THE OBSTINATE BULB

Moving beyond price-focused interventions to tackle India's persistent incandescent bulbs problem

Prayas (Energy Group)

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Summary

Demand for light-emitting diode (LED) lights has picked up remarkably in India since 2014. This rising demand has been primarily driven by the Unnat Jyoti by Affordable LEDs for All (UJALA) programme. However, the demand for incandescent bulbs (ICB) still remains high, though it is declining gradually. In 2017, about 770 million ICBs were sold in India, accounting for more than 50% of the total sales of bulbs and tube-lights in that year.

In this paper, we examine relevant aspects of the demand and supply of various lighting options available to Indian households in order to investigate the continued usage of ICBs in India. Based on our analysis, we recommend a few programme and policy interventions in order to reduce and consequently eliminate the use of ICBs in India.

We find from our survey that people are not adequately aware about LED bulbs and their benefits, especially in rural areas. Potential consumers are concerned about the quality of light emitted by LED bulbs and about how long they last, particularly considering the poor electricity supply in the country. The upfront price of LED bulbs still poses a challenge as majority of surveyed households preferred a financing scheme. The survey also indicated a limited availability of LED bulbs in local markets expecially in rural areas.

As for the supply of ICBs, there are only a few companies which produce most of the ICBs in India. The factories producing ICBs are old, depreciated, and automated. The production of ICBs involves negligible research, warranty, and marketing costs. This allows companies to sell ICBs at a very low price. Besides, there are no new entrants in the ICB industry. The LED lighting industry, on the other hand, has grown rapidly in recent years riding on high demand mostly generated by the UJALA programme. There is also a burgeoning small-scale industry to cater to this demand, as the initial capital investment is low and bulbs can be assembled manually. The Bureau of Indian Standards (BIS) and the Bureau of Energy Efficiency (BEE) have mandatory standards for the performance and safety of LED bulbs. However, there are concerns regarding the compliance of the products available in the market. The singular focus on price reduction may have resulted in companies compromising on the quality of LED bulbs, particularly on those aspects that affect their life and performance over the functional period. These may not be accurately captured by existing standards.

Policy interventions are required to move the market away from ICBs. The price focused interventions adopted so far have been successful in reducing the price of LED bulbs and consequently increasing their demand. However, there is a need to move beyond price-focused interventions to achieve a complete shift from ICBs. The BEE can conduct nation-wide campaigns to make people aware of the benefits of LED bulbs. Such campaigns can also increase awareness about buying good quality LED bulbs as differentiated by BEE's star rating programme. The BEE and BIS can conduct periodic compliance tests against standards and publish non-compliance results. Energy Efficiency Services Limited (EESL), the implementing agency for UJALA, can also conduct compliance checks on the procured LED bulbs and black-list manufacturers that supply non-compliant bulbs. EESL can also help improve public confidence in the quality of LED bulbs by ensuring a smooth process for consumers to exchange bulbs under warranty. To address the issue of upfront price, EESL can pay more attention to the on-bill financing mechanism which has been a part of the UJALA programme, but has received limited attention so far. EESL can also continue and scale up its current initiative to increase outreach to rural areas, such as distribution through post offices, petrol pumps, and the Gram Swaraj Abhiyan. The government's electrification programme, Saubhagya, could be another avenue to initiate newly

electrified households in the use of LED bulbs. These interventions aimed at increasing the awareness about LED bulbs, improving their quality, reducing their upfront price, and increasing their availability can contribute to a significant reduction in the use of ICBs in India. A phase-out of ICBs without addressing other concerns at this juncture is however not recommended as its burden will fall primarily on low-income and newly electrified households.

Contents

Abbreviations

AQSIQ	General Administration of Quality Supervision, Inspection and Quarantine, China
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BLY	Bachat Lamp Yojana
CDM	Clean Development Mechanism
CFL	Compact Fluorescent Lamps
CRS	Compulsory Registration Scheme
CSC	Common Services Centres
DeitY	Department of Electronics and Information Technology
DISCOM	(Electricity) Distribution Company
EESL	Energy Efficiency Services Ltd.
ELCOMA	Electric Lamps and Component Manufacturers' Association of India
ESMI	The Electricity Supply Monitoring Initiative
ICB	Incandescent Bulb
LED	Light Emitting Diode
MeitY	Ministry of Electronics and Information Technology
MEPS	Minimum Energy Performance Standard
MoP	Ministry of Power
MOSPI	Ministry of Statistics and Program Implementation
NABL	National Accreditation Board for Testing and Calibration Laboratories
S&L	Standards and Labelling
SEAD	Super-Efficient Equipment and Appliance Deployment
UJALA	Unnat Jyoti by Affordable LEDs for All

Introduction

In 2017, about 770 million incandescent bulbs (ICBs) were sold in India (ELCOMA, 2017), accounting for more than 50% of the total sales of bulbs and tube-lights in that year. A majority of these sales were in higher wattages such as 60W and 100W[1]. The share of ICBs in the total annual sales has gradually decreased from 59% in 2010 to 51% in 2017 (ELCOMA, 2017). However, a complete market transformation to more efficient options like Compact Fluorescent Lamps (CFLs) and Light Emitting Diode (LED) bulbs as envisaged by the large scale-government programmes—the Bachat Lamp Yojana (BLY) in 2009 and the Unnat Jyoti by Affordable LEDs for All (UJALA) in 2015—is yet to be achieved. In a reply[2] to the Lok Sabha in February 2017, the then Minister of Power clarified that there is no plan to phase out ICBs in India through a gradual ban on its production and sale. Owing to their wasteful energy consumption, ICBs are banned or being phased out in a number of countries including China, Brazil, Cuba, USA, and those in the European Union.

In this brief report, we examine different aspects related to demand and supply of ICBs as well as their alternatives like LED bulbs and CFLs. Our analysis is based on publicly available data, interviews with manufacturers, dealers, and retailers, and a consumer survey of 445 households in the rural areas of Pune district. Based on the analysis, we recommend a few policy interventions aimed at reducing and consequently eliminating the use of ICBs in India.

Why the bulb?

Incandescent bulbs are generally used by households and small commercial establishments. Lighting is estimated to account for about 18–27% of the total residential electricity consumption in India (PEG, 2017). Residential electricity consumption in turn was 24% of the total electricity consumption in the country in 2015–16 (MOSPI, 2017). An ICB consumes four times the electricity consumed by an equivalent CFL, and seven times that consumed by an equivalent LED bulb. Features of LED bulbs, CFLs, and ICBs are shown in Table 1. Replacing the inefficient ICB with an LED bulb has significant benefits at both the household and national levels.

The direct benefit at the household level is the reduction in electricity bills. An LED bulb can save about Rs 150–300 annually depending on the usage and the applicable electricity tariff. The current price of a good quality LED bulb is about a third of that in 2014 due to the significant demand generated by the UJALA programme and the global reduction in prices of LED chips (PEG, 2017). Although, the current market price of an LED bulb is still ten times the price of an ICB, the payback period for the incremental amount paid for an LED bulb is in the range of 4–9 months based on the applicable electricity tariff.[3] Hence, even LED bulbs with shorter life spans (3–5 years) can save money for households net of their upfront price.

1. Interaction with the Electric Lamp and Component Manufacturers' Association (ELCOMA), India.
2. http://164.100.47.194/loksabha/Questions/QResult15.aspx?qref=47243&lsno=16
3. At the tariff of Rs 5/kWh, the payback period is 4 months while at the tariff of Rs 2/kWh, the payback period is about 9 months. See footnote 5 for assumptions on cost, replacement and usage.

Table 1: Comparison of key features of LED bulbs, CFLs, and Incandescent bulbs

	LED bulbs	CFLs	Incandescent bulbs
Life expectancy (hours)	25000	8000	1200
Power required (W) [4]	7–9	13–15	60
Price (Rs)	120	120	15
Cost of Ownership (Rs) for 10 years[5]	330	700	2000
Hazardous materials	None	Mercury	None
Colour rendition	Wide range of colours	Restricted colour options	Restricted colour options

In the absence of reliable data on wattage, usage, and the total number of lighting points in India, certain assumptions can be made to arrive at a ballpark figure of the savings at the national level from the replacement of ICBs with LED bulbs. About 770 million ICBs were sold in India in 2017. The operational life of an ICB varies from 6 months to 1 year. If we assume that 40% of the total sales were used for replacement, the total number of lighting points with ICBs in India was around 460 million in 2017. If a 60W ICB on an average is assumed to be replaced by a 7W LED bulb at a lighting point and used for about 1280 hours annually, the resultant savings would be about 30 billion kWh of electricity. This amounts to about 12% of the total residential electricity consumption in 2015–16. The savings have the potential to reduce about 25 million tons of CO_2 (CEA, 2016) emitted by the power sector, which is approximately 1% of India's total emissions.

If we further assume that 50% of the lighting points with ICBs are switched on during the evening peak hours, the estimated peak demand reduction is about 12,000 MW. The use of ICBs is predominantly in the rural areas where there is poor supply during the evening peak hours. The Electricity Supply Monitoring Initiative (ESMI), which monitors supply quality in about 350 locations across India, observes that only 11% of the rural areas received the entire six hours of power supply during evening peak hours, i.e. 5 pm to 11 pm (PEG, 2018). Reduction in the rural peak demand can reduce the load on the distribution transformers in rural areas. This can address the issue of over-loading of the transformers leading to their tripping one of the frequent reasons for power cuts. This can result in an increase in the supply hours to rural areas, consequently leading to improved quality of life. The reduction in peak demand can also help improve the overall system load factor (the ratio of average load to maximum load), thereby reducing the system level operating costs (POSOCO, 2016).

Demand-side aspects

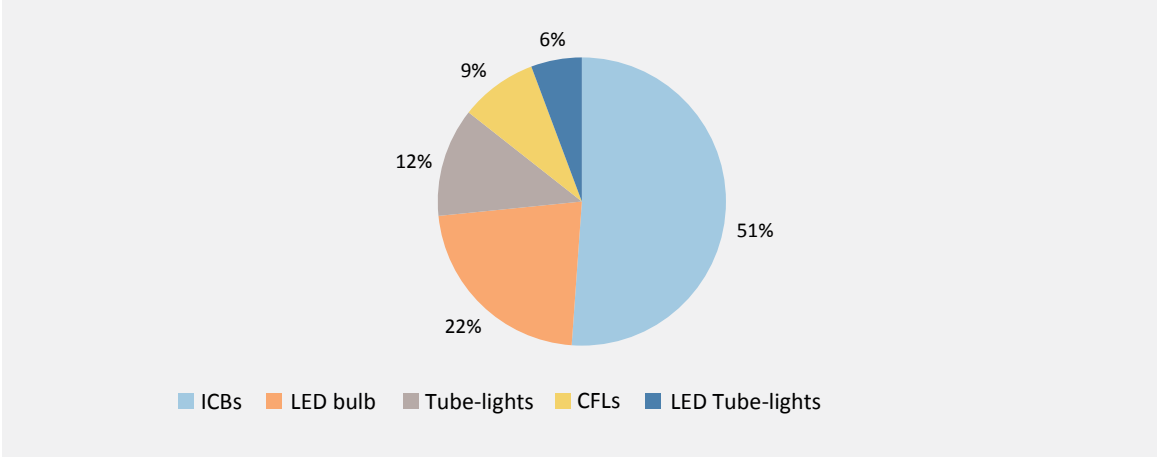
Despite the multiple benefits of replacing the incandescent bulbs with more efficient options, they are still popular in India as seen in Figure 1. An oft-cited reason for this popularity is their price. The current market price of an LED bulb, although drastically reduced since 2014, is still ten times that of an ICB. In this section, we examine the demand-side aspects of lighting in more detail to understand whether there are any other factors driving the purchase and use of ICBs.

4. The equivalence in power required depends upon the luminous efficacy (lumens/watt). Lower wattage LED bulbs with a higher efficacy can be used to replace ICBs for the same light output.
5. Assumptions: An LED bulb (7W) and CFL (15W) cost Rs 120 each, while an ICB (60W) costs Rs 15. The cost of electricity is Rs 5/kWh. Bulbs are used for 1280 hours annually. The practical life of an LED bulb is ten years and that of a CFL is three years, while it is one year for an incandescent bulb. The net present value of ownership is calculated at a 15% discount rate. The cost of ownership includes the purchase cost of ICBs and CFLs at the end of their useful life.

Sales

In 2017, ICBs accounted for 51% of the total sales of lamps (bulbs and tube-lights), followed by LED bulbs. The higher sales of ICBs are partly because of their shorter life. Quite a few of them need to be replaced twice a year. However, even accounting for the replacement, the number of lighting points with ICBs is quite high.

Figure 1: Distribution of annual sales of lamps (by quantity) in 2017

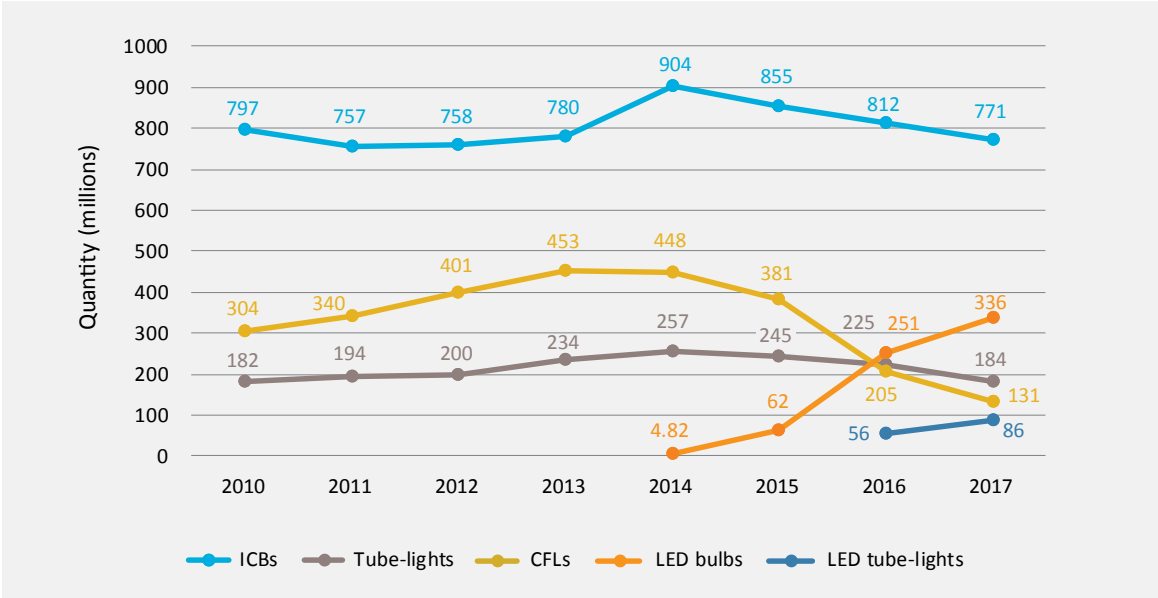


Total sales = 1,508 million

Source: (ELCOMA, 2017)

The sales trend of ICBs shows that their share in the total sales of bulbs and tube-lights (including fluorescent and LED based) has decreased from 59% in 2010 to 51% in 2017 (ELCOMA, 2017) (Figure 2). The sales have seen a steady annual decline of 5% over the last three years (2014, 2015, and 2016). This can be attributed to the government's UJALA programme which drastically reduced the price of an LED bulb through bulk procurement. However, the impact of this programme is seen more on the CFLs, where the annual sales have fallen by 15% in 2015, 46% in 2016, and 36% in 2017.

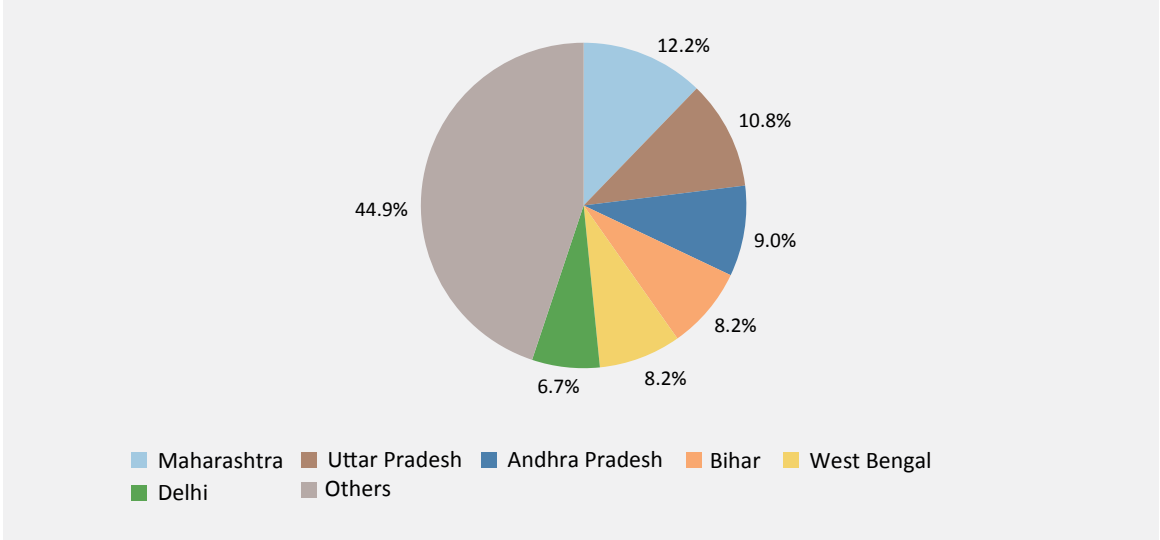
Figure 2: Sales of lighting options in India (in millions of quantity)



Source: (ELCOMA, 2017)

The sales trend of ICBs should also be seen in the context of the increased household electrification in the country. About 67 million households were electrified between 2011 and 2018 (Census, 2011; MoP, 2018). This probably added about 134 million lighting points to India's lighting stock assuming a conservative estimate of two lighting points per household. As most of these households were low income households preferring ICBs, they probably added to the sales of ICBs even as some of the households already using ICBs shifted to CFLs or LED bulbs. This can explain the declining but still popular status of ICBs. A state-wise share of sales of ICBs is available for 2012 (Figure 3) (EESL, 2014). Maharashtra topped the sales chart with a 12% share, followed by Uttar Pradesh, erstwhile Andhra Pradesh, Bihar, and West Bengal. In 2011, the household electrification rate in Maharashtra and erstwhile Andhra Pradesh was more than 80%, whereas the rates in Uttar Pradesh and Bihar were about 37% and 16% respectively (Census, 2011). A more recent state-wise sales distribution of ICBs is not available, but would be useful to connect the electrification drive to the sales of ICBs.

Figure 3: State-wise share of sales of incandescent bulbs in 2012



Source: (EESL, 2014)

Insights from survey of rural areas in Pune district

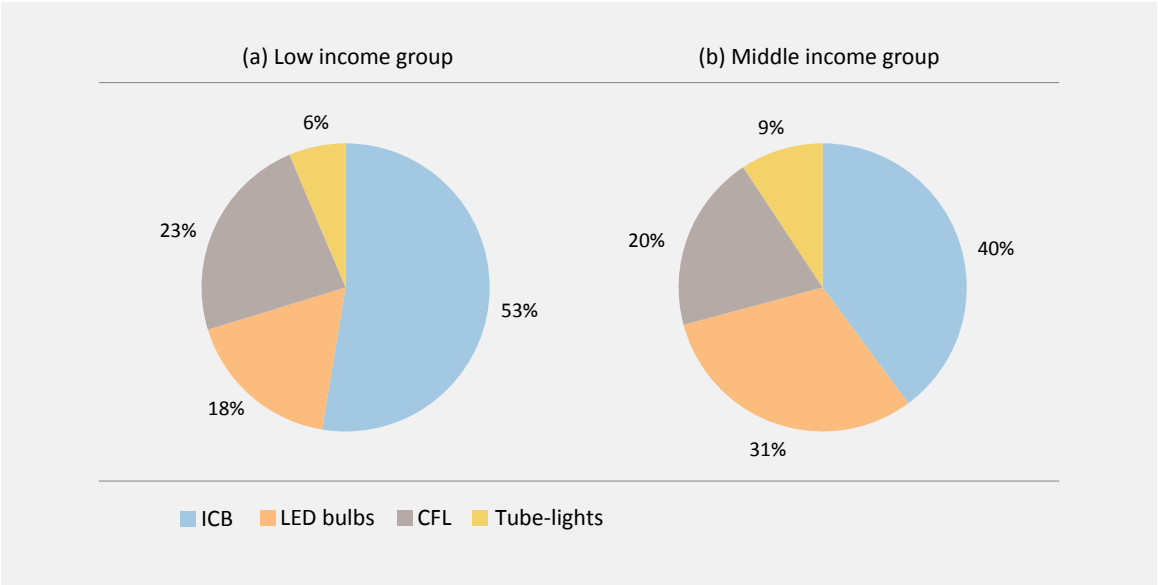
We conducted a survey of 445 households in the rural areas of Pune district to gather more insights into the behaviour of households using ICBs. Pune district has the highest sales of LED bulbs under the UJALA programme in Maharashtra.[6] Maharashtra also recorded the highest sale of ICBs in 2012. Households were selected if they met one of the two criteria: (i) there was at-least one ICB which was used for more than two hours every day; (ii) more than half of the total lighting points in the household had ICBs. This was to ensure the selection of households where ICB use was significant. The households were selected using the snowballing sampling method across 38 villages in four blocks spread over the district. Households were classified into low, medium, and high income categories based on a visual assessment. In the sample, 188 households belong to the low income group while 251 households are from the middle income group. Only six households meeting the ICB selection criteria form the high income group and hence were not considered for analysis. More details of the survey methodology can be found in Annexure 1. Key insights from the survey are summarised below.

ICBs were the most used source of lighting followed by LED bulbs, CFLs and tube-lights. The share of LED bulbs in the lighting stock of the medium income group is higher than that of the low income group (Figure 4). This is expected because of the higher price of LED bulbs. Also, the ownership of

6. http://www.ujala.gov.in/

tube-lights is significantly lower (6-9%) in both the low and medium income households. This may be because the tube-lights are expensive and also flicker with poor supply quality. Only those lighting points used for more than two hours are considered for analysis.

Figure 4: Lighting stock share in surveyed households



Source: Consumer survey by PEG

About 57% of the surveyed households did not know about LED bulbs and their benefits. Only 3% of the total households knew about the UJALA programme. The households were shown a picture of an LED bulb and were also briefed about the UJALA programme. This was done to ensure that their negative response was not because they did not know what an LED bulb looked like, or because they were unaware of what we meant by the UJALA programme. This suggests that the awareness of the availability and benefits of LED bulbs is still low in rural areas. It also highlights the urban focus of the UJALA programme.

About 38% of the surveyed households owned at-least one LED bulb. Only a fraction (5%) of households knew about LED bulbs but did not buy one, suggesting that a lack of awareness is an important barrier for owning of LED bulbs. The average price of the LED bulb bought by the households was Rs 146; the median and mode was Rs 150. This suggests that a significant portion of households (both low and medium income) are ready to buy LED bulbs even at the current market price if they are confident about their benefits. At the same time, about 84% of all the surveyed households expressed their readiness to participate in the 'on-bill' financing mechanism. Under this mechanism, the household pays Rs 15 upfront for an LED bulb, and the balance amount is paid by the consumer as a part of their monthly electricity bills. This reduces the burden of paying the price upfront. The monthly instalments can come from the monthly saving in electricity bills.

About 39% of the households with LED bulbs bought them from a shop in their own village, while 48% of the households bought them from shops at the taluka or district head-quarters. This suggests that local availability of LED bulbs is an issue. Not all the villages have shops which sell LED bulbs. Availability of bulbs in local shops can make LED bulb purchase as well as replacement under warranty easy thereby increasing their uptake.

About 28% of the households who bought LED bulbs were dissatisfied with their performance. They did not want to change all the lighting points in their homes to LED bulbs for this reason. About 51% of the households who were not satisfied with LED bulbs complained about light from the LED being too bright, while 29% complained about light being too dim. This can be due to: (i) a lack of awareness about choosing the appropriate lighting suited for the desired purpose; (ii) poor quality of LED bulbs which can result in emission of light in the 'blue' band harmful for the eyes; (iii) poor power supply quality that deteriorates the performance of LED bulbs. The exact attribution to the cause of the consumer complaints about LEDS being too bright or too dim cannot be ascertained from the survey, but needs further investigation. About 20% households reported that LED bulbs stopped working due to poor supply. This suggests that the quality of the LED bulbs is a crucial factor. Consumer's perception of low quality LED bulbs particularly in a context of poor electricity supply in India acts as an equally important barrier to a shift from ICBs to LED bulbs.

Supply-side aspects

We now examine the aspects of manufacturing and distribution of incandescent bulbs in India and compare them with that of LED and fluorescent lighting. These insights are based on available market data and interviews with industry experts, manufacturers, and retailers.

Incandescent bulbs

ICBs of all wattages are available in the range of Rs 10-15 in India, as compared to Rs 120-150 for LED bulbs and CFLs. The total conventional lamp market in India (including fluorescent lighting) in 2017 was Rs. 2,927 crores, which was 17% lower than that in 2016 (ELCOMA, 2017). An ICB is a simple device consisting of a tungsten element which heats to emit light, an inert gas like Argon to prevent tungsten from evaporating, a glass shell for housing the assembly, and a metal base with connection wires to pass current through the filament. As with any other industry in India, there are two types of manufacturers of ICBs. The first type is a small number (5-6) of large manufacturers who account for a majority of the total sales of ICBs in India. These manufacturers are part of the Electric Lamp and Component Manufacturers' Association (ELCOMA). The second type is a relatively higher number of small manufacturers who typically fall within the unorganised market. There was a thriving industry of small manufacturers making incandescent bulbs. However, the number of these manufacturers is going down as most of them are shifting to LED bulbs.

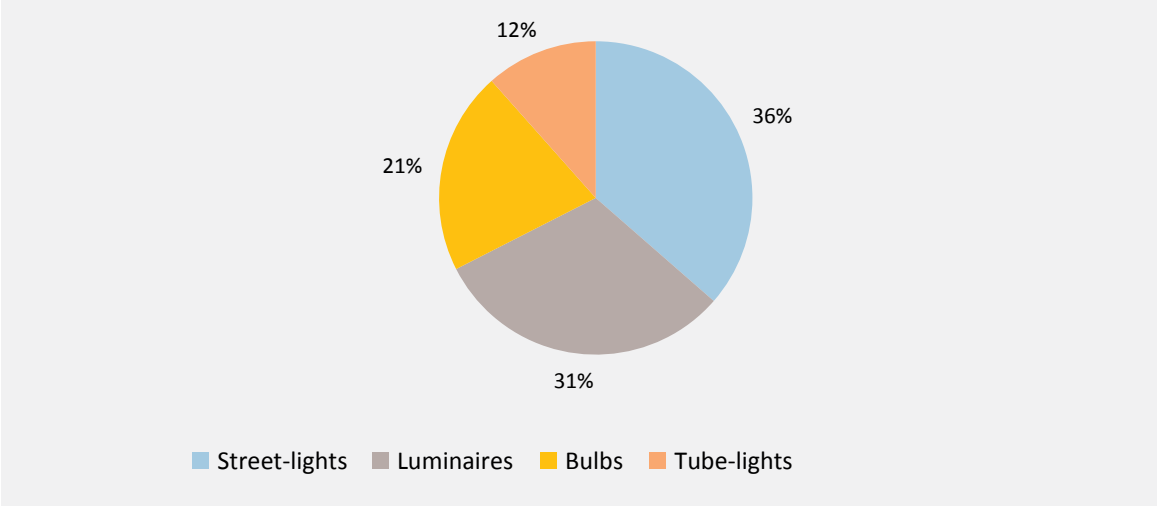
There are a few large factories in India that assemble ICBs. All of these factories are more than twenty years old with fully depreciated machinery allowing the manufacturers to sell the bulbs at a low cost. The assembly process of ICBs is automated and employs very few people. Research and development (R&D) costs for ICBs or their assembly are negligible. On the distribution side, manufacturers do not provide any warranty for ICBs. There is no marketing cost related to ICBs as they sell for themselves. Finally, as the holding cost of ICBs is less, small retailers in rural areas can easily stock them as compared to the costlier LED bulbs or CFLs. The extremely low cost of manufacturing and distribution ensures decent profits to manufacturers with minimal efforts while keeping the price low. Hence, there is no market-side compulsion on manufacturers to stop making ICBs as long as there is a demand for them. An important element of the low cost of ICBs is the fully depreciated machinery of the assembly process. Hence, no new factories have been set up in the last ten years to manufacture ICBs.

LED lighting

The LED lighting industry has burgeoned and was valued at Rs. 14,277 crores in 2017, about 70% of the total lighting market in India (ELCOMA, 2017). It has clocked a compounded annual growth rate (CAGR) of 60% since 2010. In 2017, LED street-lighting accounted for 36% of the total LED lighting market in

India by value, followed by luminaires[7], bulbs and tube-lights (Figure 5). A sudden increase in demand due to the UJALA programme, low entry barriers, and a singular focus on price has characterised the growth of the LED lighting market in India.

Figure 5: Distribution of annual LED lighting sales by different types in 2017 (by value)



Total Value = Rs 14,277 crores

Source: ELCOMA, 2017

ELCOMA data pertains to its 36 member companies that sell LED lighting in India at the retail level as their own brand. ELCOMA estimates this to be about 70–75% of the total LED lighting market in India. In the last three years, about 450 companies with their own brands have registered with the Bureau of Indian Standards (BIS)[8] under the Compulsory Registration Scheme (CRS) (DeitY, 2014) applicable to LED bulbs. About 350 companies remain operational as of May 2018. On the manufacturing end, there were about 250 registered units in India in May 2018, up from 176 in March 2017 (PEG, 2017). There are also 86 registered manufacturing units in China from where LED bulbs are imported for sale in India. There is no data on the share of imports in the total sales of LED bulbs in India. However, almost all the manufacturers in India import the main components of LED bulbs, LED chips and the drivers from China and assemble the bulbs in India. LED bulbs can be manually assembled unlike ICBs and CFLs which require some form of mechanization for assembly. LED bulb kits are also easily available which can be used to make LED bulbs. Hence the entry barrier for any new company (large or small) to start an LED lighting business is very low. Exports of LED bulbs are negligible.

The industry data and structure suggests a great flux with a number of players entering as well as leaving the LED lighting market unlike the ICB market. Low entry barriers and a high demand for LED bulbs indicate the possibility of a number of fly-by-night companies setting up shop. These companies have no incentive for maintaining the quality of their products. They can easily shut shop when the demand goes down. This can result in poor quality LED bulbs in the market. Although no person can manufacture, import, sell, or distribute LED bulbs without complying with the BIS standards for safety and performance under the Compulsory Registration Scheme (DeitY, 2014), it is doubtful that companies are adhering to these standards. According to a recent survey[9], about 76% of the LED bulbs across major cities were found to be non-compliant with the BIS standards. The non-compliance

7. A luminaire is a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and ballast (where applicable), and to connect the lamps to the power supply.
8. The Ministry of Electronics and Information Technology (MeitY) data is available at https://www.crsbis.in/BIS/listregmfr.do (Last accessed 15th May, 2018).
9. http://www.business-standard.com/article/companies/study-shows-76-of-led-bulbs-71-of-downlighters-flout-safety-standards-117103000452_1.html (Accessed on 15th May, 2018)

reported was related only to the details that are required to be printed on the package box as specified by the BIS standards. Compliance testing to check whether the LED bulbs meet the performance and safety requirements may bring out more serious issues.

Rapid price reduction of LED bulbs has been a cornerstone in the growth of India's LED lighting industry. Aggressive bidding by companies to secure bulk orders under the UJALA programme brought down the procurement price of an LED bulb from Rs 310 in 2014 to Rs 38 in 2016 (Figure 6) in successive bids. These bulbs were finally available to the consumers under UJALA for Rs 65 after accounting for the distribution costs. The price of LED bulbs under UJALA compelled companies to bring down their retail prices of bulbs sold outside UJALA to meet consumer expectations. This singular focus on price reduction may have resulted in companies compromising on the quality of LED bulbs, particularly on those aspects that affect their life and performance over the functional period. Energy Efficiency Services Ltd (EESL), the implementing agency for UJALA, procured LED bulbs that were required to meet the safety specifications as specified by the Bureau of Indian Standard (BIS), and stricter performance specifications as specified by the Bureau of Energy Efficiency (BEE) (EESL, 2016). However, recent research (Narendran, Liu, Mou, Thotagamuwa, & Eshwarage, 2016) shows that the international standards like LM-80 and TM-21 (which form the basis for BIS and BEE standards) have limitations in producing accurate life-time estimates of LED bulbs, given the different thermal environments and on-off switching patterns in operating conditions. In India, electricity supply conditions can vary significantly which can affect the life of LED bulbs.[10] Additionally, the BIS, BEE, and EESL all rely on self-certification of products by the manufacturers at a National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited laboratory. It is not clear whether any of these organisations conduct compliance tests on a random set of LED bulbs from the market. As mentioned earlier, a compliance test to check whether the LED bulbs from the market meet the performance and safety requirements as specified by the BIS and BEE standards can provide a more accurate picture of the quality of LED bulbs in India. Table 2 provides a summary of how the quality of LED bulbs is affected by the quality of its components. The table is based on interviews with technical experts.

Table 2: Components of an LED bulb and their impact on its quality

Components	Quality Impact
Diffuser	The diffuser is the dome-shaped cover of the LED bulb and is usually made of plastic. A cheap diffuser with low quality plastic does not soften the harsh LED light output adequately. This results in user discomfort and possible long-term harm.
LED chip	The LED chip emits light when regulated current passes through it. Along with the driver, it accounts for 70–75% of the total cost. Almost all the manufacturers import chips from China. The quality and hence the price varies significantly depending on the material and packaging. Poor quality chips can result in low, bluish quality light which is discomforting and can be harmful to human eye in long run. Their useful life is also low.
LED driver	The LED driver regulates the current passing through LEDs. This is particularly important given the poor electricity supply conditions in India. Drivers are also to a large extent imported from China. Poor quality drivers can result in failure of either the driver itself or the LEDs. In either case, LED bulb stops working. A poor quality driver can also result in low power factor and high total harmonic distortion which adversely impacts the power system.

10. See www.watchyourpower.org to get insights into power supply conditions across India.

Heat sink	The heat sink dissipates the heat generated in the junctions within the LED. Aluminium is the most commonly used material. A thin heat sink results in inadequate heat dissipation leading to failure of LED's life before its theoretical value.
Base	Bayonet type bases are used in India as compared to the screw bases used elsewhere mostly due to legacy issues. A bayonet base limits the weight of the LED bulb that it can hold. A heavier LED bulb with a thick heat sink and a good quality driver may bend in the holder resulting in a loose connection. Hence it requires intelligent design.

Fluorescent lighting

The fluorescent lighting market including tube-lights and CFLs is in complete decline (Figure 1). CFL sales doubled in four years after the launch of the Bachat Lamp Yojana (BLY) in 2009. The BLY subsidised CFLs, selling them at the price of ICBs using the Clean Development Mechanism (CDM), a carbon trading scheme established under the Kyoto Protocol. The strong demand for CFLs led many companies to add significant capacity of CFL production lines. In 2013, the annual production capacity reached around a billion lamps when the total sales of CFLs in that year were less than half of this capacity (PEG, 2017). The BLY stalled as the carbon prices under CDM crashed. The rapid reduction in LED bulb prices further affected the sales of CFLs. There are no new investments happening in the CFL market. Companies are trying to recover the investments made in the assembly lines during the boom period till 2013. A similar situation exists with tube-lights. LED tube-lights sales grew by 70% in 2017 mostly replacing the fluorescent tube-lights.

Interventions

Programmes targeting replacement of incandescent bulbs in Indian homes have been around for quite some time now. Both government agencies and the electricity distribution companies (DISCOMs) have been conducting these programmes at the national and local levels. These programmes have been focused on bringing down the upfront price of CFLs and LED bulbs using subsidies, a financing mechanism, and bulk procurement. A few programmes also focused on increasing awareness and outreach. The largest, the most innovative, and the most successful programme so far has been the recent UJALA programme. A detailed examination of the impacts of UJALA and a review of earlier programmes can be found in (PEG, 2017). We have seen in previous sections that the ICB market is still strong albeit gradually declining, and that the LED lighting market is growing rapidly but has its own set of problems. The demand for ICBs may further go up as the government electrifies the remaining 3 crore households under the Saubhagya Scheme[11]. The manufacturers have no incentive to stop the production and sale of ICBs as long as there is demand for them. Quality concerns, the upfront price, awareness, and availability still pose serious challenges to the mass adoption of LED bulbs. The market may take a long time to move away from ICBs if left to its own devices. Meanwhile, these ICBs will continue wasting electricity and adding to the burden of individual households as well as the society. Hence, there is a strong case for continued programme and policy interventions in India's lighting sector. Based on our analysis of demand and supply, we provide some recommendations on the nature of such interventions. Recommendations related to the UJALA programme can be incorporated in its next phase which is being funded, inter alia, by a $300 million loan from the World Bank.[12]

11. http://saubhagya.gov.in/
12. http://www.worldbank.org/en/news/press-release/2018/05/17/usd300-million-world-bank-operation-help-scale-up-india-energy-efficiency-program (Accessed 4th June, 2018)

Ensure good quality LED bulbs

People's perception of the quality of LED bulbs can be as crucial a factor as their price in their mass adoption. This assumes greater importance in India as poor electricity supply conditions can result in frequent blowing out of bulbs. One of the reasons why people buy ICBs is that they are cheap and easily available for replacement unlike LED bulbs. In the case of LED bulbs, the poor electricity supply conditions may also deteriorate the quality of light emitted over its life. These concerns can prevail over the significant reduction in electricity bills from the use of LED bulbs and deter people from buying them. Hence, interventions should focus on making good quality LED bulbs available in the Indian market.

There are already adequate regulations aimed at ensuring the quality of LED bulbs in India. The Ministry of Electronics and Information Technology (MeitY) requires that all LED bulbs sold in India should comply with the performance and safety standards specified by the Bureau of Indian Standards (BIS) (DeitY, 2014). The Bureau of Energy Efficiency (BEE) has notified that the Standards and Labelling (S&L) programme must be made mandatory for LED bulbs from 28th June, 2018 (MoP, 2017). This mandates companies to print the BEE label consisting of information on luminous efficacy, rated power and other parameters on the bulb's packaging. The companies cannot sell LED bulbs less efficient than a 1-star rating (68 lumens/watt). The mandatory S&L programme aims to inform consumers about the quality of LED bulbs and also bar the sale of less efficient LED bulbs.

However, as discussed previously, one issue of concern is the compliance with these regulations. Under the Compulsory Registration Scheme (CRS), MeitY is required to conduct periodic checks and publish data on non-compliance. Similar provisions are made in the Energy Conservation Act, 2001 requiring the BEE to check compliance with the S&L programme. MeitY data under CRS shows that surveillance was initiated for about 160 LED bulb companies since 2014, but does not provide information on the outcomes of the surveillance. As per information accessed under the Right to Information (RTI) act, MeitY tested 51 models of LED bulbs of which 5 failed to conform to BIS standards. BEE's mandatory programme for LED bulbs is yet to begin but it has not published any data related to compliance checks for other appliances under the existing mandatory programme. Periodic compliance testing and publishing of results can act as a strong deterrent to companies selling inferior quality LED bulbs. China's National Supervision and Inspection (NSI) test provides a good example (NLCT, 2010). The General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) in China conducted NSI tests on CFLs from 1998 to 2009. Annual tests were conducted on samples collected from factories as well as the market, and the data on the compliance rate was released to the public. Products showing consistent compliance were exempted from future supervision. Non-complying products were given time limits to reform, failing which they were reported to various media outlets. The compliance rate was observed to increase from 50% in 1998 to nearly 90% in 2007.

The UJALA programme can also contribute to increasing people's confidence in LED bulbs. The EESL already procures LED bulbs which comply with the BIS and BEE standards. It can commission random compliance check-testing of the procured LED bulbs and penalise companies which do not comply. Furthermore, the EESL can provide a hassle-free process for availing of the replacement of faulty bulbs under warranty. Our surveys in Puducherry, Lucknow, and Pune found that only 10–30% of the failed bulbs were replaced under warranty of the UJALA programme (PEG, 2017). The EESL can conduct periodic drives in different cities to collect failed LED bulbs and replace them with new ones. It can also make the replacement process easier by marking the LED bulbs rather than asking consumers to retain copies of the bill of purchase. Finally, EESL can collaborate with manufacturers and ask them to use their local channels for the collection and replacement of failed bulbs. All these measures will add cost to the programme but will contribute in building consumer confidence in LED bulbs.

Interventions can also focus on development of LED bulbs suitable for Indian conditions. The BEE can present annual awards for the best performing LED bulbs. In addition to luminous efficacy, these

awards can give significant weightage to parameters like lumen maintenance and lamp life particularly in Indian conditions. This would require development of special testing methods that replicate the thermal operating conditions, switching patterns, and typical electricity supply conditions observed in India. A good example of such awards is the Global Efficiency Medal Competition held since 2012 by the Super-efficient Equipment and Appliance Deployment (SEAD) initiative.[13] This competition encourages the production and sale of super-efficient equipment, appliances, and electronics by recognising the world's most energy efficient products. Such competitions can give recognition to manufacturing companies for their efforts to develop good quality LED bulbs suitable for Indian conditions.

Reduce the upfront price of LED bulbs

UJALA has been successful in bringing down the price of LED bulbs in India using the bulk procurement mechanism. The bulb is now available for Rs 65–70 under the UJALA programme. However, even this low price may not be sufficiently low for households to buy LED bulbs, for two reasons. A low income household planning to buy 3–4 LED bulbs for all the lighting points in their home may find the total cost prohibitive. Also, households may be hesitant if they are using LED bulbs for the first time, and particularly if they are concerned about the quality of LED bulbs and the warranty process. A lower upfront price can motivate these households to try LED bulbs. The UJALA programme did offer an option of an on-bill financing mechanism to the participants. Under this mechanism, a DISCOM consumer with no arrears could buy the LED bulbs for as low as Rs 15, with the balance being paid through monthly electricity bills. The monthly instalment was expected to be less than the reduction in electricity bill due to the use of the LED bulb, and hence it would pay for itself. There is no data on the number of participants who opted for the on-bill financing mechanism. Anecdotal evidence suggests that the number was very low. However, this might be because the programme's presence was predominantly in urban areas, where preference for on-bill financing has been low. Responses to surveys in Pune, Lucknow, and Puducherry confirm this low preference. Secondly, the option was rarely marketed and hence people did not know about it. Our interviews with the distribution companies (DISCOMs) revealed that most of them had discontinued the option. However, in our survey in rural areas in the Pune district, about 84% of the households said that they would be interested in participating in an on-bill financing programme. It is recommended that the on-bill financing mechanism be widely advertised in the next phase of the UJALA programme particularly to target low income households.

Increase awareness and availability of LED bulbs

Our survey in Pune district shows that the awareness in rural areas about LED bulbs and the UJALA programme is low. About 57% of the households did not know about the LED bulbs while only 3% knew about UJALA. This may not be representative of the entire country. However, it has to be noted that Pune district saw the maximum sales of LED bulbs under the UJALA programme in Maharashtra. It may be worthwhile to conduct innovative marketing campaigns at the national, state, and local levels to increase awareness about the benefits of LED bulbs. Such campaigns can also urge consumers to buy only good quality LED bulbs with an appropriate BIS mark and BEE label.

The lesser availability of LED bulbs in rural areas can also act as a barrier to their purchase. About 48% of the surveyed households who owned LED bulbs bought them from taluka or district headquarters. Making the LED bulbs available at the village level can increase their uptake. The small shop-keepers in rural areas may find it difficult to stock LED bulbs as compared to ICBs due to the relatively significant capital investment. Increased awareness about LED bulbs can result in their higher demand and consequently faster movement of their inventory.

13. https://superefficient.org/global-efficiency-medal (Accessed 4th June, 2018)

EESL is already exploring innovative ways to increase the outreach of UJALA. It has collaborated with India post and oil companies to sell LED bulbs at post offices[14] and petrol pumps[15] respectively. It has also made LED kits available to local entrepreneurs through the common service centres (CSCs) to encourage local level assembly and sales of LED bulbs.[16] EESL is also selling LED bulbs under the Gram Swaraj Abhiyan[17]. Under this initiative, EESL will send vans to about 16,000 Indian villages with large numbers of low income households. These vans will spread awareness about LED bulbs, energy efficiency and conservation, and sell LED bulbs at a discounted price of Rs 50. There is no data on how these initiatives have fared so far. EESL should continue these initiatives and also continuously evaluate their effectiveness. Another avenue for increasing the availability of LED bulbs is the Saubhagya Yojana. Under the current guidelines[18], every electrified household is given one LED bulb. This has the potential of initiating efficient lighting behaviour from the beginning. However, if the quality of LED bulbs distributed is poor, and if the household cannot replace its LED bulb easily under warranty, adoption will be delayed as it will require considerable time to change consumer perception about the low quality of LED bulbs based on their actual experience.

Phasing out ICBs is difficult

A number of countries like China, the USA, Cuba, Brazil and those in the European Union have either banned or are in the process of phasing out ICBs. Most of the countries have a transition period which allows manufacturers to shift their production to more efficient lighting options. The common policy instrument used is the Minimum Energy Performance Standard (MEPS) which sets the minimum efficiency level for the appliances to be sold in the market. In the case of lighting, MEPS prescribes a minimum value for luminous efficacy (lumen/watt). As the MEPS is gradually tightened, ICBs with low values of luminous efficacy get eliminated from the market. This also allows for a re-entry of ICBs in the market if a technological breakthrough[19] results in substantial improvement in their efficiency.

In the Indian context, phasing out of ICBs can face serious challenges. ICBs are the affordable source of light for millions of low income and particularly newly electrified households. These households may not be able to afford LED bulbs, even with their reduced prices. They may need financial assistance on a sustained basis to shift to LED bulbs and continue using them. A detailed examination of the lighting usage of these households is required before making ICBs unavailable to them. India's poor electricity supply conditions pose another challenge. This is an outcome of the more systemic issues in India's power sector which are outside the control of the lighting industry. More research needs to be done to make LED bulbs more reliable in typical operating conditions in India before they become a reliable alternative to ICBs. The availability of LED bulbs in rural areas is another concern. All these issues need to be addressed before implementing a phase-out of ICBs in India.

14. https://www.financialexpress.com/economy/ujala-scheme-led-bulb-tubelight-at-uniform-rate-across-india-post-gst/755306/ (Accessed 5th June, 2018)
15. https://www.indiatoday.in/india/story/led-bulbs-tubelights-fans-petrol-pumps-government-agencies-1029900-2017-08-16 (Accessed 5th June, 2018)
16. https://www.thehindubusinessline.com/news/common-service-centres-to-help-entrepreneurs-in-making-led-bulbs/article9077345.ece (Accessed 5th June, 2018)
17. www.eeslindia.org/DMS/gsy.pdf (Accessed 5th June, 2018)
18. https://powermin.nic.in/sites/default/files/webform/notices/FAQs_helpline_for_Saubhagya.pdf (Accessed 5th June, 2018)
19. See http://news.mit.edu/2016/nanophotonic-incandescent-light-bulbs-0111 (Accessed 5th June, 2018)

Conclusion

LED lighting demand has picked up remarkably in India since 2014, driven primarily by the UJALA programme. UJALA brought down the LED bulb prices substantially through bulk procurement and also generated significant awareness through its innovative market campaigns. However, the demand for incandescent bulbs still remains high, though it is declining gradually. Our observations indicate that the demand for LED lighting is lower in semi-urban and rural areas due to concerns about their quality, still relatively high upfront price, low availability, and a lack of awareness of their benefits. Policy and programme interventions are required to move the market away from ICBs. The price focused interventions adopted so far have been successful in reducing the price of LED bulbs and consequently increasing their demand. However, there is a need to move beyond price-focused interventions to achieve a complete shift away from ICBs.

The BEE can conduct nation-wide awareness campaigns on the use and benefits of LED bulbs particularly targeting rural areas and low income households. The campaigns can also increase the awareness on buying good quality LED bulbs as differentiated by BEE's star rating programme. The BEE and BIS can also conduct periodic compliance tests against the standards and publish non-compliance results. In addition, the EESL can conduct compliance checks on the procured LED bulbs under UJALA and black-list manufacturers that supply non-compliant bulbs. The EESL can also help improve public confidence in the quality of LED bulbs by providing a smooth process for consumers to exchange bulbs under warranty. To address the issue of upfront price, the EESL can focus more on the on-bill financing mechanism which has been a part of the UJALA programme, but has received limited attention so far. The EESL can also continue and scale up its current initiative to increase outreach to rural areas such as distribution through post offices, petrol pumps, and the Gram Swaraj Abhiyan. The government's electrification programme, Saubhagya, is another avenue which can be used to initiate newly electrified households in the use of LED bulbs. These interventions aimed at increasing the awareness about LED bulbs, improving their quality, reducing their upfront price, and increasing their availability can contribute to a significant reduction in the use of ICBs in India. A phase-out of ICBs without addressing other concerns at this juncture is however not recommended as its burden will fall primarily on low income and newly electrified households.

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Annexure:

Methodology and questionnaire for survey conducted in rural areas of Pune district

A sample size of 400 households was decided upon for the survey of the rural areas of Pune district. Pune district is divided into 5 subdivisions and 14 blocks. In order to capture any inter-district variations, it was decided that one block from every subdivision would be selected. One of the subdivisions, Pune subdivision, was not considered while selecting the sample as it mainly covers Pune city. Approximately 100 households were surveyed from each block, from a total of 38 villages. A pilot survey of 10 households was undertaken in Baramati and Velhe blocks in order to test the questionnaire and train enumerators.

The blocks that were selected were:

- Baramati (Baramati subdivision)
- Velhe (Bhor subdivision)
- Junnar (Junnar subdivision)
- Maval (Maval subdivision)

In order to compensate for any data loss due to incorrect data collection, 10 per cent oversampling was done. A total of 445 households were therefore covered under the survey in order to compensate for any data loss due to incorrect data collection.

Households were selected if they fulfilled one of the following criteria:

- The household had at least one ICB that was used for more than two hours every day.
- Fifty per cent or more of the light sources in the house were ICBs.

The surveys were conducted in Marathi by a team of seven researchers. As it was not possible to obtain a list of households in every village along with their addresses, it was not possible to use random sampling to select households. Households were therefore selected using the snowballing method. Snowballing is a non-random sampling method used in situations where it is difficult to identify sampling units before conducting a survey. In this technique, a few respondents are initially identified and are asked to identify more potential respondents. After these potential respondents are surveyed, they too are asked to recommend other respondents, and so on, until a sample of the required size has been obtained.

High, medium and low income households were identified by observation. In the sample 188 households are from the low income group while 251 households are from the middle income group. Only six high income households meeting the ICB selection criteria could be surveyed and hence were not considered while analysing the survey data.

The survey questionnaire is given below.

Consumer survey questionnaire on incandescent bulb use

HH ID: ____

Taluka name: 1) Baramati 2) Junnar 3) Maval 4) Velhe

Village name: _____

1. Do you own at least one incandescent bulb which is used for two hours or more every day?
   a. Yes
   b. No
2. Are around half or more of the light bulbs in your house incandescent bulbs?
   a. Yes
   b. No

If the respondent answers 'yes' for any one of the questions, continue with the interview.

Consumer details

3. Respondent name:
4. Age:
5. Occupation:
6. Mobile number (optional):
7. Family size:
8. No. of rooms *(not including bathrooms)*:
9. Area of house:
10. Is this house owned by you or have you taken it on rent?
    a. Rented b. Owned
11. Income group *(on the basis of observation)*:
    a. High b. Medium c. Low

Electricity and lamp usage

12. Do you receive an electricity bill?
    a. Yes
    b. No
13. If you receive an electricity bill, how often do you receive it?
    a. Every month
    b. Every two months
    c. Other (please specify):
14. How do you pay for electricity?
    a. Pay MSEDCL/ MSEB according to your electricity bill
    b. Pay the landlord according to your electricity bill

c. Pay a flat monthly fee to the landlord/person on whose name the meter is

d. Have diverted an MSEDCL electricity supply line to my house

15. How much do you pay for electricity on an average? ₹ _____

16. How many lamps do you own? : _____

17. Please tell me the following details about the different types of lamps that you own, that are used for more than two hours a day: *(Ensure that the usage period given is for the bulb that is used the most)*

		Private use		Commercial use	
Sr. No.	Type	Number of lamps used for more than two hours a day	Usage hours of lamp with highest usage	Number of lamps used for more than two hours a day	No. of hours used in a day
	Incandescent bulb				
	LED bulb				
	CFL				
	Tube light				
	Other (please specify)				
	Other (please specify)				

18. Why have you not installed LED bulbs at all the lighting points in your house?

a. Not aware of LED bulbs -→ *Go to Q.27*

b. Other bulbs are cheaper than LED bulbs

c. They are not available in the village/area

d. Waiting for present bulbs to stop working

e. Installed LED bulb(s) earlier but was not happy with the performance.

f. Other (please specify):

19. Why were you not happy with the performance of the LED bulbs?

a. The light is too bright

b. The light is not bright enough

c. Does not work well with the poor supply quality in my house

d. Other (Specify):

Ask Questions 20 to 26 ONLY if the respondent has ever bought LED bulbs. If the respondent has NEVER bought LED bulbs, go to Q.27

Purchase of LED bulbs

20. How much did you pay for an LED bulb the last time you bought one?

Price: _____

21. From where did you purchase the LED bulbs? *(tick all that are applicable)*
    a. From shop in village
    b. From shop in taluka headquarters
    c. From shop in Pune
    d. Under UJALA scheme --→ *Go to Q.24*

22. Are you aware of the UJALA programme for LED bulbs?
    a. Yes. b. No --→ *Go to Q.27*

23. Why did you not buy any bulbs under the UJALA programme?
    a. Was not interested in the programme
    b. There are no kiosks nearby
    c. Went to the kiosk but found the price too prohibitive
    d. Other (please specify):

If Q.23 has been answered, go to Q.27

Purchase of LED bulbs under UJALA

24. Where did you buy the LED bulbs under the UJALA scheme from?
    a. Village
    b. Taluka headquarters
    c. Pune

25. How did you buy the LED bulbs?
    a. Paid the entire amount upfront.
    b. Opted to pay in monthly instalments through electricity bills
    c. Bought some bulbs by paying upfront and some bulbs on monthly instalments

26. Why did you not buy the bulbs through the on-bill financing mechanism?
    a. I had no need for it
    b. I didn't know about it.
    c. I knew about it but it was not available at the kiosk
    d. Other (please specify):

Consumers' willingness to pay for LED bulbs

27. LED bulbs are an advanced type of light bulb, with the following features:
    - LED bulbs last ten times longer than ICBs
    - LED bulbs consume 1/10th of the power required by an ICB.
    - An LED bulbs costs around 100

If you were to buy an LED bulb, what would be the highest price that you would be willing to buy it for? *Show the respondent the options listed.*

a. 121 - 160
b. 81 -120
c. 41 - 80
d. 40 - 15
e. Below 15

28. Suppose there was a programme under which you could pay for an LED bulb in installments. The payment would be made by adding 10 to your electricity bill every month. Would you buy an LED bulb under such a programme?

    a. Yes b. No -→ *Go to next question*

29. Why would you not take part in such a programme?

    Response:

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1. Evaluating energy efficiency programmes in India (2018)
   http://www.prayaspune.org/peg/publications/item/374

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10. Appliance Ownership in India: Evidence from NSSO Household Expenditure Surveys 2004-05 and 2009-10 (2012)
    http://www.prayaspune.org/peg/publications/item/183

LED lighting demand has picked up remarkably in India since 2014 driven primarily by the UJALA programme. However, the demand for incandescent bulbs still remains high albeit gradually declining. In 2017, about 770 million ICBs were sold in India accounting for more than 50% of the total sales of bulbs and tube-lights in that year. In this paper, we examine the demand and supply side aspects of the various lighting options available for Indian households to investigate the continued usage of ICBs in India. Based on the analysis, we recommend a few programme/policy interventions aimed at reducing and consequently eliminating the use of ICBs in India.

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