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Environmentally Sustainable Management of Fluorescent Lamp Sector in India: Drivers and Barriers

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Abstract

For the past few decades, energy efficiency still remains as one of the roots of sustainable development in most of the energy intensive sectors including lighting sector. A rapid paradigm shift from energy inefficient Incandescent lamps to fluorescent lamps has been attained to conserve energy in lighting in India. However, the major associated environmental concern of fluorescent lighting is the management of mercury bearing fluorescent lamps from cradle to grave. Surveys conducted by CPCB in 2013-14 ascertains that, manufacture of fluorescent tube light have been suspended by most of the registered fluorescent lamp manufacturers in India and have further shifted to mercury pill dosing (environmentally sound technology), a spillage-proof & zero elemental mercury technology. Further, India's regulatory measures progressing towards sustainable fluorescent lamp sector are focusing on both energy efficiency and mercury management. Simultaneously, enough thrust on LED is being propelled, as it is affordable, more 'energy efficient' with longer life spans & 'mercury free'.

Keywords: ***Fluorescent lamp sector; India; Energy efficiency; Environmentally sound management (ESM); Mercury; Sustainable development (SD); Central pollution control board (CPCB); Urban pollution control***

Introduction

The United Nations Conference on Sustainable Development, Rio+20 took place in Rio de Janeiro, Brazil during June 20-22, 2012, wherein member states decided to launch a process to develop a set of sustainable development goals (SDGs) to build millennium development goals with thematic areas on energy, food security, oceans, cities. Energy efficiency (one of the means to achieve millennium development goals) refers to different policies, technologies and strategies that are aimed at solving issues related to energy use whether at residential, commercial, industrial and national capacities so as to minimize emissions and enhance sustainable development.

Basically, Electrification and Illumination across any country very well depicts the rate of economic growth and development linked with energy (On-grid electricity) generation potential. In the present scenario, major countries have escalated growth

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with rapid industrialization & urbanization; still there are 1.6 billion people in the world without electricity. With the present energy conservation policies, that number would fall by only 200 million by 2030. To achieve the millennium development goals, it would need to fall to less than one billion by 2015 [1].

Considering population growth, improvement of living standards, and the resulting increased energy demand, electricity consumption for lighting will grow from 2,700 TWh to 3,200 TWh in 2030 unless countries establish and enforce minimum energy performance standards for lighting products in all sectors [2]. At present, electricity for lighting sector alone accounts for between 15% [2] and 19% of global electricity with more than 33 billion lamps operating worldwide.

General lighting, automotive lighting and backlighting are the three largest sectors in lighting – with general lighting accounting for approximately 75% of the total lighting market in 2010. Of which, residential lighting has the highest share, accounting for over 40 percent of the total general lighting market. Asia is currently the largest market in general lighting and will likely strengthen its position to over 45 percent of the total market in 2020.

Over the decades, the lighting sector has been witnessing a revolution in lighting technology continuously fuelled by energy consumption and Incandescent bulbs had a reign of almost a century across the globe which is being successively replaced by the energy efficient products, compact fluorescent lamp (CFL) and fluorescent tube light (FTL). Without a palpable change in lighting quality, a market shift from inefficient incandescent lamps to CFLs would cut world lighting electricity demand by 18% [1]. Fluorescent lamps account for 20% of global lamp sales and 45% of electric-lighting energy consumption. These lamps reduce electricity consumption so that in countries that generate electricity largely from coal, there could be less electricity required for lighting, thereby saving about 10% of emissions into the environment [3].

To emphasize the need for energy efficiency together with Mercury management in lighting sector, a survey was conducted by CPCB in 2013-14. Efforts were made to conduct a questionnaire survey for collecting data on Mercury management by fluorescent lamp industrial units and various promotional schemes & regulatory measures undertaken by Government of India. Drivers and barriers involved in achieving environmental sustainability were analyzed using the above survey. It was clearly found that, for a sustainable growth and economy, a balanced approach between implementation of promotional schemes for energy conservation and laying regulatory measures for mercury management in FL sector is mandatory.

Literature Review

'Sustainable development, the ability to meet the need of the present without compromising the ability of future generations to meet their own needs, is a pressing concern the world over' [4,5].

One of the crucial parts of attaining sustainable development is through energy efficiency in electrical products and services, as many countries like India burn fossil fuels to generate electricity, emitting CO_2, SO_2 and NO into the environment and posing potential threat to future generations [6]. India has made reasonable progress in terms of improving its energy efficiency in recent years.

Further, a 2013 energy efficiency indicator survey representing ten countries including India, reviewed key trends of drivers, barriers, funding issues faced and technology mix involved in energy efficiency and energy management. The result indicates

that lighting continues to be one of the top energy efficiency measures that are being implemented in India along with other global countries [7].

The UNEP-global environment facility enlighten initiative is promoting energy efficiency through the use of efficient solutions, such as CFL. According to UNEP, an integrated policy approach to efficient lighting includes a combination of:

- Minimum energy performance standards
- Supporting policies and mechanisms
- Monitoring, verification and enforcement
- Environmentally sound management of lighting products

Enlighten commits to phase-out inefficient incandescent lamps by 2016 and accelerates the transition to advanced lighting by adopting efficient lighting policies and strategies in the commercial and outdoor lighting sectors by 2020.

As per electrical lamp manufacturers association of India (ELCOMA) report, India has approximately two billion installed lighting points – with 60% of these in the residential sector and 40% in the commercial sector. In India, the industry lighting industry has a strong growth of 59 % and value increases from Rs. 8,500 Cr in 2010 to Rs. 13,500 Cr in 2013. This has been driven by the move from GLS lamps to CFLs and, more recently, to LEDs. Several government initiatives supported this transition, including use of CFLs in government offices, providing consumers with CFLs through demand side management schemes, free lamps to below poverty line (BPL) houses, etc. [8].

For decades, the lighting technology has been fostering toward energy efficiency uninterruptedly for its own reasons. Wherein, the technology that separates incandescent lamp (ICL) from fluorescent lamp (FL) is that in the former electricity heats up a filament inside the light bulb, which exhibits resistance resulting in high temperatures and causes the filament to glow and emit light. However, in FL, light is not created from heat but from the chemical reactions that occur when electricity is applied to different gases (inert) enclosed in a glass vacuum chamber. The former consumes more energy due to excess heat dissipation (90% of the energy) while heating the filament in the bulb, whereas the latter is highly energy efficient consuming one-third of the energy.

In spite of all the above factors, the major concern still remains that mercury is widely used in compact fluorescent lamps (CFLs) and the demand for them is increasing in the quest for energy efficiency. According to the EU Directive 2002/95/EC on the restriction of hazardous substances in electrical and electronic equipment (RoHS directive), mercury content in CFLs not exceeding 5 mg per lamp is allowed [9]. As measure to eradicate mercury bearing wastes, India has signed the Minamata Convention on September 30th, 2014 and under the Minamata Convention certain FL categories (with specified wattages) shall be phased out by year 2020. Further, the FL manufacturers engaged in the above project have reduced the mercury content of lamps meeting the 5 mg limit set in the Minamata Convention with effect from January 19th, 2013. [10]. However, despite continuing industry efforts to reduce the mercury content of each CFL and proven recycling techniques allowing effective recovery of mercury at the end of a lamp's life cycle, the high global demand for CFLs might present a challenge to achieving the goal of effective reduction of mercury use.

On a whole, global population growth and urbanization are increasing the overall demand for lighting products. At the same time, resource scarcity and climate change are of increasing concern. Governments around the world are responding to this

with greater regulation towards energy efficiency, and the lighting industry is addressing the issue by pursuing the development and enhancement of more energy-efficient lighting technologies with due momentum on environmentally sound management (ESM) too.

Methodology

CPCB conducted a questionnaire survey in various FL manufacturing units before (2008-09) and after (2013-14) publishing CPCB technical guidelines on environmentally sound mercury management in fluorescent lamp sector in 2010. The survey was conducted by visiting the FL Units to inspect the environmentally sound management (ESM) of FL sector. During the survey, a questionnaire was circulated to the technical heads of the manufacturing plant for details on general profile, raw material consumption, water consumption & conservation measures, energy consumption & conservation measures, production capacity, effluent/solid waste management, emissions (air, noise), recycling options, cost factor & ESM practices.

The above survey was conducted to compare the mercury management practices before and after evolving CPCB guidelines. Further the study ascertains that ESM of Mercury and other cleaner practices are followed in FL sectors as a part of sustainability & energy efficiency measures. The study also aims to emphasize the fact that India has been evolving policy measures and institutional capacity for FL sector with strict assurance of ESM of mercury in FL sector, thereby catering the need for the growing energy crunch in the country. However, there are ample drivers and barriers remain unleashed while implementing energy conservation schemes, regulatory measures for mercury management and ESM techniques in FL sector.

Results and Discussions

In general, manufacture of fluorescent lamp sector refers to fluorescent tube lights (FTL) and compact fluorescent lamps (CFL) in India. The total number of lamps produced by different manufacturers in India in the year 2012-13 was around 1,429 million. CFL production was approximately 453 million units and FTL was 234 million units accounting for 32% and 16% of total lamp production respectively (2012-13). In India there are around 60 lamp manufacturers with manufacturing capacity of 98% CFLs and 100% FTLs used in India.

Comparison of environmentally sound management practices of fluorescent lamp sector - a survey

CPCB has published technical guidelines on environmentally sound mercury management in fluorescent lamp sector in 2010. These technical guidelines basically highlight one of the conventional ESM strategies, 3 R's in FL management from cradle to grave:

- Reduction of Mercury usage at source (Reduce Hg content in production)
- ESM of Mercury at end-of-life FL (Reuse, Recycle)

To understand the manufacturing process of FL sector, a typical compact fluorescent lamp manufacturing sector involving the following stages are presented below [11]:

- Glass Cutting & Glazing
- Annealing/Bending
- Washing & Drying
- Phosphor Coating
- Wiping & Sintering

- Baking
- End-Sealing
- Sealing
- Bridging/Pinch Sealing
- Ar Flushing & Hg Dosing
- Flashing/Aging
- Basing & Capping
- Marking & Packaging
- Inspection & Quality Check

Whereas, in case of a fluorescent tube light (otherwise called straight fluorescent tubes) tube cutting, tube washing, coating, baking, neck cleaning, mount machine (flare making, stem making, coiling machine), sealing, Ar flushing and Hg dosing, basing, soldering, aging & packaging, quality control are the stages involved in order. Two flow diagrams comprising manufacture of typical 3 U CFL and FTL are shown in FIG. 1 and 2 respectively. The above manufacturing procedures clearly show the stage where mercury is dosed.

Around ten fluorescent lamp units were surveyed between 2008 and 2009, of which six units were fluorescent tube light manufacturers, two were compact fluorescent lamp (CFL) manufacturers and two were fluorescent lamp (FTL & CFL). By and large, all the fluorescent lamp manufacturers were using liquid mercury in the lamps till 2010. Earlier to CPCB guidelines, FL units were following liquid dosing technique and now almost all the registered manufacturing units have shifted to Mercury pill dosing. Composition of a Mercury pill used is either Zn-Hg Pill=7 mg, (3 mg Hg and 4 mg Zn) or Fe-Hg Pill=9 mg (4.5 mg Hg and 4.5 mg Fe).

With duration of four years after releasing CPCB guidelines and evolving series of promotional schemes & regulatory measures for lighting sector, a similar kind of a survey was conducted by CPCB between 2013 and 2014. Three CFL units were only surveyed as most of the fluorescent lamp manufacturers have shifted to highly lucrative CFL manufacturing business. A comparative chart is prepared based on the survey conducted before (2008-09) and after (2013-14) preparing CPCB guidelines on FL sector, which clearly indicates that there is a quantum shift in mercury dosing technology in FL sector as shown in TABLE 1. This paradigm shift in mercury dosing wouldn't have been possible without regulatory measures of Government of India. The next chapter discusses about the regulatory norms and measures that paved the path for the Successful transformation in the FL sector.

Regulatory measures in fluorescent lamp sector – energy efficiency vs mercury management

Energy Conservation Act, 2001 was enacted by Government of India to explore the potential of energy savings and harness the benefits of energy efficiency. Originally there are five major provisions of the act are: identification of designated consumers; standards and labeling of appliances; energy conservation building codes; creation of an institutional set up-Bureau of Energy Efficiency and establishment of energy conservation fund. The act was amended in 2010 to facilitate energy efficiency in lighting and other energy consuming utilities as well.

In India, fluorescent lamp wastes are mercury based wastes and are governed by Hazardous Waste (Management, Handling & Trans boundary Movement) Rules, 2008 (HWMHT Rules) [12] and E-Waste (Management & Handling) Rules, 2011 (EWMH Rules) [13].

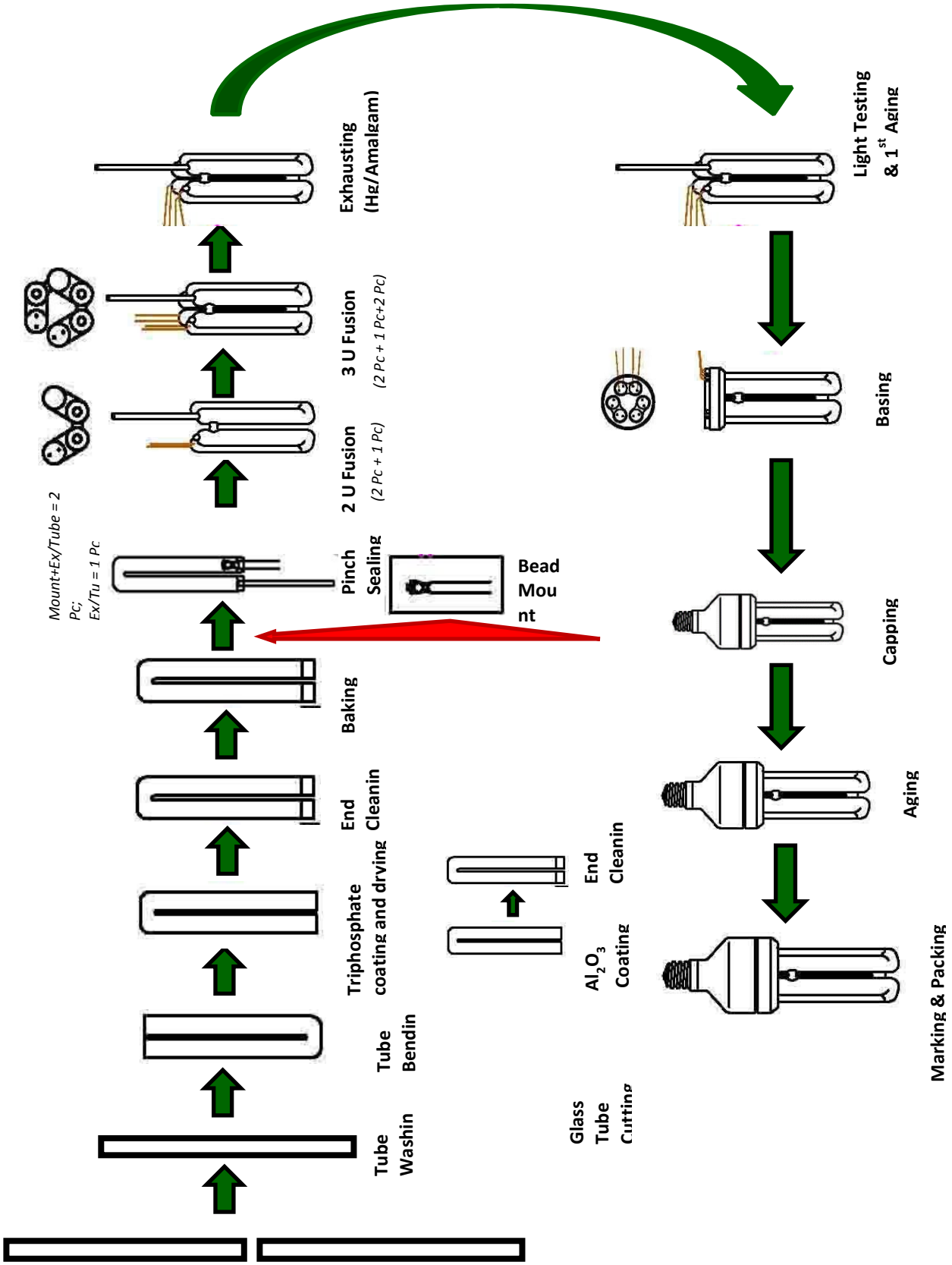

FIG. 1. **Schematic representation of 3 U compact fluorescent lamp manufacturing procedures.**

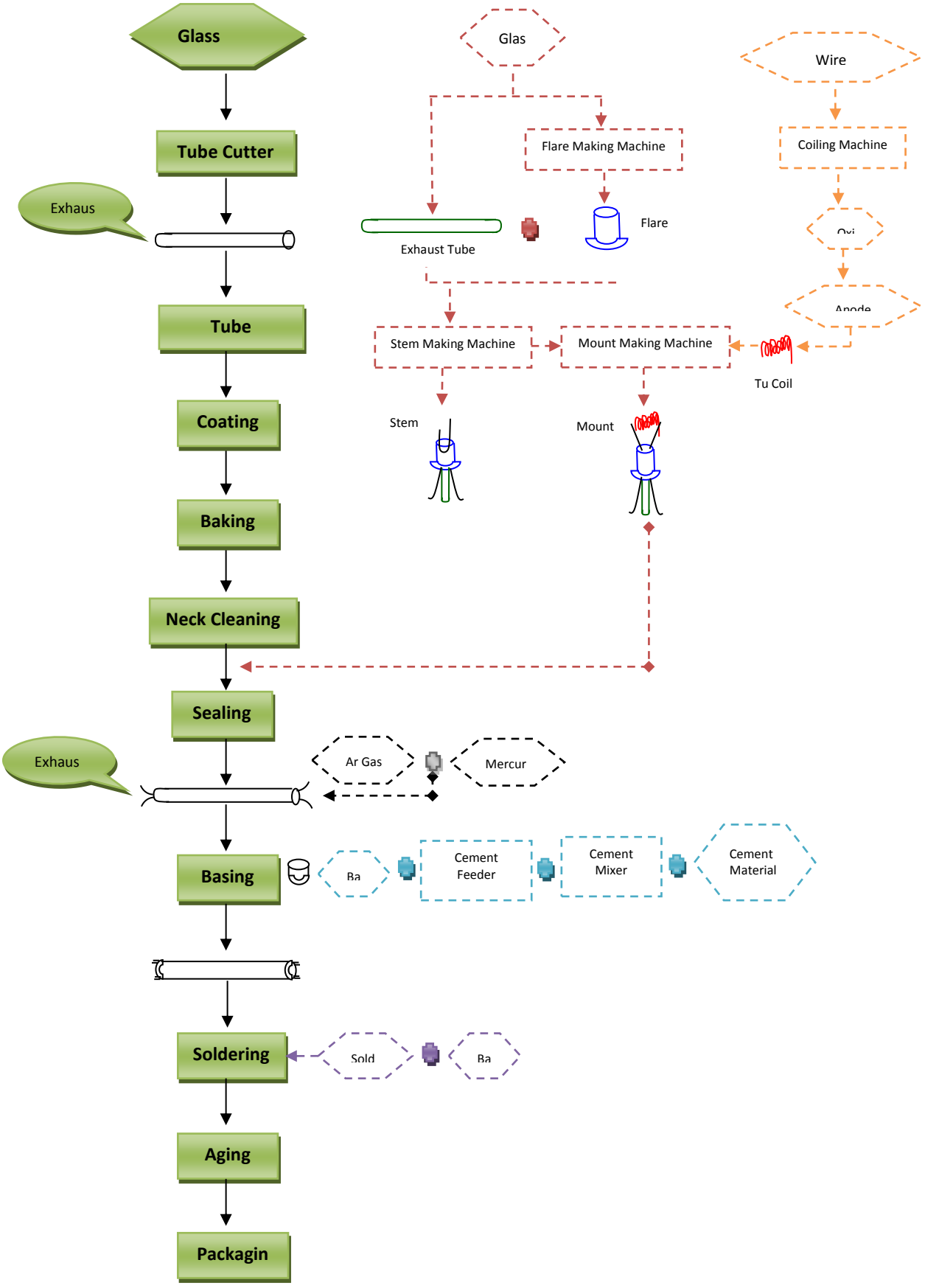

FIG. 2. **Schematic representation of fluorescent tube light manufacturing procedures.**

TABLE 1**. Environmentally sound management of fluorescent lamp sector - a survey.**

S. No	Name & Location of units manufacturing units	CFL/FTL Production Capacity	Quantum of Breakage	Mercury Treatment & Disposal	Dosing	Flushing
Survey conducted before CPCB Guidelines (2008-09)						
1.	FTL Unit 1 at Gujarat[2]	FTL:15 lacs nos./months[2]	Glass with Mercury stains (category A6) @ 22 MT/yr (5% of Production)[2]	Collection, Storage, Solidification, transportation and disposal at TSDF[2]	Liquid Hg[2]	-[2]
2.	FTL Unit 2, Gujarat[2]	FTL: 14.33 lacs nos/month[2]	Glass with Mercury stains (category A6) @ 18 MT/yr[2]	Collection, Storage, Solidification, transportation and disposal at TSDF[2]	Liquid Hg[2]	Mercury Flushing[2]
3.	FTL Unit 3, Gujarat[2]	FTL: 10000 pcs/month[2]	Glass with Mercury stains (category A6) @ 27 MT/yr[2]	Collection, storage, solidification, transportation & disposal at TSDF-BEIL[2].	Liquid Hg[2]	-[2]
4.	FL Unit, Gujarat	CFL: 12 lacs Nos/m FTL: 12 lac Nos/m Glass shell	Mercury stains (category A6) @ 1.32 MT/yr & Vacuum Oil contaminator with mercury 0.040 KL/yr	Collection, storage, solidification, transportation & disposal at TSDF-NECL Vadodara	Liquid Hg	-
5.	FTL Unit, Mysore, Karnataka[2]	FTL:20000 Nos[2]	200 Nos[2]	Mercury is recycled by triple distillation process[2]	Liquid Hg[2]	-[2]
6.	FL Unit, Mohali, Punjab	FTL: 30000 Lamp/day CFL: 55000 Lamp/day	Glass with Mercury stains (category A6) @ 0.011 MT/yr	Fused/broken lamp crushed by the Eater machine along with spray system just below the crusher in the tank-separate Fluorescent powder & Hg vapour (gravity), followed by an activated carbon treatment system.	Liquid Hg	Argon flushing
7.	FTL Unit 4, Gujarat	FTL: 50000 Lamp/day	Not Available	-	Liquid Hg	Argon Flushing
8.	FTL Unit, Shikohabad & Firozabad State, UP	FTL:42000/day	Not Available	-	Liquid Hg	Mercury Flushing

9.	CFL Unit, Neemrana, Rajasthan	CFL: 28000 Lamp/day	Not Available	No proper mercury recovery being followed	Liquid Hg	Argon flushing
10.	CFL Unit, Gujarat[1]	CFL: 76 lacs Nos/yr[1]	Mercury stains (category A6) @ 12 MT/yr[1]	Collection, storage, solidification, transportation & disposal at TSDF-NEPL[1]	Liquid Hg[1]	-[1]
Survey Conducted after CPCB Guidelines (2013-14)						
1.	CFL Unit, Mysore, Karnataka[1]	GLS 100000/- per day FTL 26800/- per day CFL 47000/- per day[1]	1 % of production[1]	-[1]	Hg Pill dosing[1]	Ar Flushing[1]
2.	CFL Unit, Neemrana, Rajasthan[1]	CFL: 28000 Lamp/ Day[1]	Not Available[1]	Recycled inhouse[1]	Hg Pill dosing[1]	Ar Flushing[1]
3.	CFL Unit, Mohali, Punjab[1]	FTL - 10 Mln/annum CFLi - 100 Mln/annum Filament - 2000 Mln/ Annum Wire- 1155 Mln Mtr / Annum[1]	Not Available[1]	Bulb Eater (Sent to Municipal Solid Waste Landfill / TSDF)[1]	Hg Pill dosing[1]	Ar Flushing[1]

[1]CFL Unit; [2]FTL unit; *Note Survey conducted on those industries (2013-14) expressed that manufacture of Fluorescent Tube Lights is suspended due to shift in demand for CFL and LED lamp.

Under Hazardous Waste (Management, Handling & Trans boundary Movement) Rules, 2008, The concentration limit for mercury is specified as 50 mg/Kg under Class A (A6 Mercury and Mercury compounds) under Schedule II [Rule 3(1): List of Waste Constituents], Mercury is classified as hazardous waste regardless of concentration limit if the waste exhibits any of the hazardous characteristics (e.g. toxicity) under Class E of the rules. Mercury is classified as wastes containing or contaminated with established toxic and eco-toxic constituents under class E4 toxic category of the rules. Storage of the Mercury waste is specified as any hazardous waste including mercury bearing waste is permitted to store on-site only for a period of 90 days unless otherwise extended by the concerned State Pollution Control Board (SPCB)/Pollution Control Committee (PCC) to the generator of any such waste.

Under Schedule II of E-Waste (Management & Handling) Rules, 2011, limits are specified for mercury for different wattages of FL, which indicates the limits for exemption of mercury in product from applicability of reduction of hazardous substances

(RoHS) provisions. However, as per Schedule-I of E-Waste Rules, end-of-life FL are not regulated as electronic wastes, hence, the limits specified for FL at Schedule II are only indicative values.

Reduction in the use of hazardous materials in the manufacture of electrical and electronic equipment is mentioned under Rule 13 of E-Waste Rule. According to sub-rule 1 under Rule 13, every producer of electrical and electronic equipment listed in Schedule I shall ensure that, new electrical and electronic equipment does not contain Mercury provided that a maximum concentration value of 0.1% by weight in homogenous material for mercury shall be permitted. Under Schedule-I (rule 3(k) (I)), Categories of E-Waste Consumer electrical and electronics are covered. The applications listed in Schedule –II shall be exempted from provisions of sub-rule (1) of rule 13 are listed in TABLE 2.

TABLE 2. **List of exempted applications.**

No	Exemption
1	Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):
1(a)	For general lighting purposes < 30 W:5 mg
1(b)	For general lighting purposes ≥ 30 W and < 50 W:5 mg
1(c)	For general lighting purposes ≥ 50 W and < 150 W:5 mg
1(d)	For general lighting purposes ≥ 150 W:15 mg
1(e)	For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm: 7mg
1(f)	For special purposes: 5mg
2(a)	Mercury in double-capped linear fluorescent lamps for general lighting purposes
2(a)(1)	Tri-band phosphor with normal lifetime and a tube diameter > 9 mm (e.g. T2): 4 mg
2(a) (2)	Tri-band phosphor with normal lifetime and a tube diameter ≥ 9mm and ≥ 17 mm (e.g. T5):3 mg
2(a) (3)	Tri-band phosphor with normal lifetime and a tube diameter >17 mm and ≤ 28 mm (e.g. T8): 3.5mg
2(a) (4)	Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T2): 5 mg
2(a) (5)	Tri-band phosphor with long lifetime (≥ 25000 h): 8mg
2(b)	Mercury in other fluorescent lamps not exceeding (per lamp):
2(b) (1)	Linear halophosphalte lamps with tube > 28 mm (e.g T 10 and T 12): 10 mg
2(b) (2)	Non- linear halophosphate lamps (all diameters): 15 mg
2(b) (3)	Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9):15 mg
2(b) (4)	Lamps for other general lighting and special purposes (e.g. induction lamps): 15mg
3	Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for special purposes not exceeding (per lamp):
3(a)	Short length (≤500 mm): 3.5mg
3(b)	Medium length (>500mm and ≤ 1500 mm): 5mg
3 (c)	Long length (>1500 mm): 13ma

Comparatively, legal provisions for fluorescent lamp sector in other countries are provided in TABLE 3 based on literature study and CPCB guidelines published in 2010. It clearly depicts that regulations are in place for fluorescent lamp sector in most of the countries. In India, Under Schedule II of E-Waste (Management & Handling) Rules, 2011, limits are specified for mercury for different wattages of fluorescent lamps, which indicates the limits for exemption of mercury in product from

applicability of Reduction of Hazardous Substances (RoHS) provisions. Further, as per Schedule-I of E-Waste Rules, end-of-life fluorescent lamps are not regulated as electronic wastes, hence, the limits specified for fluorescent lamps at Schedule II are only indicative value. However, to limit use of mercury in lamps, Bureau of Indian Standards has stipulated 5 mg per CFL for ≤ 26 Wattage under IS 15111, as most of the domestic fluorescent lamp consumption category fall under this wattage range. Further BIS under ET23 committee on Standardization of Electrical and Electronic components has proposed to develop similar standards for Fluorescent Tube lights based on wattages also.

TABLE 3. **Legal provisions in place for fluorescent lamp sector globally.**

S. No	Country	Regulation	Lamp type and amount of mercury per lamp (mg)	Reference	Collection of Used Lamps*	Disposal*
1	Europe	WEEE/RoHS	Halophosphate lamps 10 Triphosphate lamps 5-8	ROHs [14]	Producers to set up collection system for households and other end users	Authorised Treatment Facility
2	Canada	British Columbia Waste Management Act	Linear Fluorescent tubes 3-50 CFL 1-25	Environment Canada [15]	-	-
3	United States of America	Universal Waste Rule (1995/1999)	Linear Fluorescent tubes 1.25-5.96	Singhvi et al. [16]	Generator has to hand over Handler or Authorised Recycler	Authorised Recycling Unit
			CFL average 4	Energy Star [17]		
			Linear Fluorescent tubes 1.4-50	Culver [18]		
			CFL 1-6	Culver [18]		
			CFL 5-50	NEWMOA [19]		
			Linear Fluorescent tubes 0-100	NEWMOA [19]		
6	Australia	Waste Avoidance and Resource Recovery Act	CFL 0.1-13	Boughey and Webb [20]		

		2007				
8	United Kingdom	-	CFL < 10	AEA Technology [21]		
10	Taiwan	Waste Disposal Act		Ching-Hwa Lee [22]	Retailers as Collection Centers	Authorized Recycling facilities
9	India	Hazardous Waste (Management, Handling & Transboundary) Movement Rules, 2008; E-Waste Rules,2011 (Directly or Indirectly)	FTL 15-60 CFL 3-12	CPCB Guidelines [23]	See TABLE 5	
11	Germany	Recovery and Disposal Act	-		Collection Centers	Lamp Recycling Facilities
12	Sweden	Waste Ordinance			Producers' responsibility for the collection, Treatment & Disposal	Producers responsibility for recycling
13	Russia	Federal Law – Waste of Production and Consumption	FTL 15-45 CFL 12-30		-	-
14	Finland	WEEE Directive	-		Municipalities have an obligation to arrange collection of FLs and other Hg containing waste from households	Waste lamps may only be treated by a company authorized for handling hazardous waste
15	China	Law of Environmental Protection	-		-	-
16	Japan	Law for Promotion of Effective Utilization of Resources	-		-	-

CPCB Guidelines, 2008*; UNEP Toolkit 2013; P.Nance et al, 2012

Chronologically various promotional schemes for energy conservation & Regulatory Measures to control mercury for an environmentally sustainable FL sector are collated at TABLE 4 based on literature survey and CPCB status report on Fluorescent Lamp Sector published in January 2015. From the above table, it is clearly evident that Government of India is constantly developing various schemes and policies for energy conservation and mercury management in lighting sector time and again. However, there are various drivers and barriers still remain unleashed in this highly evolving Lighting Sector with particular reference to Fluorescent Lamp Sector.

TABLE 4. **Regulatory measures for sustainable management of fluorescent lamp sector - energy efficiency vs mercury management.**

Year	Regulatory Measures
2001	Ministry of Power Notified Energy Conservation Act, 2001[1]
2004	BESCOM Efficient Lighting Program (BELP) – Bangalore Electricity Supply Company (BESCOM)[1]
2005	Rajiv Gandhi Grammen Vidyuthikaran Yojana (RGGVY) – access to electricity to rural households – 104496 villages covered out of 112795.[1]
	Jyotir Gram Yojna provided 100 % rural Electrification with 30,000 CFLs installed in 15,000 Village Panchayat Offices in Gujarat[1]
2006	Standards and Labelling Programs for electrical equipments and appliances – covers 12 equipments including FL;[1]
	BSES launched 'Buy One Get One Free' CFL with Delhi Govt[1]
	Maharashtra Energy Development Agency (MEDA) sponsored a village-level CFL program[1]
2007	Energy Conservation Building Code (ECBC) launched – code limits lighting power density with EE lighting system design and installation[1]
	Haryana State Utility distributed 250,000 CFLs free of cost[1]
	Gujarat mandated replacement of ICLs with CFLs and 36 W /40 W FTL with 28 W FTL[1]
	Maharshtra State Utility sold 500,000 CFLs[1]
	Ministry of Environment, Forests & Climate Change (MoEF&CC) constituted Technical Committee and Task Force on Mercury for Environmentally Sound Management of Mercury bearing FL sector[2]
2008	Energy Conservation and safe disposal of CFLs - Bombay Suburban Electric Supply[1]
	'Lighting a Billion Lives' – TERI[1]
	MoEF&CC notified Hazardous Waste (Management, Handling and Transboundary) Movements, 2008 (Amendment)[2]
	CPCB monitored of major FL Manufacturing Units for Status of Mercury Management in FL Sector[2]
2009	UNEP and GEF launched 'enlighten' initiative[1]
	MoEF&CC published a 'Report of Task Force on Environmentally Sound Management of Mercury in FL Sector';[2]
	Bureau of Indian Standards (BIS) finalized a standard of 5 mg/CFL;[2]
	Bachat Lamp Yojna (BLY) Scheme launched - distribution of 26 million CFLs – covered Kerala, Karnataka, Punjab, Haryana, Andhra Pradesh, Orissa, Chattisgarh, Madhya Pradesh, Uttar Pradesh, Uttarakhand, Rajasthan, Goa, West Bengal, Tamil Nadu and Delhi[2]
	Awareness raising and educational program - Bureau of Energy Efficiency (BEE) & The Energy and Resources Institute (TERI)[2]
	Establishment of MEPS for CFLs – BIS[2]

2010	Central Pollution Control Board (CPCB) published 'Technical Guidelines on Environmentally Sound Management of Mercury in FL Sector';[2]
	CPCB conducted a National Workshop on 'Mercury Management in FL Sector' for disseminating the Technical Guidelines in Delhi;[2]
	BEE launched Mandatory labeling for Fluorescent Tube Lights and 46 lamp types are approved with star rating;[1]
	LED Village Campaign, village demonstration in 23 states, LED street lighting in 32 states – BEE[1]
	Multi-State DSM Program (MSDP) to stimulate LED - BEE;[1]
	In order to enhance demand for LED bulbs, the Ministry of Power has decided that henceforth all bulbs provided to below-poverty line households at the time of connection, estimated to be about 3.4 million, under the Rajiv Gandhi Grammen Vidyuthikaran Yojana (RGGVY)[1]
	National Manufacturing Competitiveness Council (NMCC) – prepared a national plan to stimulate LED lighting in India - LED exhibitions and workshops held in Hyderabad[1]
2011	BSES with Osram announced LEDs and CFLs scheme – 15 watt CFL free with LED in Delhi[3]
	LED exhibitions and workshops held in Hyderabad – NMCC[3]
	MoEF&CC notified E-Waste (Management & Handling) Rules 2011;[2]
	TERI conducted a study on Safe Collection, Transportation and disposal of mercury in FL Sector;[2]
	CPCB printed a Calendar in 2011creating awareness on Hg in CFL[2]
2012	Indian Railways was awarded Special Jury Award at UIC Conference in Venice in 2012 for supplying 1.4 million free CFLs to railway colonies to replace ICLs - a CDM program registered with UNFCCC[1]
	Super-Efficient Equipment Program (SEEP) – 25 million LEDs (2012-17)[3]
	Second phase of BLY (2012-17) – to distribute 20 million LEDs3
	LED exhibitions and workshops held in Mumbai – NMCC[3]
	Light India 2012 – a major lighting exhibition and conference[3]
	CPCB broadcasted 'Paryavaran Darshan' in Doordharshan TV show through 18 regional channels covering several environmental issues & management of FL[2]
2013	En.lighten's 'Transition to Energy Efficient Lighting in South Asia' workshop (26-27 September) – TERI[1]
	CPCB conducted two back to back workshops for southern SPCBS & Northern SPCBs in 2013;[2]
	CPCB conducted Surveys to various CFL units and found that most of the manufacturers have shifted to Pill dosing technology (Mercury dosing)[2]
2014	Ministry of Power promoted LED by distributing lamps to below-poverty line households at the time[3] of connection (estimated to be about 3.4 million) under the Rajiv Gandhi Grammen Vidyuthikaran Yojana (RGGVY)[3]
	MoEF&CC signed Minamata Convention on 30th September 2014[2]
2015	Ministry of Power jointly with Ministry of Coal launched a National Programme for LED Street lighting and LED Home lighting in 20153
2016	Phase-out of Energy Inefficient Incandescent Lamps[3]
2020	Phase-out of CFL & FL (above 5mg Hg content) – wattage specified under Minamata Convention[2]
2022	Ministry of New and Renewable Energy (MNRE) with National Bank for Agriculture and Rural Development to promote 'Solar Home Lighting Systems'[3]

[1]Regulatory Measures- Energy Efficiency; [2]Regulatory Measures - Mercury Management; [3]Regulatory Measures - Energy efficiency + Mercury Management; *CPCB, 2015; UNEP GEF enlighten initiative

Drivers and barriers of sustainable management of fluorescent lamp sector-energy efficiency versus mercury management

Drivers & barriers in energy efficiency management: Access to affordable energy has become a main objective of various government policies and programs. To achieve this, efforts must be made for improved energy efficiency and the use of cleaner forms of energy in all the energy intensive sectors of the economy. Lighting sector continues to be among the top energy conservation measures due to its omnipresence in households, automotive and industries etc.

Various prominent Drivers for energy efficient lighting system include;

- Energy Cost Savings
- Energy Security
- Standardization of Lighting Products, Testing and Quality Assurance
- Government Utility incentives/rebates
- Customer attraction & retention
- GHG Emission Control & CDM Benefit

Fluorescent Lamp sector has a huge potential for energy security and associated cost benefit in terms of reduced life cycle cost of products which includes both initial cost, operating replacement costs and Environmental costs. Although incandescent lamps have less initial cost than CFLs, total cost of operating incandescent lighting is much more because of its high electricity cost and implications on GHG emissions and mercury emissions from coal based power generation facility.

Standards and labeling programs have been identified as one of the key activities for energy efficiency improvements, as it ensures quality and performance of the Fluorescent products. BIS has developed 60 standards for lamps, control gear and lamp holders, of which 29 standards are for lamps (ICL, FTL, CFL, Halogen, and High Intensity Discharge). India currently has mandatory Minimum Energy Performance Standards (MEPS) for CFLs under IS-15111, Voluntary MEPS for FL and IEC performance standards for LEDs.

Regarding lamp testing capacity, NABL provides laboratory accreditation services in accordance with ISO/IEC 17025:2005. There are five NABL-accredited test laboratories for general lighting products:

- Electrical Research and Development Association (ERDA) – FTL and Electronic Fluorescent ballasts
- Central Power Research Institute (CPRI) – Luminaries, FTL, CFL, electronic and magnetic ballasts
- Regional Testing Centre (RTC) – Magnetic ballasts, ICL testing
- National Physics Laboratory (NPL) – Colour and harmonic tests for CFL
- Electronic Regional Test Lab, North – CFL intensity test

Regarding lamp testing methodology, Centre for Material for Electronic Technology (CMET) has tested wide variety of CFL available in the Indian market for the mercury content for establishing the test procedures as per IS15906 and modified IEC 62554 methods using Cold Vapor Atomic Absorption Spectrophotometer (CV-AAS).

Government has announced numerous energy efficiency schemes, tariffs, tax deduction for electrical household utilities including FL and thereby attracts customers. Country wide commitment towards energy efficiency policies like Incandescent

lighting phase-out ensures a permanent transition to energy efficient lighting products and thus a tremendous reduction of GHG emissions. Among all the above drivers, Energy Cost savings continue to be the leading driver of energy efficiency in India due to its direct implications on government and public.

There still remain certain key Barriers while adopting the government policies and regulatory measures for energy efficient lighting as listed below;

- Rate of electrification & Power deficits
- Technology Sharing & Technical Expertise
- Certainty of Savings
- Financial criteria, Available capital, Lack of funding
- Awareness – Energy Efficient products

About 68% of India's population still lives in rural areas and depends on conventional energy sources like wood, biomass and agricultural residue for lighting. With this current scenario of low rate of electrification and huge power deficits, energy efficient FL system faces a great challenge. With the continual trend of technological shifts in FL sector, there is a tremendous need for technology sharing and technical expertise from other countries for an efficient FL sector. Certainty of savings in terms of energy & cost depends on the cumulative effects of energy efficient FL usage, quality of the product, continuous power supply and life cycle cost. Funding for development of R & D in energy efficient FL technology is to be further enhanced.

Though awareness for energy efficient FL product is high the initial investment for the product remains a setback for complete transition to energy efficient FL. Amongst all the above, lack of funding tops the list in adopting laid energy efficiency measures in India.

Drivers & barriers in mercury management: Drivers for environmentally sound mercury management are;

- Regulatory Mechanisms and Reforms
- Environmentally Sound Technology
- Recycling Technological Options
- Mercury-free Alternatives

Regulatory norms and mechanism exist for mercury management in FL sector. Under Schedule II of E-Waste (Management & Handling) Rules, 2011, limits are specified for mercury for different wattages of FL, which indicates the limits for exemption of mercury in product from applicability of Reduction of Hazardous Substances (RoHS) provisions. Further, world countries like US federal government, EU, Japan, China, Russia, Brazil and India have already committed to phase out incandescent lamps by 2016, thereby acting as a driver to FL market and indirectly cutting the mercury emission from fossil fuel based energy generation.

Pill dosing technology (Environmentally Sound Technology) is 100% adopted in large FL units thereby doing away with handling liquid mercury (elemental) dosing that was practiced earlier.

- Features of Pill dosing: Provides up to 95% of the vapor pressure of pure mercury.
- Free flowing solid spheres-easier to handle than liquid mercury.

- Zinc is inert and doesn't interfere with lamp operation
- Can be used as a precise dispenser of Hg for lamps employing other vapor pressure regulating metals such as In, Bi, or Ag

Numerous FL Waste Recycling Technologies exist and world-wide FL waste recyclers (ex. BALCAN, Air Cycle Corp, MRT) are entering Indian market. Example: Installation of Bulb Eater (Air Cycle Corporation) in a FL Manufacturing Unit at Mohali, Punjab, installation of Drum Top Crushers by Crompton Greaves at Vadodara, Gujarat, Halonix at Noida, Uttar Pradesh, A Recycling Unit at Chennai, Reliance Facility at Kakinada, Andhra Pradesh.

Non-mercury alternatives for these FL, with similar energy saving qualities, are not yet available on the market; however, they are under development. Further, LEDs and off-grid lighting has kicked-off on a greater pace than anticipated with government interventions since 2010. Among all the above drivers, Mercury free alternatives top the list of drivers for mercury management.

The amount of mercury in FL varies according to lamp type, wattage, brand and manufacturer [18,19,24]. Mercury that is present in different lamps can also vary in different countries because of technology and associated environmental legislations [25]. In view of above, Barriers for mercury management are listed below:

- Regulatory norms
- Technology Sharing & Technical Expertise
- Inventory of Mercury bearing FL
- Reduce, Reuse, Recycling Options
- Awareness
- Financial criteria

However, as per Schedule-I of E-Waste Rules, end-of-life FL are not regulated as electronic wastes, hence, the limits specified for FL at Schedule II are only indicative values. Hence stringent regulatory norms are to be made mandatory for India to handle mercury based FL Sector. With the current scenario of power deficit and associated fluctuations, there is great need for technology sharing and technical expertise from developed countries with reference to mercury content, mercury dosing, management of end-of-life mercury bearing FL, to counter the present scenario of energy supply and demand.

Assessment or Estimation of generation of End-of-life FL remains a major challenge due to upcoming reasons. Unlike other 'recyclable' wastes, generation of 'intact' End-of-life of FLs is uncertain due to varied usage hours (life-span of FL), varied number of FL per households, very 'fragile' glass product (thickness 0.1 mm) and the product is omnipresent; Estimation/Assessment of mercury bearing end-of-life FL depends mainly on number of Hg bearing FLs fail every year, quantum of mercury present in in-use FLs; Mercury content & speciation at the end-of-life FLs. A matrix is developed examining the Legal & Technical justifications to reason out, why execution of Technical Guidelines on Environmentally Sound Mercury Management in Fluorescent Lamp Sector has been a major challenge, at TABLE 5. FL waste Recyclers exist, however are few in number. It has been reported by an Indian FL waste recycler that to sustain economic viability there is a need for ensured availability of 'adequate quantum' of FL waste.

Awareness is required for safe handling & disposal of mercury bearing FL at the level of consumers, manufacturers and environmental protection agencies.

Unlike Used/Waste Oil recycling (Hazardous Wastes (Sch IV), payback for end-of-life FL recycling is meager, as it does not carry 'value along the management chain' beginning from collection, transportation, treatment and disposal. Installation of Recycling facility, recycling technology & process is capital intensive with very little payback in terms of resource recovery, proportion of recyclables and recyclability. Like all other wastes that have potential recyclable components the informal sector plays a significant role.

Low-mercury and mercury-free options are available, but socio-economic conditions are often barriers to the adoption of better practices [26]. Among all above barriers, financial criteria top the barriers list in mercury management. Overall Strength, Weakness, Opportunities and Threat in sustainable management of FL Sector is depicted in FIG. 3.

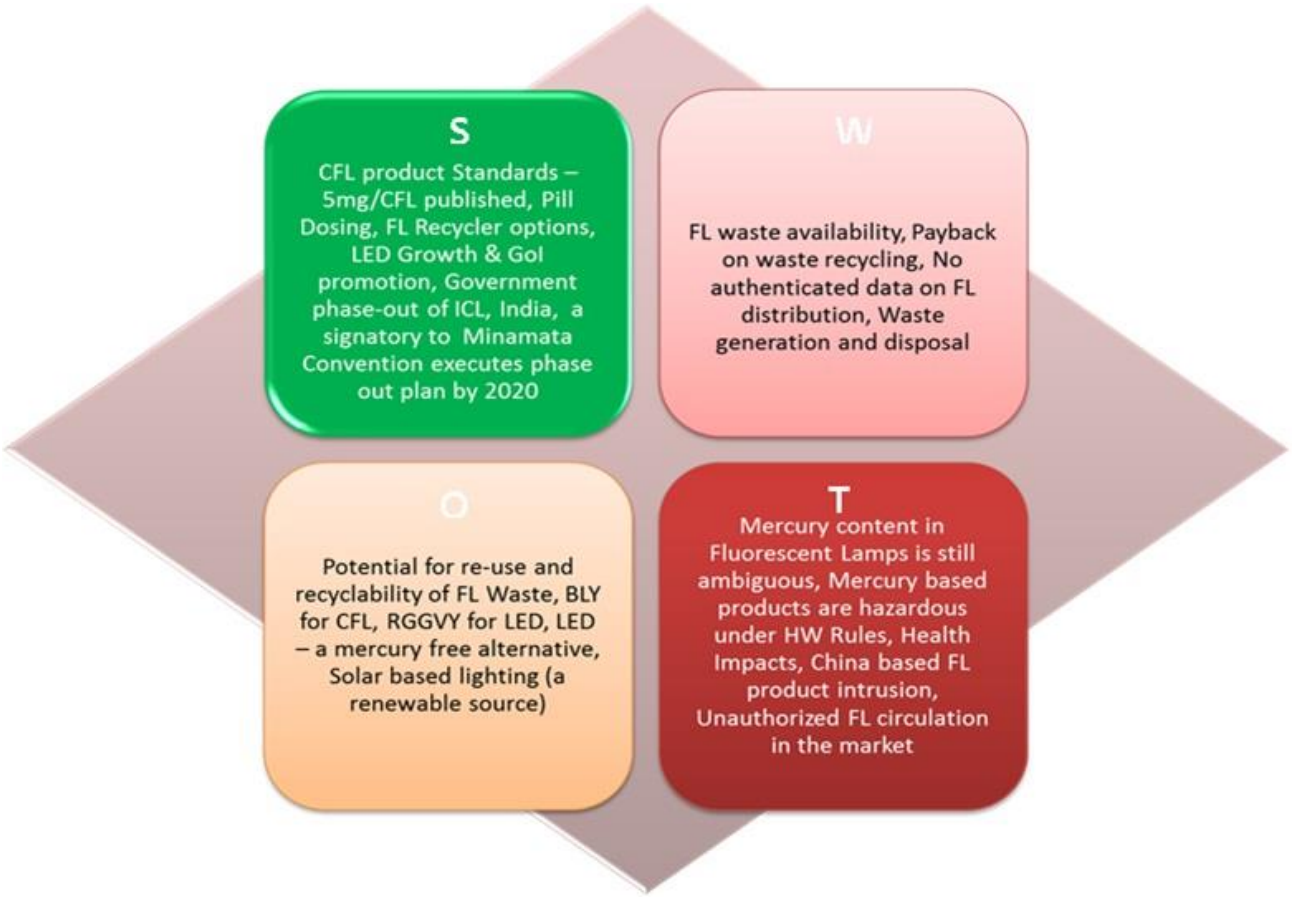

FIG. 3. **Overall SWOT of sustainable management of fluorescent lamp sector.**

TABLE 5. **Legal and technical challenges in executing CPCB guidelines – a barrier.**

General waste mgmt. activities	**BMW**	**MSW**	**PW**	**HW (Sch IV)**	**FLW**
Generation	Regular	Regular	Almost regular	Depends on the type of waste	Uncertain
Periodicity of generation	Regular	Regular	Almost regular	Regular	Uncertain

Collection	Regular	Regular	Almost regular	Systematic	Uncertain
Ease of Waste segregation	Yes	Yes	Yes	Yes	Difficult to keep FLs 'intact' because of fragile glass
Storage for disposal	Yes	Yes	Yes	Yes	Uncertain, except for bulk users/generators
Transportation requirement	Yes	Yes	Yes	Yes	Uncertain
Treatment options	Yes	Yes	Yes (recycling)	Varied	Uncertain
Disposal options	Yes	Yes	Yes	Varied	Uncertain
Potential for Reduce/Reuse/Recycling (3 R's)	Low (after waste segregation)	Compostable waste (after waste segregation)	Yes	Very High	Yes
3 R's Technology options	Less	Moderate	High	Depends on the type of HW	Limited
Legal Provisions	BMW Rules, 2011	MSW Rules, 2000	PW Rules, 2011	HWMHT Rules, 2008	HWMHT, 2008 & EW Rules, 2011
ESM	Guidelines for ESM of BMW	Implementation of Rules	Implementation of Rules	Guidelines for ESM of HW	Guidelines for ESM of FL sector
Hg content	Elemental Hg in clinical equipment	Rare	No	Yes	Amalgamated Mercury in pills; USEPA indeed insists on emphasizing that the speciation of mercury contained in FL is a controversial and complex subject
Economic Impacts - Pay Back	Rare	Less	Yes	Huge	Very meagre
Envn Impacts	High	Medium (relatively)	High	Very High	High (Relatively)
Financial Implications – Cost of 3 R's	High (with reference to environmental and health impacts)	High (with reference to quantum of waste)	High (with reference to environmental impacts)	High (with reference to treatment and maintenance)	Uncertain (with reference to quantum and nature of waste 'fragile')

*BMW-Bio Medical Waste, MSW – Municipal Solid Waste, PW – Plastic Waste, HW – Hazardous Waste, FLW-Fluorescent Lamp Waste

Conclusion & Future Prospects

A rapid shift towards energy efficient lighting, a sustainable approach, not only significantly reduces emissions of mercury through decreased coal based power consumption, but also cuts net mercury release or emission even from mercury bearing FL wastes to the environment. To add-on to effect of sustainable management of FL sector, successful implementation of Technical Guidelines on Environmentally Sound Mercury Management in Fluorescent Lamp Sector and associated regulatory measures on energy efficiency, mercury management is a must.

Though as a part of a regulatory initiative, FL sector have shifted to mercury pill dosing and suspended T12 FL manufacture, ESM of this peculiar, 'highly fragile' FL waste with variable life spans is a major challenge as compared to other recyclable wastes like municipal, plastics, Biomedical, E-wastes and other Hazardous Wastes.

The top most driver and barrier for energy efficiency in FL sector are Energy Cost Savings and Lack of Funding respectively. Similarly, top most driver and barrier for mercury management are mercury-free alternatives and financial criteria. It may be noted that a decade back FL was also promoted by Government of India for energy efficiency however in recent times LED is to 'eclipse' FL. Due to absence of mercury the manufacture of LEDs, a mercury-free, eco-friendly, non-toxic and energy efficient lamp is gaining importance.

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