GRID

# *Monitoring and Verification Report*

## Street Lighting and DELP projects

*Strictly Private and Confidential*

*September 2015*

pwc

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## List of Abbreviations and Acronyms

| | |
|---|---|
| BEE | Bureau of Energy Efficiency |
| CAGR | Compounded Annual Growth Rate |
| CEA | Central Electricity Authority |
| DELP | Domestic Efficient Lighting Program |
| EESL | Energy Efficiency Services Limited |
| GHG | Green House Gases |
| INR | Indian Rupees |
| kWh | Kilowatt hour |
| LED | Light Emitting Diodes |
| M&V | Monitoring and Verification |
| MW | Mega watt |
| $tCO_2$ | Tonnes of carbon dioxide |
| THD | Total Harmonics Distortion |
| ULB | Urban Local Bodies |

# 1. Executive Summary

Lighting sector accounts for about 20% of the total electricity consumption in India. It has been estimated that the use of LEDs in domestic and public lighting could result in 50-90% reduction in energy consumption. However, there are several barriers that limit the use of efficient LED lighting in the country, including:

- High upfront cost of LED
- Inadequate information about the life of LED
- Cycle of low consumer demand leading to lower supply capacities leading to higher costs
- Inadequate financial resources, lack of capacity and information about the benefits of LEDs at ULB/ Municipality level

The Hon'ble Prime Minister of India launched the "100 cities LED based Domestic Efficient Lighting Program (DELP) and National Street Lighting Program on 5th January, 2015 to address these barriers. Under the National Street Lighting Program, 35 million conventional street lights are to be replaced with energy efficient LED street lights. The national DELP program also envisions replacement of 770 million incandescent bulbs with energy efficient LED bulbs.

Till date, EESL has successfully implemented the street lighting program and the DELP in 18 and 5 cities respectively. EESL engaged PwC to carry out monitoring and verification of these projects. The objective of this study is to estimate the energy savings, reduction of load and reduction of GHG emissions resulting from these projects. Further these results were extrapolated for the national targets mentioned above. The results of the M&V study will set the direction for efficient lighting projects and learnings from it will help better implementation of the future projects. This would also be a key input for developing energy policies related to lighting sector in India.

## 1.1. Street Lighting

A survey was conducted for 5 street lighting projects in Varanasi, Jhalawar, Mount Abu, Visakhapatnam and Agartala.Based on the survey conducted, the project team assessed the operational status of the installed LED street lights. The key observations of the survey have been tabulated below:

| Sr. No. | District / City | Total LED street lights installed (A) | Number of defective LED street lights (B) | Percentage of defective LED street lights (B*100/A) |
|---|---|---|---|---|
| **1.** | Varanasi | 947 | 21 | 2.22% |
| **2.** | Jhalawar | 2449 | 21 | 0.86% |
| **3.** | Mount Abu | 1807 | 38 | 2.10% |
| **4.** | Visakhapatnam | 91775 | 884 | 0.96% |
| **5.** | Agartala | 34200 | 425 | 1.24% |
| | **Total** | **131178** | **1389** | **1.06%** |

It was observed during the survey that most of the installed LED street lights were in working condition and only1 percent of the installed street lights were observed to be non-working at the time of survey.

The key parameters like annual energy savings (in kWh), peak load reduction (in MW) and avoided annual GHG emission (in $tCO_2$) have been computed based on the findings of the survey. The computed results are provided below:

| Name of Cities | Number of LEDs (in thousands) | Annual energy savings (million kWh) | Avoided GHG emission (thousand tCO2) | Peak load reduction (MW) |
|---|---|---|---|---|
| Varanasi | 0.947 | 1.56 | 1.278 | 0.39 |
| Jhalawar | 2.449 | 0.37 | 0.303 | 0.09 |
| Mount Abu | 1.807 | 0.65 | 0.530 | 0.16 |

| | | | | |
|---|---|---|---|---|
| Vizag | 91.775 | 23.54 | 19.302 | 5.05 |
| Agartala | 34.200 | 3.90 | 3.200 | 0.97 |
| **Total (for 5 cities)** | **131.178** | **30.02** | **24.613** | **6.66** |
| **Total (at national level for 3.5 crore street lights)** | **35000** | **8008.59** | **6567.04** | **1777** |

It can be seen from the table that the installation of 131,178 LED street lights in the 5 cities has led to an annual energy savings of 30.02 million kWh, an avoided annual GHG emissions of 24,613 $tCO_2$ and peak load reduction of 6.66 MW.

Similarly, the installation of 35 million LED street lights will lead to an annual energy savings of 8008.59 million kWh, an avoided annual GHG emissions of 6.57 million $tCO_2$ and peak load reduction of 1,777 MW at the national level.

In order to check the lighting level on the streets, lux measurements were also carried out during the study at certain places on a sample basis. It was observed that the lux levels have increased considerably post the installation of LED street lights.

## *1.2. DELP*

Monitoring and verification activity was carried out for DELP projects implemented in Puducherry and four districts of Andhra Pradesh. Survey was carried out for 120 households in each of the five project areas. The key results from the survey are:

| Sr No. | District / City | Total LED bulbs distributed [A = B+C] | Number of LEDs found operational [B] | Number of LEDs currently not operational [C = i+ii] | Number of defective LEDs [i] | Number of LEDs kept for future purpose and others [ii] |
|---|---|---|---|---|---|---|
| **1** | Puducherry | 338 | 331 | 7 | 4 | 3 |
| **2** | Anantapur | 240 | 237 | 3 | 2 | 1 |
| **3** | Guntur | 240 | 237 | 3 | 2 | 1 |
| **5** | Srikakulam | 240 | 237 | 3 | 3 | 0 |
| **6** | W. Godavari | 240 | 238 | 2 | 1 | 1 |
| **Total** | | **1298** | **1280** | **18** | **12** | **6** |
| **Percentage** | | **100.00%** | **98.61%** | **1.39%** | **0.92%** | **0.46%** |

For the purpose of the analysis, it is assumed that the broken and damaged bulbs will be replaced with new LED bulbs by the consumers and therefore included in the number of operational LEDs. It was observed that bulbs were broken during cleaning (0.84%) and suffered from water damage (1%)

Based on these survey results, the total savings, reduction of peak load and emission reduction for every project was calculated.

| Region | Units saved for the overall project (million kWh) | Peak load reduction (MW) | Emission reduction (thousand tCO2) |
|---|---|---|---|
| Puducherry | 80.95 | 15.81 | 65.6 |
| Anantapur | 150.06 | 29.36 | 121.5 |
| Guntur | 249.33 | 48.70 | 202.0 |
| Srikakulam | 142.04 | 27.87 | 115.1 |
| W. Godavari | 214.10 | 41.82 | 173.4 |
| **Total (for five cities)** | **836.48** | **163.56** | **677.6** |
| **National Level (for 77 crores LED bulb distribution)** | **102901** | **20122** | **84379.5** |

These results were further extrapolated to the entire national program (replacement of 77 crore domestic lights). At a national level 102.9 billion kWh would be saved annually resulting in reduction of 20,100 MW peak load and 84.37 million $tCO_2$ reduction.

# 2. Background of the study

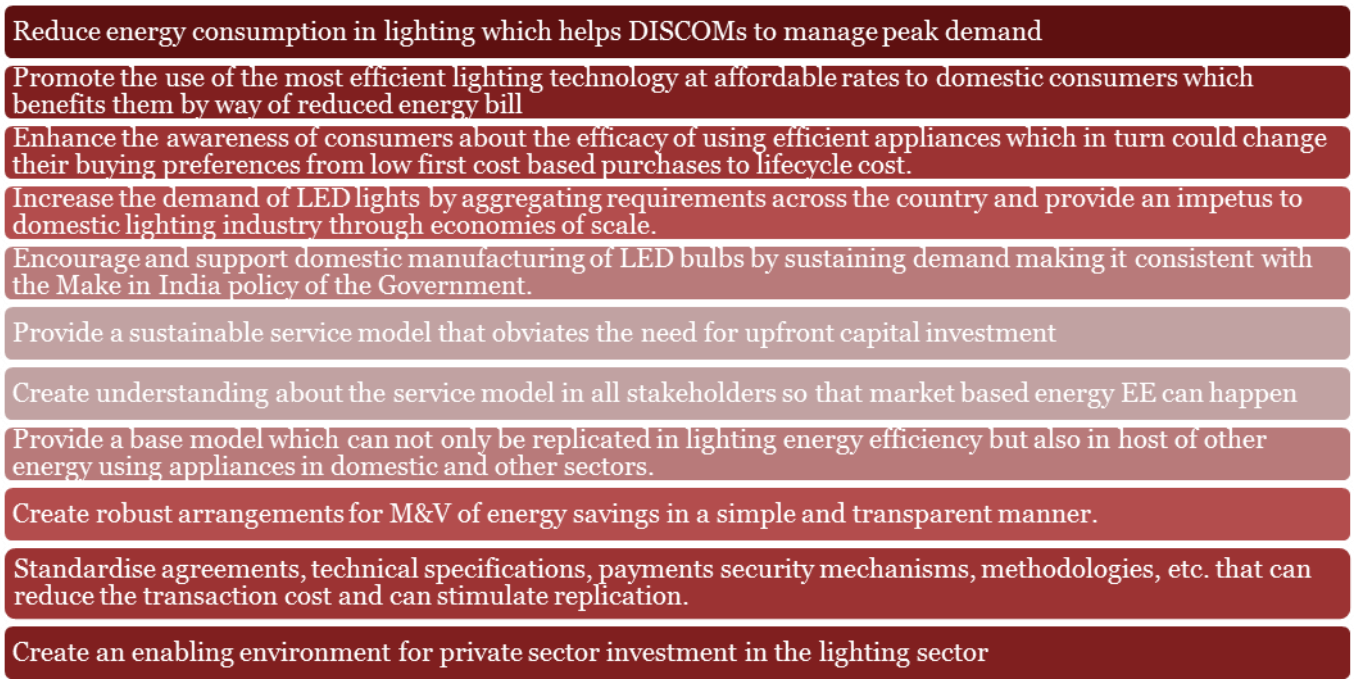
Lighting sector accounts for about 20% of the total electricity consumption in India. Most of the lighting needs in domestic and public lighting sector are met by conventional lights, including highly inefficient incandescent bulbs in domestic sector and conventional street lights in public lighting sector. LED provides better light output than conventional light.

Use of LEDs in domestic and public lighting could result in 50-90% reduction in energy consumption. However, there are several barriers that limit the use of efficient LED lighting in the country. Some of the key barriers are:

**Figure 1: Barriers limiting use of LED lighting**


To address these barriers the "100 Cities LED based Domestic Efficient Lighting Program (DELP) and Street Lighting National Program" was launched by the Prime Minister of India on 5th January, 2015. Energy Efficiency Services Limited (EESL)has been designated as the implementing agency for the program. The key objectives of the national program are:

**Figure 2: Objectives of 100 Cities LED based Domestic Efficient Lighting Program (DELP) and Street Lighting National Program**



## 2.1. Objective of the study and methodology adopted

The overall objective of this study is to conduct surveys and measurements to quantify energy savings of five DELP and street lighting projects individually, extrapolate the savings to overall program and also to evaluate the GHG emission reductions.

The key output of this study is computation of the total energy saving of the DELP and the EE street lighting national level. The results of this study would be used in developing energy policies in India.

**Figure 3: Methodology adopted for the assignment**


**Project Planning**:
- Finalization of work schedule , questionnaire and methodology with EESL
- Discussion with EESL and local authorities to finalize the sampling distribution (sampling plan)
- Support required from relevant authorities
- Collection of data from relevant authorities

**Survey and Measurement**:
- Questionnaire based survey for DELP scheme based on the approved questionnaire
- Measurement has to be taken at switch point level for few hours
- & snapshot reading shall be taken for individual pole/light for street lights

**Analysis**:
- Quantitative and Qualitative analysis of Surveys
- Based on survey and measurement calculation of actual savings, avoided capacity addition and GHG emission reduction for each project
- Extrapolation of these parameters to the entire programme

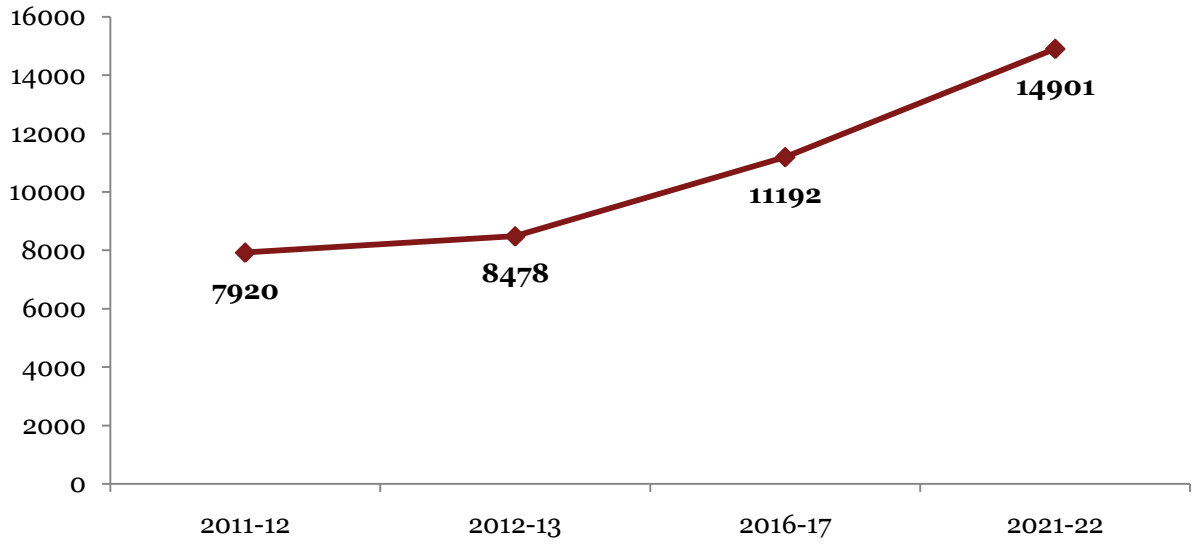
# 3. Street Lighting Projects

## 3.1. Overview of Street Lighting in India

In India, providing public lighting is one important function that urban local bodies (ULB) fulfill. Street lighting provides an important function; keeping pedestrians, drivers, and other roadway users safe, while promoting use of public spaces. Studies have shown that proper street lighting can substantially reduce fatalities and crashes with pedestrians and lighted intersections and highways have fewer crashes than their unlit counterparts. However, public lighting is costly for local governments. Street lights have high hours-of-use (they are on for over 4,000 hours per year) and thus are large consumers of energy. Different studies indicate that municipal street lighting can represent from 5% to over 60% of a ULB's electric bill, depending on the municipality's size, the services it offers, and the efficiency of its public lighting.

As per the 18th Electric Power Survey of Central Electricity Authority (CEA), the estimated energy consumption in Indian public lighting sector with 2009-10 as the base year was about 8,478 million kWh in 2012-13. This is expected to grow at a CAGR of 7% during the XII and XIII plan periods. The chart below indicates this trend:

**Figure 4: Demand of public lighting in India (in million units)**




Source: 18th Electric Power Survey, CEA

Based on the projections, the lighting demand in India for the financial year 2015-16 is 10508 Million Units. Assuming that the average public light operates for 11 hours a day throughout the year, the total connected load is 2.62 million kW. Assuming 25% of street lights are not in working condition, the total connected load of street lights across the country is around 3,400 MW.

Unfortunately, there is no comprehensive data available for street or public lighting specifying luminaire types currently installed. Some public lighting retrofit reports give detailed information on luminaire types replaced, but do not provide detail on current public lighting installations. Different type of luminaire being used in public lighting in India are Incandescent, Tungsten halogen, Compact Fluorescent, High intensity discharge, Linear fluorescent, etc. Most of these luminaire types are inefficient type of street lighting luminaires in comparison to the latest technology i.e. LED type luminaires which are highly energy efficient. Thus, there is

significant potential not only for energy-efficiency retrofits, but also for improved operational procedures in new or relocated street lighting installations.

## 3.2. Energy Efficiency Potential in Street Lighting in India

The potential impact for energy savings in street lighting in India is substantial and has been considered as one of seven key levers that India can use to reduce carbon emissions. Public lighting could have a large, swift impact, as each ULB has a substantial lighting footprint. In addition to the environmental benefits, any initiative for energy consumption reduction in public lighting will also lead to the better financial health of the ULBs.

Based on the projections, the total connected load of street lights across the country is around 3,400 MW that can be reduced to 1,400 MWby replacing conventional lights with LED based street lights. These replacements can lead to saving of approximately 9 billion kWh of energy and cost saving of INR 5,500 crore to municipalities annually.

Despite this potential, the progress in transition to energy efficient street lighting in the Municipalities and ULBs has been slow. While several states have taken steps to implement energy efficiency in the street light sector through ESCO mode, the actual implementation on the ground has been largely unsuccessful. This may be due to many factors including: inadequate baseline data, lack of performance contracts standardization, and lack of access to finance by Municipalities or poor financial position of ESCOs.

## 3.3. EESL service model

EESL, justifying its origin, started working in this sector in last 2-3 years as a government ESCO company and worked towards developing faith of the municipalities in new and innovative technologies and implemented a few successful projects in ESCO mode. EESL has evolved a service model where it replaces the conventional street lights with LEDs at its own costs (without any need for municipalities to invest) and the consequent reduction in energy and maintenance cost of the municipality is used to repay EESL over a period of time. The contracts that EESL enters into with municipalities are typically of 7 years duration where it not only guarantees a minimum energy saving (of-typically 50%) but also provides free replacements and maintenance of lights at no additional cost to the municipality during the contract period. The service model enables the municipalities to go in for state of the art street lights with no upfront capital cost and repayments to EESL are within the present level of expenditure. Thus, there is no additional revenue expenditure required to be incurred by the municipality for change over to energy efficient LED street lights.

## 3.4. Background of the Street Lighting M&V project

The Hon'ble Prime Minister of India launched the "100 cities LED based Domestic Efficient Lighting Program (DELP) and National Street Lighting Program on 5th January, 2015. Under the National Street Lighting Program, the conventional street lights are being replaced with smart and energy efficient LED street lights. EESL has been given the task of replacing conventional street lights in the selected 100 cities with the LED street lights.

At present, EESL has already successfully implemented 18 projects for street lighting. To assess the impact of the implemented projects, EESL has carried out this M&V study through PwC. The objective of this study is to evaluate the impact in terms of energy savings and reduction of GHG emissions as a result of these projects. Further, the results have been extrapolated for the entire National Street Lighting Program. The results of the M&V study will set the direction for the future street lighting projects and learnings from it will help better implementation of the future projects. This would also be a key input for developing energy policies related to street lighting in India.

## 3.5. Street Lighting projects targets

The targets for the street lighting projects are:

**Table 1: Targets for the street lighting projects**

| | |
|---|---|
| **No. of street lights to be replaced** | **35 million** |
| **Expected annual energy savings** | 9000 million kWh |
| **Expected reduction of installed street light load** | 1500 MW |
| **Estimated capital investment (excludingO&M)** | Rs. 35,000 crore |
| **Annual estimated greenhouse gas emission reductions** | 6.2 million tonnes of $CO_2$ |

## 3.6. Current Status of the Projects

To accomplish the targets of replacing35 million conventional street lights with LED street lights across India, EESL has successfully implemented projects in 18 cities and work is under progress in 82 cities. The current status of LED street lighting projects is tabulated below:

**Table 2: Status of street lighting projects**

| Parameters | Details |
|---|---|
| **No of ULBs enrolled** | 302 |
| **No of ULBs where work has been completed** | 18 |
| **No of ULBs where work is under progress** | 82 |

The M&V project has been carried out for LED street lights projects implemented in 5 cities namely Agartala, Mount Abu, Jhalawar, Visakhapatnam and Varanasi. The total numbers of LED fixtures installed in these 5 cities are reflected as:

**Table 3: Number of LED fixtures installed in 5 cities under the M&V project**

| S. No. | City | No of LED fixtures installed(nos.) |
|---|---|---|
| **1.** | Agartala | 34,200 |
| **2.** | Mount Abu | 1,807 |
| **3.** | Jhalawar | 2,449 |
| **4.** | Visakhapatnam | 91,775 |
| **5.** | Varanasi | 947 |

## 3.7. Survey Methodology

### 3.7.1. Sample Plan Distribution

The savings from street lighting projects is computed based on the sample measurements of each lighting fixture types in the towns. The sample sizes decided for the individual measurements based on 80% confidence level and 10% margin of error have been computed by using the following formula:

$$Sample\ size\ n\ = \frac{41\ X\ N}{41 + N}$$

For the switch points recording of 4 hours, one sample switch point for each lighting fixture type has been considered for carrying the measurements in all the cities.

Based on the above sampling formula and approved approach for recording measurements in the switch points, the sampling size for various types of LED fixtures types in different cities is provided below.

**Table 4: Sample size for street lighting projects**

**1.Varanasi, Uttar Pradesh**

| | | Fixture type & Numbers | | | |
|---|---|---|---|---|---|
| S. No. | Parameters | 120W | 160W (Flood Lights) | 160W (Street Lights) | 200W |
| 1 | Number of fixtures installed | 101 | 136 | 102 | 608 |
| 2 | Sample size to be covered for each fixture type | 30 | 32 | 30 | 39 |
| 3 | Sample number of switch points to be covered | 1 | 1 | 1 | 1 |

**2. Jhalawar, Rajasthan**

| | | Fixture type & Numbers | | | | | |
|---|---|---|---|---|---|---|---|
| S. No. | Parameters | 12W | 18W | 40W | 72W | 120W | 190W |
| 1 | Number of fixtures installed | 372 | 1624 | 157 | 140 | 120 | 36 |
| 2 | Sample size to be covered for each fixture type | 38 | 41 | 33 | 32 | 31 | 20 |
| 3 | Sample number of switch points to be covered | 1 | 1 | 1 | 1 | 1 | 1 |

**3. Mount Abu, Rajasthan**

| | | Fixture type & Numbers | | | |
|---|---|---|---|---|---|
| S. No. | Parameters | 15W | 35W | 70W | 120W |
| 1 | Number of fixtures installed | 551 | 119 | 966 | 171 |
| 2 | Sample size to be covered for each fixture type | 39 | 31 | 40 | 34 |
| 3 | Sample number of switch points to be covered | 1 | 1 | 1 | 1 |

**4. Visakhapatnam, Andhra Pradesh**

| | | Fixture types & Numbers | | | | | | |
|---|---|---|---|---|---|---|---|---|
| S. No. | Parameters | 20W | 40W | 70W | 120W | 150W | 160W | 210W |
| 1 | Number of fixtures installed | 60395 | 4084 | 18392 | 4578 | 3000 | 1200 | 126 |
| 2 | Sample size to be covered for each fixture type | 42 | 41 | 41 | 41 | 41 | 40 | 32 |
| 3 | Sample number of switch points to be covered | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**5. Agartala, Tripura**

| | | Fixture types & Numbers | | | | | |
|---|---|---|---|---|---|---|---|
| S. No. | Parameters | 10W | 12W | 36W | 40W | 120W | 150W |
| 1 | Number of fixtures installed | 16930 | 11286 | 984 | 656 | 3844 | 500 |
| 2 | Sample size to be covered for each fixture type | 41 | 41 | 40 | 39 | 41 | 39 |
| 3 | Sample number of switch points to be covered | 1 | 1 | 1 | 1 | 1 | 1 |

## 3.8. Survey Questionnaire

The questionnaire prepared for survey capturedthe various parameters including:

- Number of LED street lights installed and in working condition and non-working condition
- Measurement of electrical parameters like voltage, current, power, power factor, harmonics etc. for the sample of LED fixtures
- Recording of measurements of electrical parameters for 4 hours on the feeder i.e. switch point for the sample of lighting fixtures

The results of the questionnaire have been used to extrapolate the number of LED street lights in working condition. Based on the survey findings, the actual energy savings accrued due to the installation of LED street lights have also been quantified in terms of estimated energy savings in million units/annum, avoided peak load reduction in MW and reduction in GHG emissions in tonnes of $CO_2$.

The survey questionnaire prepared is attached as Annexure in this report.

## 3.9. Schedule of Surveys

The survey was carried out with the help of EESL's site officials in all the five cities. The dates of the survey are given below:

**Table 5: Schedule of the M&V survey**

| Sr. No. | Area | Date of M&V survey |
|---|---|---|
| 1 | Varanasi | 9-13 September 2015 |
| 2 | Jhalawar | 16-17 September 2015 |
| 3 | Mount Abu | 18-21 September 2015 |
| 4 | Visakhapatnam | 22-25 September 2015 |
| 5 | Agartala | 1-4 October 2015 |

## 3.10. Observations of the survey

Based on the surveys conducted, the project team analyzed the data to evaluate the operational status of the LED street lights installed. The observations of the survey have been tabulated below:

**Table 6: Observations of the M&V survey**

| Sr No. | District / City | Total LED street lights installed (A) | Number of defective LED street lights (B) | Percentage of defective LED street lights (B*100/A) |
|---|---|---|---|---|
| **1.** | Varanasi | 947 | 21 | 2.22% |
| **2.** | Jhalawar | 2449 | 21 | 0.86% |
| **3.** | Mount Abu | 1807 | 38 | 2.10% |
| **4.** | Visakhapatnam | 91775 | 884 | 0.96% |
| **5.** | Agartala | 34200 | 425 | 1.24% |
| **Total** | | 131178 | 1389 | 1.06% |

It was observed during the survey that most of the LED street lights installed were in working condition and only 1 percent of the installed street lights were observed to be non-working. Based on discussion with the officials of Municipal Corporation and local suppliers in these cities, it was found that line faults were the major reasons for non-working of LEDs. And in most cases, the drivers were replaced/repaired with the new ones.

## 3.11. Computation of key parameters

The key parameters like annual energy savings (in kWh), peak load reduction (in MW) and avoided annual GHG emission (in $tCO_2$) have been computed based on the findings of the survey. The computed results are provided below:

### 3.11.1. Energy Savings

Energy saved has been computed based on the number of LED Street lights installed. The formula used for computation is

$$Energy\ Savings = Baseline\ Consumption\ - Consumption\ post\ Project\ Implementation$$

The results of the survey were further extrapolated to the cities as provided below:

**Table 7: Key results of the M&V survey**

**1. Varanasi, Uttar Pradesh**

| Rating of street lighting lamp before LED installation (W) | Rating of installed LED lamp (W) | Average measured power of installed LED lamp (W) | Annual energy consumption before LED installation (kWh) | Annual energy consumption after LED installation (kWh) | Annual energy savings (kWh) |
|---|---|---|---|---|---|
| 250 W | 120W | 113 | 111517 | 45673 | 65843 |
| 250 W | 160W Street Lights | 159 | 112621 | 65198 | 47423 |
| 400 W | 160W Flood Lights | 161 | 360386 | 87641 | 272745 |
| 2x400 W, 400 W | 200W, 160 W | 186 | 1624910 | 452910 | 1172000 |
| | **Total Savings** | | **2209433** | **651422** | **1558011** |
| | **Total percentage savings (%)** | | | | **71%** |

### 2. Jhalawar, Rajasthan

| Rating of street lighting lamp before LED installation (W) | Rating of installed LED lamp (W) | Average measured power of installed LED lamp (W) | Annual energy consumption before LED installation (kWh) | Annual energy consumption after LED installation (kWh) | Annual energy savings (kWh) |
|---|---|---|---|---|---|
| 20 W | 12W | 12 | 29872 | 18581 | 11290 |
| 40 W | 18W | 19 | 299937 | 125661 | 174276 |
| 70 W | 40W | 43 | 47277 | 27194 | 20082 |
| 150 W | 72W | 70 | 95557 | 39132 | 56425 |
| 250 W | 120W | 128 | 132495 | 61539 | 70956 |
| 400 W | 190W | 195 | 65043 | 28136 | 36907 |
| | **Total Savings** | | **670180** | **300242** | **369938** |
| | **Total percentage savings (%)** | | | | **55%** |

### 3. Mount Abu, Rajasthan

| Rating of street lighting lamp before LED installation (W) | Rating of installed LED lamp (W) | Average measured power of installed LED lamp (W) | Annual energy consumption before LED installation (kWh) | Annual energy consumption after LED installation (kWh) | Annual energy savings (kWh) |
|---|---|---|---|---|---|
| 36 W | 15W | 16 | 79642 | 34293 | 45348 |
| 70 W | 35W | 39 | 35834 | 18526 | 17308 |
| 150 W | 70W | 76 | 659343 | 295789 | 363554 |
| 400 W | 120W | 129 | 308954 | 88885 | 220069 |
| | **Total Savings** | | 1083773 | 437493 | 646280 |
| | **Total percentage savings (%)** | | | | **60%** |

### 4. Visakhapatnam, Andhra Pradesh

| Rating of street lighting lamp before LED installation (W) | Rating of installed LED lamp (W) | Average measured power of installed LED lamp (W) | Annual energy consumption before LED installation (kWh) | Annual energy consumption after LED installation (kWh) | Annual energy savings (kWh) |
|---|---|---|---|---|---|
| 40 W | 20W | 22.08 | 13755565 | 5353873 | 8401692 |
| 70 W | 40W | 40.71 | 1431034 | 667484 | 763550 |
| 150 W | 70W | 67.66 | 13291898 | 4996571 | 8295327 |
| 250 W | 120W | 115.31 | 5514201 | 2119387 | 3394814 |
| 250 W | 150W | 146.10 | 3613500 | 1759796 | 1853704 |
| 250 W | 160W | 154.16 | 1445400 | 742722 | 702678 |
| 400 W | 210W | 212.43 | 234549 | 107466 | 127083 |

| | | | | | |
|---|---|---|---|---|---|
| | **Total Savings** | | **39286147** | **15747299** | **23538848** |
| | **Total percentage savings (%)** | | | | **60%** |

**5. Agartala, Tripura**

| Rating of street lighting lamp before LED installation (W) | Rating of installed LED lamp (W) | Average measured power of installed LED lamp (W) | Annual energy consumption before LED installation (kWh) | Annual energy consumption after LED installation (kWh) | Annual energy savings (kWh) |
|---|---|---|---|---|---|
| 18 W | 10 W | 9.03 | 1223531 | 613712 | 609819 |
| 18 W | 12 W | 11.65 | 815639 | 527883 | 287756 |
| 85 W | 36 W | 35.52 | 335815 | 140339 | 195476 |
| 85 W | 40 W | 40.06 | 223876 | 105516 | 118360 |
| 250 W | 120 W | 116.93 | 4244257 | 1804622 | 2439635 |
| 250 W | 150 W | 149.67 | 552063 | 300466 | 251596 |
| | **Total Savings** | | **7395180** | **3492538** | **3902642** |
| | **Total percentage savings (%)** | | | | **53%** |

## *3.11.2. Peak load reduction*

The peak load reduction refers to the MW savings accrued with the implementation of LED street lighting projects. This reduces the burden on the already constrained generation capacity of the nation.

The peak load reduction can be calculated by the formula:

$$Load\ reduction\ in\ kW = \frac{Number\ of\ LEDs\ installed\ (wattage\ of\ conventional\ lights - wattage\ of\ LEDs) \times Peak\ Coincidence\ Factor}{1000}$$

For the computation of peak load reduction from implementation of LED street lighting projects, the peak coincidence factor has been taken as 1 based on various load research studies.

**Table 8: Peak load reduction for 5 cities**

| Sr. No. | Cities | Peak load reduction (MW) |
|---|---|---|
| **1.** | Varanasi | 0.39 |
| **2.** | Jhalawar | 0.09 |
| **3.** | Mount Abu | 0.16 |
| **4.** | Visakhapatnam | 5.05 |
| **5.** | Agartala | 0.97 |
| **Total (for 5 cities)** | | **6.66** |
| **Total (at national level)** | | **1777** |

Based on the results achieved, the peak load reduction for street lighting projects in these 5 cities is 6.66 MW. Similarly, the installation of 35 million LED street lights at the national level will lead to peak load reduction of1,777 MW.

## 3.11.3. Emission Reduction

The reduction in GHG emission has been computed based on the Baseline Carbon Dioxide Emission Database published by Central Electricity Authority, Government of India.

$$Reduction\ in\ GHG\ emissions = Energy\ units\ saved \times Emission\ Factor$$

The most recent emission factors published by Central Electricity Authority (CEA) are:

**Table 9: Assumptions for Emission Reduction**

| Grid | Emission factor in tCO2/MWh[1] |
|---|---|
| **NEWNE** | 0.82 |
| **South** | 0.81 |
| **India** | 0.82 |

Based on the above mentioned emission factors, the emission reductions for all these projects are:

**Table 10: Emission Reduction for street lighting projects**

| Sr. No. | Region | Units Saved (million kWh) | Emission Factor | GHG Emission Reduction (thousand $tCO_2$) |
|---|---|---|---|---|
| **1.** | Varanasi | 1.56 | 0.82 | 1.278 |
| **2.** | Jhalawar | 0.37 | 0.82 | 0.303 |
| **3.** | Mount Abu | 0.65 | 0.82 | 0.530 |
| **4.** | Visakhapatnam | 23.54 | 0.82 | 19.302 |
| **5.** | Agartala | 3.90 | 0.82 | 3.20 |
| **Total (for 5 cities)** | | **30.02** | **0.82** | **24.613** |
| **Total (at national level)** | | **8008.59** | **0.82** | **6567.04** |

Based on the results achieved, the reduction in GHG emissions for street lighting projects in these 5 cities is 24,613tCO2. Similarly, the installation of 35 million LED street lights at the national level will result in the reduction of total GHG emissions of 6.57 million tCO2.

**Lighting levels**

The sample lighting levelsmeasurements were carried out at certain locations in the cities. It was observed during the survey that the lux levels have considerably improved with the installation of LED street lights in comparison to the conventional street lights. During discussions with the locals in the cities, it was found that LED street lights have also illuminated those places where there was no illumination or very little illumination.

The findings of the lighting levels measurements are tabulated below:

[1] Weighted average emission factor based on "User Guide (Version 10.0) of CO2 baseline database for the Indian Power Sector prepared by Central Electricity Authority, Ministry of Power, GoI.

**Table 11: Lighting levels measurements**

**Varanasi**

| S. No. | Name of the location/ switch point | Average lighting levels (lux) |
|---|---|---|
| 1 | ASSI Ghat | 70 |
| 2 | Ganga Mahal Ghat | 45 |
| 3 | Bhadaini Ghat | 35 |
| 4 | Harishchandra Ghat | 50 |
| 5 | Hanumana Gardhi Ghat | 15 |

The variation in the lux levels is attributed to the road width, distance between two poles etc. Based on the discussions, it was found that the lux levels have considerably increased with the installation of LED street lights as compared to conventional lights.

**Visakhapatnam**

| S. No. | Name of the location/ switch point | Average lighting levels(lux) |
|---|---|---|
| 1 | PDP/SW/01 | 7.75 |
| 2 | VM/SW/01 | 15.25 |
| 3 | RKM/SW/01 | 19.06 |
| 4 | AS/SW/01 | 19 |
| 5 | FOB/SW/01 | 20.10 |

The variation in the lux levels is attributed to the road width, distance between two poles etc. It was also observed that lux levels have considerably increased with the installation of LED street lights as compared to conventional lights.

**Agartala**

| S. No. | Name of the location/ switch point | Average lighting levels (lux) |
|---|---|---|
| 1 | Roy Medical Store | 46 |
| 2 | Old Secretariat | 42.19 |
| 3 | Gorka Basti | 56.12 |
| 4 | Governor house | 66.13 |
| 5 | Neta chowmni | 7.63 |

The variation in the lux levels is attributed to the road width, distance between two poles etc. The lux levels have considerably increased with the installation of LED street lights as compared to conventional lights.

## 3.12. Switch Point Measurements

### 3.12.1. Varanasi

There are four types of LED lighting fixtures installed in Varanasi. The electrical parameters for one switch point of each LED lighting fixture type were recorded for about 4 hours. The consolidated details of switch points covered and the number of various lighting fixtures types connected to that switch point are provided below:

### Table 12: Details of switch points in Varanasi

| S. No. | Name/ location of switch point | Details of lighting fixtures | Rated load (W) | Average measured load (W) |
|---|---|---|---|---|
| 1 | BP/RDP/SW-01 | 8X120W | 960W | 984.75W |
| 2 | DS/RMG/SW-01 | 27X160W + 1X120W | 4440W | 4480W |
| 3 | BLP/AG/SW-01 | 24X200W + 1X120W + 50X160W | 12920W | 13207.87W |
| 4 | DS/CRP/SW-01 | 4X200W | 800W | 795.08W |

Some of the observations regarding the switch point wise measurements in Varanasi are provided below:

- The power profile showed that the average measured load was close to the rated load. The maximum variation observed in the average measured load and rated load was 2.58 percent.
- The voltage and current profile showed that the variation in voltage is inversely proportional to the variation in current for most of the cases. This is due to the inherent characteristics of LED street lights in which it draws power close to its rated load. In case of over voltages during night times, the LED street lights draw a current lesser than the rated current.
- The voltage and current harmonics profile showed that the voltage and current harmonics are within the recommended limits as per IEEE standards.

## *3.12.2. Jhalawar*

There are sixtypes of LED lighting fixtures installed in Jhalawar. The electrical parameters for one switch point of each LED lighting fixture type were recorded for about 4 hours. The consolidated details of switch points covered and the number of various lighting fixtures types connected to that switch point is provided below:

**Table 13: Details of switch points in Jhalawar**

| S. No. | Name/ location of switch point | Details of lighting fixtures | Rated load (W) | Average measured load (W) |
|---|---|---|---|---|
| 1 | Manjhi Mohalla | 14X12W + 1X72W | 240W | 238.08W |
| 2 | Police Line | 18X72W + 2X190W + 20X18W + 3X70W | 2246W | 2254.61W |
| 3 | Kanchan Residency | 24X18W + 3X250W | 1182W | 1222.51W |
| 4 | Satya Chauraha/WN-21/PN-1891 | 6X40W + 3X90W + 1X190W | 700W | 620.72W |
| 5 | Master Colony Main Road | 24X40W + 1X190W | 1150W | 1111.34W |
| 6 | Bada Bazaar (next to Jain Mandir) | 33X120W | 3960W | 4065.24W |

Some of the observations regarding the switch point wise measurements in Jhalawar are provided below:

- The power profile showed that the average measured load was close to the rated load. The maximum variation observed in the average measured load and rated load was 11.33 percent.
- The voltage and current profile showed that the variation in voltage is inversely proportional to the variation in current for most of the cases. This is due to the inherent characteristics of LED street lights in which it draws power close to its rated load. In case of over voltages during night times, the LED street lights draw a current lesser than the rated current.
- The voltage and current harmonics profile showed that the voltage and current harmonics are within the recommended limits as per IEEE standards.

## 3.12.3. Mount Abu

There are four types of LED lighting fixtures installed in Mount Abu. The electrical parameters for one switch point of each LED lighting fixture type were recorded for about 4 hours. The consolidated details of switch points covered and the number of various lighting fixtures types connected to that switch point is provided below:

**Table 14: Details of switch points in Mount Abu**

| S. No. | Name/ location of switch point | Details of lighting fixtures | Rated load (W) | Average measured load (W) |
|---|---|---|---|---|
| 1 | Sophia school | 12X120W + 8X70W + 17X15w + 12X70W + 1X35W + 5X25W + 1X65W + 6x250W | 5060W | 4891.42W |
| 2 | Post office crossing | 6X120W + 13X70W + 11X15W + 21X70W + 6X15W + 3X25W + 5X1000W + 7X500W | 11930W | 11630.30W |
| 3 | Pandu Bhawan | 13X15W + 4X35W + 28X70W + 4X120W + 4X500W + 1X1000W | 5775W | 5402.38W |
| 4 | Gora Chhapra | 84X15W + 55X70W + 4X35W + 4X120W + 3X25W + 1X120W + 10x500W + 10X1000W | 20925W | 20219.76W |

Some of the observations regarding the switch point wise measurements in Mount Abu are provided below:

- The power profile showed that the average measured load was close to the rated load. The maximum variation observed in the average measured load and rated load was 6.45 percent.
- The voltage and current profile showed that the variation in voltage is inversely proportional to the variation in current for most of the cases. This is due to the inherent characteristics of LED street lights in which it draws power close to its rated load. In case of over voltages during night times, the LED street lights draw a current lesser than the rated current.
- The voltage and current harmonics profile showed that the voltage and current harmonics are within the recommended limits as per IEEE standards.

## 3.12.4. Visakhapatnam

There are seven types of LED lighting fixtures installed in Visakhapatnam. The electrical parameters for one switch point of each LED lighting fixture type were recorded for about 4 hours. The consolidated details of switch points covered and the number of various lighting fixtures types connected to that switch point is provided below:

**Table 15: Details of switch points in Visakhapatnam**

| S. No. | Name/ location of switch point | Details of lighting fixtures | Rated load (W) | Average measured load (W) |
|---|---|---|---|---|
| 1 | PDP/SW/01 | 9X20W | 180W | 183.49W |
| 2 | VM/SW/01 | 12X40W | 480W | 492.38W |

| | | | | |
|---|---|---|---|---|
| 3 | RKM/SW/01 | 5X70W | 350W | 337.92W |
| 4 | AS/SW/01 | 42X120W | 5040W | 4990.15W |
| 5 | FOB/SW/01 | 84X150W | 12600W | 12655.16W |
| 6 | NH/SW/01 | 60X160W | 9600W | 10139.14W |
| 7 | PWD/SW/01 | 6X210W | 1260W | 1295.39W |

Some of the observations regarding the switch point wise measurements in Visakhapatnam are provided below:

- The power profile showed that the average measured load was close to the rated load. The maximum variation observed in the average measured load and rated load was 5.62 percent.
- The voltage and current profile showed that the variation in voltage is inversely proportional to the variation in current for most of the cases. This is due to the inherent characteristics of LED street lights in which it draws power close to its rated load. In case of over voltages during night times, the LED street lights draw a current lesser than the rated current.
- The voltage and current harmonics profile showed that the voltage and current harmonics are within the recommended limits as per IEEE standards.




## *3.12.5. Agartala*

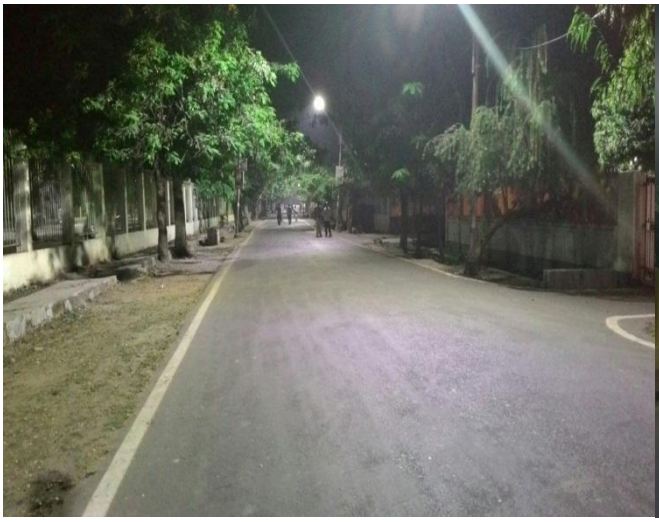
There are six types of LED lighting fixtures installed in Agartala. The electrical parameters for one switch point of each LED lighting fixture type were recorded for about 4 hours. The consolidated details of switch points covered and the number of various lighting fixtures types connected to that switch point is provided below:

**Table 16: Details of switch points in Agartala**

| S. No. | Name/ location of switch point | Details of lighting fixtures | Rated load (W) | Average measured load (W) |
|---|---|---|---|---|
| 1 | Ward no-26 kpb/001 | 31X10W | 310W | 311.12W |
| 2 | Ward no -02/vip/rd/001 | 15X12W | 180W | 174.37W |
| 3 | Ward no-20/jm/001 | 37X36W | 1332W | 1347.03W |
| 4 | Ward no-03/nc/001 | 45X40W | 1800W | 1788.22W |
| 5 | Ward no-31/pg/skk/001 | 13X120W | 1560W | 1570.63W |
| 6 | Ward no -03/vip/rd/001 | 12X150W | 1800W | 1834.69W |

Some of the observations regarding the switch point wise measurements in Agartala are provided below:

- The power profile showed that the average measured load was close to the rated load. The maximum variation observed in the average measured load and rated load was 3.13 percent.
- The voltage and current profile showed that the variation in voltage is inversely proportional to the variation in current for most of the cases. This is due to the inherent characteristics of LED street lights in which it draws power close to its rated load. In case of over voltages during night times, the LED street lights draw a current lesser than the rated current.
- The voltage and current harmonics profile showed that the voltage and current harmonics are within the recommended limits as per IEEE standards.



# 4. Domestic Energy Efficient Lighting Program

## 4.1. Overview of Domestic Lighting Sector

As per 18th Electric Power Survey, domestic sector would accounts for about 26.5% of India's total electricity consumption (16,11,808 GWh) by end of XIII th five year plan. Major part of the energy consumption is used for lighting. A significant proportion of household lighting needs are met by use of incandescent bulbs, which are extremely energy inefficient as over 90% of electricity is wasted as heat.

According to recent statistics published by lighting manufacturers association ELCOMA, sales of ICLs were to the tune of about 77 crores in 2013-14[2]. The replacement of these ICLs will give a huge immediate market for LEDs which has potential to save more than 100 billion units which is equivalent to around 20000 MW of peak load reduction. With the cost/lumens of LEDs reaching the levels of CFLs, the overall potential of replacement by LEDs could also include CFLs.

## 4.2. Introduction

DELP entails replacement of inefficient incandescent bulbs (ICLs) used in households with energy efficient LED lights. DELP proposes to promote using the basic architecture of Bachat Lamp Yojana (BLY). It would leverage DSM as a recovery investment, much in the same manner as CDM was used by BLY. Energy savings is achieved as LEDs consumes 50% less electricity for comparable quality of service than CFLs and 88% less in the case of ICLs

EESL has evolved a service model where it works with electricity distribution companies (DISCOMs) through a benefit sharing approach. The Domestic Efficient LightingProgram (DELP) obviates the need for DISCOMs to invest in the upfront cost of LED bulbs; EESLprocures the LEDs bulbs and provides to consumers at a rate of Rs. 10 each as against their marketprice of Rs. 350-400. The upfront investment made by EESL is paid back in two different ways asindicated under:

**Figure 5 : Business Models for DELP**

| DISCOM Cost Recovery | On Bill Financing (OBF) |
|---|---|
| • The investments of EESL are recovered from the DISCOMs as annuity over a period of 3-10 years by monetizing the energy savings that accrue as a result of replacement of incandescent lamps with LEDs. Each replacement leads to a reduction of load by 53W. The energy savings are monetized based on the peak procurement cost of DISCOM and is used to pay back the investment made by EESL under an approval by the State Electricity Regulatory Commission.<br>• This model has been adopted in Andhra Pradesh and Puducherry | • Cost recovery from consumers by deduction of easy instalments of Rs. 10 every month for 8-12 months. The entire cost of the LED bulbs, including the awareness, distribution and cost of capital is recovered from the consumer bills.<br>• DELP implementation in Delhi, UP and Rajasthan is through "on bill financing mechanism" |

[2] Source: ELCOMA

## 4.3. DELP targets

The targets for DELP are:

**Table 17: DELP targets**

| No of LED lights to be replaced in 3 years | 77 crore |
|---|---|
| Expected annual energy savings | 105 billion KWh |
| Expected reduction of installed load | 20,000 MW |
| Estimated capital investment (excluding O&M) | Rs. 8000 crore |
| Annual estimated greenhouse gas emission reductions | 79 million tonnes of $CO_2$ |

## 4.4. Current Status of the Projects

The project work has already been completed in 5 towns, namely Puducherry, Guntur, Anantpur, Srikakulam, and West Godavari, and is going on successfully in 8 more districts.

**Table 18: Status of DELP**

| Parameters | Details |
|---|---|
| **No of Towns enrolled** | 171 |
| **No of town where work completed** | 5 (Puducherry, Guntur, Anantpur, Srikakulam, West Godavari) |
| **No of district / towns where work is under progress** | 8 |

The total numbers of bulbs distributed in each of the 5 districts are reflected as:

**Table 19: Project Size of Completed Projects**

| S. No. | Project | No of BulbsDistributed ( in lakhs .) |
|---|---|---|
| **1.** | Puducherry | 6.09 |
| **2.** | Guntur | 11.22 |
| **3.** | Anantapur | 18.61 |
| **4.** | Srikakulam | 10.65 |
| **5.** | West Godavari | 15.91 |

## 4.5. Survey Methodology

### 4.5.1. Survey Questionnaire

The questionnaire prepared for the survey captures various parameters including:

- Number of LED bulbs installed and operating in the household
- Number of LED bulbs installed and non-operating in the household(reasons may be given, where relevant);
- Number of LED bulbs not installed, fused, broken, missing and/or replaced

The questionnaire prepared for the survey is attached as Annexure in this report.

## 4.5.2. Sample Plan Distribution

The saving from DELP projects is computed based on the survey of the sample of population availing the scheme. The survey sample sizes based on 90% confidence level and 7.5% margin of error are:

**Table 20: Sample Size for DELP**

| S. No. | Project | No of BulbsDistributed(nos.) | Sample Size at 90%Confidence Level and 7.5%margin of error |
|---|---|---|---|
| **1.** | Puducherry | 609251 | 120 |
| **2.** | Guntur | 1121845 | 120 |
| **3.** | Anantapur | 1860897 | 120 |
| **4.** | Srikakulam | 1065201 | 120 |
| **5.** | West Godavari | 1591230 | 120 |

Further, the sample was geographically distributed in the various division and subdivision based on the LED bulbs distributed in the area. The detailed Sampling plan is given below:

**Table 21: Sample distribution for DELP**

| Sr. No. | Area | Number of Surveys |
|---|---|---|
| ***1*** | ***Puducherry*** | ***120*** |
| 1 | Ashok Nagar | 20 |
| 2 | Boomianpet | 20 |
| 3 | Gorimedu | 20 |
| 4 | Lawspet | 20 |
| 5 | Mudaliarpet | 20 |
| 6 | Vengata Nagar | 20 |
| ***2*** | ***Anantapur*** | ***120*** |
| 1 | Cco Tadipatri | 6 |
| 2 | Dharmavaram | 6 |
| 3 | East/Ananthapuram | 6 |
| 4 | Gooty | 6 |
| 5 | Guntakal | 6 |
| 6 | Hindupur Rurals | 6 |
| 7 | Hindupur Town | 6 |
| 8 | Kadiir | 6 |
| 9 | Kadiri E&W | 6 |
| 10 | Kalyanadurg Rurals | 6 |
| 11 | Kalyanadurg Town | 6 |
| 12 | Madakasira | 6 |
| 13 | Penukonda | 6 |
| 14 | Puttaparthy | 6 |
| 15 | Rayadurg | 6 |
| 16 | Tadipatri | 6 |
| 17 | Town 1/Ananthapuram | 6 |
| 18 | Town 2/Ananthapuram | 6 |
| 19 | Uravakonda | 6 |
| 20 | West/Ananthapuram | 6 |
| ***3*** | ***Guntur*** | ***120*** |
| 1 | Bapatla | 5 |
| 2 | Cherukupalli | 5 |

| | | |
|---|---|---|
| 3 | Chilakaluripet | 5 |
| 4 | Dachepalli | 5 |
| 5 | Guntur-Rural1 | 5 |
| 6 | Guntur-Rural2 | 5 |
| 7 | Guntur-Town1 | 5 |
| 8 | Guntur-Town2 | 5 |
| 9 | Guntur-Town3 | 5 |
| 10 | Guntur-Town4 | 5 |
| 11 | Gurazala | 5 |
| 12 | Macherla | 5 |
| 13 | Mangalagiri | 5 |
| 14 | Narasaraopet | 5 |
| 15 | Narasaraopet-Rural | 5 |
| 16 | Nrt-Rural | 5 |
| 17 | Piduguralla | 5 |
| 18 | Ponnur | 5 |
| 19 | Repalle | 5 |
| 20 | Sattenapalli | 5 |
| 21 | Tenali-Rural1 | 5 |
| 22 | Tenali-Rural2 | 5 |
| 23 | Tenali-Town | 5 |
| 24 | Vinukonda | 5 |
| ***4*** | ***Srikakulam*** | ***120*** |
| 1 | Amadalavalasa | 12 |
| 2 | Narasannapeta | 12 |
| 3 | Palasa | 12 |
| 4 | Pathapatnam | 12 |
| 5 | Rajam | 12 |
| 6 | Seethampeta | 12 |
| 7 | Sompeta | 12 |
| 8 | Srikakulam-Rural | 12 |
| 9 | Srikakulam-Town | 12 |
| 10 | Tekkali | 12 |
| ***5*** | *West Godavari* | *120* |
| 1 | Akiveedu | 6 |
| 2 | Bhimadolu | 6 |
| 3 | Bhimavaram | 8 |
| 4 | Eluru | 6 |
| 5 | Eluru- Rural | 6 |
| 6 | Ganapavaram | 6 |
| 7 | Gopalapuram | 6 |
| 8 | Jangareddygudem | 12 |
| 9 | Jelugumilli | 6 |
| 10 | Kovvuru | 6 |
| 11 | Narsapuram | 6 |
| 12 | Nidadavole | 6 |
| 13 | Palakollu | 6 |
| 14 | Pedavegi | 6 |
| 15 | Penugonda | 6 |
| 16 | Tadepalligudem | 6 |
| 17 | Tadepalligudem- Rural | 10 |
| 18 | Tanuku | 6 |

## 4.6. Schedule of Surveys

Based on discussions with EESL, the survey was carried out in all the five districts and towns as per the schedule given below:

**Table 22: Schedule for DELP surveys**

| Sr. No. | Project | Date of Survey | No. of Days |
|---|---|---|---|
| 1 | Puducherry | 11/09/2015-13/09/2015 | 3 |
| 2 | Anantapur | 14/09/2015-16/09/2015 | 3 |
| 3 | Guntur | 17/09/2015-19/09/2015 | 3 |
| 4 | Srikakulam | 20/09/2015-23/09/2015 | 4 |
| 5 | West Godavari | 20/09/2015-23/09/2015 | 4 |

## 4.7. Results of the survey

Based on the survey conducted the project team analyzed the data to evaluate the operational status of the LED bulbs distributed. The results of the analysis have been tabulated below:

**Table 23: Results from the survey**

| Sr No. | Project | Total LED bulbs distributed [A = B+C] | Number of LEDs found operational [B] | Number of LEDs currently not operational [C = i+ii] | Number of defective LEDs [i] | Number of LEDs kept for future purpose and others [ii] |
|---|---|---|---|---|---|---|
| **1** | Puducherry | 338 | 331 | 7 | 4 | 3 |
| **2** | Anantapur | 240 | 237 | 3 | 2 | 1 |
| **3** | Guntur | 240 | 237 | 3 | 2 | 1 |
| **5** | Srikakulam | 240 | 237 | 3 | 3 | 0 |
| **6** | W. Godavari | 240 | 238 | 2 | 1 | 1 |
| **Total** | | 1298 | 1280 | 18 | 12 | 6 |
| **Percentage** | | 100.00% | 98.61% | 1.39% | 0.92% | 0.46% |

For the purpose of the analysis, it is assumed that the broken and damaged bulbs will be replaced with new LED bulbs by the consumers and therefore included in the number of operational LEDs. It was observed that bulbs were broken during cleaning (0.84%) and suffered from water damage (1%)

## 4.8. Computation of key parameters

### 4.8.1. Energy Savings

Energy saved has been computed based on the number of LED bulbs found operating based on the survey. The formula used for computation is

$$Energy\ Savings = Baseline\ Consumption\ - Consumption\ post\ Project\ Implementation$$

The baseline consumption is calculated as the energy consumption by the system before project implementation. While calculating the baseline savings, the consumption of the lighting fixtures where LED has been kept for future use has not been considered.

$$Baseline\ Consumption = (LEDs\ distributed - LEDs\ kept\ for\ future\ purpose) \times Wattage\ of\ the\ old\ luminaire\ replaced \times Hours\ of\ operation$$

Consumption post implementation has been computed for the LEDs found operational. Additionally, for the LEDs found defective, it is assumed that the consumers have moved back to using incandescent bulbs.

$$Consumtpion\ post\ Project\ Implementation = (LEDs\ operational \times wattage\ of\ LED + LEDs\ found\ defective\ (i) \times wattage\ of\ ICL) \times hours\ of\ operation$$

The assumptions used for calculations are as follow:

**Table 24: Assumption for calculations of savings for DELP**

| Parameter | Source |
|---|---|
| **Wattage of ICL** | 60 W |
| **Wattage of LED** | 7 W |
| **Operating hours / days** | 8 hrs as per load research studies |
| **Days of operation** | 320 hrs as per load research studies |

The results of the survey were further extrapolated to the division / city.

**Table 25: Energy Saved for 5 regions**

| Sr. No. | Region | Units saved annually for sample size (kWh) | Units saved per LED bulb distributed (kWh) | Units saved for the overall project (million kWh) |
|---|---|---|---|---|
| **1** | Puducherry | 44910.08 | 132.87 | 80.95 |
| **2** | Anantapur | 32102.40 | 133.76 | 150.06 |
| **3** | Guntur | 32156.16 | 133.98 | 249.33 |
| **4** | Srikakulam | 32002.56 | 133.34 | 142.04 |
| **5** | W. Godavari | 32291.84 | 134.55 | 214.10 |
| **Total** | **India Level (77 crore LEDs)** | | 133.64 | 102901.80 |

Based on the results achieved, on an average 133.64 kWh were saved for each of the bulbs distributed in DELP, therefore the total saving at national level for 77 crores bulb is approximately102.9 billion kWh. Assuming an average domestic tariff of INR 3.5 / kWh, the total savings are INR36015 crore annually.

EESL plans to replace the defective bulbs with technical problems with new bulbs, this would result in approximately annual savings at a national level to around104 billion units.

## 4.8.2. Reduction of peak installed load

Reduction of peak installed loadhas been calculated using the formula:

$$Reduction\ of\ peak\ installed\ load = Number\ of\ LEDs\ operational\ (wattage\ of\ ICL - wattage\ of\ LEDs) \times Peak\ Coincidence\ Factor$$

The peak coincidence factor has been conservatively assumed as 0.5. It should be noted that even though the reduction of peak installed load has been computed based on operational LEDs, the extrapolation would be done on total number of LEDs distributed.

**Table 26: Reduction of peak installed load for 5 cities**

| Sr. No. | Cities | Peak load reduction as per sample size (kW) | Peak load reduction per LED distributed (kW) | Peak load reduction for the entire project (kW) |
|---|---|---|---|---|
| **1** | Puducherry | 8.77 | 0.026 | 15810.78 |
| **2** | Anantapur | 6.28 | 0.026 | 29357.28 |
| **3** | Guntur | 6.28 | 0.026 | 48697.35 |
| **4** | Srikakulam | 6.28 | 0.026 | 27874.98 |
| **5** | W. Godavari | 6.31 | 0.026 | 41816.20 |
| **Total** | | | 0.026 | 20122033.90 |

Based on the results achieved, on an average 0.026 kW of peak reduction was achieved for each of the bulbs distributed in DELP, therefore the peak reduction at national level for 77 crores bulb is approximately 20100 MW.

## 4.8.3. Emission Reduction

The reduction in GHG emission would be computed based on the Baseline Carbon Dioxide Emission Database published by Central Electricity Authority, Government of India.

$$Reduction\ in\ GHG\ emissions = Energy\ units\ saved \times Emission\ Factor$$

The most recent emission factors published by CEA are:

**Table 27: Assumptions for Emission Reduction**

| Grid | Emission factor in $tCO_2/MWh$[3] |
|---|---|
| **NEWNE** | 0.82 |
| **South** | 0.82 |
| **India** | 0.82 |

Based on the above mentioned emission factors, the emission reductions for all the projects are:

[3] Weighted average emission factor based on "User Guide (Version 10.0) of $CO_2$ baseline database for the Indian Power Sector prepared by Central Electricity Authority, Ministry of Power, GoI.

**Table 28: Emission Reduction for DELP**

| Sr. No. | Region | Units Saved (million kWh) | Emission Factor | Emission Reduction (thousand $tCO_2$) |
|---|---|---|---|---|
| **1** | Puducherry | 80.95 | 0.82 | 65.570 |
| **2** | Anantapur | 150.06 | 0.82 | 121.546 |
| **3** | Guntur | 249.33 | 0.82 | 201.957 |
| **4** | Srikakulam | 142.04 | 0.82 | 115.050 |
| **5** | W. Godavari | 214.10 | 0.82 | 173.420 |
| **6** | **India** | 102901.80 | 0.82 | 84379.478 |

The DELP would result in an overall reduction of 84.37 million $tCO_2$ emissions.

# 5. Conclusion

## 5.1. Street Lights

Based on the monitoring & verification survey conducted, the key results of the installation of LED street lighting projects in 5 cities are tabulated below:

| Name of cities | Number of LEDs installed | Annual energy savings (million kWh) | Avoided GHG emission (thousand tCO2) | Peak load reduction (MW) |
|---|---|---|---|---|
| Varanasi | 947 | 1.56 | 1.278 | 0.39 |
| Jhalawar | 2449 | 0.37 | 0.303 | 0.09 |
| Mount Abu | 1807 | 0.65 | 0.530 | 0.16 |
| Vizag | 91775 | 23.54 | 19.302 | 5.05 |
| Agartala | 34200 | 3.90 | 3.200 | 0.97 |
| **Total (for 5 cities)** | **131178** | **30.02** | **24.613** | **6.66** |
| **Total (at national level)** | **35000000** | **8008.59** | **6567.040** | **1777** |

It can be seen from the table that the installation of 131,178 LED street lights in the 5 cities has led to an annual energy savings of 30.02 million kWh, an avoided annual GHG emissions of 24,613 $tCO_2$ and peak load reduction of 6.66 MW.

Similarly, the installation of 35 million LED street lights will lead to an annual energy savings of 8008.59million kWh, an avoided annual GHG emissions of 6.57 million $tCO_2$ and peak load reduction of 1,777 MW at the national level.

## 5.2. DELP

The energy savings, reduction of peak installed load and emission reduction for the five projects surveyed under this assignment are:

| Sr. No. | Region | Units saved for the overall project (million kWh) | Peak load reduction (MW) | Emission Reduction (thousand $tCO_2$) |
|---|---|---|---|---|
| **1** | Puducherry | 80.95 | 15.81 | 65.570 |
| **2** | Anantapur | 150.06 | 29.36 | 121.546 |
| **3** | Guntur | 249.33 | 48.70 | 201.957 |
| **4** | Srikakulam | 142.04 | 27.87 | 115.050 |
| **5** | W. Godavari | 214.10 | 41.82 | 173.420 |

These results were further extrapolated to the entire national program (replacement of 77 crore domestic lights). At a national level 102.9 billion kWh would be saved annually resulting in reduction of 20,100 MW peak load and 84.37 million $tCO_2$ reductions.

# 6. Appendices

## 6.1. Questionnaire for DELP

### Survey Questionnaire

**Section 1: Profiling of the household and respondent**

1. *Address (To be copied from database)*
   _____
   _____
2. *DISCOM Service Number (To be copied from database):* _____
3. *Nameof respondent* _____
4. *Age of respondent* _____
   (Thank and terminate if age is less than 18 years. Ask for another older member in the house for the interview)
5. Gender of Respondent

| **Gender** |
|---|
| Female |
| Male |

6. *Ownership status*

| **Oownership** |
|---|
| Owner |
| Tenant |
| Other |

7. *Phone Number* _____
8. *Is the DISCOM Service Number registered under your name?*

| **Single Code** |
|---|
| Yes |
| No |

9. *If No,*

| ***Relationship with the DISCOM Service Number holder*** |
|---|
| Spouse i.e. Wife/Husband |
| Daughter in law |
| Daughter/Son |
| Sibling i.e. Sister/Brother |
| Grandfather/Grandmother |
| Relative |
| Tenants i.e. rented accommodation |
| Any other, please specify |

**Section 2:**

**(A) Identification of the Project LEDs**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. Total number of LEDdistributed (as per databasese) | | | | | | |
| 2. Total number of project LEDsfound installed | | | | | | |
| | **LED #1** | | **LED#2** | | **LED#3** | |
| | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** |
| **3.** DELP logo | | | | | | |
| **4.** Where project LED found operating | | | | | | |

**(B) The reason of failure of the project LEDs**

| **Reason for failure of Project LEDs** | **LED #1** | **LED#2** |
|---|---|---|
| Defective i.e. are not in theworking condition | | |
| Broken after it was provided | | |
| In reserve i.e. will be usingsometime in the future | | |
| Sold/given away to someoneelse | | |

**(C) Whether defective project LEDs were got replaced by the household (end user)**

| | |
|---|---|
| Whether defective or brokenLEDs were got replaced by you orother household member? | |
| If LEDs were not replaced, why? | |
| No of ICLs Collected | |

## 6.2. Questionnaire for Street Lighting

### 6.2.1. Switch point wise measurements for all the cities

| S. No. | Switching Point/Locality/Zone | Pole type (tubular/concrete/ octahedron etc.) | Type of fitting | Total number of fittings | Voltage (Volts) | Current (Amperes) | PF | Power (W) | THD v (%) | THDi (%) | Time of measurement | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |

### 6.2.2. Individual lighting point wise measurements for all the cities

| S. No. | Switching Point/Locality/Zone | Pole type (tubular/concrete/ octahedron etc.) | Type of fitting | Voltage (Volts) | Current (Amperes) | PF | Power (W) | Time of measurement | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |

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