ENVIS NEWS LETTER

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A Success Story - LED Replacement Program and its impact on GHG Emission in Union Territory of Puducherry

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ENVIS centre puducherry sincerely thank

Dept. of Electricity Government of. Puducherry
Bureau of Energy Efficiency and
Energy Efficiency Services for sharing relevant information

ENVIS CENTRE PUDUCHERRY

1. INTRODUCTION

Project Background-DSM based Efficient Lighting Programme (DELP):

Bureau of Energy Efficiency (BEE) and EESL (Energy Efficiency Services Limited) have jointly developed a business model called DSM Based Efficient Lighting Program (DELP) which aims to stimulate investment in energy efficient lighting projects and overcome barriers like first cost. As DELP aims at large scale replacement of Incandescent bulbs (ICLs) by LED bulbs to households at a price similar to that of incandescent bulbs.

The main features of DELP include replacement of 60 W ICL with 7 W LED with 5 years free replacement warranty on lamps against technical defects, distribution of LED bulbs to each household on getting back equal numbers of working ICLs and monitoring. The LED bulbs will be given to the consumers at a rate of Rs10 each as against their market price of Rs. 400-500. Each replacement leads to a reduction of connected load by 53 W.

EESL has implemented this in Puducherry in coordination with the DISCOMs where about 6.5 lakh LED bulbs have been replaced in 2014. The capital cost of the LED bulbs, including distribution, awareness, storage, destruction and project management, will be recovered from the DISCOMs. The proposed Demand Side Management programme and increased electricity end use efficiency will result in better resource efficiency and cost reductions to DISCOMs and household consumers

Scope of Project:

a) Verification of Technical Specifications of LED bulbs distributed.

b) Verification of population of LED bulbs.

c) Verification of DELP logo on distributed bulbs.

d) Quantifying actual Energy savings accrued due to distribution of LED bulbs

- Estimated Energy savings in Million Units Annum
- Avoided generation capacity in MW
- Reduction in GHG emission in ton of CO_2

e) Status of collected ICLs destruction.

2. METHODOLOGY:

The main objective of this survey is to estimate the proportion of working bulbs & Estimate actual Energy savings accrued due to distribution of 7W LED bulbs in UT of Puducherry.

2.1. SURVEY SAMPLING :

Survey sampling describes the process of selecting a sample of elements from target population to conduct a survey. Survey samples can be broadly divided into two types:

a) Probability sampling :

b) Non-probability sampling :

There are four major types of probability sampling methods :

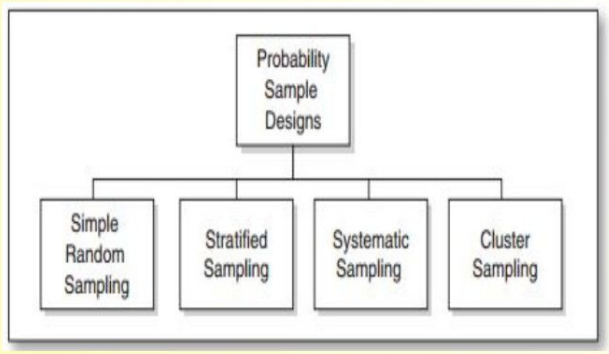
Simple random sampling:

Every element in the target population has an equal probability of being selected in the sample.

Stratified sampling:

Stratified sampling is a probability sampling procedure in which the target population is first separated into mutually exclusive segments (strata), and then a simple random sample is selected from each segment (stratum).

Here the LED bulbs distributed in the union territory of Puducherry is the target population. It is divided into 4 segments (strata) Mahe, Puducherry, Karaikal and Yanam. Simple random samples are selected from each segment. The sample size in each



strata is in proportion to its population. The samples selected from the various strata are then combined into a single sample.When subpopulations within an overall population vary, it is advantageous to choose stratified sampling. This improves the representativeness of the sample by reducing sampling error. It can produce a weighted mean that has less variability than the arithmetic mean of a simple random sample of the population.

2.2. SAMPLE SIZE:

The sample size of this statistical survey is estimated by considering the following parameters.

1) Population Size
2) Confidence Level
3) Margin of Error

Population Size

Here the target population is the LED bulbs distributed. The total Quantity of the bulbs distributed is our population size.
Population size = 6,09,251 Margin of Error:

2.2. SAMPLE SIZE:

The sample size of this statistical survey is estimated by considering the following parameters.

1) Population Size
2) Confidence Level
3) Margin of Error

The margin of error is a statistic expressing the amount of random sampling error in a survey's results.

It asserts a likelihood that the result from a sample is close to the number one would get if the whole population had been queried. We need to determine the proportion of working bulbs with a margin of error of 5%. Margin of error = 5%

Confidence Level:

A confidence level refers to the percentage of all possible samples that can be expected to include the true population parameter.

Sample size calculation:

With given Confidence Level of 95 % and maximum 5% error margin we need to determine our sample size. The calculations for sample size determination are given below.

Where

1) N= Population size = 609251
2) Confidence Level = 95 %
3) ME = margin of error= 0.05

Z-score for 95 % confidence Level = 1.96 (statistical tables) p = Proportion of statistic = 0.5 (for maximum sample size) By using the above formulae, we have Sample size = n = 384.A minimum of 384 bulbs should be surveyed to meet the given confidence level (95%) and margin of error (5%). Every household in Puducherry was provided with 3 LED bulbs. So, a minimum of 128 households should be surveyed to meet the required Confidence level and Margin of error. In our survey, we covered 459 bulbs, which is greater than required.

2.3. SELECTION OF SAMPLE HOUSEHOLDS:

The union territory of Puducherry consists of four small unconnected districts: Puducherry, Karaikal and Yanam on the Bay of Bengal and Mahe on the Arabian Sea. Puducherry and Karaikal have the largest areas and population, and are both enclaves of Tamil Nadu. Yanam and Mahe are enclaves of Andhra Pradesh and Kerala respectively.

As mentioned earlier, the target population was divided into four segments. The population of LED bulbs distributed in each segment is given below:

District	Number of LED bulbs distributed	Proportion to total
Puducherry	436798	0.7169
Karaikal	123517	0.2027
Yanam	25355	0.0416
Mahe	23581	0.0387
Total	609251	1

TABLE 1. District Wise distribution of LED bulbs

A minimum of 10 households was chosen to be surveyed in Yanam and Mahe as per the discussion with PED and BEE. The minimum number of households to be surveyed in each district are tabulated below.

DISTRICT	Minimum Number of bulbs to be surveyed	Minimum number of Households surveyed
Puducherry	276	92
Karaikal	78	26
Yanam	30	10
Mahe	30	10
Total	414	138

TABLE 2. Minimum Number of Households and bulbs to be surveyed

The district of Puducherry is the largest of the 4 districts in UT of Puducherry. It was essential to select sample households covering the entire population. The district of Puducherry is further divided into custom section offices and by using the data of LED bulbs distributed in each custom section office, the number of households to be surveyed was decided upon.

2.4. SITE SURVEY METHODOLOGY:

In Puducherry district, the number of households to be surveyed in each customer section office was decided upon to be in the same proportion of the LED population. The households were selected at random in each section office. On 20th February, two teams started visiting the chosen households in Puducherry district.

In each household, the bulbs installed were inspected. The installed LED bulbs were checked if they were in operating condition and if they had DELP logo on them. A respondent was chosen in each household, who was interviewed. It was made sure that the respondent was above 18 years. A survey questionnaire was filled based on our inspection and their response. The survey questionnaire is attached in Annexure - 1. Inspection of each household yielded the following useful data:

1) Number of LED bulbs installed/not installed
2) Number of LED bulbs operating/non-operating
3) Number of LED bulbs in reserve
4) DELP logo in each bulb
5) Number of ICLs collected

3. FINDINGS FROM SURVEY:

The survey was completed on 3rd March 2014 covering all the four districts in the union territory of Puducherry. The survey covered 153 households/ 459 bulbs across the union territory. The findings in each district are tabulated below:

The findings for 4 districts are summarized and tabulated below:

	House holds visited	LED bulbs surveyed	Defective bulbs		Broken bulbs		Reserve bulbs		Working bulbs	
	Qty	Qty	Qty	%	Qty	%	Qty	%	Qty	%
Puducherry	98	294	16	5.4	4	1.3	10	3.4	264	89.7
Karaikal	34	102	4	3.9	3	2.9	5	4.9	90	88.2
Yanam	10	30	0	0	0	0	1	33	29	96.6
Mahe	11	33	5	15.1	0	0	16		28	84.8

The findings for 4 districts are summarized and tabulated below:

District	LED bulbs surveyed	Installed LED bulbs	Lamp failure rate		LED bulbs with DELP		ICLs Collected	
	Qty	Qty	%	%	Qty	%	Qty	%
Puducherry	294	280	95.2	5.71	294	100	294	100
Karaikal	102	94	92.1	4.25	102	100	102	100
Yanam	30	29	9	0	30	100	30	100
Mahe	33	33	66	15.15	33	100	33	100
Total	459	436	94.9	5.	459	100	459	100

4. INFERENCE TO POPULATION:

As mentioned in our methodology, the sampling approach is stratified sampling. The UT of Puducherry was divided into 4 segments (strata) and the random sample survey was carried out in each district. Using these findings, the characteristics of the entire population need to be inferred. This can be done by multiplying the mean of the respective strata with its proportion of the LED population and summing them. I.e. Proportion of Population = ? NNi * Pi

Where = Population of LED bulbs each Strata / district.

N = Total population of LED bulbs in UT of Puducherry.

Pi =proportion of a parameter in respective strata.

Ni= Sampling Fraction

DISTRICT/ STRATA	Number of LED bulbs distributed	Sampling Fraction
Puducherry	436798	0.7169
Karaikal	123517	0.2027
Yanam	25355	0.0416
Mahe	23581	0.0387
Total	609251	1

TABLE 8: Sampling Fraction (Proportion) of each District

Based on the above formulae required parameters of the population are estimated. The Calculated parameters (in proportions) are tabulated below.

District	LED bulbs	Sampling fraction	Defective LED bulbs	Broken LED bulbs	Reserve LED bulbs	Working LED bulbs	LFR percentage
Puducherry	436798	0.7169	0.0544	0.0136	0.0340	0.8979	5.71
Karaikal	123517	0.2027	0.0392	0.0294	0.0492	0.8823	4.25
Yanam	25355	0.0416	0	0	0.0333	0.9666	0
Mahe	23581	0.0387	0.1515	0	0	0.8484	15.15
Total	100	1	0.0528	0.0157	0.0357	0.8957	5.54
Total (Qty)	609251	1	32188	9576	21757	545730	5.54

TABLE 9. Inference to Population calculations.

Estimation for UT of Puducherry from findings with 95 % confidence level and 5% margin of error

Number of LED bulbs distributed	609251
Number of Working LED bulbs	545730
Number of Defective LED bulbs	32188
Number of Broken LED bulbs	9576
Number of LED bulbs kept as reserve	21757
Number of LED bulbs with DELP logo	609251
Number of ICLs Collected	609251

TABLE 10. Inference to UT of Puducherry

5. ENERGY SAVINGS ESTIMATION:

The energy savings accrued in this project are calculated in accordance with the international standard Methodology approved by the CDM Executive Board. Small-scale Methodology: AMS-II. J: Demand-side activities for efficient lighting technologies. The steps in calculating the energy savings are briefly described below:

1) The nameplate/rated power of the ICLs replaced and LED bulbs provided are noted. In this case, the ICLs collected are rated 60W and the LED bulbs distributed are 7W.
2) The operating hours for each bulb are taken as 3.5 hours. This is in accordance with option: 1 Operating hours section: 5.2 CDM
3) The annual gross electricity savings are calculated by comparing the rated power of the ICL and LED bulb and multiplying them by annual operating hours and number of distributed LED bulbs/replaced ICLs.
4) The annual Net Electricity savings, for each year are calculated by correcting the gross electricity savings for leakage, a net to gross adjustment factor (NTG), transmission and distribution losses, and lamp failure rate.
5) Avoided generation capacity is then calculated by considering the average plant load factor.
6) The emission reductions are quantified by multiplying the net Energy Savings calculated with the emission factor (EF).
7) The emission factor is 0.98 tonnes of CO2/MWh Source: "CO2 Baseline data for Indian power sector - CEA"

5.1. ESTIMATED ENERGY SAVINGS:

The annual gross electricity savings are calculated by comparing the rated power of the ICL and LED bulb and multiplying them by Annual operating hours and number of distributed LED bulbs/replaced ICLs.

ES = (PICL - PLED) * O * 365/1000 * N
Where

ES = Estimated gross annual electricity savings.

PICL = The rated power of the ICL replaced (60Watt).

PLED = Rated power of the LED provided (7Watt).

O = Operating Hours = 3.5hrs per 24 hrs.

N = number of LED bulbs installed = 545730

ES = (60 – 7)*3.5*365/1000*545730 = 36.95 Million Units/annum

The Annual Gross Energy savings thus calculated are 36.95 Million units per annum

5.2. NET ELECTRICITY SAVINGS:

The annual net energy savings (Avoided Generation capacity), for each year are calculated by correcting the gross electricity savings for leakage, a net to gross adjustment factor (NTG), transmission and distribution losses, and lamp failure rate. The net energy savings is the value of power generation avoided and this takes into account the transmission and distribution losses.

NES = ES * NTG * (1/ (1-TD))

Where:

NES: Net Electricity Savings for that particular Year in kWh. ES: Gross Energy savings

NTG = 0.95 (Net-to-gross adjustment factor, a default value of 0.95 is to be used unless a more appropriate value based on a lighting use survey from the same region as per CDM standards.)

TD = 12.5 % (Source: Pondicherry Electricity Department).

Calculation:

Net Electricity savings in kWh = 36.95*0.95 * [1/ (1-0.125)] NES = 40,117.15 MWh/ annum = 40.11 Million units per annum.

Net Electricity Savings= 40.11 Million units per annum

5.3: AVOIDED GENERATION CAPACITY :

The Capacity of power generation which is avoided due to Electricity savings accrued. This takes into account the Average Plant Load Factor of generation.

Avoided Generation Capacity (MW) = NES in MU*1000 65*24*PLF3

Where PLF = Plant load factor for India = 0.7426 (As per CEA Executive summary, Power Sector, 2014) NES = 40.11 Million units / Annum

Avoided generation Capacity in MW = 365*24*0.742640.11*1000 = 6.16 MW

Avoided generation capacity = 6.16MW

5.4. REDUCTION IN GHG EMISSION (IN TONNE OF CO2):

The emission reductions are quantified by multiplying the net Energy savings calculated with the emission factor (EF). The emission factor is calculated in accordance with provisions under

"AMS-I. D: Grid connected renewable electricity generation"

GHG Emission reduction = NES * EF MWh/Annum NES = Net Electricity Savings = 40117.15 MWh

EF: Emission Factor = 0.98 tonnes of CO2/ MWh (from CEA website)

GHG emission reduction = 40117.15 * 0.98 = 39314.8 Tonne of CO2/ Annum

GHG emission reduction = 39314.8 Tonne of CO2/ Annum.

5.5. LAMP FAILURE RATE (LFR):

Lamp failure rate is the percentage of installed bulbs that have failed in operation during a year. The lamp failure rate for each strata are multiplied with their respective population proportion and added up to get the overall lamp failure rate. Fused LED bulbs and blinking LED bulbs are the main reasons bulbs failed. Lamp Failure Rate in UT of Puducherry = 5.54 %.

6. DESTRUCTION OF ICLS:

The survey estimates that for every LED distributed there was an ICL collected. The total number of ICLs collected are 50000. The ICLs collected were stored in Pondicherry. EESL nominated Eco bird Recycling company private ltd for carrying out the destruction of these ICLs. Eco birdd employed the following methodology to destroy the ICLs:

1. 20-30 ICLs are taken at a time and are put in a container. A metallic hammer is used to manually crush these bulbs. The bulbs are crushed twice.
2. The bulbs placed in the container are stroked with a metal hammer, which separates the glass bulb from the glass support.
3. The crushed bulbs are taken for screening in plastic screeners. In the screening process, the glass bulb is separated from the glass support. The aluminum and glass of the ICLs are separated manually.

4. The glass mounts / supports of the bulbs separated is further crushed manually to remove the remaining glass, lead wire and tar.
5. Finally the glass and aluminum are packed and stored in a hazardous room. All men are suited with safety glass, suits, shoes, gloves and helmet.
6. A Cyclone separator is running continuously during ICL crushing process which would absorb Nitrogen and argon gas.
7. 6000 – 8000 ICLs are being destructed and packed this way each day. The process ofdestruction started on March 2nd 2015. By March 20th about 1, 10,000 bulbs have been destroyed

Manual crushing where the glass bulb is broken from the glass mount/support

Screening process where the glass bulb is separated from the glass mount/support. Manual screening process

Glass mounts/ glass supports further crushed in this container.

7. VERIFICATION OF TECHNICAL SPECIFICATIONS

As a part of the project, the technical specifications of the bulbs need to be verified by a NABL testing agency. EESL has earlier tested the bulbs as per IS16102 (Part 1&2). The time taken for conducting all these tests was about 5 months and excluding life test it would take 25 days. As an inspecting agency, we have decided to test the major performance parameters of the bulb within the stipulated time.

The following technical specifications of the LED bulbs were tested.

1. Wattage of bulb
2. Luminous Flux
3. Efficacy
4. CCT – Color Chromaticity
5. CRI – Color Rendering Index

The testing of the LED bulbs was done at Electrical Research and Development Association (ERDA), Vadodara. ERDA is a NABL accredited testing agency for self-ballasted lamps.

The test report for the same is attached in Annexure-3. As per the test reports the Technical specifications of LED bulbs distributed were compliant with the test reports submitted by EESL.

8. CONCLUSION

The following are the survey deliverables from the survey. The estimates given below are of 95 % confidence level and a 5 % margin of error.

Number of LED bulbs installed and operating = 545730 Number of LED bulbs which are defective/fused=32188

Number of LED bulbs which are broken = 9576

Number of LED bulbs kept as Reserve = 21757 Estimated energy savings = 36.95 Million Units/ annum Net electricity Savings = 40.11 Million Units/ Annum Avoided Generation Capacity = 6.16 MW

Reduction in GHG emission in ton of CO2 = 39314.8 Ton of CO2

The DELP programme was very effectively implemented in the union territory of Puducherry where almost 80% of the population was covered under this programme. Households located in the most remote areas also participated in the programme. This programme proved most beneficial to end users especially, in the rural areas where lightening bulbs contribute substantially to the power consumption. The people interviewed were happy with reduced power consumption and electricity bill. They were also satisfied with the bulb lighting.

There were a few concerns with people, where the bulbs were in a defective condition and were not operating. The lamp failure rate is 5.54% and as per the programme the failed LED bulbs can be exchanged for new ones. It was observed that very few failed bulbs were exchanged and the reason for this is that the people were not aware of this process.

Households who have more than 1 service connection were given more than 3 bulbs. These households did not install all the LED bulbs and part of them were in reserve. These reserve bulbs would not contribute to any energy savings. It was observed that 3.5% of the bulbs were in reserve

RECOMMENDATIONS:

It was observed that the major reason for the failed bulbs not being exchanged is the lack of awareness among people about the exchange process. So it is recommended that conducting awareness camps about the exchange process would increase the awareness among the people and more people would exchange the failed bulbs.

At present there are only 5 replacement centers in the union territory of Puducherry (2 in Puducherry, 1 each in Karaikal, Yanam and Mahe). It is not economically feasible, especially for rural people to travel such long distances and get a failed LED bulb replaced, which was given to them for just 10 Rupees. The number of bulb replacement centers can be increased so that it becomes easier for people to exchange the failed bulbs. Temporary stalls can be organized in each custom section office where the failed bulb replacement can be done. Also the location of the centers and their toll free numbers should be made aware to people. It is observed that out of the estimated 30000 failed bulbs very few bulbs are being replaced. Implementing the above mentioned suggestions would help replacing the majority of the failed bulbs, thus improving the Energy savings. Also, people should be informed of the energy savings through awareness camps and they must be urged to install the LED bulbs in reserve.

S. No.	Parameter	Requirement	LED bulb 1	LED bulb 2	LED bulb 3	Remarks
1	Wattage	< 8W	7.43			Conforms
2	Luminous flux	>600 lm	690			Conforms
3	Efficacy	>80 lm/W	92.9			Conforms
4	CRI	>70	84.07	84.33	84.28	Conforms
5	CCT	5700K-6500K	5778	5725	5999	Conforms

TABLE 11. LED bulb test report Summary

EVNIS PROJECT Sponsored by
Ministry of Environment & Forests,
Government of India, New Delhi.

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