Shaping Future Green Cities: LEDs Technology adoption as an option for India

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Abstract

The sustainable development in developing and newly industrialising countries (China, India, South Africa, and Brazil) is central issue for policy makers, decision makers, academic, and planners. The attainment of sustainability has become a challenge for rapidly urbanising India. The paper focuses on the challenges for building less energy consuming cities. The cities use different technologies for lighting purposes but which technology can decarbonise them in future. Moreover, the question is, how a new technology, LEDs (Light Emitting Diodes), for lighting can shape the future green cities. What are the drivers which can determine the adoption process of LEDs technologies for lighting in India? Further the paper focuses on identifying and analysis of barriers in adoption of this technology in India. There are different technologies for lighting, but LED technology is a good option for India as well as world for shaping future green cities. There are major drivers for adopting such a technology like energy saving, emerging knowledge and awareness, better visibility and clarity, policies and new initiatives, eco-friendly and low carbon emission, long life span and long term cost effectiveness. However, the process has some barriers like high initial cost, low risk behaviour and faith deficit, culture and attitude, and existing technological regimes. Nonetheless, these barriers can be softened through collaborations, partnerships, and knowledge sharing among stakeholder along with strengthening the system through better networks.

Keywords

LED technology, energy saving, foresight, sustainability, culture

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1. Introduction

The energy demand is rapidly increasing in developing countries due to various factors including development. The present process of economic development and urbanisation in fast growing economies (China, India, South Africa, and Brazil) is increasingly adding to carbon (CO_2) emission, in lesser degree SO_2 and NOX. The urbanisation leads to more use of energy for street lights, housing lights, air conditioning, and heating. The lighting is an undeniable aspect of modern civic life. 19 percent (approximately one fifth) of the world's electricity is used to light up our lives, whether at home, in the office, in the shopping mall or even out on the street. Moreover, lighting accounts for city's 38-40 per cent of total electricity consumption in India (Express News Service, 2008). Whereas, according to the U.S. Department of energy, during year 2008 US has used 19 percent of the total electricity consumption for lighting (EIA, 2010). The lighting alone is responsible for huge greenhouse gasses emission in the environment. Therefore, effective and efficient lighting is a prerequisite for the holistic development of any city as well as for creating a feeling of well-being and security. However with the increasing cost of electricity and concerns of global warming, intelligent power consumption is the need of the hour.

2. Shaping less carbon intensive Future cities

The increasing carbon emission essentially lowered to a great extent as compared to the existing scenario of lighting in upcoming future cities. The less carbon intensive future cities signify that they produce less greenhouse gasses (specifically carbon) by use of energy.

But, How can they be shaped?

The process of shaping future less carbon intensive cities needs to bring about innovations through application of technologies and knowledge to the existing lighting infrastructure. Moreover, they have to manoeuvre their policy approach and culture for adoption of innovations. Moreover, it needs a technological shift or serious disruptive technology that should be introduced. Thus, by creating intelligent lighting system in future cities can help them in turning to smart cities with less carbon emission.

Green Future (Smart)) Cities and intelligent lighting

The concept of 'smart city' in this paper refers to the level of digital infrastructure provision and to the notion of the city functioning as an autonomous entity capable of adapting itself to external stimuli. The smartness and intelligence of such cities should not be taken only as a measure of ICT network efficiency, but also include other forms of

technologies applied for lowering level of carbon emission.Therefore, it needs an intelligent lighting system which should be focused on serving the people rather controlling or limiting functional autonomy.

The intelligent lighting system (ILS) is a network with high intelligence built through collaboration and hybridisation of technologies like Software, Sensors, (smart) LEDs[2], and Photo Voltaic Cells along with other electricity related technologies. Wherein, the smart LEDs go beyond the turned on or off properties of other present technologies like Incandescent lamp, compact fluorescent lamps (CFLs), and induction lamps. It can be turned like a radio or TV volume. It has unique controllability by users which include control over the emission spectrum, temperature, colour, temporal modulation, polarisation, hue and spatial emission pattern. The ILS has remote monitoring system which collects and reports the real-time performance data to each LEDs fixture. Therefore, any equipment failure or malfunctioning can be tracked, logged and synchronised with maintenance work program of the concerned city municipality. Moreover, the ILS provides information about the electricity usage in KWh (kilowatt-hours) by each LED fixture, particular street, specific neighbourhood, and whole city.

However, the maintaining intelligence of such intelligent system and city depends on adaptability of the society and social system, and integration of local actions, regional and national visions. Moreover, it needs synchronisation and synergies with other systems.

Therefore, when such an intelligent lighting system is deployed in future cities that can help to do better planning, reduce financial losses, eliminate theft, and get better light. In addition, it helps in controlling the intensity of carbon emission in future cities. But this depends on what kind of lighting technologies are deployed by these cities. That means the technological regime which is less carbon intensive would be a better option to shape cities as less carbon intensive. Therefore, can LEDs technology be best option?

Is LEDs Technology a solution for decarbonising smart cities and intelligent light system?

There are different technologies deployed at present in lighting sector. The major technologies which are installed world over include High pressure sodium vapour lamps, mercury vapour lamps, incandescent lamps, T5 lamps and metal halides lamps. The two

[2]An LED (light-emitting diode) is a solid-state semiconductor device that converts electricity into light. It generates light at a precise wavelength when a current is applied. Each diode is about 1/4 inch in diameter and uses about ten milliamperes to operate at about one-tenth of a watt. Multiple LEDs are networked together in a single fixture to generate (in combination) the appropriate light output for each particular application.

technology, LED and Induction lights[3], are emerging technologies in this sector with high energy efficiency with high luminosity. However, induction lights are not so sturdy and can stand with adverse vibrating conditions. Additionally, LED bulbs also contain no mercury and fewer toxins, such as iodine and lead where as HPSV and metal halide bulbs packed an average 15 milligrams of mercury each, with induction lamps averaging 6 milligrams.Moreover, they don't have novelty of LED which provides control to the user by integrating into an intelligent light system. Therefore, such novel capabilities, that make them extremely useful when going for the replacement paradigm, can result in tremendous benefits to society and humankind.

This program has shown some success in decarbonizing these adopter cities. The reflection of success can be seen in words of Charles Meeker, Mayor, City of Releigh, North Carolina (USA), '*the economic benefits for municipalities to invest in LEDs are clear as they save energy, reduce environmental impact and improve the quality of light. As leaders in one of America's fastest growing cities, it's our civic responsibility to invest in the future and ensure the highest possible quality of life and safety for our citizens in generations to come. We believe that the cost savings and benefits of LED lighting are real and achievable today*' (LED City, 2010). Another supporting view is of Steve Andresen, Mayor of the City of Port Lions. He says 'the lighting is superior, and the savings on our energy bill will have a positive impact on our City budget for many years to come' (LED City, 2010).

The governments and industry in different countries are working to evaluate, deploy and promote LED lighting technology across the full range of municipal infrastructure. The LED City program is one of such program. The key objectives of this program include saving energy, protecting the environment, reducing maintenance costs and providing better light quality for improved visibility, clarity and safety. The major participant cities of the world in this program include Tirupati, India; Tianjian and Huizhou, China; Torraca and Apecchio, Italy; Bremen, Germany;Gwangju, South Korea. USA is ahead to other part of the world in this program wherein its cities already included are Raleigh, Chapel Hill, and Durham, North Carolina; Ann Arbor, Michigan; Austin, and Fairview Texas; Anchorage, Alaska; Toronto and

[3]Induction light is basically fluorescent lamp with electromagnets wrapped around a part of the glass tube (external induction lamp), or inserted inside (internal induction lamp). In external inductor lamps, high frequency energy, from the electronic ballast, is sent through wires, which are wrapped in a coil around the ferrite inductor, creating a powerful magnet.

Induction light are discharge lamps, where the idea is to get mercury or other atoms to elevate their energy level, then discharge a photon as they fall back to normal. Induction lamps differ from fluorescents-their closest relative in the lighting family-in the way they energize the mercury atoms. Instead of striking an arc between electrodes in a tube, an electromagnetic field is generated by a carefully shaped coil. The field created by the coil induces a current flow in the gas/mercury blend within the lamp. This current excites the mercury atoms and starts the flow of photons. Mercury atoms emit UV photons; phosphors lining the lamp wall absorb the UV photons and in turn emit visible photons.

Welland, Ontario; Indian Wells, California; Danville, Virginia; and Boston, Massachusetts (LED City, 2010). This program has shown some success in decarbonizing these adopter cities.The reflection of success can be seen in words of Charles Meeker, Mayor, City of Releigh, North Carolina (USA), '*the economic benefits for municipalities to invest in LEDs are clear as they save energy, reduce environmental impact and improve the quality of light. As leaders in one of America's fastest growing cities, it's our civic responsibility to invest in the future and ensure the highest possible quality of life and safety for our citizens in generations to come. We believe that the cost savings and benefits of LED lighting are real and achievable today*' (LED City, 2010). Another supporting view is of Steve Andresen, Mayor of the City of Port Lions. He says 'the lighting is superior, and the savings on our energy bill will have a positive impact on our City budget for many years to come' (LED City, 2010).

The response of the users emerged with very high satisfaction in a study of LED fixture replacement in Releigh conducted by Mindwave Research of Austin. The 76 percent of the respondents perceived the garage as 'very safe' after the LED fixtures with bright white light were installed.

In addition, a U.S. department of energy report on LEDs reveals that the widespread adoption of the technology over the next 20 years could save 1,488 terawatt-hours of electricity, which at today's (declining) prices, is worth roughly $120 billion. This energy saving by solid-state lighting is equivalent of 24 new power plants. Such a saving could reduce greenhouse gas emissions by 246 million metric tons of carbon (Nusca, 2010). According to Walter Derzko '*Engineers and scientists predict that widespread use of LEDs over the course of 10 years would save more than $1 trillion in energy costs, eliminate the need for nearly a billion barrels of oil over 10 years, and lead to a substantial reduction in emissions of carbon dioxide, the most common greenhouse gas.'*

As energy efficiency becomes increasingly important for controlling costs, improving energy independence and reducing environmental impacts, LED lighting will become the world's leading source of manufactured light. One of the most compelling aspects of this lighting system story is that LED lighting will grow globally using the existing infrastructure. We don't have to invest billions of dollars in new power grids, new wires, new switches or new networks. The latest research data indicates that a decade from now, nearly half of the commercial lighting business will be owned by LED lighting (Watkins, 2010). Study (cradle-to-grave assessment of LEDs) streetlights by University of Pittsburgh researchers reveals that the increasingly popular lamps strike the best balance between brightness, affordability, and energy and environmental conservation when their life span-from production to disposal-

is considered (Science Daily, 2010). Therefore, LED light technology has scope to emerge as a solution for decarbonising smart cities and intelligent lighting system.

3. Drivers for adoption process of LEDs technologies (for lighting in India)

The demand of lighting is growing not only for street light, housing, offices, big malls, restaurants, business centers, recreational centers, and industrial premises in urban areas but also from rural areas for children/students studying, houses, village street and night agricultural activities.Therefore, LEDs technology can fulfill this demand with high energy efficiency and cost effectively, if taken up on mass scale. (Economy of scale will work well here). Moreover, what could be most important divers for the adoption process of LEDs technology in India?

3.1. Energy Saving

The low power consumption by new technologies in lighting sector is an important driving force for installation of energy efficient lighting system in India. The LED light luminous efficiency is 110 lumen/watt (Singh, 2010) compared to 65-80 lumen / watt of CFL (compact fluorescent lamp), 45 lumen /watt of Mercury vapour (MV) and 75 lumen /watt of metal halide (MH) or 94 lumen/watt of sodium Vapour(HPS) (Superlite Luminaries, 2010). It is significantly higher as compare to other sources of light like HPS, MV, Fluorescent and incandescent lamps. Therefore, more lumen per watt means more light is produced by the light source. To produce a particular level of lumen from light source for lighting street or office there is less need of power. LED lights are energy-efficient that can save upto six times energy in a year as compared to CFLs technology (Singh, 2010).

One of the project implemented (in two streets of Tirupati, Andhra Pradesh, India) by Avni Energy Solutions under LED City program estimates energy savings of more than 70 percent compared to traditional sodium vapor street lighting. Tirupati Municipal Corporation estimates a monthly savings of 6,187 units of electricity, which is equivalent to 288,000 Indian Rupee a year or 6,500 USD annually (LED City, 2010). Such a project became reality due to network and collaboration of corporations, municipalities and knowledge partners.

3.2. Emerging knowledge and awareness

The LEDs technology adoption process is becoming stronger and clearer with the availability more information and knowledge through media, research reports, studies, conferences, workshops, and policy debates on energy saving and climate change. The policy makers and high level decision makers are more informed through industry-academia-government

interactions on new technologies, energy, environment and sustainability. Moreover, India has started organizing annually LED Summit cum conference cum exhibition since 2009 that provides a platform and opportunities to exchange knowledge about technologies and innovations among different stake holders. Such kind of large exhibition is an opportunity for different companies to show their products to consumers. The press and electronic media cover such kind activities extensively with a persuasive appeal for adoption of such kind of technology for better future. The ministry of new and renewable energy is steering the effort for and transfer and diffusion of knowledge and it is bringing paradigm shift in technology where LED technologies adopted from rural areas to cities. While, interaction with people reflect that a significant number show the awareness about the availability and usefulness of the technology.

3.3. Better Visibility and Clarity

The light sources which are closer in properties to sun light are considered better for application for light. The LED lights have better performance on parameters which determines the level of visibility and clarity in night (Singh, 2010). The main parameters include colour rendering index (CRI) which signifies ability to reflect the true colour of the surface by a lighting source. A light source with better CRI means better colouring rendering or less colour shifting. CRI between 75 and 100 is considered as excellent, as LED also falls in this range. On the other hand HPS, MV and incandescent lamps have less than 75 CRI. A comparison between figures 1 and 2 clearly demonstrates CRI difference between the white light and HPS light.

Figure 1: Colour reflection and visibility of LED light in night

The all colour strips under the LED light in figure 1(on right hand side of the pole) are clearly visible where as under the HPS light in figure 2 brown, blue and green colour (from left to right) strips cannot be differentiated. Moreover, other colors also get yellowish. The above picture shows clearly the colours, more brightness, and clarity. Even cracks in the pavement are clearly visible. In contrast, HPS light does not show much clarity in terms of colours and cracks visibility in figure 2.

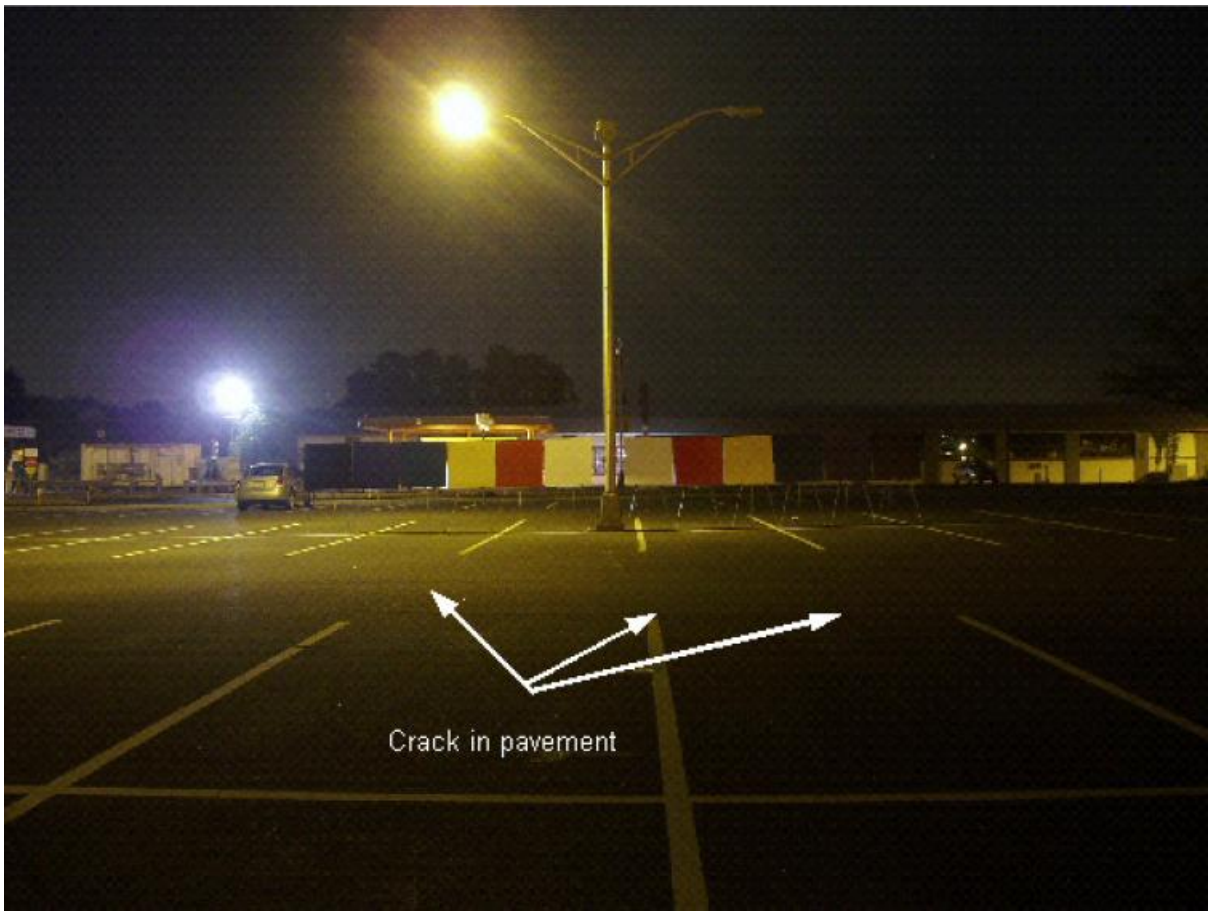

Figure 2: Colour reflection and visibility of HPS light in night

The change in color and low clarity along with low brightness causes problems to driver while they drive at high speed in cities which can lead to accidents. In capital city, Delhi, late night such Car and Truck accidents have happened due high speed driving and low visibility due to HPS vapor lamps. Therefore, the decisions about the adoption of LED technology are positively influenced by such kind of qualities.

3.4. Policies and New initiatives

The policies for promotion of energy saving technologies are motivating technology adopters to use LED lights to gain benefits under the different government schemes. Moreover, Government of India in this year's budget proposal has almost removed import duties on imports of the LEDs products. The ministry of new and renewable energy has been created to pursue adoption of innovative technologies. It has already started funding projects which are based on solar power and LED lights in rural area and cities through different state governments and government agencies. The available funding with government for adoption of such technology pushes for decisions to take pilot projects at small scale to test the technology.

The ministry of new and renewable energy has begun to motivate industry to manufacture LED products in India. Consequently, Indian industry has grabbed this opportunity and that has resulted in emergence of many new ventures and diversification in existing firms in lighting and energy sector. Therefore, this kind of synergic growth is helping in making product available in market.

3.5. Eco-Friendly and less Carbon emission

The light system produces a number of hazardous materials as a waste like mercury, sodium and glass. However, the LED lights do not contain mercury (Webster, 2009) which is dangerous to human and animal health. Further, the accumulation of mercury in the environment and the food chain is a serious environmental and health hazard. Moreover, LED lights are almost completely recyclable and the electrical waste management problem can also be addressed by shifting to LED technologies in different Indian cities. Therefore, level of hazardousness of a lighting system is important driving factor for LED technologies. The government policies and environmental activists have greater support to LED lights for its green properties.

The adoption of LED technology results in the saving of energy that mean less energy consumption for the providing lighting system at the same illumination. Consequently, less quantity of carbon is emitted by same system. A row of 24 brand new street lamps equipped with LEDs supplied by Avnet Electronics Marketing India is now saving 10th Main Street in Bangalore's Sadashivnagar neighbourhood up to 70 per cent of the energy and money burned by conventional lights. These are the first LED street lamps installed in Bangalore (Itvior, 2010). Cary Eskow believes that energy efficient LED lighting could help India to achieve the voluntary 20-25% carbon reduction commitment made by minister of state for environment and forests Jairam Ramesh in the run up to the United Nations Climate Change Conference Copenhagen 2009 (Itvior, 2010). The carbon emission rate is 1kg per kWh power production from coal in India which is imported from Australia. The carbon emission rate is more than 1 kg per kWh for lignite based power production. Therefore, with saving of 100,000 kWh power with use of LED can result in reducing 100 tonnes of carbon emission. Hence, such a scenario is an additional force to the process of adopting LED technologies for Indian lighting infrastructure.

3.6. Light system with long life span

The LED lights solid state light and do not have any filament like incandescent laps. Consequently, they are good vibration resistant and have low starting temperatures, making them a good choice for rugged operating environments. Therefore, they do not get damaged

and defunct with any kind vibrations. LED lights have long life that varies between 50,000 - 80,000Hrs (Jamal, 2009). When LEDs lights are used for 10 hours a day, the life can be more than 13 years that is 5-10 times more than the working life of traditional sodium or mercury lamps (Singh, 2010).

The durability or life span is important factor as driving force for making selection out of different kind of lights like low pressure sodium lamps, high pressure sodium lamps, mercury vapour, metal halide, incandescent bulb, and fluorescent lamps. None of among all these lighting technologies provides life span more than 20,000 hours. This feature is a potential trigger for the demand of the LED light in India.

In addition, LED lights are non-flicker, shock resistant quick light up in micro-seconds, compact, ideal for use in applications that are subject to frequent on and off cycle, and maintenance free (Jamal, 2009). Such feature make LED as part of better choice as efficient lighting system for all weather usage.

3.7. Long term cost effectiveness

The cost involved in life cycle of LED is significantly low as comparison to other kind of lights. Though, LED loghts have initial cost quite higher than other lights. But the operating cost is too less for LED lights because they need less maintenance and zero replacement till 12 years. Therefore, it saves labour cost for maintenance and replacement. As figure 2 shows that the life cycle cost for different types of lights in US wherein LED light is most cost effective.

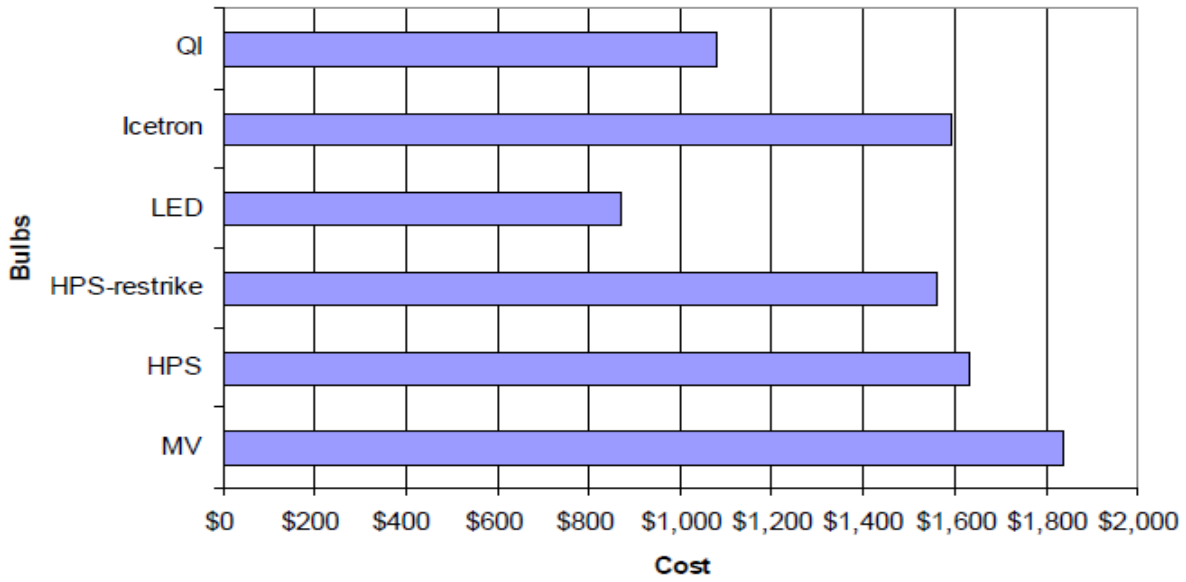

Figure 3: Total present value cost during 20 years LCCA (for one bulb) (Szary, 2005)

In India too LED light Life Cycle Cost is significantly low as it includes initial lamp or retrofit Cost, labour relamping cost, lamp relamping cost during life cycle and electricity cost. At the micro level, the use of LED lights can bring down an average citizens tariff by 45%. Mumbai's power consumption on lighting, which includes residential, public and commercial usage, amounts to around 850 MW per day. According to Ashok Pendse, If LED lights replace the existing Compact Fluorescent Lamps (CFL) at commercial and residential establishments including civic lighting then the city can save up to 225 to 300 MW every day (Times of India, 2010). It means Mumbai can save more than Rs 20 million per day. If the same argument is extended to 50 largest cities of India then this saving can be uptoRs. 400 million per day. Therefore, annually it can be Rs. 146000 million per annum in India. Though, this factor is very important drivers but still unable push much faster due higher initial cost. Therefore initial higher cost of LEDs lights becomes a barrier in the adoption process.

4. Barriers in adoption of LEDs technology (in India)

There are some factors and issues which come as hurdles in the process of LED technology adoption in lighting sector. However, India is developing with its higher economic growth but it fully does not turn into paying and investment capacity of consumers of lighting system. Therefore, what are those barriers and how they affect the process of LED technology adoption in India?

4.1. High Initial Cost

The initial cost of the LED lights is two and half to three times higher than the other technology based lights like HPSV, MV, CFL, and incandescent lamps. It is perceived too much higher by the consumers like government, industry, household users, and NGOs. The small scale users for house lights cannot afford such higher prices. But rising prices of electricity, incentives by government, lowering taxes on LED products, mass scale production and long hour's power cuts in cities can soften this barrier in upcoming future. Moreover, the low requirement power to operate LED lights can help decreasing the cost of maintaining power back up in terms of generator, inverter and batteries. For instance, resident of Gurgaon (neighboring city of capital city, Delhi) city pay more than 12 rupees (20 Cents) per unit to private parties in contrast to 5 rupees (8 Cents) to grid based power suppliers. There are 3 to 5 hours of power cuts every day that depends on season and demand of the power. Therefore, such conditions can also turn higher initial cost barrier down.

4.2. Low risk taking behavior and faith deficit

The new products and technologies carry their own initial adoption risks and benefits. The LED technology also has its own risk, as it needs more initial investment and users are not sure of its benefits. The consumers do not have faith on quality of the products and even regulatory system does not help them to create such a faith. People have experience that what they for is never given then in return. Therefore, there is faith deficit in mind of the consumers. Even, the decision makers and administrators in government at local and municipality level unable to garner the confidence for benefits of adoption of new technology like LEDs. Moreover, they do not want to take new initiative and innovative steps which may involve any kind of risk.

Further, the culture of Indian hierarchical system of governance and corporate also becomes important for the process. The hierarchy is rigid with less freedom to think, discussion, and take new initiatives. Thus, people of the system are more interested in maintaining good relations with boss and colleagues without taking any risk and new initiatives. They want to keep quiet on any new initiative and change. Consequently, unwelcoming attitude to innovation become a key obstacle to any kind of new project, initiative, plan and program that promotes LEDs or new technologies.

4.3. Culture and Attitude

India has witnessed a dichotomy over the adoption of new technologies during last 20 years. There is one part of attitude towards technology adoption which enforces for the adoption of new technologies. On the other hand, there is one part of attitude toward technology adoption which discourages adoption. The dividing line is created by the value assigned by the people to the technology and products. Those technologies, which are considered as directly and closely related and linked with esteem, ego, and relative societal status, have higher rate of adoption against those who have weaker such links. This attitude is well explained by faster adoption of ICTs technologies in India. People draw higher self-esteem, self-satisfaction and higher relative societal status when they own mobile phones, desktop computers and laptop computer. This also demonstrates a strong imitation behavior in adoption of such technologies irrespective of economic conditions. In such a situation people are ready to take risk as well spends beyond real paying capacity. One can see a mobile phone holder/adopter from urban to rural area, rich to poor person, and child to old person irrespective of his religion, region, caste, class, faith, and gender. On the other hand, LED technology does not draw any such kind of values for the people. Therefore, their behavior for adoption of new technology like LED becomes a barrier.

The higher initial cost of LED adoption has its roots in attitude towards time in Indian culture. The attitude towards the time in society of India is more related to living in present and looking to the past. People have less orientation to future from medium term to long term. They assign more value to closer time to present while they make important decisions. Therefore, people do not give importance to benefits in long terms and they are ready to adopt those technologies which have less cost in short term but higher losses and fewer benefits in long term in comparison to that technology which has more cost in short term, and more benefits and fewer losses in long term. Such societal characteristics create obstacle in technology adoption process in the country.

4.4. Competitive technologies and existing technological regime

The present technological regime does not allow emerging the new technological regime until new regime acquires a certain level of capability which can push aside to the existing regime. Hence, it led to the paradigm shift. The present technologies like CFL and Metal halides pose very high level of competition in terms of cost, product availability, business network, product knowledge, experience and habit to use the product, advertising, more investment, and more retailer commission. The decreasing prices of the present lighting technology (CFL) makes difficult to adopt the LED lights. As CFL also had the same scenario five years back when it was not affordable. However, it creates confidence to view that after five year the cost of LED technology too will come down. Therefore, the competition between different technological regimes is rising but LEDs technology regime is likely to take over the existing regimes within five to seven years.

5. Conclusion

In this paper an attempt is made to systematically understand how the future less carbon intensive cities can be shaped. Therefore, the future less carbon intensive cities can be realised through innovations and new technological adoption. But adoption of new technology like LED for Future Green (smart) Cities need a collaboration and cooperation among stakeholders within the system. The new technological regime requires a societal and structural change for its emergence. It can be concluded that LED is a very good option for decarbonising the future cities. Therefore, it is a good option for India to decrease the carbon emission for shaping up future cities with health environment and intelligent lighting system. Moreover, India has strong accepting tendency for LED technology for lighting sector. This is reflected by strong driving factors for LED technology adoption process. Somehow, the technology has a strong barrier in terms of initial higher cost for the adoption of this energy saving technology. But, with strong government support in terms of taxes,

policy, subsidies, and collaborations, and mass adoption with economy of scale (as happened to CFL technology during last five years) along with network development in system can soften this barrier. In addition the change toward a less hierarchical, less static and more open culture, integrating a long-term perspective on energy consumption is already taken place and can be stimulated by means of policies and debates. Consequently, India will show high rate of adoption of LED technology in upcoming future and led to paradigm shift in lighting sector.

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