SSL Based Green Technology Solutions for Digital India – an Overview

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ABSTRACT

The well cited studies by Pimputkar et al. (2009), Schubert et al. (2005) etc indicate that the light-emitting diode (LED) has emerged as an important solid-state lighting (SSL) solution in last few years due to its advantages of high-efficiency, small size and low power consumption. Moreover, Krames et al. (2007) has shown its potential applications in the field of energy efficient high-performance smart lighting solutions and Ghassemlooy et al. (2015) studied applications of SSLs in visible-light based communication (VLC) and high speed free-space optical (FSO) communications. The aforementioned investigations explores different dimensions of the so-called SSL technologies and their potential use. Apart from these, the contemporary analysis like reporting in LED Magazine (2011) and study by Ghassemlooy et al. (2015) illustrate that the LED based technologies are considered as green technologies because they can save huge money of industrie as well and home users. This review paper summarizes the basic characteristics, advantages, emerging applications, standardization and regulatory framework created by government in this field of the SSL technologies. The contents are interlinked to address the possibilities of their potential use in diffent emerging areas and to achieve tangible solutions for many demanding areas of so-called Digital India program, e.g., energy efficient smart lightings, high-speed wireless communications, smart navigation systems etc. The aim is to serve consolidated information for a broad spectrum of users including researchers, technologies, testing-professionals, start-ups planers, consumer, manufacturer, importer, exporter etc.

Keywords - Green technology, LED, SSLs, VLC, FSO communications, standards, regulation.

1. INTRODUCTION

As mentioned earlier, Ghassemlooy et al. (2015) has shown that the LED is called future of lighting due to its great potential for energy-efficient general illumination. Initially, LEDs were exploited in general purpose lighting solutions but interestingly, now the SSLs technology is not confined only to this specific application area rather its field of application become vast and expanding rapidly into other potential areas namely communications, sensing, dimming, navigation etc. In view of such developments, it is worth to visualize the latest advancements and their scope of applications in the context of the so-called Digital India program. There are many research papers on core technologies and articles, reports where SSL technology is discussed and it has been emphasized that it can be exploited in various thrust areas. On the other hand, many times national and international policices related issues, dynamics of world economy and its economic diplomacy remain hot matters of discussion in TV, radio, news papers and magazines. However, the long experience in research, academia, standardization, policies and industrial interaction indicates that there is considerable gap in the clear understanding of most of the potential individuls (researchers, technologist, startup planers, manufacturers, industrialist etc) regarding emerging technological trends, open market dynamics and role of government policies. These components are highly interdependent and require a holistic view if someone is planning to start his career/business/startup in any field or even has experience up to certain limit.

In this article, it is tried to encompass major techno-managerial components like characteristics, measuring parameters, advantage, standardization scenario, market dynamics at international level, domestic scenario in context of implementation of SSL technology etc at one place. The intention is to take at least some steps to ignite young brains to think non-conventional manner and try to explore career opportunities in the field of techno-managerial businesses, standardization, certifications, testing as per standards etc. In context of the recent trands, these are the thrust areas where young tech-professional may play a major role and may change the scenario. In view of recent market trends, the focus of the article will remain around general purpose lighting and VLC technologies but introductory level information is also provided about other emerging areas. Apart from introduction, the contents of this report are divided in five segments; the second section describes driving forces, advantages and basic properties of LEDs, the third part highlights scope of applications, the fourth section through light on international players in the arena and world level economic diplomacy, fifth section elaborates the role of government in this arena while the last segment is dedicated to investigate current scenario in the matter concerned.

2. DRIVING FORCES BEHIND THE SSLS

The first question appears in mind is that why this subject became very hot in last few years ? Indeed, there are several driving forces behind the rapid development of SSL technologies. Energy efficient smart lighting solutions is one of the important thrust areas. Not long ago, according to a research report by Coltrin et al. (2007), the artificial lighting for general illumination purposes accounts for over 8% of global primary energy consumption. However, the traditional lighting technologies in use today (i.e., incandescent, fluorescent, and high-intensity discharge lamps), are not considered as very efficient lighting solutions. It is concluded that in such ligh sources, less than about 25% of the input power being converted to useful light. Indeed, SSL is a rapidly evolving, emerging technology whose efficiency of conversion of electricity to visible white light is likely to approach 50% within the next few years. In view of this reason, SSL technologies became a great area of interest and world over researches are working hard to develop effective lighting sources. However, Phillips et al. (2007) indicates that world over the primary focus of researcher is on ultra-efficient general-purpose lighting solutions but Side by side the researches are exploring various possibilities to exploit SSL technology in many thrust areas. Fig. 1 illustrates the overview of emerging trends around SSLs.

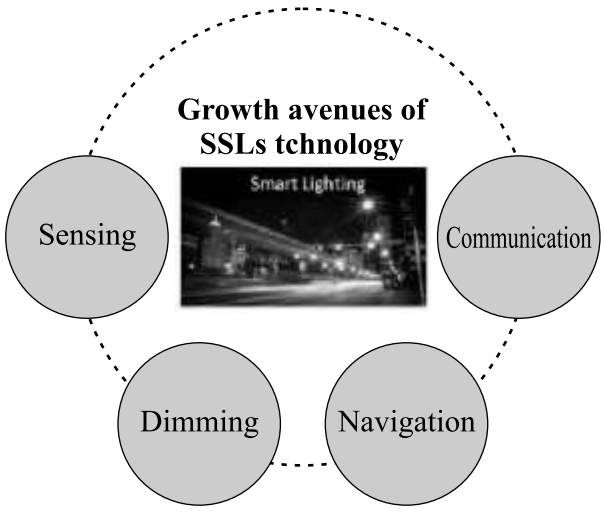

Figure 1. Overview of SSLs technology.

2.1 BASIC ADVANTAGES OF LEDS

On idc-online.com a detailed analysis regarding advantages and dis-advantages of LEDs is given according to that the basic advantages of LED light includes:

- Efficiency: LEDs are quite efficient and produce more lumen per watt than traditional light sources. This property of LED make it a ideal light source for future lighting solutions.
- Color: Lights of different colors remain always in demand. Unlike the conventional light sources, LEDs can emit light of desired color without using color filters, thus, become cost competitive.
- Size: Where smart and efficient designs are concerned, the size of the component plays an important role. As per the requirements, LEDs can be very small (smaller than 2 mm^2) and are easily populated onto printed circuit boards.
- On/Off time: In Optical Wireless Communications (OWCs), response time and frequency of on/off cycle are some of very essential requirements. LEDs light up very quickly (in microseconds), thus, they are ideal light source for OWC devices.
- Dimming: Dimming technology is one of the major thrust areas of applications wherein LED may be exploited at full potential. LEDs can very easily be dimmed either by pulse-width modulation or lowering the forward current.
- Heat radiation : Contrary to other conventional light sources, LEDs radiate very little heat in the form of IR. Wasted energy is dispersed as heat through the base assembly of the LED.
- Slow failure: The conventional light source like incandescent bulbs abruptly burn-out while LEDs mostly fail by dimming over time.
- Lifetime: Long useful life of LEDs make them most attective light source than the conventional light sources. Some reports indicate that the life of LEDs may vary from 35,000 to 50,000 hours of useful life.
- Safe light source: LEDs are SSL devices, thus, are shock resistance. Moreover, the traditional light sources e.g., incandescent bulbs, flurecent lamps, CFLs, etc are more fragile than LEDs.
- Directionality: SSL sources are basically directional light sources, thus, they can be designed to focus their light as per the requirement. To do the same thing with the conventional light sources, one may require an external reflactor to collect the light and then focus it as per the requirement.
- Environment friendly: LEDs do not contain mercury, unlike fluorescent lamps.

2.2 PROPERTIES OF LEDS

The aforementioned advantages make the LEDs a unique light source. A natural question then arises what characteristics make them so special. According to CIE 127-2007, the properties of LED can broadly be categorised in two segments (i) optical properties and (ii) electrical characteristics.

(a) **Optical properties:** the radiation from a LED can be characterised by radiometric (relating to the measurement of radiation) and spectroradiometric (measurement of spectral power distribution of a source) quantities. If the LED emits visible radiation, then photometric (related to the measurement of light perceived the human eye) and colorimetric (related to physical description and quantification of color perception by human eye) quantities. In this segment following quantities need to be measured:

(i) Spatial distribution: The optical radiation produced by a LED is generated by a semiconductor chip mounted in some form of package. The package protects the chip during operation, incorporates the electrical contacts and supports it for handling. The packaging frequently

changes the spectral and spatial distribution of the radiant power emitted from the chip by providing built-in reflectors or lenses and sometimes scattering material, coloured filters or a fluorescent layer.

(ii) Spectral distribution: The spectral distribution of the optical radiation emitted by LEDs is characteristic of these devices and differs in various aspects from that of other sources light sources.

(iii) Area of emittance: The area of emittance is characterised by its shape, size and the pattern of the luminance (the intensity of light emitted from a surface per unit area in a given direction) across it.

(b) **Electric characteristics:** the electrical parameters are also very important components to ascertain the illuminance throughput of SSL products, thus, the effective measurement of these parameters play very significant role to develop the quality LED products.

(i) Electrical operating conditions: LEDs are normally operated with DC power applied in a forward bias direction and at a constant current associated with a certain voltage (forward voltage), which is measured across the contacts of the LED.

(ii) Operation of reference standards: The apparatus used to measure LED characteristics should be calibrated with LED reference standards that have been specially selected and prepared. They should be operated at a constant current with the temperature of the chip maintained at a constant value.

(iii) Time dependent operation: In many applications, LEDs are operated under non-steady-state conditions such as modulated current, single shot or multiplexed mode. Since the output characteristics of the LED are affected by these operating conditions.

(iv) Forward voltage: The value of the forward voltage depends on the semiconductor material of the LED, with variations of up to a factor of five for the different types available.

a) Forward voltage dependence on current: Under stabilised temperature conditions, the relationship between the forward voltage of a LED and the current follows a well-established pattern common to all semiconductor diodes.

b) Forward voltage dependence on temperature: For most LEDs, when operating at normal ambient temperatures, typical values for the temperature coefficient of the forward voltage at a constant current are found to be in the range of -1.5 to 2.5 mV/K.

(v) Ambient temperature: Unless otherwise specified, an ambient temperature of Tamb = 25ºC is assumed for LED characterisation.

3. SCOPE OF APPLICATIONS

The SSL technology has a wide scope of implementation. Some major application areas are being discussed here.

3.1 LEDS IN SMART LIGHTING SOLUTIONS

The characteristics of LED like energy efficiency, environment friendly, little heat - no radiated heat from light, natural coupling for digital control makes it a core component of rapidly growing green technologies while properties like long life, high lumen efficiency and fast response are making them future of lighting. Moreover, an article at energy.gov indicates that low maintenance and no moving part like advantage enhance their durability. LED based lighting products are widely available for home as well as for commercial establishments. The product list is exponentially growing every year. The emerging modern concepts of smart cities and smart lighting systems are becoming the driving force behind the rapid development of LED technologies. In near future, LED will not only illuminate your home and surroundings but they also become source of broad-band wireless communication.

3.1.1 INDUSTRIAL AND COMMERCIAL USE OF SSL PRODUCTS

The high efficiency and directional nature of LEDs makes them ideal light source for many industrial and commercial uses. The potential of LED light sources is being exploited to manufacture railway signal lights, street lights, parking garage lighting, lightings for walkway and other outdoors, refrigerated case lighting, modular lighting, task lighting etc. The list of such products and their variants is increasing exponentially day by day.

3.1.2 SPECIAL DOMESTIC USE

Apart from the general lightings in homes, LEDs are ideal light source for specific domestic purposes. For example, due to their directional nature, LEDs are ideal for lighting the countertops for cooking and reading recipes. Moreover, the cool or blue light of specific LEDs are making them ideal light source for kitchen.

3.1.3 RECESSED DOWNLIGHTINGS AND HOLIDAY LIGHTINGS

Apart from general purpose light source and luminaires, LED based recessed downlights are commonly used in office and commercial settings, and residential kitchens, hallways, and bathrooms. The utilization is growing exponentially day by day because LEDs consume far less electricity than any other conventional light sources.

3.2 SSL BASED COMMUNICATIONS TECHNOLOGIES

Recent investigations indicate that technological trends keep on changing and new data services and applications are emerging continuously. One of the emerging trends is OWC technology, which becoming popular among researches due to its high potential of applications in indoor and outdoor wireless communications. According to an investigation by Fehske et al. (2011), there is an exponential surge in the commercial demand to pursue unlimited high-speed and ubiquitous broadband wireless access, to accommodate the ever-increasing utilization of internet and multimedia services among individual mobile users as well as residential and enterprise clusters, has provoked fantastical growth in internet traffic demand in the recent decade. As a result, the data traffic has been rising by a factor of ten every five years, which corresponds to a tremendous growth in the overall traffic volume by several hundred-fold within the next decade. The report by Mahdy et al. (2004) indicates that the OWC is growing very rapidly. The major reasons for the same are the attractive features like (i) no licensing requirements or tariffs for its utilization; (ii) virtually unlimited bandwidth for providing near-optimal capacity and supporting high-speed applications (e.g., VLC); (iii) extensive link range in excess of a few meters to 5 km; (iv) a green technology with high energy efficiency due to low power consumption, reduced interference and fading immunity; (v) high scalability and re-configurability; a high degree of security and privacy against eavesdropping; (vii) cost-effective in terms of the price per bit; and (viii) reduced time-to-market. Interestingly, OWC technology can be exploited in indoor OWC as well as outdoor OWC better known as FSO. In FSO, largely laser is used as a source; hence it is not covered in this article while LEDs can be exploited in indoor OWC.

3.2.1 SSL BASED INDOOR OWC

The investigations by Bykhovsky et al. (2014) and publication by Arnon (2015) show that the indoor VLC (visual light based communication for wavelength, λ = 380 to 780 nm) is a relatively new technology. This is being proposed as an alternative to the existing indoor infrared (IR), wavelength range, λ = 780 to 950 nm access technologies which offers a number of functionalities. Li-Fi is one of the

popular wireless VLC techniques which delivers bidirectional, high-speed, networked mobile communications by using LEDs as light source. Indeed, Li-Fi works much like the IR technology in our TV sets. It is well known that IR works on a very simple principle: a command is given (e.g. "change channel" when you press a button on your remote control) and that input is turned into binary code. The code is then transmitted via IR signals by the remote sensor, and the light signals are received by TV's IR sensor, which decodes the light signals and performs the intended action. In the case of Li-Fi , LED light source transmits the data by modulating the light waves and a photo-detector on receiver (say your phone or laptop) picks up those light waves and decodes them.

3.2.2 STANDARDS ON WOC (SHORT DISTANCE)

Since OWC technologies are being adopted in various communication devices, to maintain quality, standardization becomes vital. In this connection, Jin-Shyan et al. (2007) have thrown light and analyse various IEEE standards in this segment. The reporting indicates that IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 900 MHz and 2.4, 3.6, 5, and 60 GHz frequency bands. For Bluetooth, ultra-wideband (UWB), ZigBee and Wi-Fi, the IEEE standards IEEE 802.15.1, IEEE 802.15.3, IEEE 802.15.4, and IEEE 802.11 respectively are available. These aforementioned standards are largely used protocol standards for short range WOC with low power consumption. Every technology has its own advantages and limitations. Bluetooth works in limitated sphere and is intended for a cordless mouse, keyboard, and hands-free headset. Likewise UWB is developed for high-bandwidth multimedia links while ZigBee is designed for reliable wirelessly networked monitoring and control networks. The Wi-Fi is particularly formulated for computer-to-computer connections as an extension or substitution of cabled networks. The standards used in short distance WOC and their related technologies are shown in Fig. 2.

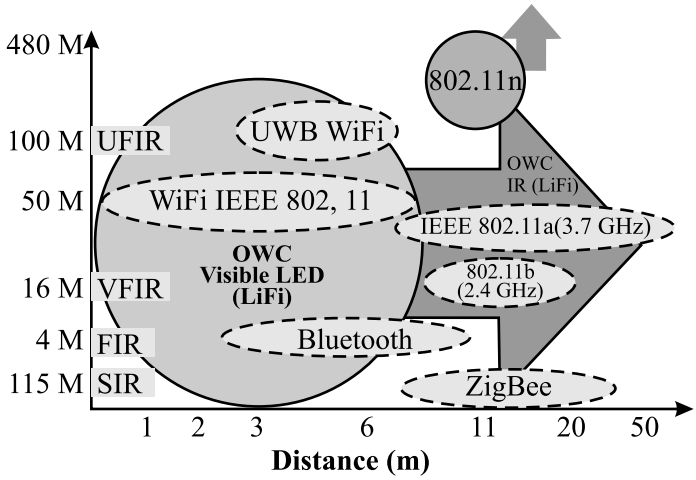

Figure 2. Wireless – technology and standards.

3.3 SSL IN NAVIGATION

Navigation is a specific sector and LED based navigation and communication systems are gradually increasing. A survey report by Navin (2010) explores LED based VLC systems and their applications including futuristic navigation systems. However, this application area is still at initial stage, but one may find several reports on internet which indicates that LED based communication devices may be widely utilized in near future for smart singaling, smart vehicle control systems, naval communication systems etc.

3.4 SSL IN DIMMING

As per the reporting by Zafar et al. (2015), LEDs can be exploited for illumination and communication simultaneously. For designing tangible devices LED based VLC devices and their implementation feasible, it is necessary to incorporate it with dimming schemes. In turn, it will provide energy savings, moods, and increase the aesthetic value of the place using this technology. Contrary to dimming techniques with the conventional light sources, LED based VLC techniques will create a desired balance between the two most basic functions of VLC, i.e., illumination and communication. Owning to the unique characteristics of the LEDs, the dimming mechanisms can easily be implemented using LED based VLC systems to save energy and provide precise illumination control.

3.5 SSL TECHNOLOGIES IN SENSING APPLICATIONS

The reporting by Takaya et al. (2014) indicates that VLC provides an additional feature, if the receiver incorporates an image sensor or a camera. Specifically, by using image or video processing to detect and recognize moving vehicles, safety applications can be integrated. In view of this, it may be evident that SSL based sensing devices may play an important role in the sensor networks, Internet of Things (IoT) etc.

4. INTERNATIONAL PLAYERS AND THE ECONOMIC DIPLOMACY

As a researcher of SSL technology, probably one may not need to understand the global business trends/economic diplomacy/regulatory framework but, in case, the end user is a big manufacturer/exporter/trader/start-up or planning to start a start-up and ambitious enough to become global player in the field of manufacturing/marketing of it's based products/technologies, then one has to have some understanding of some basic questions like (i) who controls the global trade ? (ii) what controls the quality and safety of the products/services/technologies etc ? (iii) what is the role of government in this market dynamics ?

4.1 THE CONTROLLER OF GLOBAL TRADE

As we are aware that the world becomes a global market, obviously some type of governing mechanism must be there. Yes, it is there and it is called World Trade Organization (WTO). Indeed, WTO is the only global international organization dealing with the rules of trade between nations. Internationally the trade is largely governed under the ambit of WTO-TBT (technical barrier to trade) agreements, generally called TBT agreement. India is a signatory of the agreement. The ultimate aim of TBT agreement is to help the WTO members to carry out their global trade in seamless manner. The WTO is run by its member governments and its main functions are

(a) Trade negotiations: Trade negotiations are carried out at WTO under the ambit of WTO-TBT agrement. The WTO agreements cover goods, services and intellectual property.
(b) Implementation and monitoring: The WTO members have some obligations. WTO agreements require governments to make their trade policies transparent by notifying the WTO about laws in force and measures adopted.
(c) Dispute settlement: The WTO resolves the disputs between/among its members regarding trade issues.
(d) Building trade capacity: Socio-economic conditions of the members countries are also taken care of the WTO, thus, WTO agreements contain special provision for developing countries, including longer time periods to implement agreements and commitments, measures to increase their trading opportunities, and support to help them build their trade capacity, to handle disputes and to implement technical standards.

(e) Outreach: To maintain harmony WTO keep on efforts. In this connection, the WTO maintains regular dialogue with non-governmental organizations, parliamentarians, other international organizations, the media and the general public on various aspects of the WTO.

4.2 QUALITY CONTROL BY STANDARDS AND STANDARDIZATION

The standardization is a process wherein standards remain at the core. The process of making something conform to a standard is termed as standardization. In more general terms, internationally the technical regulations and standards set out specific characteristics of a product — such as its size, shape, design, functions and performance, or the way it is labelled or packaged before it is put on sale. Although, the standards and technical regulations both set technical requirements to be met in the supply of commodities, products and services, but there is a key difference between them, standards are voluntary while the technical regulations are mandatory. For quality product and service point of view the technical regulations and standards are important, but they vary from country to country. The situation is somewhat complicated because having too many different standards makes life difficult for producers and exporters. There are various standard development bodies, some most influential organization are enlisted in the previous reporting (June 2018). Here we refer the standard development organizations (SDOs) specifically relevant to the SSL technologies and recognized by WTO. The International Electrotechnical Commission (IEC) is one of the most referred SDO which is recognized by the WTO and entrusted by it for monitoring the national and regional organizations agreeing to use the IEC's international standards as the basis for national or regional standards as part of the WTO's TBT Agreement. IEC has built a strategic partnership with WTO together with International Organization for Standardization (ISO) and International Telecommunication Union (ITU). The IEC has developed many standards in various fields including SSLs, however, Institute of Electrical and Electronics Engineers (IEEE) is one of major contributors in standard development for OWC and relevant technologies.

5. ROLE OF GOVERNMENT IN THIS ARENA

Depending on market dynamics and socio-economic conditions, the standards are adopted or implemented. The scenario is vary from one country to another. For example, in advance countries the consumers/end users are well aware and cautious about safety and quality of any the products they buy/use, thus, the things moves accordingly. To meet the such demand, and the manufacturer voluntarily adopts relevant national/international standards to improve their product quality. In contrary, the situation is quite different in the developing countries wherein the awareness is almost negligible and the consumers/end users are more cautious for prize of the product than the safety and quality. In such situation, the role of government becomes relatively more important. Some sort of machenism is required to protect the interest of the consumers/end users. Moreover, the the inflow of sub-standard products into the domestic market from overseas is also need to be taken care. In views of such situations, internationally, the the governments of developing countries make standards mandatory for specific product categories/sectors wherever they deem fit.

For developing policies obviously number of ministries may be involved. Some leading players in the formulations of Indian trade policies pertaining to SSL and its based technologies are Ministry of Electronics and Information Technology (MeitY), Ministry of Commerce and Industry, Ministry of Consumer Affairs, Food and Public Distribution, Ministry of Power, Ministry of Environment, Forest and Climate Change, Ministry of Telecommunications, Ministry of New and Renewable Energy etc. Moreover, Ministry of External Affairs is also a key player in the arena due to the involvement of international entities in global trading.

To implement the policies a lot of institutional machenism and infrastructure is required. To surve this purpose we have sufficient mechanism and the eco-system is developing rapidly. In this connection

number of other government entities related with standardization, accreditation, certifications, metrology etc are available and playing significant roles at different levels.

5.1 STANDARDIZATION AND REGULATORY ACTIVITY FOR SSLS

As discussed earlier, the standardization is a typical process; it may be voluntary or regulatory. In the first case, the manufacturer voluntarily adops standards to improve the qulity of his product to be competitive in the global market. Such manufacturers remain ready to comply with all the technical specifications of the relevant standard and conformity assessment process thereof. On the other hand, in the second case wherein the standards are made mandatory by government or any authority. In such case, no person shall by himself or through any person on his behalf manufacture or store for sale, import, sell or distribute goods which do not conform to the specified standard notified by the government/authority.

To cater national need, Bureau of Indian Standards (BIS) develops/harmonizes/provides the required standards. Where LED lightings are concerned, for convenience, most popular Indian standards and equivalent international standards are enlisted in Table-I (Aug. 2018), interested reader may refer the same. Since India is a developing country and awareness about standardization and safety is relatively less among the consumers/end users, thus, government has taken various initiatives. In this connection, MeitY has notified "Electronics and Information Technology Goods (Requirements for Compulsory Registration) Order, 2012 (CRO)" in 2012. The CRO mandates the safety standards for notified product categories to ensure the safety of the consumers/end users and to stop inflow of sub-standard electronics products. Till date 43 product categories have been covered in the ambit of CRO and the Order has come into effect for all the notified product categories including nine LED product categories indicated from S. No. 2 to 10 in Table-I (Aug. 2018)).

As discussed in Section 2.2, LED has many special photometric and electrical characteristics that make them a unique light source. To exploit is potential applications of LED lighting at maximum level, curb sub-standard LED products and keeping performance standards in mind, Bureau of Energy Efficiency (BEE) has released Schedule-20: LED Lamps on 7th July 2015 and has also notified "Bureau of Energy Efficiency (Particulars and Manner of their Display on Labels of Self-ballasted LED Lamps) Regulations, 2017" on 27th December 2017 mandating star labelling for self-ballasted LED lamps (details is available at beestarlabel.com). Popular performance standards for LED product categories are also given in Table-I at S. No. 11 to 17 (Aug. 2018).

5.2 ECO-SYSTEM AND INFRASTRUCTURE FOR SSLs

Since, till now most of the focus confined around general purpose lighting and industrial lighting products, thus, the standardization and regulatory activities are also growing around the same. According to Frank (2017), to develop Quality Infrastructure (QI) in any nation, establishment and intense coordination of dedicated entities are required. Fig. 3(a) depicts overall QI ecosystem in India. As illustrated in the figure, the ecosystem of QI largely grows over four key pillars namely standardization, metrology, conformity assessment and accreditation. However, the key elements of the QI are dynamic rather than static. The major driving force behind all components is strategic planning and continuous research in every sector. In case, we analyse the domestic scenario, every department of the QI ecosystem has sufficient and dedicated institutional mechanism for seamless functionalities (Aug. 2018). In this segment, the government is also very active and a comprehensive national policy, "Indian National Strategy for Standardization (INSS)" was notified on 19th June 2018 to implement and monitor the standardization, which is a milestone in the national standardization mission.

Where LED related initiatives are concerned, present domestic scenario is quite encouraging and may have great opening of new opportunities for next generation of startups. There is limitless scope in the

field. Fig. 3(b) illustrates an overview of the SSL ecosystem which is flourishing rapidly worldwide. The figure is self-explanatory, wherein one can easily correlate different key elements (i.e., industry, SSL technology, consumer and government) of the system in context of underneath drives (i.e., R&D, market and administrative), their role, characteristics, involved issues, connectivity, inter-dependability and thrust areas (Aug. 2018).

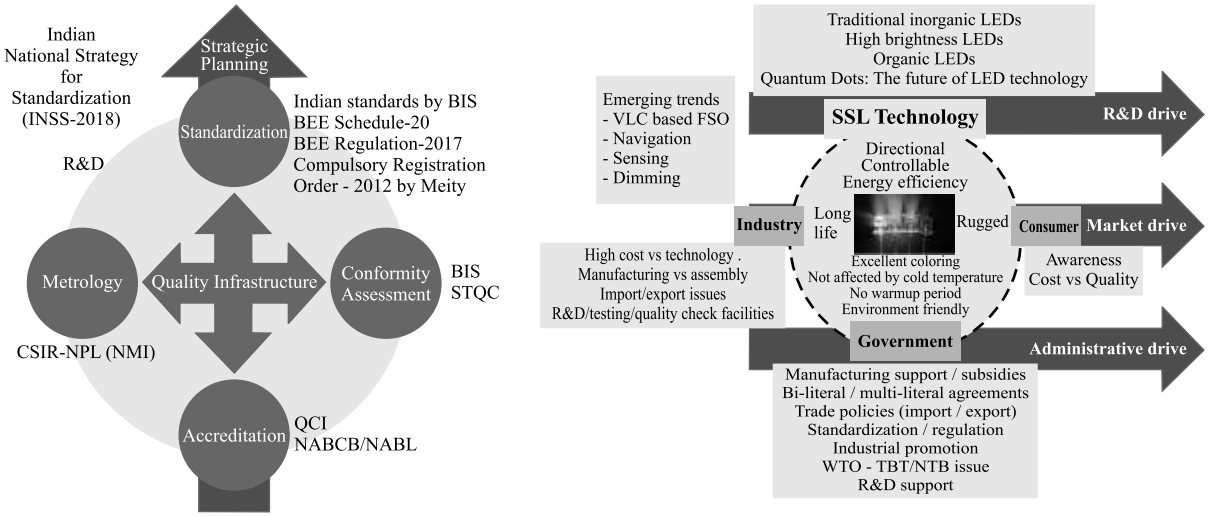

Figure 3 (a). Quality infrastructure echo system (b) Emerging SSL ecosystem.

6. PRESENT SITUATION IN SSLS FIELD

Like all over the world the Indian markets are being flooded with various kinds of LED products. As the Indian market is at budding stage, most of the SSLs and related products are being imported in CKD/SKD (completely knocked down/semi-knocked down) conditions. If one looks present Indian position in this contest, according to a report by US-based consulting firm, Frost & Sullivan (F&S) in 2014, the Indian LED market is expected to grow by over US$ 1 billion in the next few years. The market is likely to witness a growth rate of more than 40 % in forthcoming years. F&S has also predicted that the LED lighting market in India will move towards high quality, adaptable lighting with more efficient output. Khan (2016) by his reporting has also indicated that even though Indian market is facing many challenges, the LED market is likely to increase its footprint against the no-LED segment of this market with significant momentum in the next few years.

The LED lighting market specific growth avenues and challenge in domestic scenario, availability of government support by the means of various sector specific schemes are already discussed in another report by the author (Aug. 2018). Unfortunately, the other application areas of SSL technologies, like WOC/VLC, dimming, sensing, navigation etc are presently at initial stage and not getting sufficient attenting from the industry as well as government athorities. However, various reporting by many researchers and technologist indicating that the future of these aforesaid areas is very bright and numerous researchers/technologist are paying attention and exploring the futuristic feasibilities/modalities. That's why one can visualize many opportunities in this arena and may plan to start his own start-ups/business in such futuristic demanding fields, specifically WOC/VLC and Li-Fi based technologies are day by day becoming hotcakes.

7. CONCLUSION

The aim of the article is to visualize various aspects and developments in the field of SSL technology and ignite a fresh think process in the mind of end users (consumer / manufacturer / importer / exporter /

technologist / researchers / testing professional / start-ups etc.) so that they can move forward to adopt SSL technologies in their own context and as per best international practices. Owning to the great scope of opportunities in this field and availabilities of government support (Aug. 2018), many young professionals may explore new possibilities/career options in tech-product manufacturing, research in standard/standardization, international trade, create testing infrastructure / facilities as per Indian / international standards etc.

8. DISCLAIMER

Views presented in this paper pertain to author only and does not represent Government of India's views on the subject matter.

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