis for Gelephu City is based on following macro data and assumptions.

Table- 39: Street Lighting Commercial Data for Gelephu City, Bhutan

Parameter	Units	Value
Exchange rate (1USD)	BTN	73
Electricity Tariff[57]	BTN/kWh	4.1
	USD/kWh	0.1
CAGR of increase in street light energy Consumption[58]	%	3
CAGR of CPI for maintenance cost increase[59]	%	5.6
LED Cost Information[60]		
Cost of 40 W LED	BTN	3,590
	USD	49
Cost of CCMS Unit[61]	BTN	20,512
	USD	281
Installation Cost of LED[62]	BTN/LED	300
	USD/LED	4
Installation Cost of Solar Street Lighting Unit[63]	BTN/Unit	500
	USD/Unit	7
Cost of 40W Solar Street Lighting Unit[64]	BTN/Unit	31,488
	USD/Unit	431
LED Failure rate[65]	%	5
Failure rate of CCMS Unit[66]	%	5
Weighted average cost of capital (WACC) for the Country[67]	%	7.78%
Discounting Factor (same as WACC)	%	7.78%

[57] https://www.bpc.bt/electricity-tariff/
[58] https://www.ceicdata.com/en/pakistan/energy- consumption-and-supplies-annual/electricity-consumption-street-light
[59] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD
[60] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[61] EESL (India)
[62] Based on Market trend in SAARC region
[63] Based on Market trend in SAARC region
[64] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[65] Assumption based on Primary Data sources
[66] Assumption based on Primary Data sources
[67] https://www.adb.org/sites/default/files/linked-documents/44444-013-fa.pdf

3.3.1 Case:1 Replacement with LED based EE Lighting System without CCMS

The details of existing and proposed luminaires for the case are presented under Table- 40.

Table- 40: Details of Existing and proposed luminaires in Gelephu City[68]

Existing/Baseline/BAU Luminaires	
Type	CFL
Number	1,222
Wattage	90
Proposed Luminaires	
Type	LED
Number	1,222
Wattage	40

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 41 and Table- 42.

Table- 41: Details of Case-1 Energy savings, Cost savings for Gelephu City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	401.43
Average Operating Cost	BTN (Million)/year	2.42 (USD 33.08 Thousand)
Proposed		
Average Annual Energy Consumption	MWh/year	178.41
Average Operating Cost	BTN (Million)/year	1.12 (USD 15.33 Thousand)
Savings		
Average Annual Energy Savings	MWh/year	223.02
Total Cost Savings	BTN (Million)/year	1.30 (USD 17.74 Thousand)

Source: Research by East Coast Sustainable

[68] Source: Received from Primary Data sources

Table- 42: Results of Case-1 techno financial analysis for Gelephu City

Parameter	Units	Value
Total Investment Required	BTN (Million)	17.17 (USD 98.17 Thousand)
Simple Payback Period	Years	4.76
Internal Rate of Return	%	16%
Net Present Value	BTN (Million)	7.07 (USD 96.78 Thousand)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:7 to this report

3.3.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 43.

Table- 43: Details of Luminaires and CCMS units in Case-2 for Gelephu City

Existing/Baseline/BAU Luminaires	
Type	CFL
Number	1,222
Wattage	90
Proposed Luminaires	
Type	LED
Number	1,222
Wattage	40
Number of CCMS units (nos)	10

Source: Received from Primary Data sources

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 44 and Table- 45.

Table- 44: Details Case-2 Energy savings, Cost savings for Gelephu City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	401.43
Average Operating Cost	BTN (Million)/year	2.42 (USD 33.08 Thousand)
Proposed		
Average Annual Energy Consumption	MWh/year	178.36
Average Operating Cost	BTN (Million)/year	1.12 (USD 15.33 Thousand)
Savings		
Average Annual Energy Savings	MWh/year	223.06
Total Cost Savings	BTN (Million)/year	1.30 (USD 17.74 Thousand)

Source: Research by East Coast Sustainable

Table- 45: Results of Case-2 techno financial analysis for Gelephu City

Parameter	Units	Value
Total Investment Required	BTN (Million)	17.71 (USD 105.61 Thousand)
Simple Payback Period	Years	4.99
Internal Rate of Return	%	14%
Net Present Value	BTN (Million)	6.86 (USD 93.93Thousand)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:7 to this report

3.3.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 46.

Table- 46: Details of Luminaires and CCMS units in Case-3 for Gelephu City

Existing/Baseline/BAU Luminaires		
Type	-	CFL
Number	Nos	1,222
Wattage	W	90
Proposed Luminaires		
Type	-	LED
Number	Nos	1,222
Wattage	W	40
Rating of Solar PV module	Wp	60
Rating of battery for storage	Ah	300
System Voltage	V	24
No of CCMS Units	Nos	10

Source: Received from Primary Data sources

Details of energy consumption and cost of operation for Case-3 is presented in Table- 47.

Table- 47: Details Case-3 Energy savings, Cost savings and Investment for Gelephu City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	401.43
Average Operating Cost	BTN (Million)/year	2.42 (USD 33.08 Thousand)
Savings		
Average Annual Energy Savings	MWh/year	223.02
Total Cost Savings	BTN (Million)/year	1.30 (USD 17.74 Thousand)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:7 to this report

The Table- 48 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 48: Results of Case-3 techno financial analysis for Gelephu City

Results of Case-3 Techno Financial Analysis for Gelephu City, Bhutan											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period	Years	50.42	45.38	40.33	35.29	30.25	25.21	20.17	15.13	10.08	5.04
Internal Rate of Return	%	-32%	-30%	-28%	-26%	-23%	-20%	-16%	-10%	-2%	16%
Net Present Value	BTN (Million)	-9.22	-6.81	-4.41	-2.00	0.40	2.81	5.21	7.62	10.02	12.43
	USD (Million)	-0.13	-0.09	-0.06	-0.03	0.01	0.04	0.07	0.10	0.14	0.17
Total investment by end user	BTN (Million)	122.62	110.36	98.09	85.83	73.57	61.31	49.05	36.79	24.52	12.26
	USD (Million)	1.68	1.51	1.34	1.18	1.01	0.84	0.67	0.50	0.34	0.17
Total programme/Project cost	BTN (Million)	122.62	122.62	122.62	122.62	122.62	122.62	122.62	122.62	122.62	122.62
	USD (Million)	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68

Source: Research by East Coast Sustainable

The IRR becomes positive at around 90% of subsidy/grant. Thus, a minimum of 90% subsidy/grant is required to make the project viable. Further 16% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR

3.4 Case Study on Hyderabad City, India

Hyderabad is the capital of southern India's Telangana state. A major centre for the technology industry, it's home to many upscale restaurants and shops. The Hyderabad city is spread over 650 sq. km. and an elevation of 542 metres (1,778 ft)

Figure- 26: Road Lighting Hyderabad City[69]

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of FTL, HPSV/HPMV and CFL lamps with LED based efficient street lighting.

The techno-financial analysis for Hyderabad City is based on following macro data and assumptions.

[69] *Source: https://www.en.etemaaddaily.com/world/hyderabad/hyderabad-to-install-led-streetlights-by-ugadi:20678*

Table- 49: Street Lighting Commercial Data for Hyderabad City, India.

Parameter	Units	Value
Exchange rate (1USD)	INR	74
Electricity Tariff[70]	INR/kWh	7.1
	USD/kWh	0.1
CAGR of increase in street light energy consumption[71]	%	4.2
CAGR of CPI for maintenance cost increase[72]	%	5.2
LED Cost Information[73]		
Cost of 18 W LED	INR	945
	USD	12.8
Cost of 35 W LED	INR	1,250
	USD	16.9
Cost of 45 W LED	INR	1,288
	USD	17.4
Cost of 62 W LED	INR	1,800
	USD	24.3
Cost of 70 W LED	INR	1,860
	USD	25.1
Cost of 110 W LED	INR	2,718
	USD	36.7
Cost of 190 W LED	INR	4,764
	USD	64.4
Cost of 200 W LED	INR	4,852
	USD	65.6
Cost of CCMS Unit[74]	INR	20,000
	USD	270.3
Installation Cost of LED[75]	INR/Fixture	288
	USD/Fixture	3.9
Number of CCMS units installed[76]	No	23,450
Installation Cost of Solar Street Lighting Unit[77]	INR/Unit	300
	USD/Unit	4.1
SSL Cost Information[78]		
Cost of 20W Solar Street Light	INR/Unit	48,500
	USD/Unit	655.4
Parameter	**Units**	**Value**
Cost of 30W Solar Street Light	INR/Unit	68,500
	USD/Unit	925.7
Cost of 60W Solar Street Light	INR/Unit	77,555
	USD/Unit	1,048

70 https://tserc.gov.in/file_upload/uploads/Tariff%20Orders/Tariff%20Schedule/Tariff%20Schedule%20for%20FY2018-19.pdf
71 https://indiacsr.in/total-road-length-in-india-increased-at-4-2-cagr/
72 http://mospi.nic.in/sites/default/files/press_release/CPI%20Press%20Release%20January%202021.pdf
73 EESL India
74 EESL India
75 GHMC, Hyderabad, India
76 GHMC, Hyderabad, India
77 Based on Market trend in SAARC region
78 https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf

Parameter	Units	Value
Cost of 100W Solar Street Light	INR/Unit	95,330
	USD/Unit	1,288
Failure rate of LEDs[79]	%	2
Failure rate of CCMS Unit[80]	%	2
Weighted average cost of capital (WACC) for the Country[81]	%	8.29%
Discounting Factor (considered same as WACC)	%	8.29%

[79] Assumption based on general Trend of LED failure
[80] Assumption based on general Trend of CCMS failure
[81] http://www.waccexpert.com

3.4.1 Case:1 Replacement with LED based EE Lighting System without CCMS

The details of existing and proposed luminaires for the case are presented under Table- 50.

Table- 50: Details of Existing and proposed luminaires in Hyderabad City

Parameter	Units	Values					
		Type-1	Type-2	Type-3	Type-4	Type-5	Type-6
Existing/Baseline/BAU Luminaires							
Type of existing Street Lighting Fixture		FTL	HPSV	HPSV/HPMV	HPSV/HPMV	HPSV (High Mast)	LED
Typical Rating of existing Street Lighting Fixture	W	40	70	150	250	400	120
Total number of street lights	No	14,365	84,718	216,797	86,257	17,853	937
Proposed Luminaires							
Proposed LED Fixture rating	W	18	35	62	110	200	-
Total number of street lights	No	14,365	84,718	216,797	86,257	17,853	-

Source: Received from Primary data sources

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 51 and Table- 52.

Table- 51: Details of Case-1 Energy savings, Cost savings for Hyderabad City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	244,999
Average Operating Cost	INR (Million)/year	2,814 (USD 38.03 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	119,346
Average Operating Cost	INR (Million)/year	1,330 (USD 17.98 Million)
Savings		
Average Annual Energy Savings	MWh/year	125,653
Total Cost Savings	INR (Million)/year	1,484 (USD 20.05 Million)

Source: Research by East Coast Sustainable

Table- 52: Results of Case-1 techno financial analysis for Hyderabad City

Parameter	Units	Value
Total Investment Required	INR (Million)	1,134 (USD 15.33 Million)
Simple Payback Period	Years	0.8
Internal Rate of Return	%	127%
Net Present Value	INR (Million)	9,477 (USD 128.07 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:8 to this report

3.4.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 53.

Table- 53: Details Luminaires and CCMS units in Case-2 for Hyderabad City

Parameter	UOM	Values					
		Type-1	Type-2	Type-3	Type-4	Type-5	Type-6
Existing/Baseline/BAU Luminaires							
Type of existing Street Lighting Fixture		FTL	HPSV	HPSV/HPMV	HPSV/HPMV	HPSV (High Mast)	LED
Typical Rating of existing Street Lighting Fixture	W	40	70	150	250	400	120
Total number of street lights	No	14,365	84,718	216,797	86,257	17,853	937
Proposed Luminaires							
Proposed LED Fixture rating	W	18	35	62	110	200	-
Total number of street lights	No	14,365	84,718	216,797	86,257	17,853	937
Number of CCMS Units	No	23450					

Source: GHMC Officials data

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 54 and Table- 55.

Table- 54: Details Case-2 Energy savings, Cost savings for Hyderabad City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	244,999
Average Operating Cost	INR (Million)/year	2,814 (USD 38.03 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	119,315
Average Operating Cost	INR (Million)/year	1,330 (USD 17.98 Million)
Savings		
Average Annual Energy Savings	MWh/year	125,684
Total Cost Savings	INR (Million)/year	1,479 (USD 20 Million)

Source: Research by East Coast Sustainable

Table- 55: Results of Case-2 techno financial analysis for Hyderabad City

Parameter	Units	Value
Total Investment Required	INR (Million)	1,706.90 (USD 23.07 Million)
Simple Payback Period	Years	1.23
Internal Rate of Return	%	84%
Net Present Value	INR (Million)	9,376 (USD 126.71 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:8 to this report

3.4.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 56.

Table- 56: Details of Luminaires and CCMS units in Case-3 for Hyderabad City

Parameter	UOM	Values			
		Type-1	**Type-2**	**Type-3**	**Type-4**
Existing/Baseline/BAU Luminaires					
Type of existing Street Lighting Fixture		FTL	HPSV	HPSV/HPMV	HPSV/HPMV
Typical Rating of existing Street Lighting Fixture	W	40	70	150	250
Total number of street lights	No	14,365	84,718	216,797	86,257
Proposed Luminaires					
Proposed LED Fixture rating	W	20	30	60	100
Total number of street lights	No	14,365	84,718	216,797	121,963
Rating of Solar PV module	Wp	100	100	240	333
Rating of Battery for storage	Ah	75	120	200	400
System Voltage	V	12	12	24	24
No of CCMS Units	No	23,450			

Details of energy consumption and cost of operation for Case-3 is presented in the Table- 57.

Table- 57: Details of Case-3 Energy savings, Cost savings for Hyderabad City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	244,999
Average Operating Cost	INR Million/year	2,814 (USD 38.03 Million)
Savings		
Average Annual Energy Savings	MWh/year	244,999
Total Cost Savings	INR Million/year	2,393 (USD 32.35 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:8 to this report

The Table- 58 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 58: Results of Case-3 techno financial analysis for Hyderabad City

Results of Case-3 Techno Financial Analysis for Hyderabad City, India											
Parameters	**UOM**	**Subsidy 0%**	**Subsidy 10%**	**Subsidy 20%**	**Subsidy 30%**	**Subsidy 40%**	**Subsidy 50%**	**Subsidy 60%**	**Subsidy 70%**	**Subsidy 80%**	**Subsidy 90%**
Simple Payback Period (per end user)	Years	18.83	16.94	15.06	13.18	11.30	9.41	7.53	5.65	3.77	1.88
Internal Rate of Return (per end user)	%	-15%	-13%	-11%	-8%	-5%	-1%	4%	12%	24%	55%
Net Present Value (per end user)	INR (Million)	-29017.02	-24442.81	-19868.59	-15294.37	-10720.15	-6145.94	-1571.72	3002.50	7576.72	12150.93
	USD (Million)	-392.12	-330.31	-268.49	-206.68	-144.87	-83.05	-21.24	40.57	102.39	164.20
Total investment by end user	INR (Million)	49583.43	44625.09	39666.74	34708.40	29750.06	24791.71	19833.37	14875.03	9916.69	4958.34
	USD (Million)	670.05	603.04	536.04	469.03	402.03	335.02	268.02	201.01	134.01	67.00
Total programme/Project cost	INR (Million)	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47
	USD (Million)	661.03	661.03	661.03	661.03	661.03	661.03	661.03	661.03	661.03	661.03

Source: Research by East Coast Sustainable

The IRR becomes positive at around 60% of subsidy/grant. Thus, a minimum of 36% subsidy/grant is required to make the project viable. Further 60% - 70% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR.

3.5 Case Study on Male City of Maldives

Male is the capital and most populous city in the Republic of Maldives. With a population of 2,27,486 and an area of 8.30 square kilometres (3.20 sq mi) with an elevation of 2.4 metres (7.9 ft), it is also one of the most densely populated cities in the world. The city is geographically located at the southern edge of North Male Atoll (Kaafu Atoll). Administratively, the city consists of a central island, an airport island, and four other islands governed by the Male City Council.

Figure- 27: Street Lighting of Male City

Source: https://en.sun.mv/65357

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of Halogen lamps with LED based efficient street lighting.

The techno-financial analysis for Male City is based on following macro data and assumptions.

Table- 59: Street Lighting Commercial Data for Male City, Maldives

Parameter	Units	Value
Exchange rate (1USD)	MVR	15.4
Electricity Tariff[82]	MVR/kWh	4.4
	USD/kWh	0.28
CAGR of increase in street light energy consumption[83]	%	2.4
CAGR of CPI for maintenance cost increase[84]	%	0.4
LED Cost Information[85]		
Cost of 18 W LED	MVR	380
	USD	25
Cost of CCMS Unit[86]	MVR	4,200
	USD	273
Installation Cost of LED[87]	MVR/LED	100
	USD/LED	6.49
Installation Cost of Solar Street Lighting Unit[88]	MVR/Unit	200
	USD/Unit	13
Cost of 20W Solar Street Lighting Unit[89]	MVR/Unit	10,135
	USD/Unit	658
LED Failure rate[90]	%	2
Failure rate of CCMS Unit[91]	%	2
Weighted average cost of capital (WACC) for the Country[92]	%	2.95%
Discounting Factor (considered same as WACC)	%	2.95%

[82] https://www.stelco.com.mv/tariff-rates#tariff-rates-government-institutes
[83] https://knoema.com/atlas/Maldives/Urban-population
[84] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD
[85] Based on Market trend in SAARC region
[86] EESL (India)
[87] Based on Market trend in SAARC region
[88] Based on Market trend in SAARC region
[89] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[90] Assumption based on general Trend of LED failure
[91] Assumption based on general Trend of CCMS failure
[92] https://www.adb.org/sites/default/files/linked-documents/44444-013-fa.pdf

3.5.1 Case:1 Replacement with LED based EE Lighting System without CCMS

The details of existing and proposed luminaires for the case are presented under Table- 60.

Table- 60: Details of Existing and proposed luminaires in Male City

Parameter	UOM	Type-1
Existing/Baseline/BAU Luminaires		
Type of existing Street Lighting Fixture		Halogen
Typical Rating of existing Street Lighting Fixture	W	30
Total number of street lights	No	2,500
Proposed Luminaires		
Proposed LED Fixture rating	W	18
Total number of street lights	No	2,500

Source: EESL (India)

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 61 and Table- 62.

Table- 61: Details of Case-1 Energy savings, Cost savings for Male City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	328.50
Average Operating Cost	MVR (Million)/year	2.25 (USD 146 Thousand)
Proposed		
Average Annual Energy Consumption	MWh/year	197.10
Average Operating Cost	MVR (Million)/year	1.27 (USD 82 Thousand)
Savings		
Average Annual Energy Savings	MWh/year	131.40
Total Cost Savings	MVR (Million)/year	0.98 (USD 63 Thousand)

Source: Research by East Coast Sustainable

Table- 62: Results of Case-1 techno financial analysis for Male City

Parameter	Units	Value
Total Investment Required	MVR (Million)	1.41 (USD 91.49 Thousand)
Simple Payback Period	Years	1.26
Internal Rate of Return	%	78%
Net Present Value	MVR (Million)	8.22 (USD 533.63 Thousand)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:9 to this report

3.5.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 63.

Table- 63: Details Luminaires and CCMS units in Case-2 for Male City

Parameter	UOM	Type-1
Existing/Baseline/BAU Luminaires		
Type of existing Street Lighting Fixture		Halogen
Typical Rating of existing Street Lighting Fixture	W	30
Total number of street lights	No	2,500
Proposed Luminaires		
Proposed LED Fixture rating	W	18
Total number of street lights	No	2,500
Number of CCMS Units	No	09

Source: EESL India

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 64 and Table- 65.

Table- 64: Details Case-2 Energy savings, Cost savings for Male City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	328.50
Average Operating Cost	MVR (Million)/year	2.25 (USD 146,000)
Proposed		
Average Annual Energy Consumption	MWh/year	197.06
Average Operating Cost	MVR (Million)/year	1.27 (USD 82,000)
Savings		
Average Annual Energy Savings	MWh/year	131.44
Total Cost Savings	MVR (Million)/year	0.98 (USD 633,500)

Source: Research by East Coast Sustainable

Table- 65: Results of Case-2 techno financial analysis for Male City

Parameter	Units	Value
Total Investment Required	MVR (Million)	1.50 (USD 97.48 Thousand)
Simple Payback Period	Years	1.31
Internal Rate of Return	%	75%
Net Present Value	MVR (Million)	8.18 (USD 531 Thousand)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:9 to this report

3.5.3 Case:3 Solar Based Energy EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 66.

Table- 66: Details of Luminaires and CCMS units in Case-3 for Male City

Parameter	UOM	Type-1
Existing/Baseline/BAU Luminaires		
Type of existing Street Lighting Fixture		Halogen
Typical Rating of existing Street Lighting Fixture	W	30
Total number of street lights	No	2,500
Proposed Luminaires		
Proposed LED Fixture rating	W	20
Total number of street lights	No	2,500
Rating of Solar PV module	Wp	30
Rating of Battery for storage	Ah	150
System Voltage	V	12
Number of CCMS Units	No	09

Source: Research by East Coast Sustainable

Details of energy consumption and cost of operation and savings for Case-3 is presented in the following table.

Table- 67: Details of Case-3 Energy savings, Cost savings for Male City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	328.50
Average Operating Cost	INR (Million)/year	2.25 (USD 145.97 Thousand)
Savings		
Average Annual Energy Savings	MWh/year	328.50
Total Cost Savings	INR (Million)/year	1.46 (USD 94.85 Thousand)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:9 to this report

The Table- 68 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 68: Results of Case-3 techno financial analysis for Male City

Results of Case-3 Techno Financial Analysis for Male City, Maldives											
Parameters	**UOM**	**Subsidy 0%**	**Subsidy 10%**	**Subsidy 20%**	**Subsidy 30%**	**Subsidy 40%**	**Subsidy 50%**	**Subsidy 60%**	**Subsidy 70%**	**Subsidy 80%**	**Subsidy 90%**
Simple Payback Period	Years	18.05	16.24	14.44	12.63	10.83	9.02	7.22	5.41	3.61	1.80
Internal Rate of Return	%	-20%	-18%	-15%	-13%	-9%	-5%	0%	8%	21%	53%
Net Present Value	MVR (Million)	3.61	4.50	5.39	6.28	7.17	8.06	8.95	9.84	10.73	11.62
	USD (Million)	0.23	0.29	0.35	0.41	0.47	0.52	0.58	0.64	0.70	0.75
Total investment by end user	MVR (Million)	36.19	32.57	28.95	25.33	21.71	18.09	14.48	10.86	7.24	3.62
	USD (Million)	2.35	2.11	1.88	1.64	1.41	1.17	0.94	0.70	0.47	0.23
Total programme/Project cost	MVR (Million)	35.69	35.69	35.69	35.69	35.69	35.69	35.69	35.69	35.69	35.69
	USD (Million)	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32

Source: Research by East Coast Sustainable

The IRR becomes positive at around 70% of subsidy/grant. Thus, a minimum of 70% subsidy/grant is required to make the project viable. Further 70% - 80% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR.

3.6 Case Study on Kathmandu City of Nepal

Kathmandu officially the Kathmandu Metropolitan City is the capital and most populous city of Nepal. It is located in the Kathmandu Valley, a large valley in the high plateaus in central Nepal, at an altitude of 1,400 meters (4,600 feet) and the city is spread over 49.45 Sq. km (19.09 sq. mi)

Figure- 28: SSL of Kathmandu City[93]

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of CFL lamps, HPSV lamps and HPMV lamps with LED based efficient street lighting.

The techno-financial analysis for Kathmandu City is based on following macro data and assumptions.

[93] Source: https://kathmandupost.com/valley/2015/01/02/kmc-plans-more-solar-street-lamps

Table- 69: Street Lighting Commercial Data for Kathmandu City, Nepal

Parameter	Units	Value
Exchange rate (1USD)	NPR	118
Electricity Tariff[94]	NPR/kWh	7.3
	USD/kWh	0.06
CAGR of increase in street light energy consumption[95]	%	-0.021
CAGR of CPI for maintenance cost increase[96]	%	5.1
LED Cost Information[97]		
Cost of 50 W LED	NPR	8,032
	USD	68
Cost of 70 W LED	NPR	13,011
	USD	110
Cost of 120 W LED	NPR	20,867
	USD	177
Cost of CCMS Unit[98]	NPR	32,128
	USD	272
Installation Cost of LED[99]	NPR/LED	500
	USD/Unit	4
Installation Cost of Solar Street Lighting Unit[100]	NPR/Unit	1,000
	USD/Unit	8
SSL Cost Information[101]		
Cost of 20W Solar Street Lighting Unit	NPR/Unit	77,467
	USD/Unit	656
Cost of 70W Solar Street Lighting Unit	NPR/Unit	125,299
	USD/Unit	1,062
Cost of 60W Solar Street Lighting Unit	NPR/Unit	123,875
	USD/Unit	1,050
LED Failure rate[102]	%	2
Failure rate of CCMS Unit[103]	%	2
Weighted average cost of capital (WACC) for the Country[104]	%	0.75%
Discounting Factor	%	0.75%

[94] Nepal Electricity Authority Annual Report 2020-21
[95] Nepal Electricity Authority Annual Report 2020-21
[96] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD
[97] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[98] EESL, India
[99] Based on Market trend in SAARC region
[100] Based on Market trend in SAARC region
[101] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[102] Assumption based on general Trend of LED failure
[103] Assumption based on general Trend of CCMS failure
[104] https://www.adb.org/sites/default/files/linked-documents/41155-013-nep-fa.pdf

3.6.1 Case:1 Replacement with LED based EE Lighting System without CCMS

The details of existing and proposed luminaires for the case are presented under Table- 70.

Table- 70: Details of Existing and proposed luminaires in Kathmandu City

Parameter	Units	Values		
		Type-1	Type-2	Type-3
Existing/Baseline/BAU Luminaires				
Type of existing Street Lighting Fixture		CFL	HPMV	HPSV
Typical Rating of existing Street Lighting Fixture	W	90	150	250
Total number of street lights	No	14,000	1200	900
Proposed Luminaires				
Proposed LED Fixture rating	W	50	70	120
Total number of street lights	No	14,000	1,200	900

Source: The Kathmandu Post

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 71 and Table- 72.

Table- 71: Details of Case-1 Energy savings, Cost savings for Kathmandu City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	7,292.70
Average Operating Cost	NPR (Million)/year	76.59 (USD 0.65 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	3,906.96
Average Operating Cost	NPR (Million)/year	41.99 (USD 0.36 Million)
Savings		
Average Annual Energy Savings	MWh/year	3,385.74
Total Cost Savings	NPR (Million)/year	34.59 (USD 0.29 Million)

Source: Research by East Coast Sustainable

Table- 72: Results of Case-1 techno financial analysis for Kathmandu City

Parameter	Units	Value
Total Investment Required	NPR (Million)	178.57 (USD 1.51 Million)
Simple Payback Period	Years	5.22
Internal Rate of Return	%	15.24%
Net Present Value	NPR (Million)	304.54 (USD 2.58 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:10 to this report

3.6.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 73.

Table- 73: Details of Luminaires and CCMS units in Case-2 for Kathmandu City

Parameter	Units	Values		
		Type-1	Type-2	Type-3
Existing/Baseline/BAU Luminaires				
Type of existing Street Lighting Fixture	-	CFL	HPMV	HPSV
Typical Rating of existing Street Lighting Fixture	W	90	150	250
Total number of street lights	No	14,000	1,200	900
Proposed Luminaires				
Proposed LED Fixture rating	W	50	70	120
Total number of street lights	No	14,000	1,,200	900
Number of CCMS Units	No	178		

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 74 and Table- 75.

Table- 74: Details Case-2 Energy savings, Cost savings for Kathmandu City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	7,292.70
Average Operating Cost	NPR (Million)/year	76.59 (USD 0.65 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	3,906.05
Average Operating Cost	NPR (Million)/year	41.99 (USD 0.36 Million)
Savings		
Average Annual Energy Savings	MWh/year	3,386.65
Total Cost Savings	NPR (Million)/year	40.57 (USD 0.34 Million)

Source: Research by East Coast Sustainable

Table- 75: Results of Case-2 techno financial analysis for Kathmandu City

Parameter	Units	Value
Total Investment Required	NPR (Million)	180.90 (USD 1.58 Million)
Simple Payback Period	Years	5.42
Internal Rate of Return	%	18%
Net Present Value	NPR (Million)	359.83 (USD 3.05 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:10 to this report

3.6.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 76.

Table- 76: Details of Luminaires and CCMS units in Case-3 for Kathmandu City

Parameter	Units	Values		
		Type-1	Type-2	Type-3
Existing/Baseline/BAU Luminaires				
Type of existing Street Lighting Fixture		CFL	HPMV	HPSV
Typical Rating of existing Street Lighting Fixture	W	90	150	250
Total number of street lights	No	14,000	1,200	900
Proposed Luminaires				
Proposed LED Fixture rating	W	20	70	60[105]
Total number of street lights	No	14,000	1,200	1,800
Rating of Solar PV module	Wp	30	300	240
Rating of Battery for storage	Ah	75	240	200
System Voltage	V	12	24	24
No of CCMS Units	No	178		

[105] Two number of 60W LED fixtures are proposed as equivalent to 250W. Hence the number of fixtures are double

Details of energy consumption and cost of operation and energy savings for Case-3 is presented in Table- 77.

Table- 77: Details of Case-3 Energy savings, Cost savings for Kathmandu City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	7,292.70
Average Operating Cost	NPR (Million)/year	76.59 (USD 0.65 Million)
Savings		
Average Annual Energy Savings	MWh/year	7,292.70
Total Cost Savings	NPR (Million)/year	70.70 (USD 0.60 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:10 to this report

The Table- 78 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 78: Results of Case-3 techno financial analysis for Kathmandu City

Results of Case-3 Techno Financial Analysis for Kathmandu City, Nepal											
		Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	SUbsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	26.43	23.79	21.15	18.50	15.86	13.22	10.57	7.93	5.29	2.64
Internal Rate of Return (per end user)	%	-21%	-19%	-17%	-15%	-12%	-8%	-3%	3%	14%	38%
Net Present Value (per end user)	NPR (Million)	113.53	169.90	226.28	282.65	339.02	395.39	451.77	508.14	564.51	620.88
	USD (Million)	0.96	1.44	1.92	2.40	2.87	3.35	3.83	4.31	4.78	5.26
Total investment by end user	NPR (Million)	2,064.22	1,857.80	1,651.38	1,444.96	1,238.53	1,032.11	825.69	619.27	412.84	206.42
	USD (Million)	17.49	15.74	13.99	12.25	10.50	8.75	7.00	5.25	3.50	1.75
Total programme/Project cost	NPR (Million)	2,049.02	2,049.02	2,049.02	2,049.02	2,049.02	2,049.02	2,049.02	2,049.02	2,049.02	2,049.02
	USD (Million)	17.36	17.36	17.36	17.36	17.36	17.36	17.36	17.36	17.36	17.36

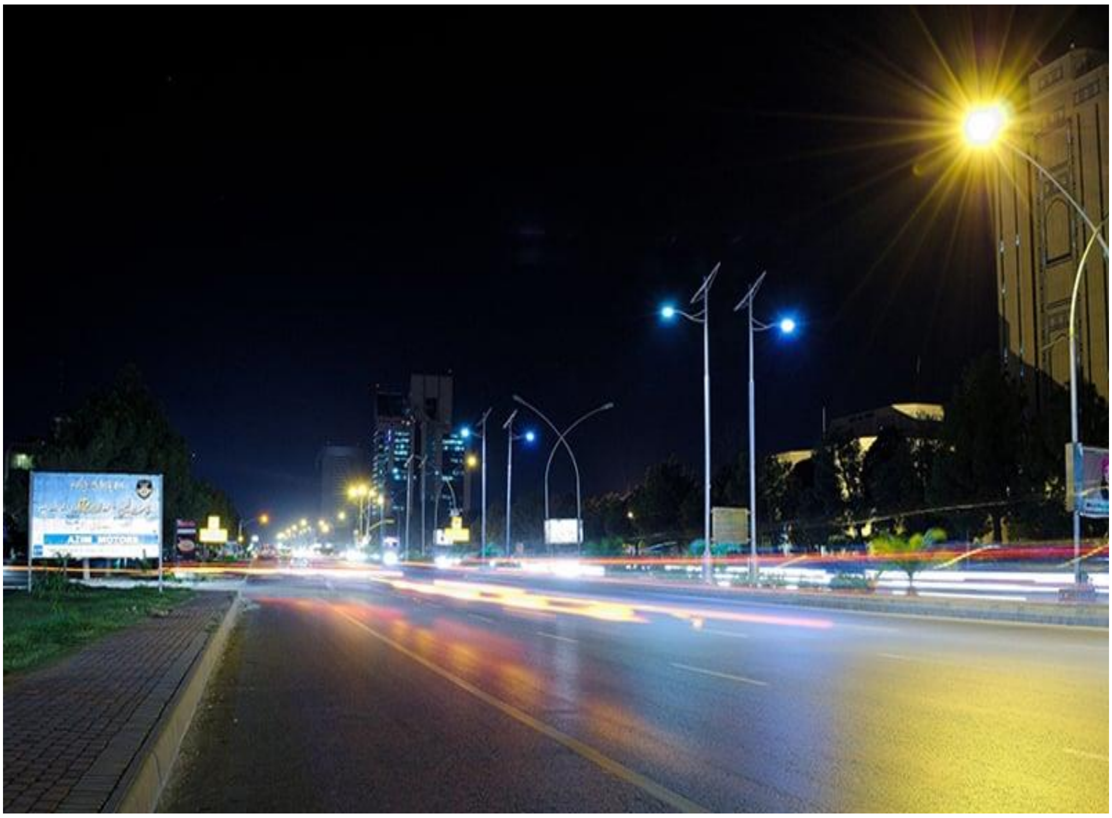
Source: Research by East Coast Sustainable

The IRR becomes positive at around 70% of subsidy/grant. Thus, a minimum of 70% subsidy/grant is required to make the project viable. Further 70% - 80% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR.

3.7 Case Study on Islamabad City of Pakistan

Islamabad is the capital city of Pakistan, and is administered by the Pakistani federal government as part of the Islamabad Capital Territory. It is the ninth-largest city in Pakistan, while the larger Islamabad–Rawalpindi metropolitan area is the country's third-largest with a population of about 4.1 million people (Wikipedia, 2021). Built as a planned city in the 1960s to replace Karachi as Pakistan's capital, Islamabad is noted for its high standards of living, safety, and abundant greenery.

Figure- 29: Road Lighting of Islamabad City



Source: https://www.dawn.com/news/1180962

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of HPSV lamps and HPMV lamps with LED based efficient street lighting.

The techno-financial analysis for Islamabad City is based on following macro data and assumptions.

Table- 79: Street Lighting Commercial Data for Islamabad City, Pakistan

Parameter	Units	Value
Exchange rate (1USD)	PKR	168
Electricity Tariff[106]	PKR/kWh	20.6
	USD/kWh	0.123
CAGR of increase in street light energy consumption[107]	%	3
CAGR of increase in maintenance cost (CPI)[108]	%	9.7
LED Cost Information[109]		
Cost of 50 W LED	PKR	11,500
	USD	68.5
Cost of 125 W LED	PKR	29,877
	USD	177.8
Cost of CCMS Unit[110]	PKR	45,347
	USD	269.9
Installation Cost of LED[111]	PKR/fixture	500
	USD/fixture	3
Installation Cost of Solar Street Lighting Unit[112]	PKR/Unit	1,000
	USD/Unit	6
SSL Cost Information[113]		
Cost of 50W Solar Street Lighting Unit	PKR/Unit	173,643
	USD/Unit	1,033.6
Cost of 60W Solar Street Lighting Unit	PKR/Unit	176,904
	USD/Unit	1,053
LED Failure rate of LEDs[114]	%	2
Failure rate of CCMS Unit[115]	%	2
Weighted average cost of capital (WACC) for the Country[116]	%	7.71%
Discounting Factor (considered same as WACC)	%	7.71%

[106] https://iesco.com.pk/index.php/customer-services/tariff-guide (accessed on 16th Sep 2021)
[107] https://www.ceicdata.com/en/pakistan/energy-consumption-and-supplies-annual/electricity-consumption-street-light
[108] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD
[109] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[110] EESL, India
[111] Based on Market trend in SAARC region
[112] Based on Market trend in SAARC region
[113] https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
[114] Assumption based on general Trend of LED failure
[115] Assumption based on general Trend of CCMS failure
[116] https://www.adb.org/sites/default/files/linked-documents/48078-002-fa.pdf

3.7.1 Case:1 Replacement with LED based EE Lighting System

The details of existing and proposed luminaires for the case are presented under Table- 80.

Table- 80: Details of Existing and proposed luminaires in Islamabad City

Parameter	Units	Values	Values
		Type-1	Type-2
Existing/Baseline/BAU Luminaires			
Type of existing Street Lighting Fixture		HPSV / HPMV	HPSV / HPMV
Typical Rating of existing Street Lighting Fixture	W	125	250
Total number of street lights	No	30,000	8,000
Proposed Luminaires			
Proposed LED Fixture rating	W	50	125
Total number of street lights	No	30,000	8,000

Source: NEECA-Pakistan ESCO Model

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 81 and Table- 82.

Table- 81: Details of Case-1 Energy savings, Cost savings for Islamabad City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	25,185.00
Average Operating Cost	PKR (Million)/year	1,170.46 (USD 6.97 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	19,050.00
Average Operating Cost	PKR (Million)/year	551.22 (USD 3.28 Million)
Savings		
Average Annual Energy Savings	MWh/year	14,235.00
Total Cost Savings	PKR (Million)/year	619.24 (USD 3.69 Million)

Source: Research by East Coast Sustainable

Table- 82: Results of Case-1 techno financial analysis for Islamabad City

Parameter	Units	Value
Total Investment Required	PKR (Million)	552.1 (USD 3.29 Million)
Simple Payback Period	Years	1.10
Internal Rate of Return	%	95%
Net Present Value	PKR (Million)	3,960.50 (USD 23.57 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:11 to this report

3.7.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 83.

Table- 83: Details of Luminaires and CCMS units in Case-2 for Islamabad City

Parameter	Units	Values	Values
		Type-1	Type-2
Existing/Baseline/BAU Luminaires			
Type of existing Street Lighting Fixture		HPSV / HPMV	HPSV / HPMV
Typical Rating of existing Street Lighting Fixture	W	125	250
Total number of street lights	No	30,000	8,000
Proposed Luminaires			
Proposed LED Fixture rating	W	50	125
Total number of street lights	No	30,000	8,000
Number of CCMS units	No	500	

Source: NEECA-Pakistan ESCO Model

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 84 and Table- 85.

Table- 84: Details Case-2 Energy savings, Cost savings for Islamabad City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	25,185.00
Average Operating Cost	PKR (Million)/year	1,170.46 (USD 6.97 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	19,046.49
Average Operating Cost	PKR (Million)/year	551.22 (USD 3.28 Million)
Savings		
Average Annual Energy Savings	MWh/year	14,238.14
Total Cost Savings	PKR (Million)/year	619.31 (USD 3.86 Million)

Source: Research by East Coast Sustainable

Table- 85: Results of Case-2 techno financial analysis for Islamabad City

Parameter	Units	Value
Total Investment Required	PKR (Million)	530.30 (USD 3.45 Million)
Simple Payback Period	Years	1.15
Internal Rate of Return	%	91%
Net Present Value	PKR (Million)	3,957.53 (USD 23.56 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:11 to this report

3.7.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 86.

Table- 86: Details of SSL and CCMS units in Case-3 for Islamabad City

Parameter	Units	Values	Values
		Type-1	Type-2
Existing/Baseline/BAU Luminaires			
Type of existing Street Lighting Fixture		HPSV / HPMV	HPSV / HPMV
Typical Rating of existing Street Lighting Fixture	W	125	250
Total number of street lights	No	30,000	8,000
Proposed Luminaires			
Proposed LED Fixture rating	W	50	60
Total number of street lights	No	30,000	16,667
Rating of Solar PV module	WP	225	240
Rating of Battery of storage	Ah	195	200
System Voltage	V	24	24
Number of CCMS units	No	500	

Source: NEECA-Pakistan ESCO Model

Details of energy consumption and cost of operation and cost savings for Case-3 is presented in the Table- 87.

Table- 87: Details of Case-3 Energy savings, Cost savings for Islamabad City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	25,185.00
Average Operating Cost	PKR (Million)/year	1,170.46 (USD 7.61 Million)
Savings		
Average Annual Energy Savings	MWh/year	25,185.00
Total Cost Savings	PKR (Million)/year	895.41 (USD 5.32 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:11 to this report

The Table- 88 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 88: Results of Case-3 techno financial analysis for Islamabad City

Results of Case-3 Techno Financial Analysis for Islamabad City, Pakistan											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	14.436	12.992	11.549	10.105	8.661	7.218	5.774	4.331	2.887	1.444
Internal Rate of Return (per end user)	%	-5%	-3%	-1%	2%	6%	10%	16%	25%	39%	77%
Net Present Value (per end user)	PKR (Million)	3,545.1	3,770.6	3,996.2	4,221.7	4,447.2	4,672.8	4,898.3	5,123.9	5,349.4	5,575.0
	USD (Million)	21.1	22.4	23.8	25.1	26.5	27.8	29.2	30.5	31.8	33.2
Total investment by end user	PKR (Million)	11,498.3	10,348.5	9,198.6	8,048.8	6,899.0	5,749.2	4,599.3	3,449.5	2,299.7	1,149.8
	USD (Million)	68.44	61.60	54.75	47.91	41.07	34.22	27.38	20.53	13.69	6.84
Total programme/Project cost	PKR (Million)	11,423.9	11,423.9	11,423.9	11,423.9	11,423.9	11,423.9	11,423.9	11,423.9	11,423.9	11,423.9
	USD (Million)	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0

Source: Research by East Coast Sustainable

The IRR becomes positive at around 50% of subsidy/grant. Thus, a minimum of 50% subsidy/grant is required to make the project viable. Further 50% - 60% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR

3.8 Case Study on Colombo City of Sri Lanka

Colombo is the commercial capital and largest city of Sri Lanka by population. According to the Brookings Institution, Colombo metropolitan area has a population of 5.6 million, and 752,993 in the Municipality. It is the financial centre of the island and a tourist destination. The Colombo city has an elevation of 1 meter (3 feet) and the Commercial capital spread over 37.31 Sq. km (14.41 sq. mi).

Figure- 30: Road Lighting of Colombo City[117]

The city is in the process of upgrading its street lighting infrastructure from conventional lamps comprising of CFL lamps, HPSV lamps and HPMV lamps with LED based efficient street lighting.

The techno-financial analysis for Colombo City is based on following macro data and assumptions.

[117] Source: https://www.ft.lk/propertyconstruction/CMC-s-energy-efficient-Smart-LED-street-lighting-drive-progressing/10516-707809

Table- 89: Street Lighting Commercial Data for Colombo City, Sri-Lanka

Parameter	Units	Value
Exchange rate (1USD)	LKR	200
Electricity Tariff[118]	LKR/kWh	17
	USD/kWh	0.09
CAGR of increase in street light energy consumption[119]	%	-0.02
CAGR of CPI for maintenance cost increase[120]	%	6.2
LED Cost Information[121]		
Cost of 20 W LED	LKR	5,951
	USD	30
Cost of 70 W LED	LKR	19,205
	USD	96
Cost of 125 W LED	LKR	35,138
	USD	176
Cost of CCMS Unit[122]	LKR	54,100
	USD	271
Installation Cost of LED[123]	LKR/LED	500
	USD/LED	3
Installation Cost of Solar Street Lighting Unit[124]	LKR/Unit	1,000
	USD/Unit	5
SSL Cost Information[125]		
Cost of 20W Solar Street Lighting Unit	LKR/Unit	131,369
	USD/Unit	657
Cost of 70W Solar Street Lighting Unit	LKR/Unit	212,485
	USD/Unit	1062
Cost of 60W Solar Street Lighting Unit	LKR/Unit	210,069
	USD/Unit	1,050
LED Failure rate[126]	%	2
Failure rate of CCMS Unit[127]	%	2
Weighted average cost of capital (WACC) for the Country[128]	%	2.60%
Discounting Factor (considered same as WACC)	%	2.60%

118 https://ceb.lk/tariff_catergory/en
119 https://www.ceicdata.com/en/sri-lanka/road-statistics/length-of-public-road-sri-lanka
120 https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=BD
121 https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
122 EESL, India
123 Based on Market trend in SAARC region
124 Based on Market trend in SAARC region
125 https://www.havells.com/content/dam/havells/brouchers/dealer/price-list/Havells_ProfessionalLuminaires.pdf
126 Assumption based on general Trend of LED failure
127 Assumption based on general Trend of CCMS failure
128 https://www.adb.org/sites/default/files/linked-documents/49216-002-fa.pdf

3.8.1 Case:1 Replacement with LED based EE Lighting System

The details of existing and proposed luminaires for the case are presented under Table- 90.

Table- 90: Details of Existing and proposed luminaires in Colombo City

Parameter	Units	Values		
		Type-1	Type-2	Type-3
Existing/Baseline/BAU Luminaires				
Type of existing Street Lighting Fixture		Fluorescent	HPMV	HPSV
Typical Rating of existing Street Lighting Fixture	W	40	150	250
Total number of street lights	No	7,616	11,946	3,676
Proposed Luminaires				
Proposed LED Fixture rating	W	20	70	120
Total number of street lights	No	7,616	11,946	3,676

Source: CEB Lighting population survey (IEI, 2015)

The details of energy savings, cost savings, investment and results of financial analysis are presented in the Table- 91 and Table- 92.

Table- 91: Details of Case-1 Energy savings, Cost savings for Colombo City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	13,208.07
Average Operating Cost	LKR (Million)/year	336.32 (USD 1.68 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	6,261.91
Average Operating Cost	LKR (Million)/year	164.47 (USD 0.82 Million)
Savings		
Average Annual Energy Savings	MWh/year	6,946.15
Total Cost Savings	LKR (Million)/year	171.85 (USD 0.86 Million)

Source: Research by East Coast Sustainable

Table- 92: Results of Case-1 techno financial analysis for Colombo City

Parameter	Units	Value
Total Investment Required	LKR (Million)	432.94 (USD 2.16 Million)
Simple Payback Period	Years	2.68
Internal Rate of Return	%	38%
Net Present Value	LKR (Million)	1,422.28 (USD 7.11 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:12 to this report

3.8.2 Case:2 Replacement with LED based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 93.

Table- 93: Details of Luminaires and CCMS units in Case-2 for Colombo City

Parameter	Units	Values		
		Type-1	Type-2	Type-3
Existing/Baseline/BAU Luminaires				
Type of existing Street Lighting Fixture	-	Fluorescent	HPMV	HPSV
Typical Rating of existing Street Lighting Fixture	W	40	150	250
Total number of street lights	No	7,616	11,946	3,676
Proposed Luminaires				
Proposed LED Fixture rating	W	20	70	120
Total number of street lights	No	7,616	11,946	3,676
Number of CCMS Units	No	286		

Source: CEB Lighting population survey (IEI, 2015)

The details of energy consumption, energy savings, cost savings, investment and results of techno-financial analysis is presented in Table- 94 and Table- 95.

Table- 94: Details Case-2 Energy savings, Cost savings for Colombo City

BAU	Units	Value
Average Annual Energy Consumption	MWh/year	13,208.07
Average Operating Cost	LKR (Million)/year	336.32 (USD 1.68 Million)
Proposed		
Average Annual Energy Consumption	MWh/year	6,260.26
Average Operating Cost	LKR (Million)/year	164.47 (USD 0.82 Million)
Savings		
Average Annual Energy Savings	MWh/year	6,947.80
Total Cost Savings	LKR (Million)/year	171.88 (USD 0.86 Million)

Source: Research by East Coast Sustainable

Table- 95: Results of Case-2 techno financial analysis for Colombo City

Parameter	Units	Value
Total Investment Required	LKR (Million)	452.61 (USD 2.26 Million)
Simple Payback Period	Years	2.79
Internal Rate of Return	%	36%
Net Present Value	LKR (Million)	1,419.35 (USD 7.10 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure: 12 to this report

3.8.3 Case:3 Solar Based EE Lighting System with CCMS

The details of existing and proposed luminaires for the case are presented under Table- 96.

Table- 96: Details of Luminaires and CCMS units in Case-3 for Colombo City

Parameter	Units	Values		
		Type-1	Type-2	Type-3
Existing/Baseline/BAU Luminaires				
Type of existing Street Lighting Fixture		Fluorescent	HPMV	HPSV
Typical Rating of existing Street Lighting Fixture	W	40	150	250
Total number of street lights	No	7,616	11,946	3,676
Proposed Luminaires				
Proposed LED Fixture rating	W	20	70	60
Total number of street lights	No	7,616	11,946	7,352
Rating of Solar PV module	Wp	30	300	240
Rating of Battery for storage	Ah	75	240	200
System Voltage	V	12	24	24
No of CCMS Units	No	286		

Source: CEB Lighting population survey (IEI, 2015)

Details of energy consumption and cost of operation and savings for Case-3 is presented in the Table- 97.

Table- 97: Details of Case-3 Energy savings, Cost savings for Colombo City

BAU	**Units**	**Value**
Average Annual Energy Consumption	MWh/year	13,208.07
Average Operating Cost	LKR (Million)/year	336.32 (USD 1.68 Million)
Savings		
Average Annual Energy Savings	MWh/year	13,208.027
Total Cost Savings	LKR (Million)/year	317.27 (USD 1.58 Million)

Source: Research by East Coast Sustainable

The detailed techno-financial analysis for the project period of 10 years is presented as Annexure:12 to this report

The Table- 98 provides details of IRR at different subsidy/grant from donor agencies and net investment (i.e., total investment minus subsidy) for project developer.

Table- 98: Results of Case-3 techno financial analysis for Colombo City

Results of Case-3 Techno Financial Analysis for Colombo City, Sri Lanka											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	21.47	19.32	17.17	15.03	12.88	10.73	8.59	6.44	4.29	2.15
Internal Rate of Return (per end user)	%	-16%	-14%	-12%	-10%	-7%	-3%	2%	9%	21%	49%
Net Present Value (per end user)	LKR (Million)	943.63	1122.83	1302.03	1481.23	1660.43	1839.63	2018.84	2198.04	2377.24	2556.44
	USD (Million)	4.72	5.61	6.51	7.41	8.30	9.20	10.09	10.99	11.89	12.78
Total investment by end user	LKR (Million)	7156.37	6440.73	5725.10	5009.46	4293.82	3578.19	2862.55	2146.91	1431.27	715.64
	USD (Million)	35.78	32.20	28.63	25.05	21.47	17.89	14.31	10.73	7.16	3.58
Total programme/Project cost	LKR (Million)	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37
	USD (Million)	35.78	35.78	35.78	35.78	35.78	35.78	35.78	35.78	35.78	35.78

Source: Research by East Coast Sustainable

The IRR becomes positive at around 70% of subsidy/grant. Thus, a minimum of 70% subsidy/grant is required to make the project viable. Further 70% - 80% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%. However, the level of subsidy may be determined by the Member State depending on what it considers as reasonable IRR.

3.9 Summary Of Techno-Financial Analysis

Based on techno-financial analysis of individual cities discussed in previous sections, the summary is prepared and presented in Table- 99.

Table- 99: Summary of Techno-financial Analysis-1

Country	Municipality	Case-1		Case-2	
		Payback Period (years)	IRR (%)	Payback Period (years)	IRR (%)
Afghanistan	Kabul	1.25	79	1.30	76
Bangladesh	Chittagong	2.96	34	3.29	30
Bhutan	Gelephu	4.76	16	4.99	14
India	Hyderabad	0.80	127	1.23	84
Maldives	Male	1.26	78	1.31	75
Nepal	Kathmandu	5.22	15	5.42	18
Pakistan	Islamabad	1.10	95	1.15	91
Sri Lanka	Colombo	2.68	38	2.79	36

Source: Research by East Coast Sustainable

In respect of solarisation (under Case-3) various cities, the financial results are summarised in the Table- 100 with the details of subsidy requirement (from government and other donors) for a reasonable IRR.

Table- 100: Summary of Techno-financial Analysis-2

Country	Municipality	Case-3		
		Subsidy (%)	Payback Period (years)	IRR (%)
Afghanistan	Kabul	40	6.0	7
		50	5.0	12
Bangladesh	Chittagong	80	6.1	10
		90	3.1	33
Bhutan	Gelephu	88	6.1	10
		90	5.0	16
India	Hyderabad	60	7.5	4
		70	5.7	12
Maldives	Male	70	5.4	8
		80	3.6	21
Nepal	Kathmandu	70	7.9	3
		80	5.3	14
Pakistan	Islamabad	50	7.2	10
		60	5.7	16
Sri Lanka	Colombo	70	6.4	9
		80	4.3	21

Source: Research by East Coast Sustainable

Summary of techno-financial analysis:

- **Afghanistan:** The EE projects with LED street lighting are financially viable with IRR ranging between 76% to 79%. The solar based LED projects are viable with 40% to 50% subsidy/grant from donors.
- **Bangladesh:** The financial viability of LED based street lighting in terms of IRR is in the range 30% to 31%. The lower electricity tariff in Bangladesh is one of the primary reasons for lack of viability for solar street lighting. The solar street lighting projects are viable with a minimum subsidy/grant of 80%.
- **Bhutan:** Bhutan is having lowest electricity tariff among SAARC Member States. The IRR for LED based street lighting projects is in the range of 14% to 16%. However, the solar based street lighting would be viable with subsidy/grant of around 90%.
- **India:** The IRR of solarisation becomes positive at around 60% of subsidy/grant. Thus, a minimum of 36% subsidy/grant is required to make the project viable. Further 60% - 70% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%.
- **Maldives:** The IRR of solarization becomes positive at around 70% of subsidy/grant. Thus, a minimum of 70% subsidy/grant is required to make the project viable. Further 70% - 80% of subsidy/grant is required for the project proponent/investor to earn an IRR of around 10%.
- **Nepal:** The lower electricity tariff is the primary reason for lack of viability of solar street lighting in Nepal wherein the financial viability come with 70% to 80% subsidy/grant from the donors. In such a situation and keeping in view the concerns of climate change, it is recommended that Nepal take suitable steps to bring in targets for solarization of street lighting and allocate budgets.
- **Pakistan:** LED based EE improvement projects have IRR of 90% to 95% that can be taken up by private sector/ESCOs. This would avoid the financial burden on the municipalities. Pakistan may take appropriate steps to bring in PPP/ESCO model of implementation for EE improvements in street lighting. The solarization of street lighting is viable with around 50% of subsidy/grant (that would provide 10% IRR). Pakistan may take suitable steps to allocate budget from internal sources or external donors for the targeted solarisation.
- **Sri Lanka:** The financial viability of solarization is possible with about 70% subsidy/grant. Sri Lanka may take appropriates steps to implement solarization of street lighting which may include setting minimum targets for solarization of street lighting in municipalities, arranging the subsidy/grant to bridge the viability gap.

4 Recommendations and Conclusions

4.1 Recommendations

4.1.1 Afghanistan

i. The policy recommendation under AEEP 2016 provides overall direction to EE and solarization projects in street lighting in Afghanistan. On account of poor grid access (especially in rural areas) and high electricity tariffs are working favourably for EE improvements in street lighting in Afghanistan.
ii. The EE projects with LED street lighting are financially viable with IRR ranging between 76% to 79%. The solar based LED projects are viable with 40% to 50% subsidy/grant from donors.
iii. In view of the AEEP direction that 50% of street lighting be converted with EE fixtures like LED and balance 50% with solar LED based street lighting, Afghanistan may take suitable actions to implement EE projects on expedited manner. With regard to solarization of street lights, which is relevant for rural areas (with limited grid access), Afghanistan is required to enlist the support from international donors.
iv. In both EE and solarisation of street lighting, economy of scale brings down the project cost. It is recommended that Afghanistan initiate a national level programme for street lighting, designate/appoint dedicated agency to oversee the implementation. The designated agency may also act as demand aggregator for various municipalities and region to brin down the project cost and improve the financial viability of the project especially for solarization of street lights.
v. Afghanistan is required to have special focus on rural areas where 80% of the population lives but with limited grid access. Solar based street lighting for rural areas would realise the objectives of AEEP 2016.
vi. The introduction of new technologies for street lighting especially solar based street lighting would require new skills and capacities for municipalities. The skill development and capacity building in these areas are crucial for faster technology adoption in Afghanistan.

4.1.2 Bangladesh

i. The financial viability of LED based street lighting in terms of IRR is in the range 30% to 31%. The lower electricity tariff in Bangladesh is one of the primary reasons for lack of viability for solar street lighting. The solar street lighting projects are viable with a minimum subsidy/grant of 80%.
ii. Energy Efficiency and Conservation Master Plan (2015-2030) of Bangladesh does not have any reference with respect to street lighting. Most of the EE and solarization projects implemented in Bangladesh have been through project mode without any policy backup. In view of climate change concerns, municipal energy efficiency shall be made part of the master plan.
iii. The partnership with EESL (India) is expected to bring in the benefits of economy of scale for street lighting projects in Bangladesh. For cities/areas which are not covered for implementation under this partnership, it is suggested that the Bangladesh take appropriate steps towards demand aggregations for EE/solarisation projects by combining

requirements of multiple municipalities into one project. The Bangladesh may also take suitable steps to designate an agency to handle such demand aggregation.

iv. The concerns of climate change require implementation of solar based street lighting that requires significant amount of subsidy/grant. Bangladesh may take suitable actions to bring down the total project cost through bulk ordering so that the available subsidy/grant from the donors is put to effective use.

4.1.3 Bhutan

i. All four major municipalities/cities Bhutan are in the advanced stages of implementing EE street lighting.

ii. Bhutan has lowest electricity tariff among SAARC Member States. The IRR for LED based street lighting projects is in the range of 14% to 16%. However, the solar based street lighting would be viable with subsidy/grant of around 90%.

4.1.4 India

i. India achieved coverage of more than 95% of cities for LED street lighting implementation. Strong legal and policy backup coupled with creation of dedicated and specialised agencies to oversee and implement EE can be attributable to the success of street lighting programme in India.

ii. The demand aggregation and bulk procurement by National ESCO (i.e., EESL) have helped reduce the project cost for EE in street lighting. A similar outcome is expected from solar street lighting projects being piloted by EESL. The commercial success of the EE projects of EESL is largely on account of the business model and contractual arrangements with respective municipalities and State (Provincial) governments. EESL shall disseminate such information with concerned authorities in other Member States.

iii. India may extend support of EESL in capacity building of other Member States in the areas of contractual arrangements for EE in street lighting. This would help the other Member States to avoid any mistakes while entering similar contracts with ESCOs.

iv. The EE enhancements such as dimming facility for LED based street lighting are expected to increase the energy savings and improve the financial viability. India may take up few demonstration projects and establish the viability of the technology.

4.1.5 Maldives

i. Maldives have already implemented EE street lighting in the city of Male where 40% of the population lives. With regard to islands, Maldives is planning to install solar street lights in other islands.

ii. Maldives may take appropriate actions to develop skills among the local municipalities to attend operation and maintenance issues related to solar street lighting system components. This would enable to attend any O&M requirements and improve service levels to the citizens.

4.1.6 Nepal

i. National Energy Efficiency Strategy of 2013 focused on replacing inefficient lighting fixtures in domestic and commercial sectors with efficient fixtures like LED lamps. It also intended to ban incandescent lamps in a phased manner. However, no specific direction or targets for EE/solarization in street lighting have been envisaged in NEES.
ii. Most of the solar street lighting projects that have been implemented without policy backing by NEES but were based on operational factors such as availability of funds from donors (e.g., ADB) when load shedding was prevailing. It is recommended that Nepal may take appropriate steps to include municipal/street lighting sector in NEES with specific targets for penetration of EE/solar street lighting over a period of time.
iii. The lower electricity tariff is the primary reason for lack of viability of solar street lighting in Nepal wherein the financial viability come with 70% to 80% subsidy/grant from the donors. In such a situation and keeping in view the concerns of climate change, it is recommended that Nepal take suitable steps to bring in targets for solarization of street lighting and allocate budgets.
iv. The municipalities in Nepal are implementing EE projects in street lighting individually in phased manner. Each of such phased implementation is having separate tendering/procurement process. Apparently, this is done keeping in view the budget constraints of individual municipalities. Such an approach is not efficient both in terms of time and cost. It is recommended that Nepal to procure EE street lighting on a bulk basis by aggregating demand of various municipalities.
v. Nepal may take suitable steps to build capacities of municipal administrators in the areas of business models for EE implementation especially in ESCO model to overcome constraints related to the budget. This would expedite the implementation of EE street lighting in Nepal.

4.1.7 Pakistan

i. EE/solarization in street lighting has regulatory force in the form of INDCs and National Energy Efficiency and Conservation Act, 2016 of Pakistan. EE in street lighting is also a focus are in Sustainable Energy Efficiency Development Program of Pakistan prepared by ADB in 2009 (ADB, Sustainable Energy Efficiency Development Program, 2009). However, in terms of specific actions and time lines, the street lighting sector is not included in the Energy Efficiency Roadmap for Pakistan[129] (2019). It is recommended to include targets in terms of time lines for EE and solarisation of street lights in the roadmap. This would enable municipalities to complete the EE/solarization of street lighting in an expedited manner.
ii. LED based EE improvement projects have IRR of 90% to 95% that can be taken up by private sector/ESCOs. This would avoid the financial burden on the municipalities. Pakistan may take appropriate steps to bring in PPP/ESCO model of implementation for EE improvements in street lighting.

[129] Prepared by World Bank

iii. The solarization of street lighting is viable with around 50% of subsidy/grant (that would provide 10% IRR). Pakistan may take suitable steps to allocate budget from internal sources or external donors for the targeted solarisation.
iv. NEECA and its provincial partners may take appropriate steps to bundle EE/solarization projects in street lighting for multiple municipalities to bring in economy of scale that would benefit the projects in terms of time and cost efficiency. This would further improve the financial viability.

4.1.8 Sri Lanka

i. Sri Lanka has introduced PPP/ESCO model for EE improvements in street lighting for its Capital city. It is recommended that Sri Lanka may take appropriate steps to implement EE in street lighting by introducing roadmap with time-based targets that would enable Sri Lanka to complete the EE projects in street lighting in all municipalities in expedited manner.
ii. The financial viability of solarization is possible with about 70% subsidy/grant. Sri Lanka may take appropriates steps to implement solarization of street lighting which may include setting minimum targets for solarization of street lighting in municipalities, arranging the subsidy/grant to bridge the viability gap.

4.2 Conclusions

I. LED based street lighting system with or without CCMS is being implemented in all SAARC Member States which is also a global practice. The CCMS system for street lighting can be seen more as a productivity multiplier reducing manpower deployment for control and monitoring of street lighting systems resulting in O&M cost besides energy saving. The productivity improvement on account of smart controls increases with the scale of operation (number of street lights connected).

II. The ROI/Payback period and internal rate of return for efficiency enhancement in street lighting are very attractive. The ROI/payback and IRR are in the range of 0.8 – 5.2 years and 15% - 127% respectively under Case-1 i.e., efficiency enhancement with LED based street lighting without smart control. The higher payback periods for Case-1 in few Member States (e.g., Bangladesh, Bhutan and Nepal) is primarily on account of lower electricity tariff and higher capital cost of equipment due to procurement in small quantity. Similarly, where the capital cost of implementation is relatively lower on account of large-scale procurement by aggregating procurement quantity of multiple municipalities (e.g., India), the project payback period is low and IRR is high.

III. In respect of efficiency enhancement under Case-2 i.e., LED based street lighting with smart control, the ROI/Payback and IRR of the project are estimated to be ranging from 0.9 to 4.9 years and 14% - 105% respectively. The additional savings from smart controls (e.g., CCMS) improve the project NPV. The biggest driver for smart control implementation is in terms of improved service level of street lighting system.

IV. The most popular smart controls (e.g., CCMS) are IoT based control and monitoring system where it is possible to dynamically programme the street light operations, monitor operating status, burning hours that would enable to expedite fault/failure detection and corrective action. The smart controls are amenable for additional features such as dimming based on time or traffic detection.

V. Solarisation of street lighting is under pilot studies in various Member States of SAARC region. The key driver for solarisation presently is lack of or limited access to grid in few Member States especially in rural areas and remote areas. The techno-financial analysis indicates that a capital subsidy/grant ranging between 50% to 90% for a reasonable minimum IRR of 8% - 10%. This is on account of higher initial cost and replacement cost of batteries during the project life.

VI. The financial viability of solar based street lighting can improve with price reduction as the adoption of the technology increases as was the case with LED based street lighting. The donor agencies are required to contribute the subsidy component for few pilot projects with the aim of breaking the price barrier of the technology so that the subsequent solarisation projects would become viable without any requirement of subsidy. Another well-known method of breaking the price barrier for market transformation is the bulk procurement by aggregating the demand of multiple municipalities as was done by EESL (India) for many EE technologies such as LED street lighting, LED lamps, star labelled electrical appliances.

VII. SAARC Member States are at different level in respect of penetration of efficiency enhancement and solarisation of street lighting. India which is largest electricity consumer of SAARC region has already replaced more than 100 million street lights with LED based street lighting with IoT based smart controls in most of the municipalities and implementing similar projects in rural areas. Other SAARC Member States are also implementing similar projects in different phases. Such efficiency enhancement is expected to be completed in 4 to 5 years and the average energy savings over 10 years period (2021 – 2030) is estimated to be between 28% - 32% for various Member States. Similarly, the solarisation is estimated to bring an average energy saving of 41% to 47% over a period of 2021 – 2030 under assumption that the solarisation will be viable and penetration would gradually reach 90% in 2029. Given such energy efficiency potential, the municipalities and concerned agencies is required to work towards creating an enabling environment for expedited implementation.

VIII. Some of the key factors for successful implementation of EE and solarisation in street lighting are:

a) Take advantage of latest Information and Communication Technologies (ICT) for objective verification of energy savings that are crucial in PPP/ESCO model to cover technical risks.
b) The municipalities or other project proponents may utilise risk management instruments such as Partial Risk sharing Facility (PRSF) made available in India with the support of the World Bank. PRSF provides partial credit guarantees to Participating Financial Institutions (PFIs) to cover a share of default risk faced by them in extending loans to Energy Efficiency (EE) projects implemented by the Host entity through Energy Service Companies (ESCOs)[130].
c) The respective governments of the Member States may designate or create nodal agencies for implementation with demand aggregation of EE fixtures for multiple municipalities to bring in economy of scale towards reducing procurement cost, develop and harmonise technical and quality specifications of hardware, software, installation and O&M practices.

IX. The cities selected for case study under this research represents diversity in terms of population, time, geographical terrine. Despite such diversity the aspiration and competitive spirit are the same when it comes to implementing efficiency enhancement and solarisation in street lighting. The different penetration of such EE projects is primarily on account of issues related to availability of financial resources and governance that can be overcome with the regulatory force of NDCs, adoption of financial mechanisms / business models involving public/private owned specialised agencies such as ESCO.

[130] For details please visit: http://prsf.sidbi.in/user/pages/viewpage/p_brief

5 Bibliography

ADB. (2013). Bangladesh: Energy Efficiency Improvement .
ADB. (2013). Bangladesh: Energy Efficiency Improvement .
ADB. (2013). Energy Efficiency Improvement TA-7642-Bangladesh. ADB.
ADB-EESL. (2020). International Competative Bidding Document of EESL.
AEEP. (2016). Afghanistan Energy Efficiency Policy.
AEPC. (2016). Technical Guidelines for Solar Street Lighting systems in Nepal.
Bank, W. (2015). Energy-Efficient Street Lighting—Implementation and Financing Solutions.
Bank, W. (2015). Republic of India Energy-Efficient Urban Street Lighting. https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/India%20EE%20Street%20Lighting%20Implementation%20and%20Financing%20%28P149482%29%20June%2027%202015_Optimized.pdf.
Bank, W. (2019). Energy Efficiency Roadmap for Pakistan.
BEE. (2015). Guide Book-3 for Certified Energy Auditor/Managers. In BEE, Energy Efficiency in Electrical Utilities (p. 234 (lighting chapter: 223 to 245)).
BEE. (2019-20). IMPACT OF ENERGY EFFICIENCY MEASURES. BEE.
Business Recoder. (2021). p. https://www.brecorder.com/news/40096495.
CBC. (2021, September 14). Retrieved from http://www.cbc.gov.pk/en/street-light
CCC. (2021). Retrieved from Chittagong City Corporation: http://ccc.org.bd/street_lighting
EESL. (2021, September 8). Retrieved from https://eeslindia.org: https://eeslindia.org/en/atal-jyoti-yojana/
Expert, T. F. (2018, July 18). Retrieved from https://thefinancialexpress.com.bd/national/country/solar-power-street-lights-illuminate-chirirbandar-1531913365
Glamox. (n.d.). Retrieved from https://glamox.com/gsx/led-lifetime-and-the-factors-that-affect-it#:~:text=The%20lifetime%20of%20a%20LED,do%2C%20it%20slowly%20dims%20down.
Glamox. (n.d.). Retrieved from https://glamox.com/gsx/led-lifetime-and-the-factors-that-affect-it#:~:text=The%20lifetime%20of%20a%20LED,do%2C%20it%20slowly%20dims%20down.
Hindu, T. (2021). Pole-mounted EV charging stations set up in Kozhikode.
IEA. (2010). Retrieved from https://www.iea.org/policies/2215-promote-energy-conservation-and-energy-efficiency-policy-no-3-maldives-national-energy-policy-and-strategy-2010
IEA. (2021). India Energy Outlook.
IEEE. (2014). Electrification of streets of Dhaka city using solar and piezoelectric energy. Retrieved from https://ieeexplore.ieee.org: https://ieeexplore.ieee.org/document/6850746
IEI, S. L. (2015). Analysis on Energy Efficiency and Optimality of LED and Photovoltaic based Street Lighting. In E. -V. XLVIII.
iFLUX. (2021, September 14). Retrieved from http://www.ifluxlighting.com: http://www.ifluxlighting.com/index.php?g=portal&m=news&a=show&id=135
India.com. (2018). Delhi Street Lights Will Now Feature Pollution Monitors, CCTV & WiFi To Combat With Air Pollution.
inteli. (n.d.). Retrieved from https://intelilight.eu/smart-street-lighting/
Intelligence, P. &. (2020, June). Solar Street Lighting Market Research Report. https://www.psmarketresearch.com/market-analysis/solar-street-lighting-market.
KPK, G. O. (2020). Technical Evaluation Report.
Kuensel. (2017, May). kuensel. Retrieved from https://kuenselonline.com: https://kuenselonline.com/streetlights-make-pipaldara-road-safe/
Little, A. D. (2019). The evolution of the Street Lighting Market.
MoPEBD. (2019). National Energy Policy and Strategies.
Morning, T. (2021, September 13). Retrieved from themorning.lk: https://www.themorning.lk/transforming-colombo-with-smart-street-lighting/

(2019). NEE&C.
NEECA. (2020). NEEKA-Pakistan, ESCO Model. Signify.
NEES. (2013). National Energy Efficiency Strategy .
Post, T. K. (2021, September 13). Retrieved from https://kathmandupost.com: https://kathmandupost.com/national/2020/07/29/lalitpur-to-install-669-smart-electric-street-lamps-on-three-routes
PWC. (2017). Handbook on Quality Control for Street Lighting Projects of EESL.
RERL. (2019). MUNICIPAL ENERGY PLAN PHIKKAL RURAL MUNICIPALITY.
RGoB. (2019). TWELFTH FIVE YEAR PLAN 2018-2023. Gross National Happiness Commission Royal Government of Bhutan.
RISE. (2021, September 12). Retrieved from https://rise.esmap.org/country/afghanistan
SEC. (2018). SAARC Energy Outlook 2030. SAARC Energy Center/CRISIL.
Sky, B. C. (2021, September 24). Retrieved from https://www.blancocountynightsky.org/guidelines.php
TERI. (2014). Regional Report on the Transition to Efficient Lighting in South Asia.
Today, P. (2017). Retrieved from https://archive.pakistantoday.com.pk/2017/03/05/islamabad-glitters-with-led-street-lights/
Today, P. (2017). pp. https://archive.pakistantoday.com.pk/2017/03/31/mci-replaces-339-conventional-street-lights-with-leds/. Retrieved from https://archive.pakistantoday.com.pk: https://archive.pakistantoday.com.pk/2017/03/31/mci-replaces-339-conventional-street-lights-with-leds/
WB. (2009). Energy Efficient Lighting Options for Afganistan.
Wikipedia. (2021). Retrieved from https://en.wikipedia.org/wiki/Islamabad

Annexure-1:
OEM price list:

Outdoor LED Luminaires
STREET LIGHTS

ENDURA PEARL 25 W MP

New generation energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high efficient LED as lighting source and PC cover having TOP Opening seperate driver compartment with IP66 protection and impact resistance of IK07.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLSL15WLED757SASYTOPCMP	9405	2100.00	1 N
ENDURAPEARLSL20WLED757SASYTOPCMP	9405	2200.00	1 N
ENDURAPEARLSL25WLED757SASYTOPCMP	9405	2300.00	1 N
Suitable for pole dia Ø 43 mm (max.)			

ENDURA PEARL 30 W MP

New generation energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high efficient LED as lighting source and PC cover having TOP Opening seperate driver compartment with IP66 protection and impact resistance of IK07.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLSL30WLED757SASYTOPCMP	9405	2800.00	1 N
Suitable for pole dia Ø 43 mm (max.)			

ENDURA CITYLITE PLATINUM PLUS

Energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high power LED as lighting source and lens embedded PC cover having IP65 protection and impact resistance of IK07 with 10KV Built-in Surge Protection Device.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURACITYLITEPLATPLUSSL30WLED757SASYBOPC	9405	3200.00	1 N
ENDURACITYLITEPLATPLUSSL35WLED757SASYBOPC	9405	3400.00	1 N
Suitable for pole dia Ø 43 mm (max.)			

ENDURA PEARL NEO

New generation energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high power LED as lighting source and lens embedded PC cover having TOP Opening seperate driver compartment with IP66 protection and impact resistance of IK07.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLNEOSL40WLED757PASYTOPC	9405	4300.00	1 N
ENDURAPEARLNEOSL45WLED757PASYTOPC	9405	4600.00	1 N
ENDURAPEARLNEOSL48WLED757PASYTOPC	9405	5000.00	1 N
ENDURAPEARLNEOSL60WLED757PASYTOPC	9405	6500.00	1 N
Suitable for pole dia Ø 43 mm (max.)			

ENDURA CITYLINER NEO

New generation energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high efficient LED as lighting source with toughened glass having IP66 protection and impact resistance of IK07.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURACITYLINERNEOSL70WLED757PASYBOTG	9405	7100.00	1 N
ENDURACITYLINERNEOMPSL80WLED757PASYBOTG	9405	8100.00	1 N
Suitable for pole dia Ø 54 mm (max.)			

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Professional Luminaires List Price w.e.f. 1st January, 2020

Outdoor Luminaires

STREET LIGHTS

ENDURA PEARL PLUS

New generation energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high power LED as lighting source and lens embedded PC cover having TOP OPENING seperate driver compartment with IP66 protection and impact resistance of IK07 with 10KV Built-in Surge Protection Device.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLPLUSSL90WLED757PASYTOPCASTHO	9405	9250.00	1 N
Suitable for pole dia Ø 54 mm (max.)			

PEARL MAGNUM

New generation energy saving and environmental friendly long life LED street light made up of pressure die cast aluminium housing with high power LED as lighting source with toughened glass top cover. TOP OPENING seperate driver compartment with IP66 protection and impact resistance of IK07 with 10KV Built-in Surge Protection Device.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLMAGNUMSL100WLED757PASYTOTGAST	9405	10500.00	1 N
ENDURAPEARLMAGSL120WLED757PASYTOTGASTHO	9405	12990.00	1 N
Suitable for pole dia Ø 58 mm (max.)			

PEARL MAGNUM PLUS

New generation energy saving & environmental friendly long life Versatile pressure die-cast aluminium IP66 roadway luminaire with high power LED as light source.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLMAGPLUSSL135WLED757PASYTOTG	9405	14000.00	1 N
ENDURAPEARLMAGPLUSSL150WLED757PASYTOTG	9405	16200.00	1 N
Suitable for pole dia Ø 60 mm (max.)			

PEARL GRAND

New generation energy saving & environmental friendly long life Versatile pressure die-cast aluminium IP66 roadway luminaire with high power LED as light source.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLGRANDSL170WLED757PASYTOTG	9405	21900.00	1 N
ENDURAPEARLGRANDSL190WLED757PASYTOTG	9405	22300.00	1 N
ENDURAPEARLGRANDSL200WLED757PASYTOTG	9405	22700.00	1 N
Suitable for pole dia Ø 63 mm (max.)			

PEARL GRAND PLUS

New generation energy saving & environmental friendly long life Versatile pressure die-cast aluminium IP66 roadway luminaire with high power LED as light source.

Item Description	HSN Code	List Price in ₹ Per Unit	Case Lot No. of unit/s
ENDURAPEARLGRANDPLUSSL250WLED757PASYTOTG	9405	31500.00	1 N
Suitable for pole dia Ø 63 mm (max.)			

Professional Luminaires List Price w.e.f. 1st January, 2020

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Outdoor LED Luminaires

SOLAR STREET LIGHTS/MINI MAST

Solar LED Standalone Street Light Range - (2 Days Backup)

For Panel, Battery, Pole and SCC specification pls. contact branch office or refer Catalogue

Solar Standalone Street Light system mentioned below includes LED street Light with in-built SCC, SPV Panel, Battery, HDG Tubular Pole.

Description	HSN Code	Luminaire Wattage (W)	System Voltage (V)	Lumen lm	MPPT/ PWM	Solar Panel Wp	Battery (LMLA/GEL) Ah	HDG Tubular Pole above ground	List Price (₹) for LMLA	List Price (₹) for GEL
15 W Solar SLS	8541	15	12	1500	PWM	75	40	5 m TUB Pole	38100.00	38600.00
20 W Solar SLS	8541	20	12	2100	PWM	100	60	5 m TUB Pole	44200.00	47600.00
24 W Solar SLS	8541	24	12	2400	PWM	125	60	5 m TUB Pole	47900.00	51500.00
21 W Solar SLS	8541	21	12	2205	MPPT	80	60	5 m TUB Pole	44400.00	47900.00
24 W Solar SLS	8541	24	12	2400	MPPT	100	60	5 m TUB Pole	47400.00	51000.00
30 W Solar SLS	8541	30	12	3150	MPPT	125	75	6 m TUB Pole (B)	55000.00	58600.00
36 W Solar SLS	8541	36	12	3780	MPPT	150	75	6 m TUB Pole (B)	62000.00	65600.00
39 W Solar SLS	8541	39	12	4095	MPPT	160 (80x2)	100	6 m TUB Pole (B)	66800.00	73200.00
45 W Solar SLS	8541	45	24	4725	MPPT	200 (100x2)	120 (60x2)	6 m TUB Pole (B)	82800.00	89900.00
60 W Solar SLS	8541	60	24	6300	MPPT	250 (125x2)	150 (75x2)	7 m Oct	116000.00	123300.00
70 W Solar SLS	8541	70	24	7350	MPPT	300 (150x2)	150 (75x2)	7 m Oct	129000.00	136300.00

* PWM - Pulse Width Modulation * MPPT - Maximum Power Point Tracking * (B) - Pole with base plate * LMLA - Low Maintanace Lead Acid Tubular * GEL - VRLA Solar Gel
* Blue tooth & Hybrid Option avaiable from 7 W to 70 W. * Any change in the specfication other than above mentioned specfication for Solar PV module, Battery,Luminaire, Pole, Hybrid, Bluetooth etc will be charged extra. * Price : Ex Works Noida. *Taxes : Extra as applicable * Transportation :- Extra as appliacble * Warranty :- 1 year for complete system against manufacturing defect only, Additional warranty will be charged extra.

Solar LED Standalone Street Light Range - (3 Days Backup)

For Panel,Battery, Pole and SCC specification pls. contact branch office or refer Catalogue

Solar Standalone Street Light system mentioned below includes LED street Light with in-built SCC, SPV Panel, Battery, HDG Tubular Pole.

Description	HSN Code	Luminaire Wattage (W)	System Voltage (V)	Lumen lm	MPPT/ PWM	Solar Panel Wp	Battery (LMLA/GEL) Ah	HDG Tubular Pole above ground	List Price (₹) for LMLA	List Price (₹) for GEL
7 W Solar SLS	8541	7	12	735	PWM	40	40	4 m TUB Pole	29900.00	29500.00
12 W Solar SLS	8541	12	12	1200	PWM	60	40	5 m TUB Pole	35600.00	38300.00
15 W Solar SLS	8541	15	12	1500	PWM	75	60	5 m TUB Pole	41800.00	45400.00
20 W Solar SLS	8541	20	12	2100	PWM	100	75	5 m TUB Pole	46400.00	49900.00
24 W Solar SLS	8541	24	12	2400	PWM	125	75	5 m TUB Pole	50900.00	54700.00
21 W Solar SLS	8541	21	12	2205	MPPT	80	75	5 m TUB Pole	46700.00	50100.00
24 W Solar SLS	8541	24	12	2400	MPPT	100	75	5 m TUB Pole	50400.00	54200.00
30 W Solar SLS	8541	30	12	3150	MPPT	125	100	6 m TUB Pole (B)	58800.00	65000.00
36 W Solar SLS	8541	36	12	3780	MPPT	150	120	6 m TUB Pole (B)	67700.00	75600.00
39 W Solar SLS	8541	39	12	4095	MPPT	160 (80x2)	150	6 m TUB Pole (B)	73300.00	81700.00
45 W Solar SLS	8541	45	24	4725	MPPT	200 (100x2)	150 (75x2)	6 m TUB Pole (B)	86900.00	96300.00
60 W Solar SLS	8541	60	24	6300	MPPT	250 (125x2)	200 (100x2)	7 m Oct	123600.00	136000.00
70 W Solar SLS	8541	70	24	7350	MPPT	300 (150x2)	240 (120x2)	7 m Oct	140300.00	156000.00

* PWM - Pulse Width Modulation * MPPT - Maximum Power Point Tracking * (B) - Pole with base plate * LMLA - Low Maintanace Lead Acid Tubular * GEL - VRLA Solar Gel
* Blue tooth & Hybrid Option avaiable from 7 W to 70 W. * Any change in the specfication other than above mentioned specfication for Solar PV module, Battery,Luminaire, Pole, Hybrid, Bluetooth etc will be charged extra. * Price : Ex Works Noida. *Taxes : Extra as applicable * Transportation :- Extra as appliacble * Warranty :- 1 year for complete system against manufacturing defect only, Additional warranty will be charged extra.

Solar Mini Mast

For Panel, Battery, Mast and SCC specification pls. contact branch office or refer Catalogue.

Luminaire Type	HSN Code	Luminaire Wattage	System Voltage	Solar Panel Wp	Battery Ah	Solar Charge Controller	Metal Battery Box Powder Coated	Octagonal Pole HD Galvanized	List Price in ₹ Per Unit
Street Light	8541	4x30 W	24	500 Wp	400 Ah	MPPT	Mounting at 4 metre from ground	9 m	300000.00
Flood Light	8541	3x33 W	24	400 Wp	300 Ah	MPPT	Mounting at 4 metre from ground	9 m	272000.00
Flood Light	8541	4x33 W	24	500 Wp	400 Ah	MPPT	Mounting at 4 metre from ground	9 m	331500.00
Flood Light	8541	3x45 W	24	500 Wp	400 Ah	MPPT	Mounting at 4 metre from ground	9 m	334900.00

* Blue tooth & Hybrid Option avaiable. * Any change in the specfication other than above mentioned specfication for Solar PV module, Battery, Luminaire, Pole, Hybrid, Bluetooth etc will be charged extra. * Price : Ex Works Noida. *Taxes : Extra as applicable * Transportation :- Extra as appliacble * Warranty :- 1 year for complete system against manufacturing defect only, Additional warranty will be charged extra. * Street Light - standard item. * Flood Light - project item. * Octagonal 4 mm thick.

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Professional Luminaires List Price w.e.f. 1st January, 2020

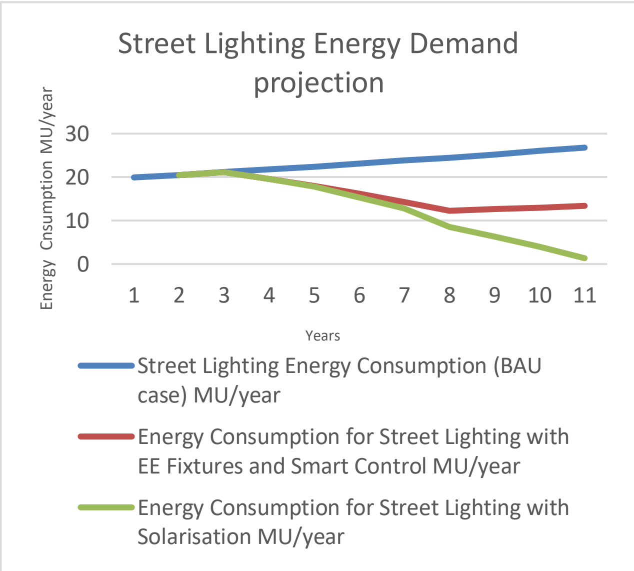
Annexure-2:
Energy demand projection and Saving potential of Afghanistan:

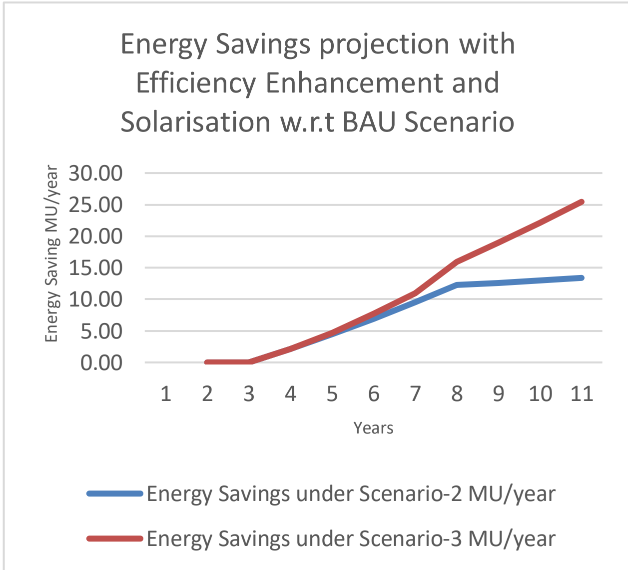
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	3.00	
CAGR of Electrical Energy Demand Growth	%	6.20	SAARC Energy Outlook 2030 (2018 data)
Annual Energy Consumption	MU	4981	SAARC Energy Outlook 2030 (2018 data)
Street Lighting Energy Consumption	%	0.40	
	MU	19.9	
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	4981	5290	5618	5966	6336	6729	7146	7589	8060	8559	9090	75363
Street Lighting Energy Consumption (BAU case)	MU/year	20	20.52	21.14	21.77	22.42	23.10	23.79	24.50	25.24	26.00	26.78	255
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		20.52	21.14	19.59	17.94	16.17	14.27	12.25	12.62	13.00	13.39	160.89
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**

Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		20.52	21.14	19.59	17.76	15.36	12.85	8.58	6.31	3.90	1.34	127.34
Energy Savings under Scenario-2	**MU/year**		**0.00**	**0.00**	**2.18**	**4.48**	**6.93**	**9.52**	**12.25**	**12.62**	**13.00**	**13.39**	**74.37**
	%												**29.14**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**0.00**	**2.18**	**4.66**	**7.74**	**10.94**	**15.93**	**18.93**	**22.10**	**25.44**	**107.91**
	%												**42.29**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

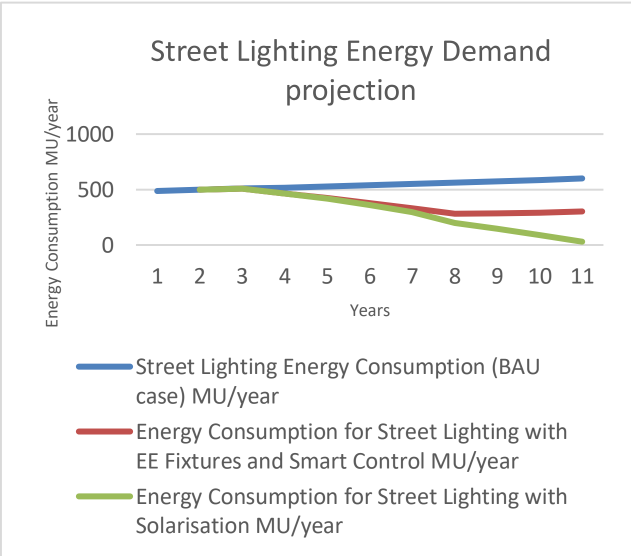
Energy demand projection and Saving potential of Bangladesh:

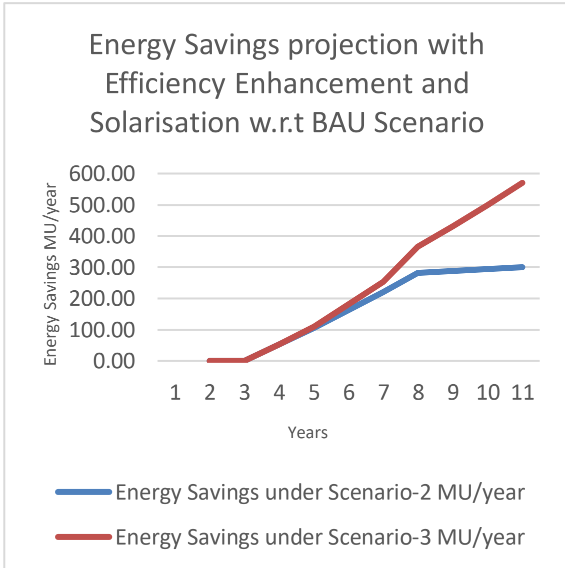
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	2.1	https://www.statista.com/statistics/455782/urbanization-in-bangladesh/
CAGR of Electrical Energy Demand Growth	%	5.50	SAARC Energy Outlook
Annual Energy Consumption	MU	67668	Bangladesh Power Development Board Annual Report 2019-20
Street Lighting Energy Consumption	%	0.72	Considered as Sri Lanka
	MU	487.2	
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	67668	71390	75316	79459	83829	88439	93304	98435	103849	109561	115587	986836
Street Lighting Energy Consumption (BAU case)	MU/year	487	497.49	507.99	518.71	529.65	540.83	552.24	563.89	575.79	587.94	600.34	5962
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		497.49	507.99	466.83	423.72	378.58	331.34	281.94	287.89	293.97	300.17	3769.93

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		497.49	507.99	466.83	419.48	359.65	298.21	197.36	143.95	88.19	30.02	3009.17
Energy Savings under Scenario-2	**MU/year**		**0.00**	**0.00**	**51.87**	**105.93**	**162.25**	**220.89**	**281.94**	**287.89**	**293.97**	**300.17**	**1704.92**
	%												**28.60**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**0.00**	**51.87**	**110.17**	**181.18**	**254.03**	**366.53**	**431.84**	**499.75**	**570.32**	**2465.68**
	%												**41.36**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

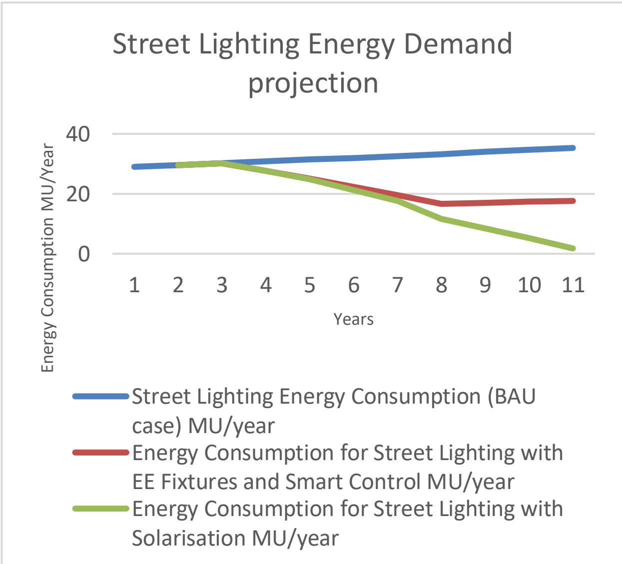
Energy demand projection and Saving potential of Bhutan:

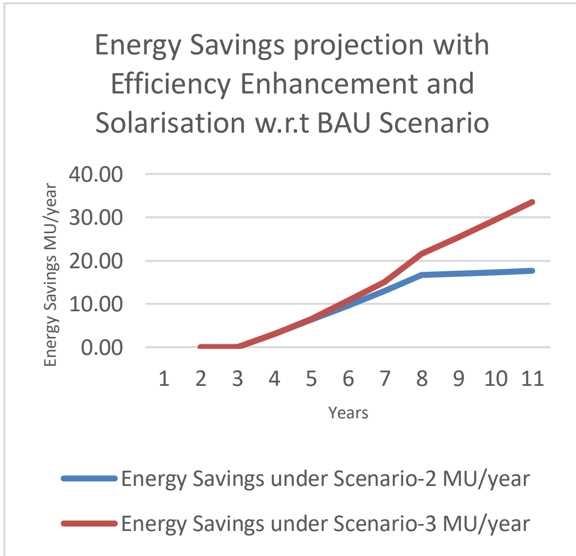
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	1.98	Considered same as Nepal
CAGR of Electrical Energy Demand Growth	%	8.80	SAARC Energy Outlook
Annual Energy Consumption	MU	2398	Bhutan Druk Green Annual Report 2019
Street Lighting Energy Consumption	%	1.21	Annual Electricity report 2019
	MU	29.0	
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	2397.83	2609	2838	3088	3360	3656	3977	4327	4708	5122	5573	41657
Street Lighting Energy Consumption (BAU case)	MU/year	29	29.59	30.17	30.77	31.38	32.00	32.64	33.28	33.94	34.61	35.30	353
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		29.59	30.17	27.69	25.10	22.40	19.58	16.64	16.97	17.31	17.65	223

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		29.59	30.17	27.69	24.85	21.28	17.62	11.65	8.49	5.19	1.76	178
Energy Savings under Scenario-2	**MU/year**		**0.00**	**0.00**	**3.08**	**6.28**	**9.60**	**13.05**	**16.64**	**16.97**	**17.31**	**17.65**	**101**
	%												**28.52**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**0.00**	**3.08**	**6.53**	**10.72**	**15.01**	**21.63**	**25.46**	**29.42**	**33.53**	**145**
	%												**41.22**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

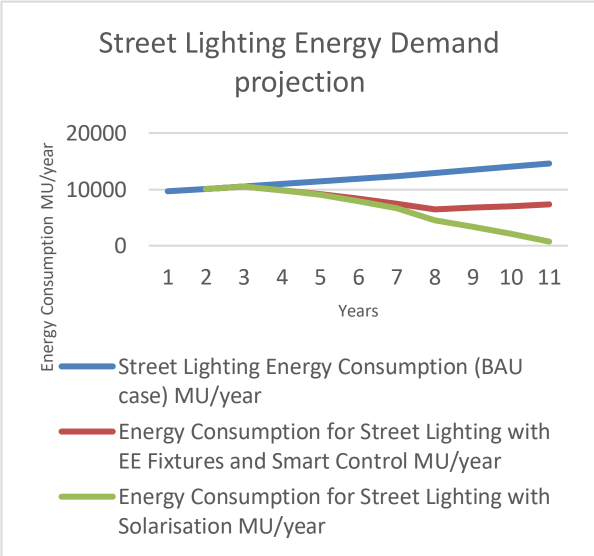
Energy demand projection and Saving potential of India:

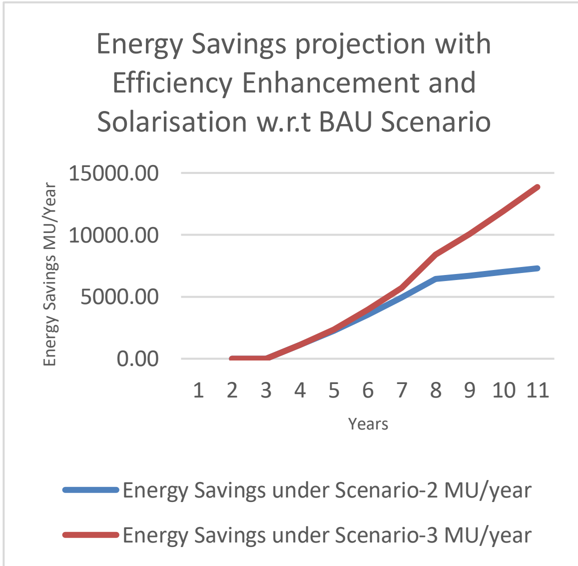
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	4.2	https://indiacsr.in/total-road-length-in-india-increased-at-4-2-cagr/
CAGR of Electrical Energy Demand Growth	%	6.00	SAARC Energy Outlook
Annual Energy Consumption	MU	1207000	India Energy Outlook 2021
Street Lighting Energy Consumption	%	0.80	
	MU	9669.1	https://cea.nic.in/dashboard/?lang=en
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	1207000	1279420	1356185	1437556	1523810	1615238	1712153	1814882	1923775	2039201	2161553	18070773
Street Lighting Energy Consumption (BAU case)	MU/year	9669	10075	10498	10939	11399	11877	12376	12896	13438	14002	14590	131761
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		10075	10498	9845	9119	8314	7426	6448	6719	7001	7295	82741

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		10075	10498	9845	9028	7899	6683	4514	3359	2100	730	64731
Energy Savings under Scenario-2	**MU/year**		**0**	**0**	**1094**	**2280**	**3563**	**4951**	**6448**	**6719**	**7001**	**7295**	**39351**
	%												**29.87**
Energy Savings under Scenario-3	**MU/year**		**0**	**0**	**1094**	**2371**	**3979**	**5693**	**8382**	**10078**	**11902**	**13861**	**57360**
	%												**43.53**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

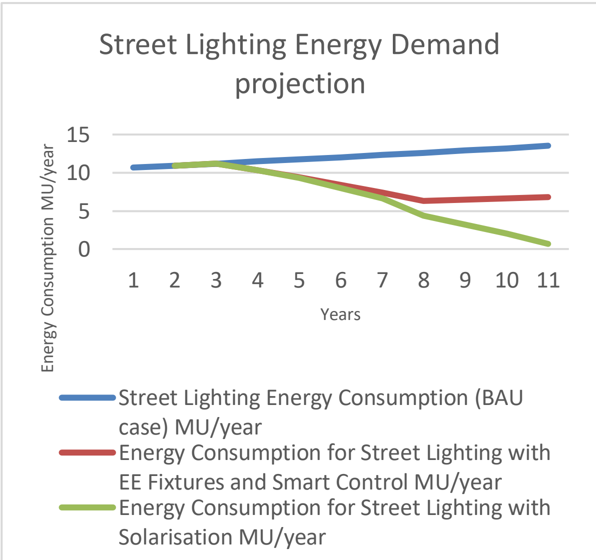
Energy demand projection and Saving potential of Maldives:

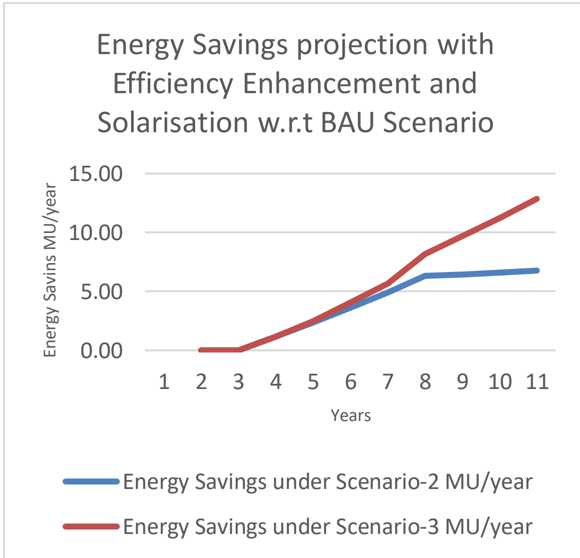
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	2.4	https://knoema.com/atlas/Maldives/Urban-population
CAGR of Electrical Energy Demand Growth	%	6.50	SAARC Energy Outlook 2030
Annual Energy Consumption	MU	1405	SAARC Energy Outlook 2030 (2017 data)
Street Lighting Energy Consumption	%	0.76	
	MU	10.7	
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	1405	1496	1594	1697	1807	1925	2050	2183	2325	2476	2637	21597
Street Lighting Energy Consumption (BAU case)	MU/year	11	10.93	11.20	11.47	11.74	12.02	12.31	12.61	12.91	13.22	13.54	133
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		10.93	11.20	10.32	9.39	8.42	7.39	6.30	6.45	6.61	6.77	84

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		10.93	11.20	10.32	9.30	7.99	6.65	4.41	3.23	1.98	0.68	67
Energy Savings under Scenario-2	**MU/year**		**0.00**	**0.00**	**1.15**	**2.35**	**3.61**	**4.92**	**6.30**	**6.45**	**6.61**	**6.77**	**38**
	%												**28.77**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**0.00**	**1.15**	**2.44**	**4.03**	**5.66**	**8.19**	**9.68**	**11.24**	**12.86**	**55**
	%												**41.66**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

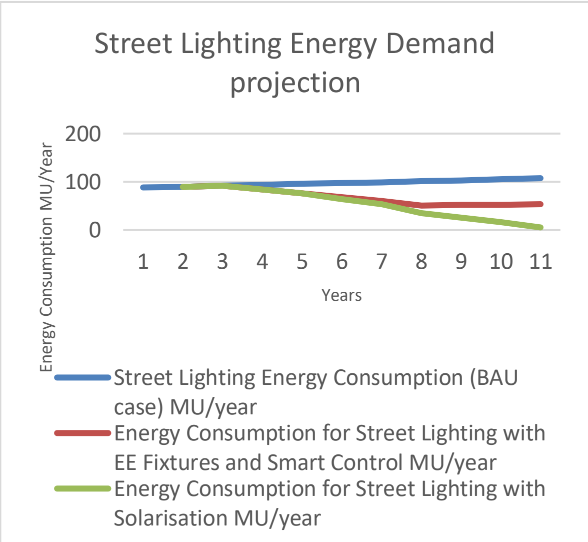
Energy demand projection and Saving potential of Nepal:

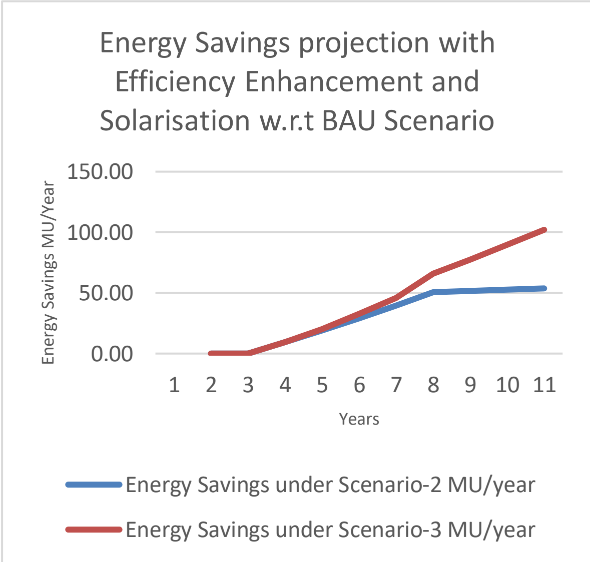
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	1.98	Nepal Electricity Authority Annual Reports 2020/2021
CAGR of Electrical Energy Demand Growth	%	9.10	SAARC Energy Outlook
Annual Energy Consumption	MU	7277	Nepal Electricity Authority Annual Reports 2020/2021
Street Lighting Energy Consumption	%	1.21	Nepal Electricity Authority Annual Reports 2020/2021
	MU	88.3	Nepal Electricity Authority Annual Reports 2020/2021
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	7277	7939	8662	9450	10310	11248	12272	13389	14607	15936	17386	128477
Street Lighting Energy Consumption (BAU case)	MU/year	88	90	92	94	96	97	99	101	103	105	107	1074
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		90.07	91.85	84.30	76.42	68.19	59.61	50.66	51.66	52.68	53.73	679

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		90.07	91.85	84.30	75.66	64.78	53.65	35.46	25.83	15.80	5.37	543
Energy Savings under Scenario-2	**MU/year**		**0.00**	**0.00**	**9.37**	**19.11**	**29.23**	**39.74**	**50.66**	**51.66**	**52.68**	**53.73**	**306**
	%												**28.52**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**0.00**	**9.37**	**19.87**	**32.63**	**45.70**	**65.85**	**77.49**	**89.56**	**102.08**	**443**
	%												**41.22**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

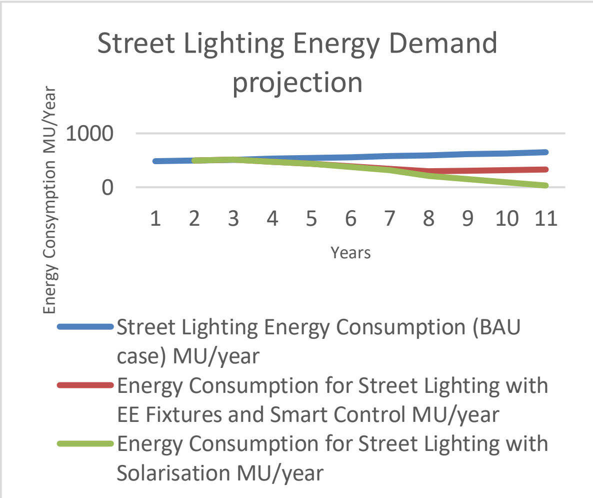
Energy demand projection and Saving potential of Pakistan:

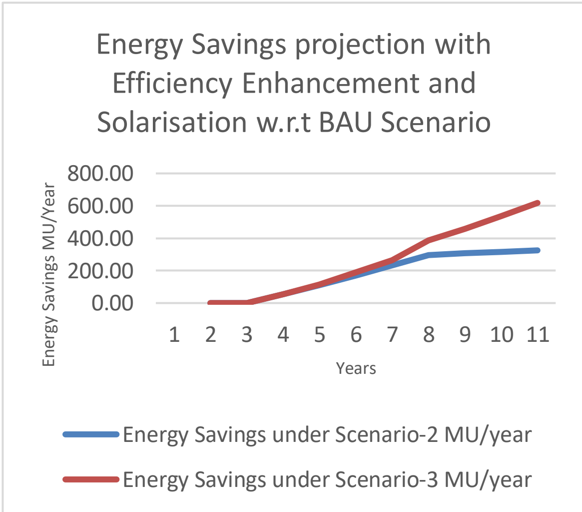
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	3.00	https://www.ceicdata.com/en/pakistan/energy-consumption-and-supplies-annual/electricity-consumption-street-light
CAGR of Electrical Energy Demand Growth	%	4.00	SAARC Energy Outlook
Annual Energy Consumption	MU	120392	SAARC Energy Outlook
Street Lighting Energy Consumption	%	0.40	https://www.ceicdata.com/en/pakistan/energy-consumption-and-supplies-annual/electricity-consumption-street-light
	MU	484.0	https://www.ceicdata.com/en/pakistan/energy-consumption-and-supplies-annual/electricity-consumption-street-light
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	120392	125208	130216	135425	140842	146475	152334	158428	164765	171355	178210	1623649
Street Lighting Energy Consumption (BAU case)	MU/year	484	498.52	513.48	528.88	544.75	561.09	577.92	595.26	613.12	631.51	650.46	6199
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	0	20	40	60	80	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		498.52	513.48	475.99	435.80	392.76	346.75	297.63	306.56	315.76	325.23	3908

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	0	1	5	10	30	50	70	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		498.52	513.48	475.99	431.44	373.12	312.08	208.34	153.28	94.73	32.52	3093
Energy Savings under Scenario-2	**MU/year**		**0.00**	**0.00**	**52.89**	**108.95**	**168.33**	**231.17**	**297.63**	**306.56**	**315.76**	**325.23**	**1807**
	%												**29.14**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**0.00**	**52.89**	**113.31**	**187.96**	**265.84**	**386.92**	**459.84**	**536.78**	**617.93**	**2621**
	%												**42.29**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

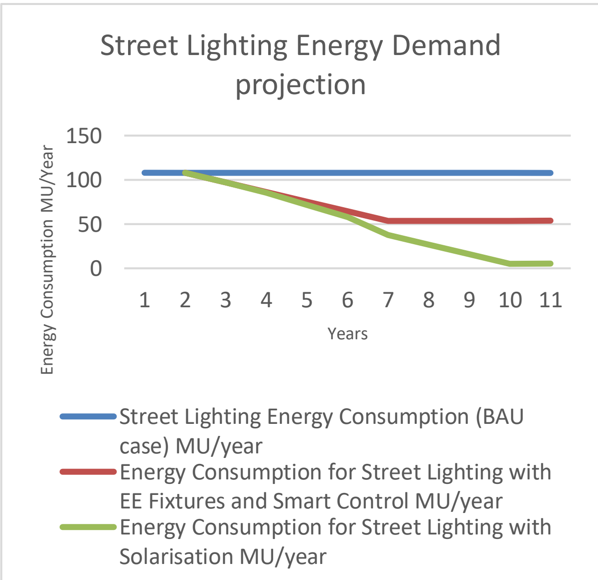
Energy demand projection and Saving potential of Sri Lanka:

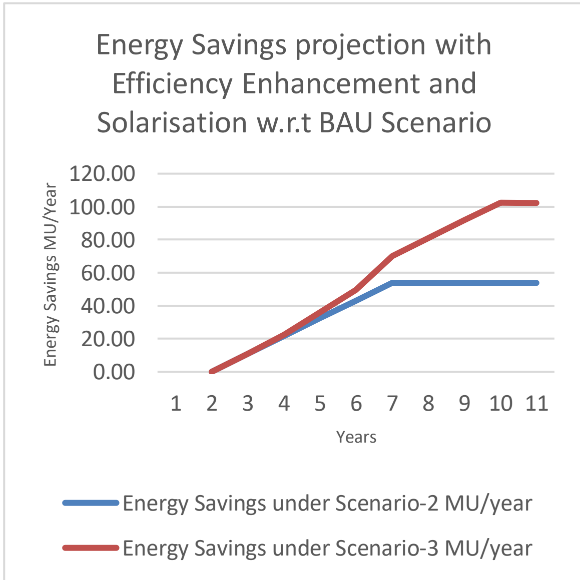
Macro Data			
Description	**Units**	**Value**	**Source of Data**
CAGR of increase in street light energy consumption	%	-0.02	Statistical Digest 2020 (CEB annual reports 2017 - 2020))
CAGR of Electrical Energy Demand Growth	%	5.10	SAARC Energy Outlook
Annual Energy Consumption	MU	14286	Statistical Digest 2020 (CEB)
Street Lighting Energy Consumption	%	0.76	Statistical Digest 2020 (CEB)
	MU	108.0	Statistical Digest 2020 (CEB)
Percentage Energy Savings with EE fixtures with Smart Control	%	50	Assumption based

Energy Demand Projection and Saving Potential													
Description	**Units**	**BAU**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**	**Total**
Scenario-1: BAU Case		**0**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	
Total Energy Consumption	MU/year	14286	15015	15780	16585	17431	18320	19254	20236	21268	22353	23493	204022
Street Lighting Energy Consumption (BAU case)	MU/year	108	107.98	107.96	107.94	107.91	107.89	107.87	107.85	107.83	107.81	107.78	1187
Scenario-2: EE lighting fixtures with smart controls													
Cumulative percentage of Replacement with EE fixtures with Smart Control	%		0	20	40	60	80	100	100	100	100	100	
Energy Consumption for Street Lighting with EE Fixtures and Smart Control	MU/year		107.98	97.16	86.35	75.54	64.74	53.94	53.92	53.91	53.90	53.89	701.33

Description	Units	BAU	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10	Total
Scenario-3: Solarisation based on LED with Smart Control													
Cumulative percentage of Solarisation of Street lighting with EE fixtures with Smart Control	%		0	0	1	5	10	30	50	70	90	90	
Energy Consumption for Street Lighting with Solarisation	MU/year		107.98	97.16	85.48	71.76	58.26	37.75	26.96	16.17	5.39	5.39	512.32
Energy Savings under Scenario-2	**MU/year**		**0.00**	**10.80**	**21.59**	**32.37**	**43.16**	**53.94**	**53.92**	**53.91**	**53.90**	**53.89**	**377.48**
	%												**31.81**
Energy Savings under Scenario-3	**MU/year**		**0.00**	**10.80**	**22.45**	**36.15**	**49.63**	**70.12**	**80.89**	**91.65**	**102.42**	**102.39**	**566.49**
	%												**47.73**

Source: Research by East Coast Sustainable





Source: Research by East Coast Sustainable

Annexure-3:
Key Steps Involved in EESL's Implementation Model

Key Steps Involved in EESL's Implementation Model

Stages	Description
MoU	MoU to be signed between municipalities and EESL
DPR/ Revalidation of DPR	Detailed walk-through energy audit for data validation of existing DPR and Joint Verification
Technology Demonstration	To assess actual energy savings and determination of annuity payments and finalizing technical specifications
Agreement	Agreement to be signed between municipalities and EESL for implementation.
Payment Mechanism	The Payment security mechanism to be finalized
Implementation	EESL will implement the project based on own resources
M&V	Deemed saving approach used

Annexure-4:
Technical Specifications of LEDs and CCMS and SSL Configurations

Typical LED Luminaire specifications

S No.	Parameters	Requirements
1	Light source	SMD LED chip
2	Wattage of LED Package	1W minimum to 5W maximum
3	Wattage at Operating current	1W minimum to 3W maximum
4	Luminous Efficacy	>135 lumens/watt
5	CRI	> 70
6	CCT	5000K and 5700K
7	Estimated Life Span	> 50,000 hrs
8	Limits of Harmonic Currents (THD)	< 10%
9	System Efficacy	110 lumens/watt
10	Junction temp	Maximum 85°C
11	PF	> 0.95
12	Frequency	50Hz ± 3%
13	Operating Voltage	110 V – 320 V
14	Operating Current	>=350 mA<1000 mA
15	Surge Voltage	> 4 kV
16	Ambient Temp	-10 to 50 deg C
17	Working Humidity	10% - 90% RH
18	Degree of protection	IP-66
19	Luminaire Body Temp	should not exceed 30 deg. C from ambient (45 deg. C) with tolerance of 10 deg C after 24 Hrs
20	Lens/ Lens module for LEDs	LED Lights shall be provided with Lenses/Lens modules. Lens should be of material resistant to de-gradation during service, due to atmospheric components, to avoid adverse impact on light output. Lens shall be bolted (and not pasted - However, bolted AND pasted is acceptable) on to the MCPCB above the chips and the lens should be minimum IK07 impact resistant if it is also used as a lens cover
21	Cover Glass / Lens Cover	Glass - Distortion free, clear, heat resistant, toughened, UV stabilized glass; Lens Cover - Lens should be of material non-degradable during service, due to atmospheric components, to avoid adverse impact on light output.

S No.	Parameters	Requirements
22	Cover Frame	Polycarbonate/ Al alloy cover fixed to the housing means of stainless-steel screws.
23	Heat Dissipation/ Heat Sink	INSITU/Thermal Test will cover this parameter. Manufacture must submit design/ drawing indicating maximum temperature point on LED array. This value shall not exceed junction temperature of Tj - 85 deg C
24	Impact Resistance	The Street Light shall be built in such a way that it can withstand wind speed of 150 Kmph.

Source: (ADB-EESL, 2020)

Typical CCMS specifications used in SLNP (India)

Central Control & Monitoring System Specifications	
Rated Electrical Parameters	
Items	**Specified Operating Range**
Connection type	System for Single Phase/Three Phase Switching points
Voltage	240 volts P-N (+20% to -40% V_{ref}) on each phase
Current	10 - 60 A for each phase (Withstands 120% Imax), Starting current- 0.2%I_b
Frequency	50 Hz ±5% (47.5 to 52.5) Hz
Power Factor	Zero(lag)-Unity-Zero (Lead)
Accuracy	1
Withstand Voltage	440V up-to 5 minutes between Phase – Phase
Rating	Rating of the CCMS units for each phase (including rating of safety equipment's - MCB, Relay, etc.) should be – • For 30% quantity of CCMS units in a ULB- 3 KW connected load is to be considered • For 10% CCMS Units in ULB - 5 KW connected load to be considered • For 20% CCMS Units in ULB – 7.5 KW connected load to be considered • For 20% CCMS Units in ULB - 10 KW connected load to be considered • For remaining 20% CCMS Units in ULB - 15 KW connected load is to be considered.
Functional Specifications	
Data	The Smart meter unit Should be able to capture (record) andprovide following parameters at variable time-intervals • Cumulative Active Energy • Average Power Factor • Power on hours • Monthly Load on/off Smart meter has the provision to store last 30 days' data at one hour interval. All these data is accessible for reading, recording by downloading through HHT (Hand Held Unit) through optical

Central Control & Monitoring System Specifications	
	port or USB/Bluetooth given on smart meter front. For HHT, a smartphone-based solution for collecting/accessing data is alsoacceptable
Tampers	Following tampers are logged with occurrence and restoration in FIFO manner: • Low Load • Over load • Low Power Factor • Under voltage • Over voltage • Magnet
RTC	The smart meter has a built-in calendar & clock, having an accuracy of +/- 5 minute per year or better, however meter may confirm to accuracy as per IS 13779. A separate internal Lithium battery back-up is provided for continuous operation of smart meter RTC for at least two years under smart meter un-powered conditions
Astronomical Calendar for switching operation	On the basis of latitude and longitude of the installation place smart meter itself decides switch on –off timings
Maintenance Mode of switching	Suitable scheme to be provided for disconnecting power for the safe maintenance purpose
Switch Weld & SwitchFail events	When Switch "on" operation failed condition is logged as switch fail event and when Switch "off" operation fails condition islogged as switch weld event
Power on-off events	Last 20 power on-off events with power off duration will belogged
Separate Energy Consumption registration for unscheduled switch on period	Last 20 events of maintenance mode with snap of energy register and date/time is logged in meter. In BCS, with these events, duration of these events and energy consumption during that period is also shown
Switching on Overload /Over current	SMART METER will continue monitor over current & overload condition against the threshold defined in smart meter and if condition persist for predefined time period (default 5 minutes) then disconnection of switch will have occurred. Smart meter will reconnect the switch after some predefined time interval (default 10 minutes) and will check again for the event condition, if condition persist again, switch will disconnect again else will run normally. In case of disconnection, smart meter will try for defined trial count (default 5 count) and after that will disconnect the switch for long defined sleep period (default 30 minutes). After sleep period switch reconnect, activity will restart in same described manner. Every switching operation will be logged in meter.
Lamp	RYB Phase indication to be provided on enclosure front
Communication	SMART METER stored data can be downloaded through its optical port or USB using HHT (Hand held Unit) or directly by Laptop using Base computer

Central Control & Monitoring System Specifications	
	software. SMART METER should be able to interface with the communication module through a serial port
Programmable Scheduling	The schedule for light operations can be programmed on field orduring installation overriding the astronomical-clock
Operating temperature	0^0 C to 70^0 C
Storage temperature	-20^0 C to 80^0 C
Humidity	95% non-condensing

Source: EESL (India)

Typical Solar Street Lighting System Specifications

PV Module Specifications	
Description	**Specification**
PV module Type	Mono or Poly Crystalline or Thin Film
Operating voltage corresponding to the power output (Vmp)	At least 34 Vmp for each module of 24V and 17 Vmp for each module of 12 V for crystalline For thin film the Vmp of the module must be at least 40% higher than the system voltage
Minimum Module efficiency at STC:	Crystalline: Minimum 14% Thin Film: Minimum 10%
Power degradation	A letter provided by principal PV module manufacturer in their letter head stating the warranty period for their PV module. The warranty period for the PV Module must be at least 10 years against a maximum 10% reduction and 20 years against a maximum 20% reduction of output power at STC.
Junction Box	IP 65 or above
Module Mounted Structure	Non corrosive support structures to be fixed on the top of pole.For areas where there is problem of shading in some of the site of installation, the solar PV module of that particular solar street light system can be installed at rooftop of nearby house. An agreement has to be signed between the user community and the owner of the house for such installations.
Tilt Angle and direction	towards due south around local latitude
Support structure design and foundation mounting arrangements should withstand	Wind Speed up to 180 km/hr
Fasteners (nuts and bolts)	Stainless Steel or hot deep galvanized.
IEC 61215 (2nd Edition) IEC 61646	Crystalline silicon terrestrial photovoltaic (PV) modules - Design Qualification and type approval. Thin-film Terrestrial Photovoltaic (PV) Modules-Design Qualification and Type Approval
IEC 61730	PV module safety qualification
Charge Controller Specifications	
Description	**Specification**
Type	Solar Charge Controller or Regulator
Control Mode	For Type 1, 2 & 3- PWM or MPPT For Type 4, 5, 6 & 7 – MPPT will be preferred With Dusk to Dawn i.e., the lamp automatically switches ON after the sunset and switches OFF after sunrise. Also include at least two stage of dimming function. First stage-system should function at 100% load for six hours and second stage: system should function at 50% load for next 6 hours (with reduced illumination).

Working Temperature & Humidity	-5 to +55 °C/35 to 85%RH (Without Condensation)
Protection Function	Solar reverse-charging protection, solar reverse-connection protection, battery over charge protection, battery over-discharge protection, battery reverse-connection protection
Certifications	RETS Certified
Battery Specifications	
Description	**Specification**
Battery Type	Lead Acid Sealed- Gel Tubular VRLA solar deep cycle or Lithium ion with proper protection
Battery Voltage	For Lead Acid battery: 12V For Lithium-Ion battery the bidder must propose the voltage compatible to system
Battery Efficiency	Minimum 85%
Pressure Regulation	The battery shall be provided with pressure regulation valve, which shall be self-re-sealable and flame retardant
Self-Discharge	Less than 3% per month
Operating Temperature	-5 °C to 55°C
Instruction	Charging instructions shall be provided along with the batteries
Warranty	5 years replacement guarantee.

Source: (AEPC, 2016)

Typical Solar Street Lighting Packages adopted by AEPC, Nepal

Lamp Size (Watt)	Minimum Solar PV Module Size (Wp)	Minimum Battery Size for Lead Acid (AH)	Minimum Battery Size for Lithium Ion (AH)	Minimum Charge Controller Size (A)	Height of pole in meter	Recommended for road having Right of Way (ROW)
10	50	40	30	5	7	Less than 4 m
20	100	60	45	10	7	4-6 M
30	150	80	60	12	7	>6-10 M
40	200	100	75	15	8 or 9	>10 -14 M
60	300	150	115	25	8 or 9	>14 -20 M
80	400	200	150	30	10	>20 – 30 M
100	500	250	180	40	10	>30 M

Source: (AEPC, 2016)

Annexure-5:
Techno Financial Case Study of Kabul City of Afghanistan

Case-1: Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of energy consumption and cost of operation for Case-1 for Kabul Municipality

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline/BAU Scenario												
Annual Energy Consumption	MWh/year	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841
Annual Electricity Bill	AFN Million	149.057	152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.11
Annual Maintenance Cost	AFN Million	35.48	36.29	37.13	37.98	38.85	39.75	40.66	41.60	42.55	43.53	44.53
Total Operating Cost	AFN Million	184.53	188.78	193.12	197.56	202.10	206.75	211.51	216.37	221.35	226.44	231.65
	USD Million	2.17	2.22	2.27	2.32	2.38	2.43	2.49	2.55	2.60	2.66	2.73
After Implementation												
Annual Energy Consumption	MWh/year		5059	5059	5059	5059	5059	5059	5059	5059	5059	5059
Annual Electricity Bill	AFN Million		69.6	72.8	74.5	76.2	77.9	79.7	81.6	83.4	85.4	87.3
Annual Maintenance Cost	AFN Million		4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3
Total Operating Cost	AFN Million		73.8	77.3	79.0	80.8	82.7	84.6	86.6	88.5	90.6	92.7
	USD Million		0.87	0.91	0.93	0.95	0.97	1.00	1.02	1.04	1.07	1.09

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Kabul Municipality

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	5782	5782	5782	5782	5782	5782	5782	5782	5782	5782
Annual Electricity Cost Savings	AFN Million	-	82.925	83.196	85.109	87.067	89.069	91.118	93.214	95.358	97.551	99.795
Annual Maintenance Cost Savings	AFN Million	-	32.03	32.67	33.42	34.19	34.98	35.78	36.60	37.45	38.31	39.19
Total Cost Savings	AFN Million	-	114.96	115.87	118.53	121.26	124.05	126.90	129.82	132.80	135.86	138.98
	USD Million	-	1.35	1.36	1.39	1.43	1.46	1.49	1.53	1.56	1.60	1.64
Investment												
Original Investment of LED	AFN Million	136.37	-	-	-	-	-	-	-	-	-	-
Investment for LED Failure	AFN Million	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
Investment for End-of-life replacement	AFN Million	0.00										
Installation Cost	AFN Million	4.95	0.00									
Total Investment	AFN Million	144.05	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
	USD (,000)	1690.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Subsidy/Grant	%	No Subsidy										
Investment from end user	AFN Million	144.05	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
	USD (,000)	1690.00	30	30	30	30	30	30	30	30	30	30
Net savings	AFN Million	-144.05	112.23	113.14	115.80	118.53	121.32	124.17	127.09	130.08	133.13	136.26
	USD Million	-1.69	1.32	1.33	1.36	1.39	1.43	1.46	1.50	1.53	1.57	1.60

Source: Research by East Coast Sustainable

Case-2: Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Kabul Municipality

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Annual Energy Consumption	MWh/year	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841
Annual Electricity Bill	AFN Million	149.057	152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.11
Annual Maintenance Cost	AFN Million	35.48	36.29	37.13	37.98	38.85	39.75	40.66	41.60	42.55	43.53	44.53
Total Operating Cost	AFN Million	184.53	188.78	193.12	197.56	202.10	206.75	211.51	216.37	221.35	226.44	231.65
	USD Million	2.17	2.22	2.27	2.32	2.38	2.43	2.49	2.55	2.60	2.66	2.73
Proposed Scenario												
Total Connected Load	MW	-	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Annual Energy Consumption	MWh/year	-	5059	5294	5416	5541	5668	5798	5932	6068	6208	6351
Number of CCMS Units	No	-	231	-	-	-	-	-	-	-	-	-
Avoided hours of Operation due to timely switch ON and Off	Hr	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Electricity Bill	AFN Million	-	69.6	72.8	74.5	76.2	77.9	79.7	81.6	83.4	85.4	87.3
Annual Maintenance Cost	AFN Million	-	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3
Total Operating Cost	AFN Million	-	73.8	77.3	79.0	80.8	82.7	84.6	86.6	88.5	90.6	92.7
	USD Million	-	0.87	0.91	0.93	0.95	0.97	1.00	1.02	1.04	1.07	1.09

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Kabul Municipality

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year	-	5782.00	5782.00	5782.00	5782.00	5782.00	5782.00	5782.00	5782.00	5782.00	5782.00
Annual Energy Savings with CCMS Units	MWh/year	-	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Total Energy Savings	MWh/year	-	5783.00	5783.00	5783.00	5783.00	5783.00	5783.00	5783.00	5783.00	5783.00	5783.00
Annual Cost Savings with LED Retrofit	AFN Million	-	82.93	83.20	85.11	87.07	89.07	91.12	93.21	95.36	97.55	99.80
Annual Cost Savings with CCMS units	AFN (,000)	-	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Annual Maintenance Cost Savings	AFN Million	-	32.03	32.67	33.42	34.19	34.98	35.78	36.60	37.45	38.31	39.19
Total Cost Savings	AFN Million	-	114.98	115.89	118.55	121.28	124.07	126.92	129.84	132.82	135.88	139.00
	USD Million	-	1.35	1.36	1.39	1.43	1.46	1.49	1.53	1.56	1.60	1.64
Investment												
Original Investment for LED retrofit	AFN Million	136.40	-	-	-	-	-	-	-	-	-	-
Investment for LED Failure	AFN Million	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
Investment for End-of-life replacement of LED	AFN Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for One CCMS Unit	AFN (,000)	-	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Original Investment for CCMS units	AFN Million	5.38	-	-	-	-	-	-	-	-	-	-
Investment for CCMS Failure	AFN Million	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for End-of-life replacement of CCMS	AFN Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	AFN Million	4.95	-	-	-	-	-	-	-	-	-	-
Total Investment	AFN Million	149.56	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
	USD (,000)	1760.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	AFN Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	AFN Million	149.56	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86	2.86
	USD (,000)	1.76	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Net savings	AFN Million	-149.56	112.12	113.03	115.69	118.42	121.21	124.06	126.98	129.96	133.02	136.14
	USD Million	-1.76	1.32	1.33	1.36	1.39	1.43	1.46	1.49	1.53	1.56	1.60

Source: Research by East Coast Sustainable

Case-3: Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Kabul Municipality

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Annual Energy Consumption	MWh/year	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841
Annual Electricity Bill	AFN Million	149.06	152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.11
Annual Maintenance Cost	AFN Million	35.48	36.29	37.13	37.98	38.85	39.75	40.66	41.60	42.55	43.53	44.53
Total Operating Cost	AFN Million	184.53	188.78	193.12	197.56	202.10	206.75	211.51	216.37	221.35	226.44	231.65
	USD Million	2.17	2.22	2.27	2.32	2.38	2.43	2.49	2.55	2.60	2.66	2.73
Proposed Scenario												
Total Connected Load (Off Grid)	MW		1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Annual Energy Consumption from Grid	MWh/year		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Energy Savings	MWh/year		10841	10841	10841	10841	10841	10841	10841	10841	10841	10841
Number of CCMS Units	No		231.00	231.00	231.00	231.00	231.00	231.00	231.00	231.00	231.00	231.00
Annual Electricity Cost Savings	AFN Million		152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.12
Total Cost Savings	AFN Million		152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.11
	USD Million		1.79	1.84	1.88	1.92	1.96	2.01	2.06	2.10	2.15	2.20

Source: Research by East Coast Sustainable

Details Case-3 Energy savings, Cost savings and Investment for Kabul Municipality

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	10841	10841	10841	10841	10841	10841	10841	10841	10841	10841
Annual Electricity Cost Savings	AFN Million	-	152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.12
Total Cost Savings	AFN Million	-	152.49	155.99	159.58	163.25	167.01	170.85	174.78	178.80	182.91	187.11
	USD Million	0	1.79	1.84	1.88	1.92	1.96	2.01	2.06	2.10	2.15	2.20
Investment												
Original Investment for Solar LED Street Lights	AFN Million	1502.60	-	-	-	-	-	-	-	-	-	-
Investment for LED Failure	AFN Million	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Investment for One CCMS Unit	AFN Million	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	AFN Million	5.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	AFN Million	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for End-of-life replacement of CCMS	AFN Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	AFN Million	0.00	0.00	0.00	0.00	0.00	601.04	0.00	0.00	0.00	0.00	0.00
Installation Cost	AFN Million	9.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	AFN Million	1518.10	0.21	0.21	0.21	0.21	601.24	0.21	0.21	0.21	0.21	0.21
	USD Million	17.86	0.00	0.00	0.00	0.00	7.07	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant	%	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Subsidy/Grant from external donors	AFN Million	683.15	0.09	0.09	0.09	0.09	270.56	0.09	0.09	0.09	0.09	0.09
	USD Million	8.04	0.00	0.00	0.00	0.00	3.18	0.00	0.00	0.00	0.00	0.00
Investment from end user	AFN Million	834.96	0.11	0.11	0.11	0.11	330.68	0.11	0.11	0.11	0.11	0.11
	USD Million	9.82	0.00	0.00	0.00	0.00	3.89	0.00	0.00	0.00	0.00	0.00
Net savings	AFN Million	-834.96	152.37	155.88	159.47	163.14	-163.68	170.73	174.66	178.68	182.79	187.00
	USD Million	-9.82	1.79	1.83	1.88	1.92	-1.93	2.01	2.05	2.10	2.15	2.20

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Kabul Municipality

Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	9.96	8.96	7.97	6.97	5.97	4.98	3.98	2.99	1.99	1.00
Internal Rate of Return (per end user)	%	-5%	-3%	0%	3%	7%	12%	19%	30%	49%	101%
Net Present Value (per end user)	AFN Million	922.31	974.45	1026.60	1078.74	1130.89	1183.03	1235.18	1287.32	1339.47	1391.61
	USD Million	10.85	11.46	12.08	12.69	13.31	13.92	14.53	15.15	15.76	16.37
Total investment by end user	AFN Million	2121.21	1909.09	1696.97	1484.85	1272.72	1060.60	848.48	636.36	424.24	212.12
	USD Million	24.96	22.46	19.96	17.47	14.97	12.48	9.98	7.49	4.99	2.50
Total programme/Project cost	AFN Million	2121.21	2121.21	2121.21	2121.21	2121.21	2121.21	2121.21	2121.21	2121.21	2121.21
	USD Million	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96	24.96

Source: Research by East Coast Sustainable

Annexure-6:
Techno Financial Case Study of Chittagong City of Bangladesh

Case-1: Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of Energy consumption and Cost of operation in Chittagong City

Existing/Baseline/BAU Scenario												
Parameter	**Units**	**Year-0**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**
Annual Energy Consumption	MWh/year	8853.08	8853.08	8853.08	8853.08	8853.08	8853.08	8853.08	8853.08	8853.08	8853.08	8853.08
Annual Electricity Bill	BDT Million	68.17	72.05	76.16	80.50	85.09	89.94	95.07	100.49	106.21	112.27	118.67
Annual Maintenance Cost	BDT Million	5.91	6.24	6.60	6.98	7.37	7.79	8.24	8.71	9.20	9.73	10.28
Total Operating Cost	BDT Million	74.08	78.30	82.76	87.48	92.46	97.74	103.31	109.19	115.42	122.00	128.95
	USD Million	0.87	0.92	0.97	1.03	1.09	1.15	1.22	1.28	1.36	1.44	1.52
Proposed Scenario												
Annual Energy Consumption	MWh/year	-	3930.69	3930.69	3930.69	3930.69	3930.69	3930.69	3930.69	3930.69	3930.69	3930.69
Annual Electricity Bill	BDT Million	-	30.27	33.81	35.74	37.78	39.93	42.21	44.62	47.16	49.85	52.69
Annual Maintenance Cost	BDT Million	-	3.40	3.79	4.01	4.24	4.48	4.73	5.00	5.29	5.59	5.91
Total Operating Cost	BDT Million	-	33.66	37.61	39.75	42.02	44.41	46.94	49.62	52.45	55.44	58.60
	USD Million	-	0.40	0.44	0.47	0.49	0.52	0.55	0.58	0.62	0.65	0.69

Source: Research by East Coast Sustainable

Details Case-1 Energy savings, Cost savings and Investment for Chittagong City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year		4922.39	4922.39	4922.39	4922.39	4922.39	4922.39	4922.39	4922.39	4922.39	4922.39
Annual Electricity Cost Savings	BDT Million		41.79	42.35	44.76	47.31	50.01	52.86	55.87	59.06	62.42	65.98
Annual Maintenance Cost Savings	BDT Million		2.85	2.81	2.97	3.14	3.31	3.50	3.70	3.91	4.14	4.37
Total Cost Savings	BDT Million		44.64	45.15	47.73	50.45	53.32	56.36	59.58	62.97	66.56	70.35
	USD Million		0.53	0.53	0.56	0.59	0.63	0.66	0.70	0.74	0.78	0.83
Investment												
Original Investment of LED	BDT Million	119.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	BDT Million	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Investment for End-of-life replacement	BDT Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	BDT Million	10.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	BDT Million	132.10	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
	USD (,000)	1550.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	BDT Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	BDT Million	132.10	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
	USD (,000)	1550.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Net savings	BDT Million	-132.10	42.25	42.76	45.34	48.06	50.93	53.97	57.18	60.58	64.17	67.96
	USD Million	-1.55	0.50	0.50	0.53	0.57	0.60	0.63	0.67	0.71	0.75	0.80

Source: Research by East Coast Sustainable

Case:2 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Chittagong City

Existing/Baseline/BAU Scenario												
Parameter	**Units**	**Year-0**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**
Total Connected Load	MW	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
Annual Energy Consumption	MWh/year	8853	8853	8853	8853	8853	8853	8853	8853	8853	8853	8853
Annual Electricity Bill	BDT Million	68.169	72.05	76.16	80.50	85.09	89.94	95.07	100.49	106.21	112.27	118.67
Annual Maintenance Cost	BDT Million	5.91	6.24	6.60	6.98	7.37	7.79	8.24	8.71	9.20	9.73	10.28
Total Operating Cost	BDT Million	74.08	78.30	82.76	87.48	92.46	97.74	103.31	109.19	115.42	122.00	128.95
	USD Million	0.87	0.92	0.97	1.03	1.09	1.15	1.22	1.28	1.36	1.44	1.52
Proposed Scenario												
Total Connected Load	MW		0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Annual Energy Consumption	MWh/year		3931	3931	3931	3931	3931	3931	3931	3931	3931	3931
Number of CCMS Units	No		196	196	196	196	196	196	196	196	196	196
Avoided hours of Operation due to timely switch ON and Off	Hr		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Electricity Bill	BDT Million		30.3	33.8	35.7	37.8	39.9	42.2	44.6	47.2	49.8	52.7
Annual Maintenance Cost	BDT Million		3.4	3.8	4.0	4.2	4.5	4.7	5.0	5.3	5.6	5.9
Total Operating Cost	BDT Million		33.7	37.6	39.8	42.0	44.4	46.9	49.6	52.4	55.4	58.6
	USD Million		0.40	0.44	0.47	0.49	0.52	0.55	0.58	0.62	0.65	0.69

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Chittagong City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year	-	4922	4922	4922	4922	4922	4922	4922	4922	4922	4922
Annual Energy Savings with CCMS Units	MWh/year	-	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Total Energy Savings	MWh/year	-	4923.00	4923.00	4923.00	4923.00	4923.00	4923.00	4923.00	4923.00	4923.00	4923.00
Annual Cost Savings with LED Retrofit	BDT Million	-	41.79	42.35	44.76	47.31	50.01	52.86	55.87	59.06	62.42	65.98
Annual Cost Savings with CCMS units	BDT (,000)	-	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Annual Maintenance Cost Savings	BDT Million	-	2.85	2.81	2.97	3.14	3.31	3.50	3.70	3.91	4.14	4.37
Total Cost Savings	BDT Million	-	44.65	45.16	47.74	50.46	53.33	56.37	59.58	62.98	66.57	70.36
	USD Million	-	0.53	0.53	0.56	0.59	0.63	0.66	0.70	0.74	0.78	0.83
Investment												
Original Investment for LED retrofit	BDT Million	119.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	BDT Million	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Investment for End-of-life replacement of LED	BDT Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for One CCMS Unit	BDT (,000)	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Original Investment for CCMS units	BDT Million	4.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for CCMS Failure	BDT (,000)	90.00	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Investment for End-of-life replacement of CCMS	BDT Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	BDT Million	20.37	-	-	-	-	-	-	-	-	-	-
Total Investment	BDT Million	146.91	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
	USD (,000)	1730.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	BDT Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	BDT Million	146.91	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
	USD (,000)	1730.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Net savings	BDT Million	-146.91	42.14	42.66	45.23	47.95	50.83	53.87	57.08	60.48	64.06	67.86
	USD Million	-1.73	0.50	0.50	0.53	0.56	0.60	0.63	0.67	0.71	0.75	0.80

Source: Research by East Coast Sustainable

Case:3 Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Chittagong City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
Annual Energy Consumption	MWh/year	8853	8853	8853	8853	8853	8853	8853	8853	8853	8853	8853
Annual Electricity Bill	BDT Million	68.169	72.05	76.16	80.50	85.09	89.94	95.07	100.49	106.21	112.27	118.67
Annual Maintenance Cost	BDT Million	5.91	6.24	6.60	6.98	7.37	7.79	8.24	8.71	9.20	9.73	10.28
Total Operating Cost	BDT Million	74.08	78.30	82.76	87.48	92.46	97.74	103.31	109.19	115.42	122.00	128.95
	USD Million	0.87	0.92	0.97	1.03	1.09	1.15	1.22	1.28	1.36	1.44	1.52
Proposed Scenario												
Total Connected Load (Off grid)	MW	-	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Annual Energy Consumption from Grid	MWh/year	-	0	0	0	0	0	0	0	0	0	0
Total Energy Savings	MWh/year	-	8853	8853	8853	8853	8853	8853	8853	8853	8853	8853
Number of CCMS Units	No	-	196	196	196	196	196	196	196	196	196	196
Annual Electricity Cost Savings	BDT Million	-	72.054	76.161	80.503	85.091	89.941	95.068	100.487	106.215	112.269	118.668
Total Cost Savings	BDT Million	-	72.05	76.16	80.50	85.09	89.94	95.07	100.49	106.21	112.27	118.67
	USD Million	-	0.85	0.90	0.95	1.00	1.06	1.12	1.18	1.25	1.32	1.40

Source: Research by East Coast Sustainable

Details Case-3 Energy savings, Cost savings and Investment for Chittagong City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	8853	8853	8853	8853	8853	8853	8853	8853	8853	8853
Annual Electricity Cost Savings	BDT Million	-	72.05	76.16	80.50	85.09	89.94	95.07	100.49	106.22	112.27	118.67
Total Cost Savings	BDT Million	-	72.05	76.16	80.50	85.09	89.94	95.07	100.49	106.21	112.27	118.67
	USD Million	-	0.85	0.90	0.95	1.00	1.06	1.12	1.18	1.25	1.32	1.40
Investment												
Original Investment for Solar LED Street Lights	BDT Million	2170.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	BDT Million	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Investment for One CCMS Unit	BDT Million	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	BDT Million	11.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	BDT Million	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Investment for End-of-life replacement of CCMS	BDT Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	BDT Million	0.00	0.00	0.00	0.00	0.00	868.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR Million	20.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	BDT Million	2202.41	0.43	0.43	0.43	0.43	868.60	0.43	0.43	0.43	0.43	0.43
	USD Million	25.91	0.01	0.01	0.01	0.01	10.22	0.01	0.01	0.01	0.01	0.01
Subsidy/Grant	%	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Subsidy/Grant from external donors	BDT Million	1761.93	0.34	0.34	0.34	0.34	694.88	0.34	0.34	0.34	0.34	0.34
	USD Million	20.73	0.00	0.00	0.00	0.00	8.18	0.00	0.00	0.00	0.00	0.00
Investment from end user	BDT Million	440.48	0.09	0.09	0.09	0.09	173.72	0.09	0.09	0.09	0.09	0.09
	USD Million	5.18	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.00	0.00
Net savings	BDT Million	-440.48	71.97	76.08	80.42	85.01	-83.78	94.98	100.40	106.13	112.18	118.58
	USD Million	-5.18	0.85	0.90	0.95	1.00	-0.99	1.12	1.18	1.25	1.32	1.40

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Chittagong city

Results of Case-3 Techno Financial Analysis for Chittagong City, Bangladesh											
Parameters	**UOM**	**Subsidy 0%**	**Subsidy 10%**	**Subsidy 20%**	**Subsidy 30%**	**Subsidy 40%**	**Subsidy 50%**	**Subsidy 60%**	**Subsidy 70%**	**Subsidy 80%**	**Subsidy 90%**
Simple Payback Period (per end user)	Years	30.57	27.51	24.45	21.40	18.34	15.28	12.23	9.17	6.11	3.06
Internal Rate of Return (per end user)	%	-23%	-21%	-19%	-17%	-14%	-10%	-6%	0%	10%	33%
Net Present Value (per end user)	BDT Million	44.62	123.24	201.87	280.49	359.11	437.74	516.36	594.99	673.61	752.24
	USD Million	0.52	1.45	2.37	3.30	4.22	5.15	6.07	7.00	7.92	8.85
Total investment by end user	BDT Million	3074.83	2767.35	2459.87	2152.38	1844.90	1537.42	1229.93	922.45	614.97	307.48
	USD Million	36.17	32.56	28.94	25.32	21.70	18.09	14.47	10.85	7.23	3.62
Total programme/Project cost	BDT Million	3054.34	3054.34	3054.34	3054.34	3054.34	3054.34	3054.34	3054.34	3054.34	3054.34
	USD Million	35.93	35.93	35.93	35.93	35.93	35.93	35.93	35.93	35.93	35.93

Source: Research by East Coast Sustainable

Annexure-7:
Techno Financial Case Study of Gelephu City of Bhutan

Case:1 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of Energy consumption and Cost of operation in Gelephu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline/BAU Scenario												
Annual Energy Consumption	MWh/year	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43
Annual Electricity Bill	BTN (,000)	1645.85	1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
Annual Maintenance Cost	BTN (,000)	122.20	129.04	136.27	143.90	151.96	160.47	169.46	178.94	188.97	199.55	210.72
Total Operating Cost	BTN (,000)	1768.05	1867.06	1971.62	2082.03	2198.62	2321.74	2451.76	2589.06	2734.05	2887.15	3048.83
	USD (,000)	24.22	25.58	27.01	28.52	30.12	31.80	33.59	35.47	37.45	39.55	41.76
Proposed Scenario												
Annual Energy Consumption	MWh/year	-	178.41	178.41	178.41	178.41	178.41	178.41	178.41	178.41	178.41	178.41
Annual Electricity Bill	BTN (,000)	-	731.49	815.71	861.39	909.63	960.57	1014.36	1071.16	1131.15	1194.49	1261.38
Annual Maintenance Cost	BTN (,000)	-	91.65	102.20	107.93	113.97	120.35	127.09	134.21	141.72	149.66	158.04
Total Operating Cost	BTN (,000)	-	823.14	917.91	969.32	1023.60	1080.92	1141.45	1205.37	1272.87	1344.15	1419.43
	USD (,000)	-	11.28	12.57	13.28	14.02	14.81	15.64	16.51	17.44	18.41	19.44

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Gelephu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	223.02	223.02	223.02	223.02	223.02	223.02	223.02	223.02	223.02	223.02
Annual Electricity Cost Savings	BTN (,000)	-	1006.53	1019.64	1076.74	1137.03	1200.71	1267.95	1338.95	1413.93	1493.11	1576.73
Annual Maintenance Cost Savings	BTN (,000)	-	37.39	34.07	35.98	37.99	40.12	42.36	44.74	47.24	49.89	52.68
Total Cost Savings	BTN (,000)	-	1043.92	1053.70	1112.71	1175.02	1240.83	1310.31	1383.69	1461.18	1543.00	1629.41
	USD (,000)	-	14.30	14.43	15.24	16.10	17.00	17.95	18.95	20.02	21.14	22.32
Investment												
Original Investment of LED	BTN (,000)	4386.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	BTN (,000)	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35
Investment for End-of-life replacement	BTN (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	BTN (,000)	366.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	BTN (,000)	4972.93	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35
	USD (,000)	68.12	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	BTN (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	BTN (,000)	4972.93	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35
	USD (,000)	68.12	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Net savings	BTN (,000)	-4972.93	824.57	834.36	893.36	955.68	1021.48	1090.96	1164.34	1241.83	1323.65	1410.06
	USD (,000)	-68.12	11.30	11.43	12.24	13.09	13.99	14.94	15.95	17.01	18.13	19.32

Source: Research by East Coast Sustainable

Case:2 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Gelephu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Annual Energy Consumption	MWh/year	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43
Annual Electricity Bill	BTN (,000)	1645.85	1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
Annual Maintenance Cost	BTN (,000)	122.20	129.04	136.27	143.90	151.96	160.47	169.46	178.94	188.97	199.55	210.72
Total Operating Cost	BTN (,000)	1768.05	1867.06	1971.62	2082.03	2198.62	2321.74	2451.76	2589.06	2734.05	2887.15	3048.83
	USD (,000)	24.22	25.58	27.01	28.52	30.12	31.80	33.59	35.47	37.45	39.55	41.76
Proposed Scenario												
Total Connected Load	MW		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Annual Energy Consumption	MWh/year		178.41	178.41	178.41	178.41	178.41	178.41	178.41	178.41	178.41	178.41
Number of CCMS Units	No		10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Avoided hours of Operation due to timely switch ON and Off	Hr		0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Annual Electricity Bill	BTN (,000)		731.49	815.71	861.39	909.63	960.57	1014.36	1071.16	1131.15	1194.49	1261.38
Annual Maintenance Cost	BTN (,000)		91.65	102.20	107.93	113.97	120.35	127.09	134.21	141.72	149.66	158.04
Total Operating Cost	BTN (,000)		823.14	917.91	969.32	1023.60	1080.92	1141.45	1205.37	1272.87	1344.15	1419.43
	USD (,000)		11.28	12.57	13.28	14.02	14.81	15.64	16.51	17.44	18.41	19.44

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Gelephu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year		223.02	223.02	223.02	223.02	223.02	223.02	223.02	223.02	223.02	223.02
Annual Energy Savings with CCMS Units	MWh/year		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total Energy Savings	MWh/year		223.06	223.06	223.06	223.06	223.06	223.06	223.06	223.06	223.06	223.06
Annual Cost Savings with LED Retrofit	BTN (,000)		1006.53	1019.64	1076.74	1137.03	1200.71	1267.95	1338.95	1413.93	1493.11	1576.73
Annual Cost Savings with CCMS units	BTN (,000)		0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Annual Maintenance Cost Savings	BTN (,000)		37.39	34.07	35.98	37.99	40.12	42.36	44.74	47.24	49.89	52.68
Total Cost Savings	BTN (,000)		1044.13	1053.91	1112.92	1175.23	1241.03	1310.52	1383.89	1461.38	1543.21	1629.61
	USD (,000)		14.30	14.44	15.25	16.10	17.00	17.95	18.96	20.02	21.14	22.32
Investment												
Original Investment for LED retrofit	BTN (,000)	4386.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	BTN (,000)	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35	219.35
Investment for End of life replacement of LED	BTN (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for One CCMS Unit	BTN (,000)	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51
Original Investment for CCMS units	BTN (,000)	205.12										
Parameter	**Units**	**Year-0**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**
Investment for CCMS Failure	BTN (,000)	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26
Investment for End-of-life replacement of CCMS	BTN (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	BTN (,000)	366.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	BTN (,000)	5208.82	250.12	250.12	250.12	250.12	250.12	250.12	250.12	250.12	250.12	250.12
	USD (,000)	71.35	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	BTN (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	BTN (,000)	5208.82	250.12	250.12	250.12	250.12	250.12	250.12	250.12	250.12	250.12	250.12
	USD (,000)	71.35	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
Net savings	BTN (,000)	-5208.82	794.01	803.79	862.80	925.11	990.91	1060.40	1133.78	1211.26	1293.09	1379.50
	USD (,000)	-71.35	10.88	11.01	11.82	12.67	13.57	14.53	15.53	16.59	17.71	18.90

Source: Research by East Coast Sustainable

Case:3 Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Gelephu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Annual Energy Consumption	MWh/year	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43
Annual Electricity Bill	BTN (,000)	1645.85	1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
Annual Maintenance Cost	BTN (,000)	122.20	129.04	136.27	143.90	151.96	160.47	169.46	178.94	188.97	199.55	210.72
Total Operating Cost	BTN (,000)	1768.05	1867.06	1971.62	2082.03	2198.62	2321.74	2451.76	2589.06	2734.05	2887.15	3048.83
	USD (,000)	24.22	25.58	27.01	28.52	30.12	31.80	33.59	35.47	37.45	39.55	41.76
Proposed Scenario												
Total Connected Load off grid	MW	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Annual Energy Consumption from Grid	MWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of CCMS Units	No		10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Energy Savings	Hr		401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43
Annual Electricity Cost Savings	BTN (,000)		1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
Total Cost Savings	BTN (,000)		1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
	USD (,000)		23.81	25.14	26.55	28.04	29.61	31.26	33.02	34.86	36.82	38.88

Source: Research by East Coast Sustainable

Details Case-3 Energy savings, Cost savings and Investment for Gelephu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43	401.43
Annual Electricity Cost Savings	BTN (,000)	-	1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
Total Cost Savings	BTN (,000)	-	1738.02	1835.35	1938.13	2046.66	2161.27	2282.31	2410.12	2545.08	2687.61	2838.11
	USD (,000)	-	23.81	25.14	26.55	28.04	29.61	31.26	33.02	34.86	36.82	38.88
Investment												
Original Investment for Solar LED Street Lights	BTN (,000)	86762.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	BTN (,000)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Investment for One CCMS Unit	PKR (,000)	20.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	PKR (,000)	205.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	PKR (,000)	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26	10.26
Replacement cost of Battery	BTN (,000)	0.00	0.00	0.00	0.00	0.00	34704.80	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR (,000)	611.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	BTN (,000)	87608.95	10.32	10.32	10.32	10.32	34715.12	10.32	10.32	10.32	10.32	10.32
	USD (,000)	1200.12	0.14	0.14	0.14	0.14	475.55	0.14	0.14	0.14	0.14	0.14
Subsidy/Grant	%	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00	88.00
Subsidy/Grant from external donors	BTN (,000)	77095.88	9.08	9.08	9.08	9.08	30549.30	9.08	9.08	9.08	9.08	9.08
	USD (,000)	1056.11	0.12	0.12	0.12	0.12	418.48	0.12	0.12	0.12	0.12	0.12

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment from end user	BTN (,000)	10513.07	1.24	1.24	1.24	1.24	4165.81	1.24	1.24	1.24	1.24	1.24
	USD (,000)	144.01	0.02	0.02	0.02	0.02	57.07	0.02	0.02	0.02	0.02	0.02
Net savings	BTN (,000)	-10513.07	1736.78	1834.11	1936.89	2045.42	-2004.54	2281.07	2408.88	2543.84	2686.37	2836.87
	USD (,000)	-144.01	23.79	25.12	26.53	28.02	-27.46	31.25	33.00	34.85	36.80	38.86

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Gelephu City

Results of Case-3 Techno Financial Analysis for Gelephu City, Bhutan											
Parameters	**UOM**	**Subsidy 0%**	**Subsidy 10%**	**Subsidy 20%**	**Subsidy 30%**	**Subsidy 40%**	**Subsidy 50%**	**Subsidy 60%**	**Subsidy 70%**	**Subsidy 80%**	**Subsidy 90%**
Simple Payback Period (per end user)	Years	50.42	45.38	40.33	35.29	30.25	25.21	20.17	15.13	10.08	5.04
Internal Rate of Return (per end user)	%	-32%	-30%	-28%	-26%	-23%	-20%	-16%	-10%	-2%	16%
Net Present Value (per end user)	BTN Million	-9.22	-6.81	-4.41	-2.00	0.40	2.81	5.21	7.62	10.02	12.43
	USD Million	-0.13	-0.09	-0.06	-0.03	0.01	0.04	0.07	0.10	0.14	0.17
Total investment by end user	BTN Million	122.62	110.36	98.09	85.83	73.57	61.31	49.05	36.79	24.52	12.26
	USD Million	1.68	1.51	1.34	1.18	1.01	0.84	0.67	0.50	0.34	0.17
Total programme/Project cost	BTN Million	122.62	122.62	122.62	122.62	122.62	122.62	122.62	122.62	122.62	122.62
	USD Million	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68

Source: Research by East Coast Sustainable

Annexure-8:
Techno Financial Case Study of Hyderabad City of India

Case:1 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of Energy consumption and Cost of operation in Hyderabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline Scenario												
Annual Energy Consumption	MWh/year	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999
Annual Electricity Bill	INR Million	1793.200	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
Annual Maintenance Cost	INR Million	315	331.35	348.55	366.63	385.66	405.68	426.73	448.88	472.18	496.68	522.46
Total Operating Cost	INR Million	2108	2218	2333	2454	2581	2715	2856	3004	3160	3324	3497
	USD Million	28.49	29.97	31.52	33.16	34.88	36.69	38.59	40.60	42.70	44.92	47.25
Proposed Scenario												
Annual Energy Consumption	MWh/year	-	119346	119346	119346	119346	119346	119346	119346	119346	119346	119346
Annual Electricity Bill	INR Million	-	940.6	1040.8	1094.8	1151.6	1211.4	1274.2	1340.4	1409.9	1483.1	1560.1
Annual Maintenance Cost	INR Million	-	60.0	66.4	69.8	73.5	77.3	81.3	85.5	89.9	94.6	99.5
Total Operating Cost	INR Million	-	1000.6	1107.2	1164.6	1225.1	1288.6	1355.5	1425.9	1499.9	1577.7	1659.6
	USD Million	0.00	13.52	14.96	15.74	16.55	17.41	18.32	19.27	20.27	21.32	22.43

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Hyderabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	125653	125653	125653	125653	125653	125653	125653	125653	125653	125653
Annual Electricity Cost Savings	INR Million	-	945.67	943.40	992.36	1043.86	1098.04	1155.03	1214.97	1278.03	1344.36	1414.13
Annual Maintenance Cost Savings	INR Million	-	271.00	282.00	297.00	312.00	328.00	345.00	363.00	382.00	402.00	423.00
Total Cost Savings	INR Million	-	1217.00	1226.00	1289.00	1356.00	1426.00	1500.00	1578.00	1660.00	1746.00	1837.00
	USD Million	0	16.45	16.56	17.42	18.33	19.28	20.28	21.33	22.44	23.60	24.83
Investment												
Original Investment	INR Million	830.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for Failure	INR Million	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
Investment for End-of-life replacement	INR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR Million	121.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	INR Million	968.35	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
	USD Million	13.09	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	INR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	INR Million	968.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	13.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net savings	INR Million	-968.00	1200.00	1209.00	1273.00	1339.00	1410.00	1484.00	1562.00	1644.00	1730.00	1820.00
	USD Million	-13.09	16.22	16.34	17.20	18.10	19.05	20.05	21.10	22.21	23.38	24.60

Source: Research by East Coast Sustainable

Case:2 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Hyderabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84
Annual Energy Consumption	MWh/year	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999
Annual Electricity Bill	INR Million	1793.200	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
Annual Maintenance Cost	INR Million	315	331.35	348.55	366.63	385.66	405.68	426.73	448.88	472.18	496.68	522.46
Total Operating Cost	INR Million	2108	2218	2333	2454	2581	2715	2856	3004	3160	3324	3497
	USD Million	28.49	29.97	31.52	33.16	34.88	36.69	38.59	40.60	42.70	44.92	47.25
Proposed Scenario												
Total Connected Load	MW	-	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73	29.73
Annual Energy Consumption	MWh/year	-	119346	132055	138909	146119	153702	161679	170070	178897	188182	197948
Number of CCMS Units	No	-	23450	23450	23450	23450	23450	23450	23450	23450	23450	23450
Avoided hours of Operation due to timely switch ON and Off	Hr	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Electricity Bill	INR Million	940.6	980.1	1040.8	1094.8	1151.6	1211.4	1274.2	1340.4	1409.9	1483.1	1560.1
Annual Maintenance Cost	INR Million	60.0	63.1	66.4	69.8	73.5	77.3	81.3	85.5	89.9	94.6	99.5
Total Operating Cost	INR Million	1000.6	1043.2	1107.2	1164.6	1225.1	1288.6	1355.5	1425.9	1499.9	1577.7	1659.6
	USD Million	13.52	14.10	14.96	15.74	16.55	17.41	18.32	19.27	20.27	21.32	22.43

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Hyderabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year	-	125653	112944	106090	98881	91297	83320	74929	66102	56818	47051
Annual Energy Savings with CCMS Units	MWh/year	-	30.51	30.51	30.51	30.51	30.51	30.51	30.51	30.51	30.51	30.51
Total Energy Savings	MWh/year	-	125684	112974	106121	98911	91328	83351	74959	66133	56848	47081
Annual Cost Savings with LED Retrofit	INR Million	-	906.16	943.40	992.36	1043.86	1098.04	1155.03	1214.97	1278.03	1344.36	1414.13
Annual Cost Savings with CCMS units	INR Million	-	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Annual Maintenance Cost Savings	INR Million	-	268.23	282.16	296.80	312.20	328.41	345.45	363.38	382.24	402.08	422.95
Total Cost Savings	INR Million	-	1174.61	1225.77	1289.38	1356.28	1426.66	1500.69	1578.57	1660.49	1746.65	1837.29
	USD Million	0	15.87	16.56	17.42	18.33	19.28	20.28	21.33	22.44	23.60	24.83
Investment												
Original Investment for LED retrofit	INR Million	830.78	-	-	-	-	-	-	-	-	-	-
Investment for LED Failure	INR Million	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62	16.62
Investment for End-of-life replacement of LED	INR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for One CCMS Unit	INR Million	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Original Investment for CCMS units	INR Million	469.00	-	-	-	-	-	-	-	-	-	-
Investment for CCMS Failure	INR Million	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for End-of-life replacement of CCMS	INR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR Million	121.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	INR Million	1446.75	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
	USD Million	19.55	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	INR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	INR Million	1446.75	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
	USD Million	19.55	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Net savings	INR Million	-1446.75	1148.62	1199.77	1263.38	1330.29	1400.67	1474.70	1552.57	1634.49	1720.66	1811.30
	USD Million	-19.55	15.52	16.21	17.07	17.98	18.93	19.93	20.98	22.09	23.25	24.48

Source: Research by East Coast Sustainable

Case:3 Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Hyderabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84	67.84
Annual Energy Consumption	MWh/year	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999
Annual Electricity Bill	INR Million	1793.20	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
Annual Maintenance Cost	INR Million	315.00	331.35	348.55	366.63	385.66	405.68	426.73	448.88	472.18	496.68	522.46
Total Operating Cost	INR Million	2108.00	2218.00	2333.00	2454.00	2581.00	2715.00	2856.00	3004.00	3160.00	3324.00	3497.00
	USD Million	28.49	29.97	31.52	33.16	34.88	36.69	38.59	40.60	42.70	44.92	47.25
Proposed Scenario												
Total Connected Load (Off grid)	MW		30	30	30	30	30	30	30	30	30	30
Annual Energy Consumption from Grid	MWh/year	0	0	0	0	0	0	0	0	0	0	0
Total Energy Savings	MWh/year	-	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999
Number of CCMS Units	No	-	23450	23450	23450	23450	23450	23450	23450	23450	23450	23450
Annual Electricity Cost Savings	INR Million	-	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
Total Cost Savings	INR Million	-	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
	USD Million	0	25.49	26.81	28.2	29.67	31.21	32.83	34.53	36.32	38.21	40.19

Source: Research by East Coast Sustainable

Details of Case-3 Energy savings, Cost savings and Investment for Hyderabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	244999	244999	244999	244999	244999	244999	244999	244999	244999	244999
Number of CCMS Units	No	-	23450	23450	23450	23450	23450	23450	23450	23450	23450	23450
Annual Electricity Cost Savings	INR Million	-	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
Total Cost Savings	INR Million	-	1886.27	1984.16	2087.14	2195.47	2309.41	2429.27	2555.35	2687.97	2827.48	2974.22
	USD Million	0	25.49	26.81	28.2	29.67	31.21	32.83	34.53	36.32	38.21	40.19
Investment												
Original Investment for Solar LED Street Lights	INR Million	34940.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	INR Million	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Investment for One CCMS Unit	INR Million	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	INR Million	469.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	INR Million	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38	9.38
Investment for End-of-life replacement of CCMS	INR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	INR Million	0.00	0.00	0.00	0.00	0.00	13976.11	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR Million	94.76	-	-	-	-	-	-	-	-	-	-
Total Investment	INR Million	35513.44	9.39	9.39	9.39	9.39	13985.49	9.39	9.39	9.39	9.39	9.39
	USD Million	479.91	0.13	0.13	0.13	0.13	188.99	0.13	0.13	0.13	0.13	0.13
Subsidy/Grant	%	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Subsidy/Grant from external donors	INR Million	24149.14	6.38	6.38	6.38	6.38	9510.14	6.38	6.38	6.38	6.38	6.38
	USD Million	326.34	0.09	0.09	0.09	0.09	128.52	0.09	0.09	0.09	0.09	0.09
Investment from end user	INR Million	11364.30	3.00	3.00	3.00	3.00	4475.36	3.00	3.00	3.00	3.00	3.00
		153.57	0.04	0.04	0.04	0.04	60.48	0.04	0.04	0.04	0.04	0.04
Net savings	INR Million	-11364.30	1883.26	1981.16	2084.14	2192.46	-2165.95	2426.26	2552.34	2684.97	2824.47	2971.22
	USD Million	-153.57	25.45	26.77	28.16	29.63	-29.27	32.79	34.49	36.28	38.17	40.15

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Hyderabad City

Results of Case-3 Techno Financial Analysis for Hyderabad City, India											
Parameters	**UOM**	**Subsidy 0%**	**Subsidy 10%**	**Subsidy 20%**	**Subsidy 30%**	**Subsidy 40%**	**Subsidy 50%**	**Subsidy 60%**	**Subsidy 70%**	**Subsidy 80%**	**Subsidy 90%**
Simple Payback Period (per end user)	Years	18.83	16.94	15.06	13.18	11.30	9.41	7.53	5.65	3.77	1.88
Internal Rate of Return (per end user)	%	-15%	-13%	-11%	-8%	-5%	-1%	4%	12%	24%	55%
Net Present Value (per end user)	INR Million	-29017.02	-24442.81	-19868.59	-15294.37	-10720.15	-6145.94	-1571.72	3002.50	7576.72	12150.93
	USD Million	-392.12	-330.31	-268.49	-206.68	-144.87	-83.05	-21.24	40.57	102.39	164.20
Total investment by end user	INR Million	49583.43	44625.09	39666.74	34708.40	29750.06	24791.71	19833.37	14875.03	9916.69	4958.34
	USD Million	670.05	603.04	536.04	469.03	402.03	335.02	268.02	201.01	134.01	67.00
Total programme/Project cost	INR Million	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47	48916.47
	USD Million	661.03	661.03	661.03	661.03	661.03	661.03	661.03	661.03	661.03	661.03

Source: Research by East Coast Sustainable

Annexure-9:
Techno Financial Case Study of Male City of Maldives

Case:1 Replacement of Conventional Lighting Fixtures with LED based E Lighting System without CCMS

Details of Energy consumption and Cost of operation in Male City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline Scenario												
Annual Energy Consumption	MWh/year	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50
Annual Electricity Bill	MVR (,000)	1428.98	1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
Annual Maintenance Cost	MVR (,000)	770.00	773.08	776.17	779.28	782.39	785.52	788.67	791.82	794.99	798.17	801.36
Total Operating Cost	MVR (,000)	2198.98	2207.77	2216.60	2225.47	2234.37	2243.31	2252.28	2261.29	2270.34	2279.42	2288.53
	USD (,000)	142.79	143.36	143.94	144.51	145.09	145.67	146.25	146.84	147.42	148.01	148.61
Proposed Scenario												
Annual Energy Consumption	MWh/year		197.10	197.10	197.10	197.10	197.10	197.10	197.10	197.10	197.10	197.10
Annual Electricity Bill	MVR (,000)		857.39	864.26	867.71	871.19	874.67	878.17	881.68	885.21	888.75	892.30
Annual Maintenance Cost	MVR (,000)		385.00	388.09	389.64	391.20	392.76	394.33	395.91	397.49	399.08	400.68
Total Operating Cost	MVR (,000)		1242.39	1252.34	1257.35	1262.38	1267.43	1272.50	1277.59	1282.70	1287.83	1292.98
	USD (,000)		80.67	81.32	81.65	81.97	82.30	82.63	82.96	83.29	83.63	83.96

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Male City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	131	131	131	131	131	131	131	131	131	131
Annual Electricity Cost Savings	MVR (,000)	-	577.31	576.17	578.48	580.79	583.11	585.45	587.79	590.14	592.50	594.87
Annual Maintenance Cost Savings	MVR (,000)	-	388.08	388.09	389.64	391.20	392.76	394.33	395.91	397.49	399.08	400.68
Total Cost Savings	MVR (,000)	-	965.39	964.26	968.12	971.99	975.88	979.78	983.70	987.63	991.58	995.55
	USD (,000)	-	62.69	62.61	62.86	63.12	63.37	63.62	63.88	64.13	64.39	64.65
Investment												
Original Investment of LED	MVR (,000)	950.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	MVR (,000)	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
Investment for End-of-life replacement	MVR (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	MVR (,000)	250.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	MVR (,000)	1219.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
	USD (,000)	79.16	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	MVR (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	MVR (,000)	1219.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
	USD (,000)	79.16	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
Net savings	MVR (,000)	-1219.00	946.39	945.26	949.12	952.99	956.88	960.78	964.70	968.63	972.58	976.55
	USD (,000)	-79.16	61.45	61.38	61.63	61.88	62.13	62.39	62.64	62.90	63.15	63.41

Source: Research by East Coast Sustainable

Case:2 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Male City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Annual Energy Consumption	MWh/year	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50
Annual Electricity Bill	MVR (,000)	1428.98	1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
Annual Maintenance Cost	MVR (,000)	770.00	773.08	776.17	779.28	782.39	785.52	788.67	791.82	794.99	798.17	801.36
Total Operating Cost	MVR (,000)	2198.98	2207.77	2216.60	2225.47	2234.37	2243.31	2252.28	2261.29	2270.34	2279.42	2288.53
	USD (,000)	142.79	143.36	143.94	144.51	145.09	145.67	146.25	146.84	147.42	148.01	148.61
Proposed Scenario												
Total Connected Load	MW	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Annual Energy Consumption	MWh/year	-	197.10	206.71	211.70	216.80	222.02	227.37	232.85	238.47	244.21	250.10
Number of CCMS Units	No	-	9.00									
Avoided hours of Operation due to timely switch ON and Off	Hr	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Annual Electricity Bill	MVR (,000)	-	857.39	864.26	867.71	871.19	874.67	878.17	881.68	885.21	888.75	892.30
Annual Maintenance Cost	MVR (,000)	-	385.00	388.09	389.64	391.20	392.76	394.33	395.91	397.49	399.08	400.68
Total Operating Cost	MVR (,000)	-	1242.39	1252.34	1257.35	1262.38	1267.43	1272.50	1277.59	1282.70	1287.83	1292.98
	USD (,000)	-	80.67	81.32	81.65	81.97	82.30	82.63	82.96	83.29	83.63	83.96

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Male City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year		131.4	131.4	131.4	131.4	131.4	131.4	131.4	131.4	131.4	131.4
Annual Energy Savings with CCMS Units	MWh/year		0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total Energy Savings	MWh/year		131.44	131.44	131.44	131.44	131.44	131.44	131.44	131.44	131.44	131.44
Annual Cost Savings with LED Retrofit	MVR (,000)		577.31	576.17	578.48	580.79	583.11	585.45	587.79	590.14	592.5	594.87
Annual Cost Savings with CCMS units	MVR (,000)		0	0	0	0	0	0	0	0	0	0
Annual Maintenance Cost Savings	MVR (,000)		388.08	388.09	389.64	391.2	392.76	394.33	395.91	397.49	399.08	400.68
Total Cost Savings	MVR (,000)		965.39	964.26	968.12	971.99	975.88	979.78	983.7	987.63	991.58	995.55
	USD (,000)		62.69	62.61	62.86	63.12	63.37	63.62	63.88	64.13	64.39	64.65
Investment												
Original Investment for LED retrofit	MVR (,000)	950	0	0	0	0	0	0	0	0	0	0
Investment for LED Failure	MVR (,000)	19	19	19	19	19	19	19	19	19	19	19
Investment for End-of-life replacement of LED	MVR (,000)	0	0	0	0	0	0	0	0	0	0	0
Investment for One CCMS Unit	MVR (,000)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Original Investment for CCMS units	MVR (,000)	37.8	0	0	0	0	0	0	0	0	0	0
Investment for CCMS Failure	MVR (,000)	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Investment for End-of-life replacement of CCMS	MVR (,000)	0	0	0	0	0	0	0	0	0	0	0
Installation Cost	MVR (,000)	250	0	0	0	0	0	0	0	0	0	0
Total Investment	MVR (,000)	1261.76	23.96	23.96	23.96	23.96	23.96	23.96	23.96	23.96	23.96	23.96
	USD (,000)	81.93	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Subsidy/Grant	%	0	0	0	0	0	0	0	0	0	0	0
Subsidy/Grant from external donors	MVR (,000)	0	0	0	0	0	0	0	0	0	0	0
	USD (,000)	0	0	0	0	0	0	0	0	0	0	0
Investment from end user	MVR (,000)	1261.76	23.96	23.96	23.96	23.96	23.96	23.96	23.96	23.96	23.96	23.96
	USD (,000)	81.93	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Net savings	MVR (,000)	-1261.76	941.43	940.3	944.16	948.03	951.92	955.82	959.74	963.68	967.63	971.59
	USD (,000)	-81.93	61.13	61.06	61.31	61.56	61.81	62.07	62.32	62.58	62.83	63.09

Source: Research by East Coast Sustainable

Case:3 Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Male City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Annual Energy Consumption	MWh/year	328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5
Annual Electricity Bill	MVR (,000)	1428.98	1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
Annual Maintenance Cost	MVR (,000)	770	773.08	776.17	779.28	782.39	785.52	788.67	791.82	794.99	798.17	801.36
Total Operating Cost	MVR (,000)	2198.98	2207.77	2216.6	2225.47	2234.37	2243.31	2252.28	2261.29	2270.34	2279.42	2288.53
	USD (,000)	142.79	143.36	143.94	144.51	145.09	145.67	146.25	146.84	147.42	148.01	148.61
Proposed Scenario												
Total Connected Load (Off grid)	MW		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Annual Energy Consumption from Grid	MWh/year	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Energy Savings	MWh/year		328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50	328.50
Number of CCMS Units	No		9.00									
Annual Electricity Cost Savings	MVR (,000)		1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
Total Cost Savings	MVR (,000)		1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
	USD (,000)	0	93.16	93.53	93.91	94.28	94.66	95.04	95.42	95.80	96.18	96.57

Source: Research by East Coast Sustainable

Details of Case-3 Energy savings, Cost savings and Investment for Male City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year		328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5	328.5
Annual Electricity Cost Savings	MVR (,000)		1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
Total Cost Savings	MVR (,000)		1434.69	1440.43	1446.19	1451.98	1457.78	1463.62	1469.47	1475.35	1481.25	1487.17
	USD (,000)	0	93.16	93.53	93.91	94.28	94.66	95.04	95.42	95.8	96.18	96.57
Investment												
Original Investment for Solar LED Street Lights	MVR (,000)	25337.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	MVR (,000)	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Investment for One CCMS Unit	MVR (,000)	4.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	MVR (,000)	37.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	MVR (,000)	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Investment for End-of-life replacement of CCMS	MVR (,000)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	MVR (,000)	0.00	0.00	0.00	0.00	0.00	10135.01	0.00	0.00	0.00	0.00	0.00
Installation Cost	MVR (,000)	500.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	MVR (,000)	25895.28	15.76	15.76	15.76	15.76	10150.77	15.76	15.76	15.76	15.76	15.76
	USD (,000)	1681.51	1.02	1.02	1.02	1.02	659.14	1.02	1.02	1.02	1.02	1.02
Subsidy/Grant	%	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00
Subsidy/Grant from external donors	MVR (,000)	19421.46	11.82	11.82	11.82	11.82	7613.07	11.82	11.82	11.82	11.82	11.82
	USD (,000)	1261.13	0.77	0.77	0.77	0.77	494.36	0.77	0.77	0.77	0.77	0.77
Investment from end user	MVR (,000)	6473.82	3.94	3.94	3.94	3.94	2537.69	3.94	3.94	3.94	3.94	3.94

	USD (,000)	420.38	0.26	0.26	0.26	0.26	164.79	0.26	0.26	0.26	0.26	0.26
Net savings	MVR (,000)	-6473.82	1430.75	1436.49	1442.25	1448.04	-1079.91	1459.68	1465.53	1471.41	1477.31	1483.23
	USD (,000)	-420.38	92.91	93.28	93.65	94.03	-70.12	94.78	95.16	95.55	95.93	96.31

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Male City

Results of Case-3 Techno Financial Analysis for Male City, Maldives											
Parameters	**UOM**	**Subsidy 0%**	**Subsidy 10%**	**Subsidy 20%**	**Subsidy 30%**	**Subsidy 40%**	**Subsidy 50%**	**Subsidy 60%**	**Subsidy 70%**	**Subsidy 80%**	**Subsidy 90%**
Simple Payback Period (per end user)	Years	18.05	16.24	14.44	12.63	10.83	9.02	7.22	5.41	3.61	1.80
Internal Rate of Return (per end user)	%	-20%	-18%	-15%	-13%	-9%	-5%	0%	8%	21%	53%
Net Present Value (per end user)	MVR Million	3.61	4.50	5.39	6.28	7.17	8.06	8.95	9.84	10.73	11.62
	USD Million	0.23	0.29	0.35	0.41	0.47	0.52	0.58	0.64	0.70	0.75
Total investment by end user	MVR Million	36.19	32.57	28.95	25.33	21.71	18.09	14.48	10.86	7.24	3.62
	USD Million	2.35	2.11	1.88	1.64	1.41	1.17	0.94	0.70	0.47	0.23
Total programme/Project cost	MVR Million	35.69	35.69	35.69	35.69	35.69	35.69	35.69	35.69	35.69	35.69
	USD Million	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32

Source: Research by East Coast Sustainable

Annexure-10:
Techno Financial Case Study of Kathmandu City of Nepal

Case:1 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of Energy consumption and Cost of operation in Kathmandu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline Scenario												
Annual Energy Consumption	MWh/year	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293
Annual Electricity Bill	NPR Million	53.237	55.95	58.81	61.80	64.96	68.27	71.75	75.41	79.26	83.30	87.55
Annual Maintenance Cost	NPR Million	4.43	4.65	4.89	5.14	5.40	5.68	5.97	6.27	6.59	6.93	7.28
Total Operating Cost	NPR Million	57.66	60.61	63.70	66.94	70.36	73.95	77.72	81.68	85.85	90.23	94.83
	USD Million	0.49	0.51	0.54	0.57	0.60	0.63	0.66	0.69	0.73	0.76	0.80
Proposed Scenario												
Annual Energy Consumption	MWh/year	-	3907	3907	3907	3907	3907	3907	3907	3907	3907	3907
Annual Electricity Bill	NPR Million	-	28.5	31.5	33.1	34.8	36.6	38.4	40.4	42.5	44.6	46.9
Annual Maintenance Cost	NPR Million	-	3.2	3.6	3.7	3.9	4.1	4.3	4.6	4.8	5.0	5.3
Total Operating Cost	NPR Million	-	31.7	35.1	36.8	38.7	40.7	42.8	45.0	47.3	49.7	52.2
	USD Million	0.00	0.27	0.30	0.31	0.33	0.34	0.36	0.38	0.40	0.42	0.44

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Kathmandu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	3386	3386	3386	3386	3386	3386	3386	3386	3386	3386
Annual Electricity Cost Savings	NPR Million	-	27.43	27.30	28.69	30.16	31.70	33.31	35.01	36.80	38.67	40.65
Annual Maintenance Cost Savings	NPR Million	-	1.00	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00
Total Cost Savings	NPR Million	-	29.00	29.00	30.00	32.00	33.00	35.00	37.00	39.00	41.00	43.00
	USD Million	-	0.24	0.24	0.26	0.27	0.28	0.30	0.31	0.33	0.34	0.36
Investment												
Original Investment of LED	NPR Million	139.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	NPR Million	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Investment for End-of-life replacement	NPR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	NPR Million	8.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	NPR Million	150.62	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
	USD Million	1.28	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	NPR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	NPR Million	150.62	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
	USD Million	1.28	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Net savings	NPR Million	-150.62	26.07	25.84	27.30	28.83	30.45	32.14	33.93	35.80	37.77	39.83
	USD Million	-1.28	0.22	0.22	0.23	0.24	0.26	0.27	0.29	0.30	0.32	0.34

Source: Research by East Coast Sustainable

Case:2 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Kathmandu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
Annual Energy Consumption	MWh/year	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293
Annual Electricity Bill	NPR Million	53.237	55.95	58.81	61.80	64.96	68.27	71.75	75.41	79.26	83.30	87.55
Annual Maintenance Cost	NPR Million	4.43	4.65	4.89	5.14	5.40	5.68	5.97	6.27	6.59	6.93	7.28
Total Operating Cost	NPR Million	57.66	60.61	63.70	66.94	70.36	73.95	77.72	81.68	85.85	90.23	94.83
	USD Million	0.49	0.51	0.54	0.57	0.60	0.63	0.66	0.69	0.73	0.76	0.80
Proposed Scenario												
Total Connected Load	MW	-	0.89	0.93	0.95	0.96	0.98	1.00	1.02	1.04	1.06	1.09
Annual Energy Consumption	MWh/year	-	3907	3907	3907	3907	3907	3907	3907	3907	3907	3907
Number of CCMS Units	No	-	178	178	178	178	178	178	178	178	178	178
Avoided hours of Operation due to timely switch ON and Off	Hr	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Electricity Bill	NPR Million	-	28.5	29.7	30.2	30.8	31.5	32.1	32.7	33.4	34.0	34.7
Annual Maintenance Cost	NPR Million	-	3.2	3.6	3.7	3.9	4.1	4.3	4.6	4.8	5.0	5.3
Total Operating Cost	NPR Million	-	31.7	33.2	34.0	34.8	35.6	36.4	37.3	38.2	39.1	40.0
	USD Million	0.00	0.27	0.28	0.29	0.29	0.30	0.31	0.32	0.32	0.33	0.34

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Kathmandu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year		3386	3386	3386	3386	3386	3386	3386	3386	3386	3386
Annual Energy Savings with CCMS Units	MWh/year		0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Total Energy Savings	MWh/year		3387	3387	3387	3387	3387	3387	3387	3387	3387	3387
Annual Cost Savings with LED Retrofit	NPR Million		27.431	29.144	31.556	34.109	36.811	39.67	42.694	45.892	49.273	52.848
Annual Cost Savings with CCMS units	NPR Million		0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Annual Maintenance Cost Savings	NPR Million		1.43	1.33	1.4	1.47	1.55	1.63	1.71	1.8	1.89	1.99
Total Cost Savings	NPR Million		28.87	30.48	32.96	35.59	38.37	41.3	44.41	47.7	51.17	54.84
	USD Million	0	0.24	0.26	0.28	0.3	0.33	0.35	0.38	0.4	0.43	0.46
Investment												
Original Investment for LED retrofit	NPR Million	139.8										
Investment for LED Failure	NPR Million	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Investment for End-of-life replacement of LED	NPR Million	0	0	0	0	0	0	0	0	0	0	0
Investment for One CCMS Unit	NPR Million	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321	0.0321
Original Investment for CCMS units	NPR Million	5.72	0	0	0	0	0	0	0	0	0	0

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for CCMS Failure	NPR Million	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Investment for End-of-life replacement of CCMS	NPR Million	0	0	0	0	0	0	0	0	0	0	0
Installation Cost	NPR Million	8.05	0	0	0	0	0	0	0	0	0	0
Total Investment	NPR Million	156.48	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94
	USD Million	1.33	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Subsidy/Grant	%	0	0	0	0	0	0	0	0	0	0	0
Subsidy/Grant from external donors	NPR Million	0	0	0	0	0	0	0	0	0	0	0
	USD Million	0	0	0	0	0	0	0	0	0	0	0
Investment from end user	NPR Million	156.48	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94
	USD Million	1.33	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Net savings	NPR Million	-156.48	25.93	27.54	30.02	32.65	35.42	38.36	41.47	44.75	48.23	51.9
	USD Million	-1.33	0.22	0.23	0.25	0.28	0.3	0.33	0.35	0.38	0.41	0.44

Source: Research by East Coast Sustainable

Case-3: Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Kathmandu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
Annual Energy Consumption	MWh/year	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293
Annual Electricity Bill	NPR Million	53.237	55.95	58.81	61.80	64.96	68.27	71.75	75.41	79.26	83.30	87.55
Annual Maintenance Cost	NPR Million	4.43	4.65	4.89	5.14	5.40	5.68	5.97	6.27	6.59	6.93	7.28
Total Operating Cost	NPR Million	57.66	60.61	63.70	66.94	70.36	73.95	77.72	81.68	85.85	90.23	94.83
	USD Million	0.49	0.51	0.54	0.57	0.60	0.63	0.66	0.69	0.73	0.76	0.80
Proposed Scenario												
Total Connected Load (Off grid)	MW	-	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
Annual Energy Consumption from Grid	MWh/year	-	0	0	0	0	0	0	0	0	0	0
Total Energy Savings	MWh/year	-	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293
Number of CCMS Units	No	-	178	178	178	178	178	178	178	178	178	178
Annual Electricity Cost Savings	NPR Million	-	55.952	58.805	61.804	64.956	68.269	71.751	75.410	79.256	83.298	87.546
Total Cost Savings	NPR Million	-	55.95	58.81	61.80	64.96	68.27	71.75	75.41	79.26	83.30	87.55
	USD Million	0.00	0.47	0.50	0.52	0.55	0.58	0.61	0.64	0.67	0.71	0.74

Source: Research by East Coast Sustainable

Details of Case-3 Energy savings, Cost savings and Investment for Kathmandu City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	7293	7293	7293	7293	7293	7293	7293	7293	7293	7293
Annual Electricity Cost Savings	NPR Million	-	55.952	58.805	61.804	64.956	68.269	71.751	75.41	79.256	83.298	87.546
Total Cost Savings	NPR Million	-	55.95	58.81	61.8	64.96	68.27	71.75	75.41	79.26	83.3	87.55
	USD Million	0	0.47	0.5	0.52	0.55	0.58	0.61	0.64	0.67	0.71	0.74
Investment												
Original Investment for Solar LED Street Lights	NPR Million	1457.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	NPR Million	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Investment for One CCMS Unit	NPR Million	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	NPR Million	5.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	NPR Million	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Investment for End-of-life replacement of CCMS	NPR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	NPR Million	0.00	0.00	0.00	0.00	0.00	583.15	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR Million	15.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	NPR Million	1479.02	0.21	0.21	0.21	0.21	583.35	0.21	0.21	0.21	0.21	0.21
	USD Million	12.53	0.00	0.00	0.00	0.00	4.94	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant	%	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00	78.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Subsidy/Grant from external donors	NPR Million	1153.64	0.16	0.16	0.16	0.16	455.01	0.16	0.16	0.16	0.16	0.16
	USD Million	9.78	0.00	0.00	0.00	0.00	3.86	0.00	0.00	0.00	0.00	0.00
Investment from end user	NPR Million	325.38	0.05	0.05	0.05	0.05	128.34	0.05	0.05	0.05	0.05	0.05
	USD Million	2.76	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00
Net savings	NPR Million	-325.38	55.91	58.76	61.76	64.91	-60.07	71.71	75.36	79.21	83.25	87.50
	USD Million	-2.76	0.47	0.50	0.52	0.55	-0.51	0.61	0.64	0.67	0.71	0.74

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Kathmandu City

Results of Case-3 Techno Financial Analysis for Kathmandu City, Nepal											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	SUbsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	26.43	23.79	21.15	18.5	15.86	13.22	10.57	7.93	5.29	2.64
Internal Rate of Return (per end user)	%	-21%	-19%	-17%	-15%	-12%	-8%	-3%	3%	14%	38%
Net Present Value (per end user)	NPR Million	113.5	169.9	226.3	282.7	339.0	395.4	451.8	508.1	564.5	620.9
	USD Million	1.0	1.4	1.9	2.4	2.9	3.4	3.8	4.3	4.8	5.3
Total investment by end user	NPR Million	2064.2	1857.8	1651.4	1445.0	1238.5	1032.1	825.7	619.3	412.8	206.4
	USD Million	17.5	15.7	14.0	12.3	10.5	8.8	7.0	5.3	3.5	1.8
Total programme/Project cost	NPR Million	2049.0	2049.0	2049.0	2049.0	2049.0	2049.0	2049.0	2049.0	2049.0	2049.0
	USD Million	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4

Source: Research by East Coast Sustainable

Annexure-11:
Techno Financial Case Study of Islamabad City of Pakistan

Case-1: Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of energy consumption and cost of operation for Case-1 is presented in the following table

Details of Energy consumption and Cost of operation in Islamabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline Scenario												
Annual Energy Consumption	MWh/year	28207	28207	28207	28207	28207	28207	28207	28207	28207	28207	28207
Annual Electricity Bill	PKR Million	581.915	638.36	700.28	768.21	842.72	924.47	1014.14	1112.51	1220.43	1338.81	1468.67
Annual Maintenance Cost	PKR Million	160	175.08	192.06	210.69	231.13	253.55	278.15	305.13	334.72	367.19	402.81
Total Operating Cost	PKR Million	742	813	892	979	1074	1178	1292	1418	1555	1706	1871
	USD Million	4.41	4.84	5.31	5.83	6.39	7.01	7.69	8.44	9.26	10.15	11.14
Proposed Scenario												
Annual Energy Consumption	MWh/year	-	10950	10950	10950	10950	10950	10950	10950	10950	10950	10950
Annual Electricity Bill	PKR Million	-	225.9	271.8	298.2	327.1	358.9	393.7	431.9	473.8	519.7	570.1
Annual Maintenance Cost	PKR Million	-	95.8	115.2	126.4	138.7	152.1	166.9	183.1	200.8	220.3	241.7
Total Operating Cost	PKR Million	-	321.7	387.1	424.6	465.8	511.0	560.6	615.0	674.6	740.0	811.8
	USD Million	-	1.91	2.30	2.53	2.77	3.04	3.34	3.66	4.02	4.40	4.83

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Islamabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	17257	17257	17257	17257	17257	17257	17257	17257	17257	17257
Annual Electricity Cost Savings	PKR Million	-	412.462	428.433	469.991	515.580	565.591	620.454	680.638	746.659	819.085	898.537
Annual Maintenance Cost Savings	PKR Million	-	79	77	84	92	101	111	122	134	147	161
Total Cost Savings	PKR Million	-	492	505	554	608	667	732	803	881	966	1060
	USD Million	-	2.93	3.01	3.30	3.62	3.97	4.36	4.78	5.24	5.75	6.31
Investment												
Original Investment of LED	PKR Million	437.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	PKR Million	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74
Investment for End-of-life replacement	PKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	PKR Million	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	PKR Million	464.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74
	USD Million	2.77	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	PKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	PKR Million	464.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74
	USD Million	2.77	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Net savings	PKR Million	-464.74	483.04	496.52	545.53	599.29	658.27	722.97	793.95	871.81	957.22	1,050.92
	USD Million	-2.77	2.88	2.96	3.25	3.57	3.92	4.30	4.73	5.19	5.70	6.26

Source: Research by East Coast Sustainable

Case:2 Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Islamabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44
Annual Energy Consumption	MWh/year	28207	28207	28207	28207	28207	28207	28207	28207	28207	28207	28207
Annual Electricity Bill	PKR Million	581.915	638.36	700.28	768.21	842.72	924.47	1014.14	1112.51	1220.43	1338.81	1468.67
	USD Million	3.464	3.800	4.168	4.573	5.016	5.503	6.037	6.622	7.264	7.969	8.742
Annual Maintenance Cost	PKR Million	159.60	175.08	192.06	210.69	231.13	253.55	278.15	305.13	334.72	367.19	402.81
	USD Million	0.950	1.042	1.143	1.254	1.376	1.509	1.656	1.816	1.992	2.186	2.398
Total Operating Cost	PKR Million	742	813	892	979	1074	1178	1292	1418	1555	1706	1871
	USD Million	4.41	4.84	5.31	5.83	6.39	7.01	7.69	8.44	9.26	10.15	11.14
Proposed Scenario												
Total Connected Load	MW	-	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Annual Energy Consumption	MWh/year	-	10950	13177	14456	15858	17396	19083	20934	22965	25193	27636
Number of CCMS Units	No	-	500	500	500	500	500	500	500	500	500	500
Avoided hours of Operation due to timely switch ON and Off	Hr	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Electricity Bill	PKR Million	-	225.9	271.8	298.2	327.1	358.9	393.7	431.9	473.8	519.7	570.1
	USD Million	-	1.34	1.62	1.78	1.95	2.14	2.34	2.57	2.82	3.09	3.39
Annual Maintenance Cost	PKR Million	-	95.8	115.2	126.4	138.7	152.1	166.9	183.1	200.8	220.3	241.7
	USD Million	-	0.57	0.69	0.75	0.83	0.91	0.99	1.09	1.20	1.31	1.44
Total Operating Cost	PKR Million	-	321.7	387.1	424.6	465.8	511.0	560.6	615.0	674.6	740.0	811.8
	USD Million	-	1.91	2.30	2.53	2.77	3.04	3.34	3.66	4.02	4.40	4.83

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Islamabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year	-	17257.20	17257.20	17257.20	17257.20	17257.20	17257.20	17257.20	17257.20	17257.20	17257.20
Annual Energy Savings with CCMS Units	MWh/year	-	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
Total Energy Savings	MWh/year	-	17260.71	17260.71	17260.71	17260.71	17260.71	17260.71	17260.71	17260.71	17260.71	17260.71
Annual Cost Savings with LED Retrofit	PKR Million	-	412.46	428.43	469.99	515.58	565.59	620.45	680.64	746.66	819.09	898.54
	USD Million	-	2.46	2.55	2.80	3.07	3.37	3.69	4.05	4.44	4.88	5.35
Annual Cost Savings with CCMS units	PKR Million	-	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	USD Million	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual Maintenance Cost Savings	PKR Million	-	79.32	76.83	84.28	92.45	101.42	111.26	122.05	133.89	146.88	161.12
	USD Million	-	0.47	0.46	0.50	0.55	0.60	0.66	0.73	0.80	0.87	0.96
Total Cost Savings	PKR Million	-	491.86	505.33	554.34	608.11	667.08	731.78	802.76	880.62	966.03	1059.73
	USD Million	-	2.93	3.01	3.30	3.62	3.97	4.36	4.78	5.24	5.75	6.31
Investment												
Original Investment for LED retrofit	PKR Million	437.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Investment for LED Failure	PKR Million	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74	8.74
Parameter	**Units**	**Year-0**	**Year-1**	**Year-2**	**Year-3**	**Year-4**	**Year-5**	**Year-6**	**Year-7**	**Year-8**	**Year-9**	**Year-10**
Investment for End-of-life replacement of LED	PKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for One CCMS Unit	PKR Million	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Original Investment for CCMS units	PKR Million	22.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	PKR Million	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Investment for End-of-life replacement of CCMS	PKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	PKR Million	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	PKR Million	487.91	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24
	USD Million	2.90	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	PKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	PKR Million	487.91	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24	9.24
	USD Million	2.90	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Net savings	PKR Million	-487.91	482.62	496.09	545.10	598.87	657.85	722.55	793.52	871.38	956.80	1050.49
	USD Million	-2.90	2.87	2.95	3.24	3.56	3.92	4.30	4.72	5.19	5.70	6.25

Source: Research by East Coast Sustainable

Case-3: Solar Based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Islamabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	6.44	6.63	6.83	7.04	7.25	7.47	7.69	7.93	8.16	8.41	8.66
Annual Energy Consumption	MWh/year	28207	29056	29931	30832	31760	32716	33700	34715	35760	36836	37945
Annual Electricity Bill	PKR Million	581.915	599.43	617.47	636.06	655.20	674.93	695.24	716.17	737.72	759.93	782.80
Annual Maintenance Cost	PKR Million	160	175.08	192.06	210.69	231.13	253.55	278.15	305.13	334.72	367.19	402.81
Total Operating Cost	PKR Million	742	775	810	847	886	928	973	1021	1072	1127	1186
	USD Million	4.41	4.61	4.82	5.04	5.28	5.53	5.79	6.08	6.38	6.71	7.06
Proposed Scenario												
Total Connected Load (Off grid)	MW	-	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Annual Energy Consumption from Grid	MWh/year	0	0	0	0	0	0	0	0	0	0	0
Total Energy Savings	MWh/year	-	29056	29931	30832	31760	32716	33700	34715	35760	36836	37945
Number of CCMS Units	No	-	500	-	-	-	-	-	-	-	-	-
Annual Electricity Cost Savings	PKR Million	-	599.430	617.473	636.059	655.204	674.926	695.241	716.168	737.725	759.930	782.804
Total Cost Savings	PKR Million	-	599.43	617.47	636.06	655.20	674.93	695.24	716.17	737.72	759.93	782.80
	USD Million	-	3.57	3.68	3.79	3.90	4.02	4.14	4.26	4.39	4.52	4.66

Source: Research by East Coast Sustainable

Details of Case-3 Energy savings, Cost savings and Investment for Islamabad City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	29056	29931	30832	31760	32716	33700	34715	35760	36836	37945
Annual Electricity Cost Savings	PKR Million	-	599.43	617.47	636.06	655.20	674.93	695.24	716.17	737.73	759.93	782.80
Total Cost Savings	PKR Million	-	599.43	617.47	636.06	655.20	674.93	695.24	716.17	737.72	759.93	782.80
	USD Million	-	3.57	3.68	3.79	3.90	4.02	4.14	4.26	4.39	4.52	4.66
Investment												
Original Investment for Solar LED Street Lights	PKR Million	8157.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	PKR Million	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Investment for One CCMS Unit	PKR Million	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	PKR Million	22.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	PKR Million	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Investment for End-of-life replacement of CCMS	PKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	PKR Million	0.00	0.00	0.00	0.00	0.00	3263.10	0.00	0.00	0.00	0.00	0.00
Installation Cost	PKR Million	46.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	PKR Million	8227.87	0.73	0.73	0.73	0.73	3263.83	0.73	0.73	0.73	0.73	0.73
	USD Million	48.98	0.00	0.00	0.00	0.00	19.43	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant	%	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Subsidy/Grant from external donors	PKR Million	4936.72	0.44	0.44	0.44	0.44	1958.30	0.44	0.44	0.44	0.44	0.44
Investment from end user	PKR Million	3291.15	0.29	0.29	0.29	0.29	1305.53	0.29	0.29	0.29	0.29	0.29
	USD Million	19.59	0.00	0.00	0.00	0.00	7.77	0.00	0.00	0.00	0.00	0.00
Net savings	PKR Million	-3291.15	599.14	617.18	635.77	654.91	-630.61	694.95	715.87	737.43	759.64	782.51
	USD Million	-19.59	3.57	3.67	3.78	3.90	-3.75	4.14	4.26	4.39	4.52	4.66

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Islamabad City

Results of Case-3 Techno Financial Analysis for Islamabad City, Pakistan											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	13.73	12.35	10.98	9.61	8.24	6.86	5.49	4.12	2.75	1.37
Internal Rate of Return (per end user)	%	-11%	-9%	-7%	-4%	0%	4%	10%	19%	34%	74%
Net Present Value (per end user)	PKR Million	2,362.50	2,588.10	2,813.60	3,039.20	3,264.70	3,490.20	3,715.80	3,941.30	4,166.90	4,392.40
	USD Million	14.10	15.40	16.70	18.10	19.40	20.80	22.10	23.50	24.80	26.10
Total investment by end user	PKR Million	11,498.30	10,348.50	9,198.60	8,048.80	6,899.00	5,749.20	4,599.30	3,449.50	2,299.70	1,149.80
	USD Million	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
Total programme/Project cost	PKR Million	11,423.90	11,423.90	11,423.90	11,423.90	11,423.90	11,423.90	11,423.90	11,423.90	11,423.90	11,423.90
	USD Million	64.20	64.20	64.20	64.20	64.20	64.20	64.20	64.20	64.20	64.20

Source: Research by East Coast Sustainable

Annexure-12:
Techno Financial Case Study of Colombo City of Sri Lanka

Case-1: Replacement of Conventional Lighting Fixtures with LED based EE Lighting System without CCMS

Details of Energy consumption and Cost of operation in Colombo City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Existing/Baseline Scenario												
Annual Energy Consumption	MWh/year	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208
Annual Electricity Bill	LKR Million	224.537	238.46	253.24	268.94	285.62	303.33	322.13	342.11	363.32	385.84	409.76
Annual Maintenance Cost	LKR Million	13	14.31	15.20	16.14	17.14	18.21	19.34	20.54	21.81	23.16	24.60
Total Operating Cost	LKR Million	238	253	268	285	303	322	341	363	385	409	434
	USD Million	1.19	1.26	1.34	1.43	1.51	1.61	1.71	1.81	1.93	2.05	2.17
Proposed Scenario												
Annual Energy Consumption	MWh/year	-	6262	6262	6262	6262	6262	6262	6262	6262	6262	6262
Annual Electricity Bill	LKR Million	-	106.5	120.1	127.5	135.4	143.8	152.7	162.2	172.2	182.9	194.3
Annual Maintenance Cost	LKR Million	-	10.5	11.8	12.5	13.3	14.1	15.0	15.9	16.9	18.0	19.1
Total Operating Cost	LKR Million	-	116.9	131.9	140.0	148.7	157.9	167.7	178.1	189.2	200.9	213.4
	USD Million	0.00	0.58	0.66	0.70	0.74	0.79	0.84	0.89	0.95	1.00	1.07

Source: Research by East Coast Sustainable

Details of Case-1 Energy savings, Cost savings and Investment for Colombo City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings	MWh/year	-	6946	6946	6946	6946	6946	6946	6946	6946	6946	6946
Annual Electricity Cost Savings	LKR Million	-	132.006	133.181	141.438	150.207	159.52	169.411	179.914	191.069	202.915	215.496
Annual Maintenance Cost Savings	LKR Million	-	4	3	4	4	4	4	5	5	5	6
Total Cost Savings	LKR Million	-	136	137	145	154	164	174	185	196	208	221
	USD Million	-	-	-	-	-	-	-	-	-	-	-
Investment												
Original Investment of LED	LKR Million	345.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	LKR Million	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91
Investment for End-of-life replacement	LKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	LKR Million	11.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	LKR Million	363.87	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91
	USD (,000)	1820.0	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	LKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	LKR Million	363.87	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91
	USD (,000)	1820.0	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Net savings	LKR Million	-363.87	128.96	129.68	138.15	147.14	156.69	166.84	177.61	189.05	201.20	214.10
	USD Million	-1.82	0.64	0.65	0.69	0.74	0.78	0.83	0.89	0.95	1.01	1.07

Source: Research by East Coast Sustainable

Case-2: Replacement of Conventional Lighting Fixtures with LED based EE Lighting System with CCMS

Details of Energy consumption and Cost of operation in Case-2 for Colombo City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
Annual Energy Consumption	MWh/year	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208
Annual Electricity Bill	LKR Million	224.537	238.46	253.24	268.94	285.62	303.33	322.13	342.11	363.32	385.84	409.76
Annual Maintenance Cost	LKR Million	13	14.31	15.20	16.14	17.14	18.21	19.34	20.54	21.81	23.16	24.60
Total Operating Cost	LKR Million	238	253	268	285	303	322	341	363	385	409	434
	USD Million	1.19	1.26	1.34	1.43	1.51	1.61	1.71	1.81	1.93	2.05	2.17
Proposed Scenario												
Total Connected Load	MW	-	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Annual Energy Consumption	MWh/year	-	6262	6262	6262	6262	6262	6262	6262	6262	6262	6262
Number of CCMS Units	No	-	286	-	-	-	-	-	-	-	-	-
Avoided hours of Operation due to timely switch ON and Off	Hr	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Annual Electricity Bill	LKR Million	-	106.5	120.1	127.5	135.4	143.8	152.7	162.2	172.2	182.9	194.3
Annual Maintenance Cost	LKR Million	-	10.5	11.8	12.5	13.3	14.1	15.0	15.9	16.9	18.0	19.1
Total Operating Cost	LKR Million	-	116.9	131.9	140.0	148.7	157.9	167.7	178.1	189.2	200.9	213.4
	USD Million	-	0.58	0.66	0.70	0.74	0.79	0.84	0.89	0.95	1.00	1.07

Source: Research by East Coast Sustainable

Details Case-2 Energy savings, Cost savings and Investment for Colombo City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Annual Energy Savings with LED Retrofit	MWh/year	-	6946	6946	6946	6946	6946	6946	6946	6946	6946	6946
Annual Energy Savings with CCMS Units	MWh/year	-	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Total Energy Savings	MWh/year	-	6948	6948	6948	6948	6948	6948	6948	6948	6948	6948
Annual Cost Savings with LED Retrofit	LKR Million	-	132.01	133.18	141.44	150.21	159.52	169.41	179.91	191.07	202.92	215.50
Annual Cost Savings with CCMS units	LKR Million	-	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Annual Maintenance Cost Savings	LKR Million	-	3.86	3.41	3.62	3.84	4.08	4.33	4.60	4.89	5.19	5.51
Total Cost Savings	LKR Million	-	135.89	136.62	145.08	154.08	163.63	173.77	184.54	195.98	208.13	221.04
	USD Million	-	0.68	0.68	0.73	0.77	0.82	0.87	0.92	0.98	1.04	1.11
Investment												
Original Investment for LED retrofit	LKR Million	345.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	LKR Million	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91
Investment for End-of-life replacement of LED	LKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Investment for One CCMS Unit	LKR Million	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Original Investment for CCMS units	LKR Million	15.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	LKR Million	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Investment for End-of-life replacement of CCMS	LKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installation Cost	LKR Million	11.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	LKR Million	379.71	7.27	7.27	7.27	7.27	7.27	7.27	7.27	7.27	7.27	7.27
	USD (,000)	1900.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Subsidy/Grant	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant from external donors	LKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	USD Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment from end user	LKR Million	379.71	7.27	7.27	7.27	7.27	7.27	7.27	7.27	7.27	7.27	7.27
	USD (,000)	1900.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Net savings	LKR Million	-379.71	128.62	129.35	137.81	146.81	156.36	166.50	177.27	188.71	200.86	213.77
	USD Million	-1.90	0.64	0.65	0.69	0.73	0.78	0.83	0.89	0.94	1.00	1.07

Source: Research by East Coast Sustainable

Case:3 Solar Based Energy EE System with CCMS

Details of Energy consumption and Cost of operation in Case-3 for Colombo City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Baseline Scenario												
Total Connected Load	MW	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
Annual Energy Consumption	MWh/year	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208
Annual Electricity Bill	LKR Million	224.537	238.46	253.24	268.94	285.62	303.33	322.13	342.11	363.32	385.84	409.76
Annual Maintenance Cost	LKR Million	13	14.31	15.20	16.14	17.14	18.21	19.34	20.54	21.81	23.16	24.60
Total Operating Cost	LKR Million	238	253	268	285	303	322	341	363	385	409	434
	USD Million	1.19	1.26	1.34	1.43	1.51	1.61	1.71	1.81	1.93	2.05	2.17
Proposed Scenario												
Total Connected Load (Off grid)	MW	-	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Annual Energy Consumption from Grid	MWh/year	-	0	0	0	0	0	0	0	0	0	0
Total Energy Savings	MWh/year	-	13208	13208	13208	13208	13208	13208	13208	13208	13208	13208
Number of CCMS Units	No	-	286	-	-	-	-	-	-	-	-	-
Annual Electricity Cost Savings	LKR Million	-	238.458	253.243	268.944	285.618	303.327	322.133	342.105	363.316	385.841	409.764
Total Cost Savings	LKR Million	-	238.46	253.24	268.94	285.62	303.33	322.13	342.11	363.32	385.84	409.76
	USD Million	0.00	1.19	1.27	1.34	1.43	1.52	1.61	1.71	1.82	1.93	2.05

Source: Research by East Coast Sustainable

Details of Case-3 Energy savings, Cost savings and Investment for Colombo City

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Savings												
Total Energy Savings	MWh/year	-	13208.00	13208.00	13208.00	13208.00	13208.00	13208.00	13208.00	13208.00	13208.00	13208.00
Annual Electricity Cost Savings	LKR Million	-	238.46	253.24	268.94	285.62	303.33	322.13	342.11	363.32	385.84	409.76
Total Cost Savings	LKR Million	-	238.46	253.24	268.94	285.62	303.33	322.13	342.11	363.32	385.84	409.76
	USD Million	0	1.19	1.27	1.34	1.43	1.52	1.61	1.71	1.82	1.93	2.05
Investment												
Original Investment for Solar LED Street Lights	LKR Million	5083.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for LED Failure	LKR Million	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Investment for One CCMS Unit	LKR Million	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Original Investment for CCMS units	LKR Million	15.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment for CCMS Failure	LKR Million	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Investment for End-of-life replacement of CCMS	LKR Million	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Replacement cost of Battery	LKR Million	0.00	0.00	0.00	0.00	0.00	2033.31	0.00	0.00	0.00	0.00	0.00
Installation Cost	INR Million	19.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Investment	LKR Million	5118.79	0.43	0.43	0.43	0.43	2033.74	0.43	0.43	0.43	0.43	0.43
	USD Million	25.59	0.00	0.00	0.00	0.00	10.17	0.00	0.00	0.00	0.00	0.00
Subsidy/Grant	%	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00

Parameter	Units	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9	Year-10
Subsidy/Grant from external donors	LKR Million	3839.09	0.32	0.32	0.32	0.32	1525.30	0.32	0.32	0.32	0.32	0.32
	USD Million	19.20	0.00	0.00	0.00	0.00	7.63	0.00	0.00	0.00	0.00	0.00
Investment from end user	LKR Million	1279.70	0.11	0.11	0.11	0.11	508.43	0.11	0.11	0.11	0.11	0.11
	USD Million	6.40	0.00	0.00	0.00	0.00	2.54	0.00	0.00	0.00	0.00	0.00
Net savings	LKR Million	-1279.70	238.35	253.14	268.84	285.51	-205.11	322.03	342.00	363.21	385.73	409.66
	USD Million	-6.40	1.19	1.27	1.34	1.43	-1.03	1.61	1.71	1.82	1.93	2.05

Source: Research by East Coast Sustainable

Results of Case-3 techno financial analysis for Colombo City

Results of Case-3 Techno Financial Analysis for Colombo City, Sri Lanka											
Parameters	UOM	Subsidy 0%	Subsidy 10%	Subsidy 20%	Subsidy 30%	Subsidy 40%	Subsidy 50%	Subsidy 60%	Subsidy 70%	Subsidy 80%	Subsidy 90%
Simple Payback Period (per end user)	Years	21.47	19.32	17.17	15.03	12.88	10.73	8.59	6.44	4.29	2.15
Internal Rate of Return (per end user)	%	-16%	-14%	-12%	-10%	-7%	-3%	2%	9%	21%	49%
Net Present Value (per end user)	LKR Million	943.63	1122.83	1302.03	1481.23	1660.43	1839.63	2018.84	2198.04	2377.24	2556.44
	USD Million	4.72	5.61	6.51	7.41	8.3	9.2	10.09	10.99	11.89	12.78
Total investment by end user	LKR Million	7156.37	6440.73	5725.1	5009.46	4293.82	3578.19	2862.55	2146.91	1431.27	715.64
	USD Million	35.78	32.2	28.63	25.05	21.47	17.89	14.31	10.73	7.16	3.58
Total programme/Project cost	LKR Million	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37	7156.37
	USD Million	35.78	35.78	35.78	35.78	35.78	35.78	35.78	35.78	35.78	35.78

Source: Research by East Coast Sustainable