Market perception of efficient light source technologies: a case study on sustainable energy transitions in Sri Lanka

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Abstract: Developing countries are transitioning towards more sustainable practices with the hopes of increasing energy efficiency and savings. A conceptual model, questionnaire surveys and structured interviews were used to assess the current situation of the Sri Lankan market on their perceptions towards transitioning to light emitting diodes (LEDs). The results of the study suggested that the main key factors influencing choices on artificial lighting included: high price, size, limited LEDs knowledge, low intervention of apex bodies, and individual perceptions of the technology. Regardless of the multiple benefits of LEDs, customer acceptance for LED solutions was minimal in comparison to other emerging energy technologies and lighting solutions. This paper suggests that energy policy related apex bodies should incorporate some incentives to popularise LED solutions in the market. The methodology employed and the recommendations derived can be used as guidelines to similar types of energy-related green research in the developing nations.

Keywords: light emitting diodes; LEDs; sustainability; key success factors; market acceptance; energy savings; Sri Lanka.

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1 Introduction

The implementation of energy efficiency solutions is considered one of the simplest and most reliable methods for the reduction of greenhouse gases and environmental impact. The transition towards more efficient, commercial energy sources and technologies is currently gaining popularity throughout the developing world (Elias and Victor, 2005). The introduction of energy-efficient solutions such as high brightness (HB) technologies have contributed towards this transition. Light emitting diodes (LEDs) are an example of HB technologies, they are fourth-generation light sources, whose inception began in the 1960's, yet have recently been used as alternatives to indoor and outdoor lighting (Hazrati, 2019). LEDs are semiconductors that emit light when a potential current is applied across the device.

Countries worldwide have adopted HB LEDs based lighting solutions to help governments, utilities, and facility owners achieve their green objectives and significantly reduce their operating costs (Jefferson, 2006). LEDs offer the advantages of increased lifetime, lower power consumption, higher brightness and better spectral purity, when compared to traditional devices (Kovac et al., 2003). Silicon is used as the key material for HB LEDs due to its excellent thermal stability and optical properties (high light transmittance). Hence, increasing its suitability in new applications such as backlighting for displays, automotive lighting, general lighting and new consumer products like flash

for camera phones or compact projectors (Chang et al., 2012). In general, silicon in HB LEDs, provide better electrical and environmental protection, increasing light-extraction, minimising heat build-up and forming lenses that provide options for specific light distribution patterns and intensities. Furthermore, products created with silicon offer good compatibility with standard LED manufacturing techniques and provide enhanced lifetime and reliability (Yang and Yan, 2013). In the future, HB LEDs are expected to become brighter, last longer, cost less and be compatible with lead-free processing (Gao et al., 2007).

Even tough, LEDs have several advantages, many challenges are still faced in attracting consumption, due to concerns related to price and lack of information (Chang et al., 2012). On the other hand, a driving force for the growth of LED lighting is the lower energy consumption, which in turn could potentially result in lower energy bills (Kovac et al., 2003). As an example, the higher efficacy of the LEDs reduces power consumption by as much as 88% and dramatically reduces carbon emissions required to generate and transmit the electric power for lighting (Reineke et al, 2009). The transition from traditional incandescent and fluorescent bulbs to LED lighting could save up to 10% of the total current energy consumption worldwide (Almeida, 2014). Economically, reports estimate that LEDs are cost effective while increasing efficiency when used in commercial/residential lighting markets compared to incandescent, fluorescent and high-pressure sodium bulbs (Adkins et al., 2010). Moreover, LED light bulbs contain no mercury and are also less susceptible to breakage (Weir, 2012). When compared to compact fluorescent light bulbs (CFL), LED light bulbs, have the capability to turn on instantly, last much longer and is more energy efficient. Furthermore, lifetime isn't affected by frequent cycling on and off, so they're especially suitable for light fixtures that don't stay on very long or for light fixtures that stay on so long that the extra energy efficiency is significant. Manufacturers are making efforts to produce LED lights that are both affordable and offer light equivalent to that produced by incandescent light bulbs. Due to the market competition, prices for LED lighting have declined making them an excellent choice for standard household use (Adkins et al., 2010).

Electrical energy is an essential commodity in Sri Lanka, expenditure on the monthly electricity bill is a critical component in the daily life. Especially, in Colombo district, electricity consumption is very high due to its versatile nature and hence conservation is a national goal. In recent years, the Sri Lankan government begun to promote LED technology with the support of the local Sustainable Energy Authority (Jensen, 1993). However, popularity amongst Sri Lankan buyers have been minimal, as there is no synergy between governmental organisation policies and manufactures/importers to better promote the green solution (Sri Lanka Sustainable Energy Authority, 2017). A recent report published by Weerasinghe and Ramachandra (2020), demonstrated that green retrofitting of conventional buildings using LED lights provide higher economic return within a short time (Weerasinghe and Ramachandra, 2020). In Sri Lanka only, a few private ventures manufacturing of LED lighting solutions and some people importing various types of LED lighting solutions to local market are observed. Hence, Sri Lankan customers are still not well aware of the advantages of new lighting technologies. There is limited research available on the reasons for this lack of awareness.

Considering all the benefits of LED solutions and the low popularity of this green alternative in Sri Lanka, the main objective of this study is to identify the key factors affecting the market acceptance and growth of LEDs lighting solutions in Sri Lanka. Moreover, this paper aims to recommend appropriate policies to promote LED lighting as

an energy solution to aid in the country transitions into adapting sustainable development goals.

2 Methodology

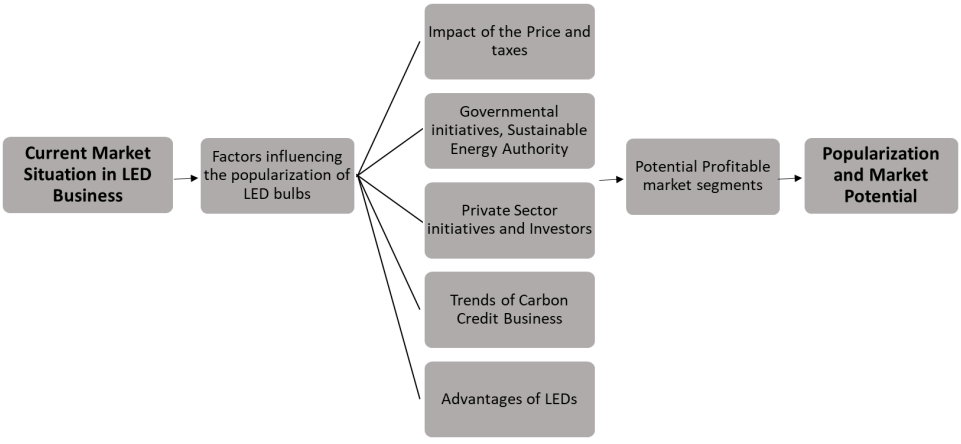
The methodology of this paper is divided in two main parts:

1 a survey of the population on their perceptions of external and internal factors affecting the implementation of LEDs in the private and governmental sectors

2 the development of recommendations and policy implementation ideas that will increase the level of education of consumers, retailers and governments of Sri Lanka.

The conceptual model of the methodology executed in this paper is shown in Figure 1.

Figure 1 Conceptual model of the methodology



2.1 Target population and target sampling

The sampling plan consisted of the sampling universe and frame, the sampling procedure and the sample size. In this study, the sampling universe covers all the direct and indirect public and private organisations within Sri Lanka. The organisations in Sri Lanka consist of 121,421 small industries (Department of Census and Statistics, 2008). After confirming the total number of registered institutes in the Colombo district, a selected sample of 10% were selected for this study. Governmental, private, small and medium institutes were selected as the target population; however, households were excluded from the study, as they offer minimal to no potential business cases according to a comprehensive literature review.

Cluster sampling was used as the sampling technique to analyse the population. To enhance the specificity of this work, the sampling frame was directed primarily to the private and public organisations in the Colombo district. The questionnaires were performed during the months of September to December of 2018. Eighty-five respondents completed the survey, from which, 31 were performed through in person interviews, and 54 were completed through online surveys or though phone interviews.

2.2 Preliminary surveys for data gathering

Questionnaires allowed for the collection of necessary data, followed by a data analysis of the responses to assess the current situation of the lighting industry in the Colombo District. In person and telephone interviews were conducted on a population consisting of current customers using HB LEDs, manufactures of LED bulbs, and importers of HB LEDs. Each completed questionnaire was carefully revised for completion and consistency and transferred to a SPSS spreadsheet and excel spreadsheet. Data gathered was analysed, both, quantitatively and qualitatively. Both methods were used to compare the analyses whenever required. This part of the study was intended to determine the key factors affecting the growth of HB LED lighting solutions. Moreover, the qualitative aspect obtained in this part of the study was validated through the structured interviews with industry experts, consumers, technological, financial decision makers, financial institutes and government regulators. To gather primary information from corporate and government users a series of questions related to the individual's knowledge of the general information about the lighting solutions, knowledge of users and questions to identify the key success factors were incorporated (Figure 1). The majority of the survey questions followed the Likert scale. Survey questions included the following parts:

1 demographics of the respondents

2 basic knowledge about LEDs measuring potential and energy reductions

3 LEDs properties

4 availability of financial support and policies targeted towards the usage of LEDs.

3 Results

3.1 Population demographics

The survey was conducted on a population that consisted of members of the private and government sector. The results of the survey show that industrial consumers and retailers in the private sector accounted for 69.4% of the responses and 30.6% of the responses, represented the government sector (Table 1). This study identifies that to implement the use of energy efficient LED in the average consumer market, it is important to carefully involve decision makers in order the analyse their knowledge influence on the subject. Accordingly, for a nation to implement new sustainable practices for improving energy load, high technological knowledge of the evaluators and decision makes is imperative. The results of the demographics survey allowed us to identify the decision makers and the appropriate team for the decision-making process. Thirty-five percent of the surveyed individuals were engineers/technologists, followed by proprietors and department heads (28%). According to the survey, the majority of lighting applications was for factories and commercial buildings. Interestingly, only 12% of the respondents monitor their power consumption daily, 36% occasionally monitored their power consumption and 53% of the respondents never monitored their power consumption in any means, hence, demonstrating the lack of awareness when controlling the power within their organisation as seen in Table 1.

Table 1 Demographics and power consumption of surveyed individuals

Measure	*Categories*	*Percentage (%)*
Sector	Private sector	69.4
	Government sector	30.6
Profession	Engineer/technologist	35.3
	Chief finance officer	5.9
	Chief Technology officer	5.9
	Department head – Government	12.9
	Proprietor-SME	15.3
	LED manufacture	3.5
	LED import and reseller	8.2
	Banker	4.7
	Investor	5.9
	Others	2.4
Application of lighting	Factory	25.9
	Commercial buildings	34.1
	Outdoor	20.0
	Swimming pool	5.9
	Street light	2.4
	Studio	0.0
	Others	11.8
Monthly electricity bill (SLRs)	Less than 10,000	35.3
	10,001–30,000	28.2
	30,001–50,000	17.6
	More than 50,000	18.8
Power consumption monitoring	Daily	11.8
	Occasionally	35.3
	Never	52.9

Source: Sample survey

3.2 LED perceptions amongst consumers and retailers

3.2.1 Awareness of the capacity of LED for low power consumption

Table 2 shows the results of the survey questions about respondent's awareness to LED light solutions. A total of 32 % of surveyed individuals had average to excellent knowledge about LEDs in general (average of 1.2 ± 0.68). Out of 85 responses, 57 indicated that, they have poor or very poor knowledge about the LEDs, indicating that in general poor knowledge of LEDs exists in Sri Lanka, regardless of their profession.

Similar results were obtained when inquired about their perception on the pricing. Surveyed individuals were also inquired about their knowledge on light measurement and energy, a high percentage of 55.3% indicated poor or very poor knowledge, as compared to 45% of the individuals who expressed average to excellent knowledge. The last question, of this part of the survey study was directed at obtaining information on whether respondents were aware about the LED efficiency as a low power consumption device. The results showed that more than half of the respondents were unaware of this important component. In general, the responses provided an indication of the necessity of improving communication on the various properties of LEDs with possible buyers as a way to increase the market acceptance of such products.

Table 2 Population awareness about basic information on HBLEDs

Measure	*Response percentage (%)*				
	Excellent	*Good*	*Average*	*Poor*	*Very poor*
Knowledge about LED	2.4	9.4	21.2	38.8	28.2
Knowledge about the cost of LED vs. other alternative products	3.5	11.8	23.5	30.6	30.6
Knowledge about light measurement energy	2.4	16.5	25.9	38.8	38.8
Knowledge of potentiality of LEDs sources to reduce cost of energy	11.8	16.5	14.1	50.6	7.1

Source: Sample survey

Awareness of the properties of LEDs

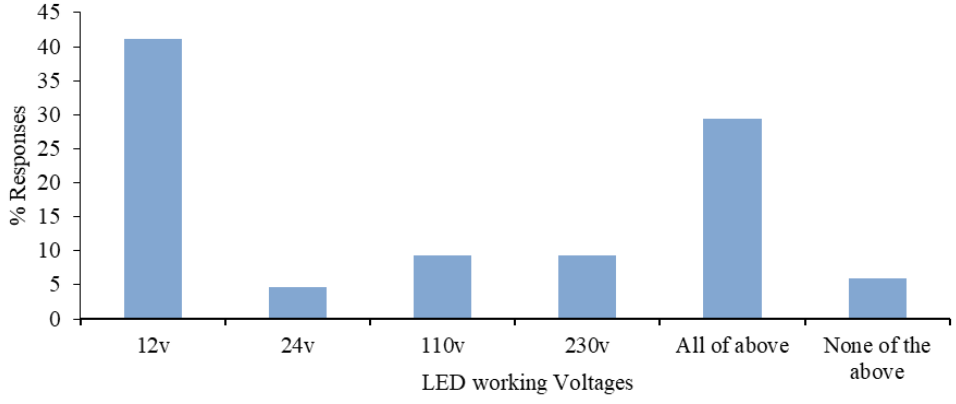
The third component of the survey was directed towards respondent's knowledge of the specific properties of LEDs. Some important key properties of LEDs were gathered through literature search and included in the survey questions. Table 3, shows that 53% of respondents believed that LED would emit very poor lighting. The responses are a clear indication that some of the surveyed individuals had early experiences with low lighting LEDs, introduced in the early stages, but have not followed up on the improved technologies. On the other hand, 65 % of the respondent's indicated average to excellent knowledge about the heat emissions of LED, indicating the belief that LEDs have more heat generation (1.7 ± 0.87). Moreover, it demonstrates the misconceptions about LEDs, as studies show that they will emit very low heat compared to the other traditional lighting sources such as CFL and incandescent (Gao et al., 2007; Krames et al., 2007). When exploring the public knowledge regarding the working voltages of the HB LEDs, results show that 41% of the surveyed individuals believe that the working voltage for LEDs is 12v, indicating respondents previous experience with low voltage LEDs. HB LEDs typically work in the low voltage such as 12v and 24v, but literature shows their potential capability to work in the 110v and 230v, as well. Figure 2 shows that only 29% of respondents believe that LED is capable of performing at 12v, 24v, 110v and 230v.

Table 3 Public awareness about specific properties of HBLEDs

Measure	*Response percentage (%)*				
	Excellent	*Good*	*Average*	*Poor*	*Very poor*
Knowledge about amount of light emission	2.4	16.5	14.1	14.1	52.9
Knowledge about amount of heat emission	9.4	37.6	17.6	16.5	18.8
Knowledge about hazardous nature of CFL bulb	5.9	11.8	35.3	41.2	5.9
Knowledge about substitutability of LEDs with CFL bulbs	35.3	25.9	14.1	15.3	9.4

Source: Sample survey

Figure 2 Survey responses (%) about population knowledge related to LEDs working voltage (see online version for colours)



3.3 Governmental incentives and financing

Identifying government and private sector financial support for new investments of LED is an important task for supporting the development and growth of LED businesses, especially in less developed countries. Not only for the start-up of new business opportunities, but for the import, resell and investments of green products in Sri Lanka. Hence, this work gathered related information from several sources, especially from financial institutions. Tables 4 and 5, present the results of the survey on questions related to financial support, government efforts and policies. Results clearly show that most interviewees are not aware of loans available for investments of LED, neither of any special interest rates for importing or selling HB LEDs. These results support our theory that not enough awareness exists amongst the population. Furthermore, according to the results, awareness of availability of angel investors for LED projects was 27.1%, with 72.9% believing that there are no investors for LED businesses. It is essential to communicate the benefits of green investments within the business communities to increase their interest in investing in such green areas. In order to develop green products, it is essential to have governments apply special tax exceptions for low power consumption products. Through this survey (Table 4), awareness of the existing

government tax exceptions proves that it is indispensable to enhance public awareness of existing tax exceptions and in the lack of, it is necessary to develop such tax exceptions.

Table 4 Public awareness survey on the availability of financial support

Measure	*Response Percentage (%)*		
	Yes	*No*	*I don't know*
Awareness on loans available for new investments on LED products	5.9	28.2	65.9
Is there any special interest rate for import or sell HB LEDs	14.1	23.5	62.4
Awareness on the availability of funding agencies (angel investors)	27.1	72.9	
Existence of tax exceptions for green energy products.	41.2	35.3	23.5

Source: Sample survey

Table 5 Public awareness survey on the existence of governmental policies

Measure	*Response percentage (%)*				
	Excellent	*Good*	*Average*	*Poor*	*Very poor*
Existence of government new policies to promote green concept	11.8	17.6	11.8	27.1	31.8
Knowledge on the availability of proper mechanism to address issues	5.9	9.4	11.8	41.2	31.8
Awareness on the effort taken by the local government to reduce the hazardous elements released from HB LEDs.	5.9	9.4	11.8	41.2	31.8
Awareness on the effort taken by the local government to recycle the hazardous elements released from HB LEDs.	4.7	9.4	4.7	41.2	40.0
Awareness on available programs to access various international grants under Certified Emissions Reduction (CER)	4.7	9.4	10.6	48.2	27.1

Source: Sample survey

Table 5 shows that respondent attitudes towards the government approach to create new policies to promote green concepts, was negative since 32% of the responses were very poor and 27% were poor responses. Hence, it is important to provide solutions to overcome such policy issues in green initiatives. It is widely known that CFL generates hazardous elements such as mercury during the manufacturing and removal process, making it a national responsibility to recycle such elements in the proper way (Kumar et al., 2019). On the other hand, the US Department of Energy has shown that LED lamps have 70% less environmental impact than CFLs (Scholand and Dillon, 2012). The results of the present survey (Table 5) show that overall; around 73% of the respondents did not think that there were efforts taken by the local government to reduce the hazardous elements released from HB LEDs. Similar results were obtained when asked if there were efforts taken by governments to recycle the hazardous element from HB LEDs. The lack of a channel of communication between the market retailers and the government remains an evident issue. Thereby, the need to provide incentives and implementation practices

for the promotion of energy efficient and sustainability driven attitudes in society is imperative towards the transition into effectual energy management. Moreover, a mean value of 1.4 and 0.34 standard deviation show that poor knowledge exists about CER programs, which are used by countries to reach their emissions target.

4 Discussion and conclusions

The in-depth analysis of the results presented in this study through surveys indicates that the transitioning towards more efficient LED technologies remains a long endeavour. The current situation in Sri Lanka shows that the use of the technology is not yet prioritised in the industrial sectors. A previous study suggested that hotels in Sri Lanka operate at a level of 39% inefficiency or resources wastage, which could be attributed to the lack of knowledge on the subject (Kularatne et al., 2019). Several factors highlighted in the results of the present study illuminate this aversion towards implementation, such as, the higher initial cost of the devices, the low knowledge about LEDs and the low governmental intervention. Yet, available literature suggest that initial subsidies directed at alleviating initial capital costs of new technologies, are more effective and sustainable that the ones which reduce recurrent operating costs (Elias and Victor, 2005). Moreover, financial aspects, size, the perception of the technology, the level of energy saving, power consumption, and availability of different devices are very important to increase the popularity of LED solutions on energy savings.

A positive correlation of consumer awareness on various aspects of LED and the use of LED fixtures, was observed. In addition, the results show a significant correlation between population awareness and the consumers monthly electricity bill. In general, the corporate customer feels that for the high initial cost, LEDs should provide added performance, such as energy efficiency and longer life, without inconveniences, such as flicker or poor fit. Others simply would not use LED lamps in their organisations due to lack of awareness of available technologies, hazardous nature of conventional CFLs, poor knowledge of available voltages and their dependence on different types of CFLs. Few do not prefer LEDs due to the mismatching on their wide range of applications. Nevertheless, the perspectives on wanting to transition towards LED solutions, and the welcomed benefits associated with the implementation serve as important incentives and offer insights into the willingness towards progressive technologies.

Nonetheless, establishing an authority to lead sustainability practices remains an issue in the private sector due to a perceived lack of urgency and resources to tackle the matter. In terms of national policy on energy, the government has taken the initiative through the establishment of the Sri Lanka Sustainable Energy Authority (SLSEA). The SLSEA aims to effectively manage the demand in an energy intense economy while innovating the renewable energy sector (Sri Lanka Sustainable Energy Authority, 2017). The authority has also published several standards and policies regarding sustainable energy management transitions, however, the enforcement and implementation of these policies are insufficient and often directed towards individual companies/industries in the private sector.

To provide guidance for policy makers and stakeholders; product and marketing managers in the lighting divisions at a few LED manufacturers available in Sri Lanka were asked to extrapolate their experiences to new enhanced lighting technologies, such as LEDs. The following recommendations are stated to serve as a guide for policy makers

and private market stakeholders to implement in accordance with the Sri Lanka Sustainable Energy Authority Act, No.35 of 2007:

1 *Educating the consumer:* It is a compulsory need to educate consumers on the benefits of LEDs.

2 *Marketing strategies:* Manufactures have to improve the marketing strategies, ensuring that enough information is provided to customers on the benefits and capability of new technologies at the retail level.

3 *Educating retailers:* Retailers need to be convinced that a product is going to perform as stated by the manufacturer. The package is a great place to educate, although retailers have asked about discontinuing the blister pack to gain more shelf space since this packaging requires more room. Lighting manufacturers are concerned that this would leave less space for advertising copy. It is also critical for the consumer to see the product before purchasing.

4 *Focus on Energy efficiency:* For marketing purposes, it is best to focus on the benefits of LEDs at the packaging level, including terms such as long life and energy savings, rather than LED. Keywords such as wattage replacement are used to the advantage of improving consumers understanding of the merchandise.

5 *Energy-efficiency programs:* Manufacturers agreed that energy-efficiency programs support help increase consumer awareness and sales of LEDs.

6 *Pricing:* A strategy to price LED is required in order to satisfy both customers and retailers. If the LED is inexpensive and lasts 50,000100,000 hours, it could lead to an overall reduced lighting sales and profits for retailers. If retailers make less on LEDs than they do on incandescent, there is no strong motivation for them to carry the LEDs.

7 *Technology improvement:* Manufacturers should work closely with energy efficiency groups to help establish the minimum performance requirements that the manufacturers can meet and the efficiency groups are willing to support.

8 *Identification of the right market:* Retailers should identify niche markets (building sub-markets) where the benefits of the new technology make good sense, and where the initial sales can be built. As an example, hotels and multi-family housing markets, where energy savings and reduced maintenance costs are important drivers.

9 *Advertising:* Mass media is vital to the widespread of a new technology; hence, it is necessary to pay attention to both paid and unpaid advertisements.

10 *Awareness programs:* Utility programs and/or manufacturer field representatives can be a very helpful link between manufacturers and retailers, as they can educate and train retailers, set up displays, distribute promotions, and explain the value of the product. Utilities have found that developing enthusiastic and on-going retailer participation is a key to market introduction programs. Lighting manufacturers, who generally have regional sales staff, should ensure that these staff are well trained on the new technology and can provide information to retailers. Once regional efforts are in place, a new lighting technology with strong energy-saving potential is likely to benefit from regional support and coordinated approaches to promotional programs, versus a variety of approaches introduced by individual utilities.

The results of this study and the recommendations suggested can be used as guidelines to similar types of energy-related green research in developing nations and for governments to revise current policies. As it has been widely reported at least 19% of the world's electricity use comes from lighting, but inefficiency in the lighting sources is a major drawback (Nardelli et al., 2017. The authors of this paper suggest that in the future Sri Lanka, specifically Colombo district, should focus on converting all the street lamps, the traffic signal lamps, illuminations on signboards and advertising frames of the main cities to LED. The results of this paper present an option for improving public awareness and the potential for introducing a simple source which can result in great potential for electricity savings. Moreover, it adds significant new knowledge to the existing literature, a set of guidelines for future energy research and development requirements and emphasises the required national policy directives towards the sustainable development of the country. In addition, this study can be used as a guideline for other developing countries trying to enhance their sustainability practices.

References

Adkins, E., Eapen, S., Kaluwile, F., Nair, G. and Modi, V. (2010) 'Off-grid energy services for the poor: Introducing LED lighting in the millennium villages project in Malawi', *Energy Policy*, Vol. 38, No. 2, pp.1087–1097 [online] https://www.sciencedirect.com/science/article/pii/S0301421509008209.

Almeida, A.D., Santos, B., Paolo, B. and Quicheron, M. (2014) 'Solid state lighting review – potential and challenges in Europe', *Renewable and Sustainable Energy Reviews*, Vol. 34, pp.30–48 [online] https://www.sciencedirect.com/science/article/pii/S1364032114001506.

Chang, M.H., Das, D., Varde, P. and Pecht, M. (2012) 'Light emitting diodes reliability review', *Microelectronics Reliability*, Vol. 52, pp.762–782 [online] https://doi.org/10.1016/j.microrel.2011.07.063.

Department of Census and Statistics (2008) *Census of Industry Report Online* [online] http://catalog.ihsn.org/index.php/catalog/3489/download/49626 (accessed February 2020).

Elias, R.J. and Victor, D.G. (2005) *Energy Transitions in Developing Countries: A Review of Concepts and Literature*, Program on Energy and Sustainable Development Working Paper #40 [online] https://fsi-live.s3.us-west-1.amazonaws.com/s3fs-public/energy_transitions.pdf.

Gao, S., Hong, J., Choi, S. and Yi, S. (2007) 'Heat transfer analysis and design optimization of ALOX high brightness light emitting diode package', *ASME 2007 InterPACK Conference*, Vol. 2, pp.423–428 [online] http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1595594.

Hazrati, M.I. (2019) 'Comparison of light efficiencies between high intensity discharge (HID) and light emitting diodes (LED) lights', *Journal of Physics and Astronomy Research*, Vol. 5, pp.94–96.

Jefferson, M. (2006) 'Sustainable energy development: performance and prospect', *Renewable Energy*, Vol. 31, No. 5, pp.571–582 [online] https://www.sciencedirect.com/science/article/pii/S0960148105002466.

Jensen, M.C. (1993) 'The modern industrial revolution, exit, and the failure of internal control systems', *Journal of Finance*, Vol. 48, No. 3, pp.831–880 [online] https://onlinelibrary.wiley.com/doi/full/10.1111/j.1540-6261.1993.tb04022.x.

Kovac, J., Perwenai, L. and Lengyel, O. (2003) 'Advanced light emitting diodes structures for optoelectronic applications', *Thin Solid Films*, Vol. 443, Nos. 1–2, pp.22–26 [online] https://www.sciencedirect.com/science/article/pii/S0040609003003146.

Krames, M.R., Shchekin, O.B., Mueller-Mach, R., Mueller, G.O., Zhou, L., Harbers, G. and Craford, M.G. (2007) 'Status and future of high-power light-emitting diodes for solid-state lighting', *IEEE/OSA Journal of Display Technology*, Vol. 3, pp.160–175, https://doi.org/10.1109/JDT.2007.895339.

Kularatne, T., Wilson, C., Månsson, J., Hoang, V. and Lee, B. (2019) 'Do environmentally sustainable practices make hotels more efficient? A study of major hotels in Sri Lanka', *Tourism Management*, Vol. 71, pp.213–225, https://doi.org/10.1016/j.tourman.2018.09.009.

Kumar, A., Kuppusamy, V.K., Holuszko, M., Song, S. and Loschiavo, A. (2019) 'LED lamps waste in Canada: generation and characterization', *Resources, Conservation and Recycling*, Vol. 146, pp.329–336, https://doi.org/10.1016/j.resconrec.2019.04.006.

Nardelli, A., Deuschle, E., Azevendo, L.D., Pessoz, J.L.N. and Ghisi, E. (2017) 'Assessment of Light Emitting Diodes technology for general lighting: a critical review', *Renewable and Sustainable Energy Reviews*, Vol. 75, pp.368–379 [online] https://www.sciencedirect.com/science/article/pii/S136403211630781X.

Reineke, S., Lindner, F., Schwartz, G., Seidler, N., Walzer, K., Lussem, B. and Leo, K. (2009) 'White organic light-emitting diodes with fluorescent tube efficiency', *Nature*, Vol. 459, pp.234–238 [online] https://www.nature.com/articles/nature08003.

Scholand, M. and Dillon, H.E. (2012) *Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part 2: LED Manufacturing and Performance*, Richland, WA, USA, https://doi.org/10.2172/1044508.

Sri Lanka Sustainable Energy Authority (2017) *Sustainable Energy in Sri Lanka* [online] http://www.energy.gov.lk/ (accessed December 2019)).

Weerasinghe, A.S. and Ramachandra, T. (2020) 'Costs and benefits of green retrofits: a case of industrial manufacturing buildings in Sri Lanka', in *Lecture Notes in Mechanical Engineering*, pp.227–237, Springer, https://doi.org/10.1007/978-981-15-1910-9_19.

Weir, B. (2012) 'Driving the 21st century's lights', *IEEE Spectrum*, Vol. 49, No. 3, pp.42–47, https://ieeexplore.ieee.org/abstract/document/6156864/authors (accessed December 2019).

Yang, L. and Yan, X. (2013) 'Design for reliability of solid-state lighting products', in Van Driel W. and Fan, X. (Eds.): *Solid State Lighting Reliability*, Solid State Lighting Technology and Application Series, Vol. 1, Springer, New York, NY [online] https://doi.org/10.1007/978-1-4614-3067-4_19.