

TOWARDS SSL BASED LED LUMINAIRES: POLICY FRAMEWORKS AND GLOBAL BEST BENCHMARK PRACTICES ETHIOPIA NEEDS TO EXPLORE AND ADOPT

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ABSTRACT

Lighting, which solely accounts for about 20% of world energy consumption, is one of the major sources of greenhouse gas emission and environmental degradation. In the 21st century where factors like, environmental pollution, global warming, climate change and resource depletion are threatening earth, energy efficient lighting control strategies and systems are increasingly becoming an obligation. Solid State Lighting (SSL) evolution with the parallel miniaturization and advances in sensing, electronics and computing technologies in the last few decades, has brought a very robust, precise and energy-efficient Light Emitting Diode (LED) based luminaire systems. Hence, many countries in the European union, America and Asia took the leading initiatives and responsibility in setting frameworks and policies in their lighting sector of the economy and also incentivizing and implementing projects in the transformation process towards LED based luminaire systems with promising outcomes. Ethiopia, as a country with a great ambition to become a power house in East Africa in the coming few years, it needs to explore, craft and or adopt clear lighting standards, policies and strategies, to shift towards SSL based LED luminaire, benchmarking global best practices.

Keywords: Lighting Luminaire LED, Policy and Framework. SSL,

INTRODUCTION

As global warming, environmental pollution and resource depletions are becoming major concerns of the present world, efficient energy production and consumption goals are one of the major challenges worldwide [1]-[3]. At present, environmental protection and energy savings are critical for the planet's future and its residents more than ever before. Hence, energy saving is becoming one of the basic requirements and necessities in all economic sectors including lighting.

Globally, lighting solely accounts for almost a fifth of overall energy consumptions which in turn is accountable for about 6% of global Greenhouse Gases (GHG) emissions and environmental pollution[3-11]. Therefore, beginning the past few decades', studies on maximizing energy efficiency, monitoring and control in the lighting domain has been one of the major research focal points [12]. Several studies presented that energy consumption in lighting can be significantly reduced if different appropriate lighting systems were put in place [5], [6]. Of the many recommended findings and suggested solutions, energy efficient artificial lightings based on Solid-State Lighting (SSL) devices and building designs, which maximize natural daylight benefits, are more frequently investigated and premeditated compared to other practices [13].

SSL technologies, like LEDs, offer a dramatic energy saving of 50-60% with higher durability, limited maintenance cost, environmental friendliness and longer life span [14]. LEDs have radically transformed the lighting industry with brand new valuable characteristics and also possibilities of smart electronics control integration [4]. They offer improved brightness, tunable light spectrums (good color property), compact size, high luminous efficacy, durability, longevity and tremendous energy efficiency [3,15]. Further, automatic control of illumination and color temperature of lighting sources is possible in LED luminaires resulting in improved quality of life, experience and comfort [14]. These lighting systems are the future of the lighting industry and can be applied in a wide range of specialized lighting systems including industrial, commercial and residential applications.

Currently, LED based lighting systems are becoming increasingly popular in the lighting industry and are aggressively controlling the market [3], [4], [10], [14], [16]-[18]. They are widely used in many applications including in automotive, industrial, domestic, digital signage and televisions, backlight units (BLUs), and in public lightings [17], [18]. They are also extensively used in consumer electronic products, televisions displays, mobile phones, domestic lighting and vehicle industry [3]. Supplementary, with the continuous advancement & evolution of electronics, sensing, communication and actuation technologies, further reliable and robust advanced smart lighting systems with better power efficiency, users' comfort and safety are expected to be better accomplished in the near future [19].

Smart lighting systems are automatic smart lighting systems that deliver visually comfortable lighting illumination and color temperature with an efficient energy savings depending on users-response, wellbeing, activities and comforts [14]. Smart lighting control systems achieve automatic lighting control via integrating different sensors, actuators, electronics and communication schemes with a closed-loop control system [9]. Such systems can be designed not to only reduce lighting energy consumption significantly but also boosting users experience and comfort.

Smart lighting systems provide different proper illumination levels and color temperatures depending on activities and visual well-being [14]. Hence, smart lighting control plays a vital role in boosting users experience and energy efficiency. It helps in tailoring lighting conditions to tasks and users' preferences and requirements and possible amendments in buildings configuration and purposes [2]. They are typically capable of arbitrary spectra, brightness, color temperatures, intensity reproductions for better user experience with greater, faster and better responses [20]. With smart and advanced LED luminaires it is possible to achieve as high as 80% energy consumption cut [21].

Studies showed that by 2050 cities are expected to be populated by almost two thirds of the total global population, i.e. more than seven billion people, and anticipated to account for about 70% of greenhouse gas emissions and energy consumptions [4]. Therefore, cities all over the world are expected to be significantly affected by environmental pollution, resource depletion, climate change and their practice of lighting designs [2].

Therefore, taking this into consideration, optimizing lighting systems to save energy is a vital requirement and responsibility [7], [10], [11]. Thus, as the global population is rapidly increasing and if the effects of this scenario on the environment and quality of living are deemed to be minimized, the right lighting systems and policies should be in place way before it is too late. Many studies and researches underway currently in the world target addressing energy conservation and optimization of lighting sector via introducing different flexible lighting systems and techniques [7]. Hence, detailed analysis, studies and researches for improved luminaire systems and setting the right policies and strategies in advance is a necessity for a better future.

ETHIOPIA'S CONTEXT

To the authors' knowledge and the date of this paper writing, Ethiopia does not have any officially reported policy, guideline, rules and expectations in the lighting sector of its economy to shift towards SSL based luminaires. The country's very few and infant LED assembling companies only have the capability of assembling LED luminaires, lacking the ability to meet the market demand and compete with imported products. The country's pioneer lighting industry, daylight engineering, has stopped working on lightings and shifted its operation to glass manufacturing some years back. Even though there is no officially conducted research or study to analyze the country's human capacity in the lighting industry sector, it is clear that the country lacks the expected skilled man power and technology.

Energy efficiency and conservation aspects in Ethiopia is monitored, regulated and controlled by "Ethiopian Energy Authority (EEA)", which is mandated via proclamation

[22]. The EEA is authorized for formulating directives and guidelines for energy consumption conservation and efficiency in all economic sectors including lighting, manufacturing, domestic appliances, transportation, agriculture, building and industry. Although most of the activities under progress and draft formulations underway by the agency need some time to be implemented country wide, most of the activities target reducing and regulating the energy sector in terms of safety, conservation, efficiency, quality, source diversification and the like based on standards, directives and regulations in different economic sector of the country including households. However, by far it has mainly focused on, substitution of fuel wood with improved stoves and biofuel sources to narrow the gap between energy demand and supply in the country to improve environmental degradation.

In addition, conferring to the "Second Growth and Transformation Plan (GTP II)" of the country, it positions the need to elevate the country's energy source management, efficiency, diversification, conservation and extenuation of energy losses to international standards [23]. The Government of Ethiopia (GoE) targets to reduce energy losses in the country by the end of GTP II to internationally acceptable average from its present staggering 20%. In order to comprehend that, it states the need for upgrading the existing distribution systems in the country to internationally tolerable energy loss emblematic standards.

However, the document lacks clarity and lucidity in setting any clear and explicit economic sector targets for energy consumption reductions for any economic sector in the country, including lighting. Further, residential target of distributing low power consuming compact fluorescent lamps that was being carried out by the

Ethiopian Electric Power corporation (EEP) some years back at a national level to make energy usage more efficient seems not to be comprehending as planned and is now being halted due to some unspecified official reasons. Further, the recent study on the awareness of lighting efficiency and LED, which was done in AAiT with ALTO University showed that there is a serious awareness gap and lack of preparedness to shift to SSL based luminaires in the country.

Although there are no officially reported or clearly stated national lighting energy consumption standards, guidelines or regulation mechanisms set in the country, there are several huge urban and rural electrification projects planned and underway to boost electricity coverage. Further, there are also numerous planned and already operational projects set to connect Ethiopia to its neighbors and far through a sub-regional power interconnection to export electric energy to generate income. To comprehend this, it is clear that the country needs to focus on the future of lighting, like SSL based energy efficient systems, to save energy. Thus, there is no doubt that the country needs to formulate and follow a national policy/roadmap towards realizing energy efficient lighting systems in the country like other countries in the world.

GLOBAL BEST PRACTICES AND POLICIES

Countries that can and do mobilize all the necessary finance, formulate policies & standards and rationalize private investment in LED luminaire manufacturing capacity are expected to rule the lighting industry and claim the jobs and market it will create globally. Nations like China, that have a good balance of well-coordinated policies, standards, market aggression initiatives and subsidies in LED based SSL luminaires are capitalizing the global LED luminaire markets being leaders of SSL based LED revolutions [21], [24]. Such systematic and

structured bold moves are being taken as a role model by many other countries in adapting and adopting valuable policies, experiences, practices, challenges and successes in realizing energy efficiency in lighting.

In recent years many countries and multi-national organizations globally have actively promoted political and economic campaigns towards LED based luminaire system transformation for improved energy efficiency [12]. Hence, in order to supplement, assist, promote, accelerate and realize this ambitious global march, many countries crafted tidy policies & standards and instigated exemplary projects initiating and supplementing LED based luminaire initiatives and movements. Today, China, Taiwan, Japan, Europe, USA, South Korea, Russia and India are major world LED manufacturers, consumers and beneficiaries [21]. The following subsections highlight on selected global best benchmark practices and policies.

EUROPEAN UNION (EU)

The EU set policy to reduce its carbon emission by a fifth from its amount in 1990's by 2020 and realized that successfully in 2019 [25], [26]. In order to realize this goal, it has set up a wide range of legislative measures and policies in SSL lightings researches and deployments [27]. There are many mandatory and voluntary guidelines and policies put in place to support deployment of LED based luminaires across the European Union member countries.

The EU has also achieved complete incandescent light phase out by September 2012 through its well-crafted environmental policies and guidelines [21]. EU through the Competitiveness and Innovation Framework Programme (CIP) assists and supports SSL based lighting innovations to further their

efficiencies and provide financial access. Further, EU introduced “EU public procurement for a better environment” in 2008 and “EU Green public procurement” by the end of 2011 for traffic signals and street lightings. It also supported different lighting projects. Cities like, Amsterdam, Eindhoven and Tilburg in Netherland, Mechelen in Belgium, Lyon in France, Copenhagen in Denmark, Hódmezővásárhely in Hungary and Birmingham in the UK are some of the best implemented success project examples [21], [28].

CHINA

China developed policies identifying the need for SSL technologies and their unique benefits for the country economy and draws clear national guidelines and principles in how to innovate, develop, deploy and safeguard SSL based luminaires in the country [29]. It introduced incentives for promotion of SSL including via reducing taxations in order to save significant amount of energy [21]. Financial institutions in china provided financial support for SSL based lighting plans in line with the national policies set in the country to boost and penetrate more economic sectors in the country. The targeted economic sectors included street lighting, offices, agriculture, transportation and high technologies. Different organs of the government further provided financial subsidy promotion programs towards shifting to the more energy efficient SSL systems.

China set a national roadmap in phasing out incandescent lighting systems in the country and supported the process through policy incentives and providing financial supports [30]. China formulated an ambitious lighting electricity consumption of an annual 5% reduction and planned to make urban lighting based on SSL to 85%. It also set

government procurements to be using energy efficient lighting products since 2007. Another best practice from china is the economic development area of Tianjin, a city which is solely build from LED lighting under the international initiatives of boosting LED lighting consumption for a better future and efficient energy consumption [31]. Tianjin Economic Development Area (TEDA) was the first municipal in china to join the rapidly expanding international consortium of promoting, deploying and accessing LED lighting technologies across its municipals. The Chinese government also took the initiative to successfully implement ‘21 cities of 10,000 lights program’ targeting to save 220 kWh annually through 1 million indoor and outdoor LED luminaire installation in 10 cities [32].

USA

USA is one of the countries in the world that formulated and benefited from lighting policy strategies and implementations [25]. U.S. department of environment is the leading and responsible organ of US government for setting national polices for SSL programs [33]. The department, supported by the government industry linkage programs, targets to financially support and assist low cost energy efficient advanced semiconductor-based technologies for the lighting industry [34]. It also carved ‘next generation lighting initiatives’ to support and develop more efficient long-lasting lighting systems with minimized energy consumptions.

The US department of energy and its supporting partners in SSL developed a multi-year R&D plan to assist SSL funding of new products from the stage of development to the test and deployment in the laboratories and the market. The plans and policies set frameworks in how to R&D, manufacture and deploy SSL lighting

systems for domestic, commercial, industrial and street luminaires [21], [35]. It also plays crucial role in introducing and creating awareness and giving support in the country. It also introduced incentive measures for SSL based lightings innovation researches and deployments. The US government also forced governmental procurements and deployments in the lighting arena to be energy efficient lighting systems based on SSL. Los Angeles world's first largest, New York, Las Vegas and Seattle LED street light retrofit work projects are examples of the successful implementation of the policies, frameworks and besieged goals [36].

The government forced government procurements to be energy efficient lighting system deployment after President Bush ratified the 'Energy Independence and Security Act (EISA)' in 2007. The EISA further forced roughly 25% greater efficiency for light bulbs in lighting energy efficiency, phased in from 2012 through 2014 forcing phasing out of incandescent lamps since 2012 [37]. The US department of energy forecasted that the LED penetration is projected to reach 84% of all lighting installation in all over USA by 2035. The US realized a combined LED installed in commercial, residential, industrial and outdoor of 19% in 2017, 35% in 2020 and is forecasted to reach 60% by 2025, 76% by 2030 and 84% by 2035 [38].

JAPAN

In Japan, "Ministry of Economy, Trade and Industry (METI)", is responsible for setting national policies and regulations. It has established exemplary policies and roadmaps to replace lightings in Japan by an energy efficient luminaire by 2020 and formulated new energy conservation standards for lighting equipment and light bulbs by 2027 [39]. Japan expects all new luminaire shipments to be based on SSL technology from 2020 onwards and all

building and outdoor luminaires to be replaced via SSL based technologies by 2030 [37]. SSL based luminaires penetration reached 18% in 2010 and is thriving in recent years. METI introduced tax incentive measures to foster LED luminaire deployments for small and medium sized enterprises. It also introduced economic stimulus package to foster energy efficient air conditioners, lightings, refrigerators, and televisions [29]. This program was crafted to minimize greenhouse-gas emissions and energy consumption across Japan.

After Fukushima disaster in 2011, power shortage and public pressure forced Japan government to seek better ways for reducing energy consumption and realized 50% LED lighting deployment [40]. Further, under the Green purchasing law, the Japanese government encouraged eco-friendly lighting deployments to reduce environmental impact and pollutions. The policies and law set by the government forces green purchasing by the government, public organizations, local governments, business and citizens of Japan. The government further supports Light for the 21st Century lighting, medical equipment, and therapeutic techniques projects, which are based on LED's.

KOREA REPUBLIC

The republic of Korea formulated "Low Carbon, Green growth" strategy on 2009 which mainly focuses on SSL luminaires [41]. It invested significantly on new LED lamp installation and retrofit works in the country. It also set LED lighting expansion and distribution policies making them mandatory in commercial and public buildings. The government of Korea continuously revised and updated its policies and regulations according to the LED technology development and market reality. It has also introduced lucrative incentive measures and set ambitious goals in its light

and lighting to be based on LED systems. One good indicator is, its plan to equip Seoul city government office to be 100% LED based lighting by the end of 2018 and accomplished it successfully [42]. The government of Korea has also significantly expanded LED lighting of the country through boosting government procurements.

Furthermore, through the 'LED 2060' plan the government targets to reach LED lighting penetration of 100% in public institution and 60% countrywide by 2020 and is aggressively working on it [43]. It puts a way forward and determined to realize the ambitious targets via financial funding and supporting different projects. It is providing low-interest loans and tax initiatives all over the country for efficient SSL lighting research, development and deployment. It has also launched a major 'The Photonics Industry Project' project, which deals with the lighting and photonic industry of the country.

SOUTH AFRICA

South Africa is the first African country who banned incandescent lighting products and set a national policy to identify and support efficient lighting system in key areas of its economy. It has set a target to phase out its incandescent lighting products completely by 2016 [44]. However, a policy and a framework which specifically focuses on LED lighting is yet to be formulated and effected.

BRAZIL

Brazil also sets exemplary polices and laws including 'Law No.10295 – Energy Efficiency Law, which set out minimum energy performance standards for equipment and buildings', 'Law No. 9991 – Energy Efficiency Programs of Distribution Utilities' and 'PBE – Brazilian Labeling Program, which focus on energy

conservation through informative labels about energy efficiency of equipment sold in the country' to reduce its energy consumption in different sectors including in its lighting [45]. The government also introduced government procurement directions towards energy efficient systems in public investments. Through its 'Brazilian Energy Efficient Lighting Program' it has also drafted a framework to step by step transit towards less energy consuming lighting systems countrywide [46].

INDONESIA

Indonesia also laid national policies including 'The Energy Law (Law No. 30/2007)' and 'National Energy Policy (Presidential Regulation No.5/2006)' [47]. It has also standards for minimum energy performances in different electrical appliances including the lighting sector. The government further introduces fiscal and tax exemptions for investments and imports of low energy electrical utensils to meet its energy conservation plan. It also set mandatory requirements for energy efficient lighting systems in its regional governments, agencies and departments and commanded their monthly energy usage reports.

INDIA

India also realized the importance of SSL lighting transition and set its first ever policy framework in 2010 [29]. The frame works are primarily set to overcome the barriers and obstacles that the transition could pose including, technological, incentive, standard and policy barriers. Indian ministry of commerce drafted a law that is advisory for all medium & small cities and municipalities street lighting with LED based systems via funding to more than 180 bodies. The government introduced incentive measures via subsidizing and forming LED test facilities for LED lighting across the

country. It also set roadmap for government procurement in its major investments of the future [48].

BOEING, VSMPO-AVISMA, BRITISH PETROL AND SHELL

Multinational companies like Boeing, VSMPO-AVISMA, Shell and British Petrol have also joined the march in introducing and deploying LED based lighting across the globe supplementing the effort of governments. These proved that not only government organs and bodies but also companies can play their crucial role in LED lighting deployment and energy conservations. Shell and British Petrol (BP) are retrofitting their gas stations with LED based luminaires to assist the march moving towards to energy efficient eco-friendly lighting systems in the world [21]. These retrofit works are expected to cut lighting energy consumption by 50% with an increased safety and comfort to users.

Further, Boeing Manufacturing plant located in Ural (UBM), and VSMPO-AVISMA Corporation, one of the largest metallurgy industries in the world, also replaced their lightings to LED based systems in the support of energy efficient manufacturing. Consequently, the LED retrofit work both resulted in 60% lighting intensity increase and safer working environment on top of the energy consumption reduction [49]. Further, Boeings Utah Recycler hanger was also retrofitted with the state-of-art LED based smart lighting which was also designed to boost its sunlight help for artificial lighting [50]. Further, Boeing has set a framework for its future new buildings to use only energy efficient LED based lighting technologies whenever possible, in support of eco-friendliness.

ROADMAP FOR SSL MANUFACTURING

Production of SSL products are tough for developing countries, like Ethiopia, as

patents, Intellectual property (IP) rights, and confidentiality issues, makes it hard [51], [52]. Further, manufacturing of LED electronic drivers has diverse manufacturing steps and processes and electronic circuit integrations. Generally, SSL manufacturing involves two stages. The first stage comprises component collection, package production and LED chip manufacturing. The second stage encompasses assembling of the LED luminaires. LED chip manufacturing is the most complicated and capital intensive of all [53]. However, experiences from nations like India, China, Korea and USA showed that by formulating the necessary policies, standards, and mobilizing incentives, investments and starting from SSL assembling leads in to becoming a leading SSL manufacturer [29].

Korea supports public investment in SSL industries and offers tax incentives. It has also funded numerous SSL based R&D and market roadmap development works. USA has financed several innovation competitions, awards and recognitions accelerating and inspiring SSL innovations. India has significantly invested in SSL assemblies first and later worked extensively in empowering SSL based production and skilled manpower capacity building. It has policies promoting SSL based luminaire systems and subsidization of SSL establishments. China has heavily invested in the SSL industry via crafting policies and strategies that support the steadily development level of SSL industry, implement incentive policies, support SSL technology innovations, conducted SSL introduction, education and training boosting its skilled manpower in the sector.

Hence, developing nations can start from SSL assembling via promoting SSL luminaires with incentives and supporting domestic assembling. In the long run, by significantly investing on education,

awareness, capacity building, and attracting major corporation in the SSL industry, they can steadily grow to SSL manufacturing. Further, the fact that SSL manufacturing cost is dropping exponentially since 2000, paves the way and presents an opportunity to put their finger prints in the area [29].

CONCLUSIONS

Indoor and outdoor lighting matters in energy conservation marches as it solely accounts for about 1.9 billion tons of carbon dioxide emission worldwide and almost a fifth of electric energy consumptions. On average 40% reduction in energy usage in this sector is possible via adopting LED based lighting systems. It is equivalent to reducing carbon dioxide emission by staggering 760 million tons globally. With smart and advanced LED luminaires it is even possible to achieve as high as 80% energy consumption cut.

Given its capacity to accomplish significant energy consumption cut, boost users' safety and comfort, minimize environmental impact, LED luminaires are crucial and one of the cutting age technologies of the 21st century with huge potential of carbon dioxide emission cuts and environmental pollution. Among the many stakeholders in the lighting arena, governments have the highest responsibility for the transformative scale-up and overcoming the primary obstacles of deploying LED lightings. This will bring immense economic and environmental benefits and also improved quality of living.

Cities all over the world are expected to adopt and follow economic policies and frameworks that help them transit their lighting systems from the traditional lamps to the LED based systems in the near future. Today, politicians, policy makers and leaders all over the world have the perfect

opportunity to shape the future of our planet with a huge visionary step of promoting and enforcing LED lighting with long lasting positive impacts, more than ever before. Governments and multi-national corporations are expected to be the main propellers and prime movers of the LED market demand.

It is a must that governments, including GoE, and corporations all over the world be committed to make LED lighting as an essential part of their energy efficiency policies and frameworks as it offers many positive impacts. LEDs market barriers should be cleared and supported via different organs of a government in order to accelerate their market share and penetration for a better economic and environmental returns. Some of the schemes can be;

- Government procurement: as different government organs are one of the main consumers of artificial lightings, they should set a policy in which they could become the prime adopters, procurers and deployers of LED lighting systems.
- Incentive measure: to scale-up LED lighting adoption and deployment, nations administrations and states in the world should craft different incentive measures to overcome economic and financial barrier.
- Education and capacity building: nations should enlighten their citizens regarding the advantages of LED luminaires in comparison to the traditional lighting system and create strong man power in the lighting sector research and development.

- Setting lighting standards: different agencies and institutions in any country responsible for lighting should set relevant lighting standards that favors LED technologies to speed up their deployments.

Therefore, the government of Ethiopia and its branches responsible for energy efficiency and conservation should look into and thoroughly investigate policy frameworks and global best benchmark practices in order to benefit and explore SSL based LED luminaire scheme benefits. Furthermore, it should also benchmark these global prolific practices in order to formulate, adapt and/or adopt policy frameworks and roadmaps in to its national policies and plans.

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