Market Analysis for High Power LED

By
Aaron Davis
Brianna Goncalves
Zachary Karalis
Chandlor Lyles

Light Emitting Diodes: A two-lead semiconductor light source

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By
Aaron Davis
Brianna Goncalves
Zach Karalis
Chandlor Lyles

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Professor Adrienne Hall-Phillips
Worcester Polytechnic Institute

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Background

Light emitting diodes (LEDs) have become a huge centerpiece for light efficiency throughout the last 50 years. A diode is a semiconductor device with two terminals (cathode, anode), typically allowing the flow of current in one direction only. The concept of LEDs allowed the capacity to replace halogen lamps. The progression of lights and LEDs overall has been tremendous.

The parts include the screw base, the driver, the heatsink, and the LED chip. These common parts work together in order to make energy efficient LED lights. The base feeds raw electricity to the driver which converts the energy to a DC (direct current) electricity that is designated by the chip maker. The heatsink makes up the body of the LED. It has little fins that take in small amounts of natural air that flows around the bulb in order to cool down the bulb. Lastly, the LED chip is located at the top of the heatsink. A very specific electrical current that runs from the driver to the LED chip makes light. Figure 1, is a visual representation of all the basic parts and their places in an LED light bulb (Habul, 2013).

Aside from basic parts of a LED light bulb, the chips of the LED light share many of the same basic components as well. LEDs work on the principle of electroluminescence. Electroluminescence is the ability of some materials to emit light when an electric current flows through them. As previously mentioned, there are two major wires within an LED chip, the anodes and the cathodes. Anodes are the positive wire of the LED and cathodes are the negative wire. A semiconductor crystal is located between the anode and the cathode. The anode and cathode are major reasons as to why an LED emits light (How LEDs Work, 2013).

There are several contributing factors as to why LEDs are such a popular choice in the market amongst other lighting competitors. The first reason is that is last up to 10 times as long as compact fluorescents and other incandescent lighting fixtures. The structure of LEDs is a large component to its durability and its ability to remain cool as opposed to heating up when plugged in (Eartheasy, 2014). They are more energy efficient and solely use 2-17 watts of electricity comparative to Incandescent of CFL lighting, which generally use one third of electricity. Not only do LEDs use less energy, it last ten to fifteen times longer than incandescent bulbs (Eartheasy, 2014). LEDs are not only energy efficient, but cost effective. The initial cost of LEDs is more expensive than incandescent bulbs; however, the durability of LEDs causes them to be more cost effective.

Objectives and Corresponding Methods

This project was designed to study industrial LEDs by investigating its advantages and disadvantages as well as examine the possible marketing opportunities for LED lights. Consequently, an analysis was constructed in order to show possible avenues when entering a competitive industry. This industry analysis determined the feasibility of new players entering the market. In order to accomplish this goal; we completed the following objectives:

1. Identified LED technology and market opportunities (B2B, B2C, B2G) of LED lights
2. Identified disadvantages and advantages (i.e. SWOT, Four P's) of LED lights domestically and globally
3. Completed a cost benefit analysis of Industrial LEDs
4. Evaluated the feasibility of new products entering the Industrial LED market

In order to evaluate LED technology and its marketing opportunities utilizing (B2B, B2C, B2G), we first completed research on the topic. As a result, we learned how LEDs work, their major components, and market gains. A cost benefit analysis was then conducted to determine the

strengths and weaknesses of a company, business or any situation to better understand the entirety of it to help reach a conclusion. The analysis focused on the price, economic impact, energy efficiency, energy cost and environmental impact of LEDs versus Incandescent lighting and compact fluorescent lighting.

In depth, we collected our data from the public and our project stakeholders through conducting interviews. After conducting 7 interviews, we created a spreadsheet to analyze each of them. We went through each interview individually so that all seven interviews were analyzed four times. Creating the spreadsheet, allowed us to see what common trends were noted throughout all interviews. Subsequently, we each went through the spreadsheet to find any themes from the interviews.

Findings for the LED Industry

Throughout this project, retailers, manufacturers and affiliates describe our data collection substantially. From our interviews we were able to conclude that the lighting industry market is a highly competitive place, making market entry difficult for smaller firms or innovators to succeed in penetrating the market. “Despite this difficulty, there are several new firms entering the lighting industry everyday” said, Vice President VP, of manufacturing initiatives. Major companies dominate the market through the control of the market share. Based on our interviews several companies are working on cutting the price of LED technology by shortening the shelf-life of the bulb. We were able to conclude from all of our research that the LED industry is no longer in its introductory phase of the product cycle; it has now entered its growth phase. As more individuals adopt the technology the industry should expand. With LED technology entering the growth phase of its product life cycle we should see new innovations and further development of LED technologies. This allows us to understand just where LED technology is currently in relevance to its product life cycle. There is still major room for growth

within this industry, as technologies (i.e. batteries, wiring, and platforms) that support LED light bulbs and fixture improve, LED's themselves will be able to become more advanced and efficient, LED's have a bright future within the lighting industry.

Benefits/use of LEDs

Throughout our research about LED bulbs and LED light fixtures our group found that there are several benefits to the use of LEDs. One well-known benefit of LED bulbs is that they are more energy efficient than incandescent and CFLs. The LED bulbs use less energy to generate light, which is beneficial to the environment and also saves companies money in the long run. Another major benefit of using LEDs is that there are government incentives on saving energy. A company can get rewarded for saving energy by switching to LED bulbs. As explained by the VP of Manufacturing Initiatives, the LED bulb and the LED fixtures are two completely different industries. Businesses such as airports and retail stores are starting to switch to LED lights throughout their facilities.

Challenges

Amongst all of the interviews that took place, we found a common trend throughout each interview, and that was challenges with LEDs. There were three main challenges: 1) - packaging and recycling 2) - installations 3) - price and consumer understanding of LEDs. We found that there are specific requirements that must be met in order to properly dispose of LEDs and if expectations are not met, fines are given. We also found that converting to LEDs is not simple, and that there is a significant process to install LEDs that require extensive labor and cost. The last main challenge we found was the initial cost of LEDs. We found that with a lack of understanding the benefits and technology of LEDs consumers choose to pay for a cheaper lighting fixture, causing a lower number in LED conversion.

Future for LEDs

While discussing the future of LED lights, a Product Marketing Manager II, retailer and manufacturer, stated, that their "Company maintains more than $6 billion and is ranked the 2nd largest company in the lighting industry. Using this information we determined that LEDs are becoming more dominant throughout the lighting industry. In addition, the cost for them is increasing yearly, moving them higher and higher in rankings.

Room for Improvement

After conversing with various industry professionals, "The LED business will totally change when batteries get better and wiring is not an issue," a Program Manager of Growth & Innovation, an affiliate, stated. LED batteries and wiring has become a weakness of LED technologies. Thus, problems may fester if not addressed and resolved for all future endeavors. Another room for improvement is the energy and cost of LED technology.

Conclusion

Collectively, our data helped us identify 5 major topics: the lighting industry, benefits/use of LEDs, challenges, the future of LEDs and room for improvement with respect to LED technology. Our research showed that LEDs are continuously growing in market but price plays a huge role in its utilization. It is quite clear that the benefits of LEDs are that they are energy efficient and in the long-run save money. Specifically, there are many government incentives for utilizing LEDs that help with saving money. LEDs have three main challenges: 1) - LED packaging & recycling, 2) - LED installation and as previously mentioned 3) - Price. Full comprehension of these challenges should be noted and addressed. In doing so, new market entries can affect the future of LEDs. According to the Supervisor Structural of Maintenance, the "upsurge of LEDs is, "the answer" unless we go back to candles.

Introduction

As the population of the world increases along with the energy consumption both here in the U.S. and globally people are looking for alternatives to increase energy efficiency. Countries across the globe are striving to enforce laws on commercial and industrial sectors to limit green gas emissions and promote energy conservation (EPA, 2015). As more and more countries adopt and implement these laws, companies are looking for alternatives to cut down emissions via energy consumption. In 2014, the top three countries; Italy, Germany and the UK accounted for 55.62 cents/kilowatt/hour (EPA, 2016). Globally, countries are looking for alternatives to minimize cost per kilowatts for illuminating commercial buildings. Light emitting diode (LED) technology has become the new and improved alternative for energy efficient lighting. As a result, LED technology has grown into a huge market that penetrates both domestically and globally. LEDs offer energy efficiency and low cost for long-term use providing the customer with long term savings as well as benefits from government incentives. A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n joint diode, which produces light when activated. This project will study LED technology by investigating its disadvantages and advantages. In addition, it will examine the possible marketing opportunities for LEDs. Consequently, it will also examine LED technology as a whole to determine the feasibility of LEDs to help new market entries.

At the beginning of this project, our group was initially interested in LEDs because we knew it was a growing market. Our motivation stemmed from the efficiency LEDs provided and caused many curiosities. Consequently, this led to further research in order to help us better understand the future for LEDs. We also wanted to see where LEDs are currently being implemented along with what companies plan to incorporate them in the future. This only further developed our motivation because we saw how dominant LEDs were becoming within the

industrial market so we focused our research on the industrial lighting industry. As a result, the project moved along and contact with the original project sponsor became limited. Based on the motivation of our project and the sponsor's change in focus, we decided to no longer focus on the original project idea our sponsor's new technology, but rather the industrial LED sector as a whole.

Background

History of Light Emitting Diodes (LED)

Light emitting diodes (LEDs) have become a huge centerpiece for light efficiency throughout the last 50 years. A diode is a semiconductor device with two terminals (cathode, anode), typically allowing the flow of current in one direction only. The development from the first spark of innovation in 1907 to the first car to fully use LEDs in its headlights in 2008 has truly evolved. The impact of technology has had a strong influence in the creation of energy efficient lights. The concept of LEDs allowed the capacity to replace halogen lamps. The progression of lights and LEDs overall has been tremendous.

It all began in the late 1890s, early 1900s with Thomas Edison and Nikola Tesla's breakthrough with fluorescent lamps. They started the evolution of experimenting with different chemical elements to see what different light sources could be emitted. In 1907, British experimenter, Henry Round, realized when adding 10 volts to carborundum (silicon carbide) crystal, a yellow light was apparent (History of Lighting, n.d.). Within that same year, scientist Oleg Vladimiroovich Losey, experimented and concluded the equivalent of Henry Round. In 1927 Oleg published a text about the first light-emitting diode.

Round and Losey's discovery further lead to other breakthroughs with light-emitting diodes. In 1955, Rubin Braunstein, an employee at Radio Corporation, disclosed that simple

diodes emit infrared light when they are connected to an electrical current (History of Lighting, n.d.). A similar case, in 1961, Gary Pittman and Bob Biard, workers from Texas Instruments, identified gallium-arsenide diode emits infrared light each time it connected to a current (History of Lighting, n.d.). Later on that year, they obtained a patent for infrared LED. In just the following year, an employee at General Electrics, Nick Holonyak Jr., developed the first visible-spectrum of LEDs in the form of red diodes (Energy.gov, 2013).

Moving into the 1970s researchers and experimenters began to develop the technology of LEDs. In 1972, a scientist, M. George Craford, invented the first yellow LED and a brighter red LED (History of Lighting, n.d.). Moving into 1976 another researcher, Thomas P Pearsall developed a higher brightness light-emitting diode using fiber optics within telecommunications (History of Lighting, n.d.). As companies further innovated red diodes and their manufacturing, LEDs began to be utilized as indicator lights and used for calculator displays (Energy.gov, 2013). The technology for LEDs flourished; however, they were extremely expensive, costing two hundred dollars apiece. Due to the high cost and unaffordability, LEDs were primarily used for lab equipment in high professional settings (History of Lighting, n.d.). In the late 1970s, the company Fairchild Semiconductors was able to utilize a planar process in production of semiconductor chips for LEDs reducing costs to only $0.05 per piece. Their innovative methods permitted them to make it into a commercial product (History of Lighting, n.d.).

Transitioning into the 1990s and early 2000s, the innovation for LEDs really expanded. Blue diode discoveries led to white diode discoveries. To do this, researchers realized coating blue diodes with phosphor made it appear white. These breakthroughs led to a variety of applications such as implications of LEDs in traffic lights, flashlights and TVs (Energy.gov, 2013) In 2000, the Energy Department partnered with a private industry to further enhance white

LED technology to create more efficient devices (Energy.gov, 2013). To do this, the Energy Department announced the L Prize Competition in 2008. The objective of this competition was to design and develop ultra-efficient solid-state lighting products to replace common lighting technologies (Energy.gov, 2013). The results of this competition lead to a category for 60-watt incandescent light replacements and the cost of LED bulbs to fall more than 85% (Energy.gov, 2013).

Basic LED Parts & Components

No matter the type of LED bulb, they all share the same basic parts. The parts include the screw base, the driver, the heat sink, and of course the LED chip. These common parts work together in order to make energy efficient LED lights. The base feeds raw electricity to the driver, which converts the energy to a DC (direct current) electricity that is designated by the chip maker. The heatsink makes up the body of the LED. It has little fins that take in small amounts of natural air that flows around the bulb in order to cool down the bulb. Lastly, the LED chip is located at the top of the heatsink. A very specific electrical current that runs from the driver to the LED chip makes light. A visual representation of all the basic parts and their places in an LED lightbulb are displayed in Figure 1.

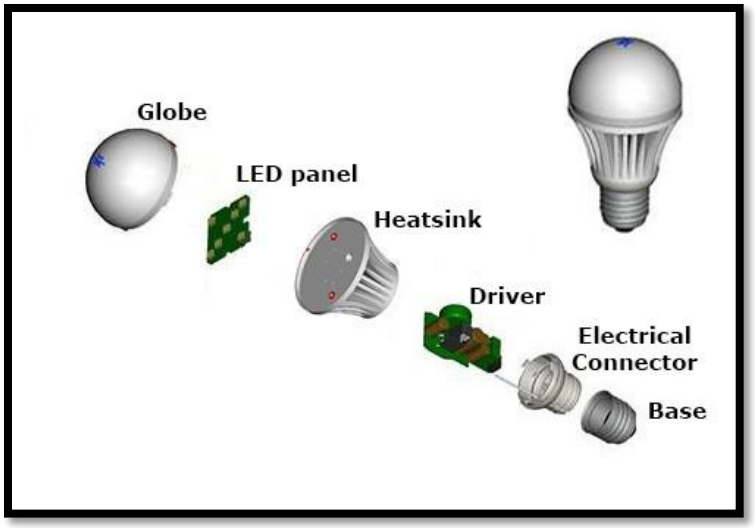

Figure 1: Basic Parts of LED Light Bulbs
Photo By: S. Habul, 2013

Aside from basic parts of a LED light bulb, the chips of the LED light share many of the same basic components as well. LEDs work on the principle of electroluminescence. Electroluminescence is the ability of some materials to emit light when an electric current flows through them. As previously mentioned, there are two major wires within an LED chip, the anodes and the cathodes. Anodes are the positive wire of the LED and cathodes are the negative wire. A semiconductor crystal is located between the anode and the cathode. The anode and cathode are major reasons as to why an LED emits light.

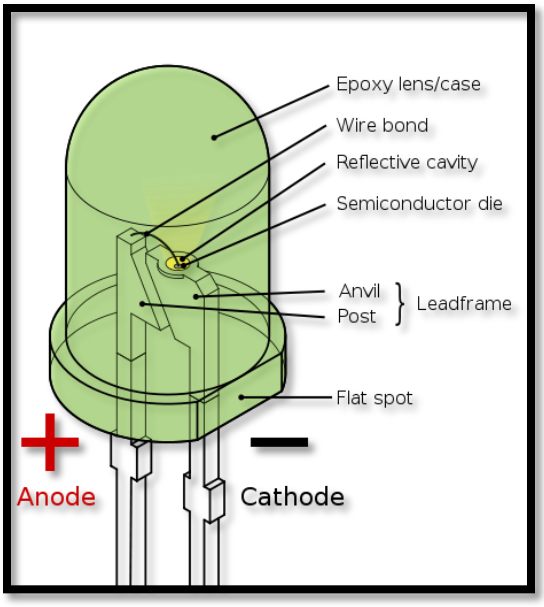

Figure 2: Basic Component of an LED Photo By: S. Habul, 2013

Regulations of LEDs

Today, the general lighting landscape is continuously evolving. LED lighting for universal illumination is being adopted as a sustainable alternative for old-fashion lighting. This modification is due to its unique characteristics and its potential energy conservation (OSRAM, 2015). As a result, new technologies such as, LED lights must fall under and abide specific standardizations and regulations. Standards and regulations provide a platform for consistent language in reference to its definitions, test methods, laboratory accreditations, and product designs, manufacturing and testing. However, regulations assist in ensuring public safety, providing consumer protection, regulating energy consumption and monitoring environmental issues (OSRAM, 2015). Standards are voluntary and regulations are obligatory. This section will explore the specific principles of LED lights, while highlighting their beneficiaries.

The Energy Independence and Security Act (EISA) of 2007 ignited many modifications in the lighting industry. The most momentous modification states, "It is required to have a 25

percent increase in energy efficiency of light bulbs" (LEDinside, 2015). Manufacturers have continuously struggled with increasing incandescent bulbs to this percentage level. In 2012, Section 321 of EISA stated, "Once implemented, the act will essentially eliminate 40W, 60W, 75W, and 100W medium screw-base incandescent light bulbs" (Cree Inc., 2015). The new minimum efficiency standards are represented in Figure 3.

Rated Lumen Ranges	Typical Current Lamp Wattage	Maximum Rate Wattage	Minimum Rated Lifetime	Effective Date	California Effective Date
1490-2600	100	72	1,000 hours	1/1/2012	1/1/2011
1050-1489	75	53	1,000 hours	1/1/2012	1/1/2012
750-1049	60	43	1,000 hours	1/1/2014	1/1/2013
310-749	40	29	1,000 hours	1/1/2014	1/1/2013

Figure 3: New Minimum Efficiency Standards

The effective dates listed in Figure 3, indicate the first dates that non-compliant products were forbidden from manufacturing or introduced into the U.S. California being the first, implemented these standards one year before anywhere else in the world (California Energy Commission, n.d.). These new standards are based on efficacy and minimum Lumen per Watt (lm/W) requirements. Lumens per Watt (lm/W) approximate how much lumens are received from light bulbs compared to the amount of energy (wattages) retrieved. The light bulb that extracts the most lumens per one watt of energy is the utmost efficient Thus; incandescent lights will eventually become obsolete. As incandescent bulbs dwindle, fluorescent and LED bulbs will increase in consumption. Both of these technologies are more energy efficient than incandescent lighting, but fluorescent bulbs contain mercury vapor. This could result in disposal issues as the

bulbs become more widely used (LEDinside, 2015). Therefore, LED lights will become the default for consumer consumption.

LEDs have shown to save energy in limited applications, but are they ready for wide-scale adoption? An often-overlooked yet integral part of our communities' landscapes, parking lots influence many different life aspects. Parking lots are very demanding in energy and money. If energy and money could be conserved on this matter, it definitely should be taken advantage of. Many business owners have long recognized the possibilities of LED technology, specifically in parking lots. The world's largest retailer, Wal-Mart operates more than 4,300 facilities in the United States. Wal-Mart actively participated in building and testing its specification of LED lights for its parking lot usage (Office of Energy Efficiency & Renewable Energy, 2013).
At its Supercenter in Leavenworth, Kansas, the first site to implement the LED site lighting specification. Wal-Mart now anticipates energy savings of over 125,000 kWh per year and a 30% reduction in maintenance costs (Office of Energy Efficiency & Renewable Energy, 2013).

To create the maximum benefits of LED Lighting, and the avoidance of LED stigmas that they only conserve energy, the framework of Standards and Regulations should be adapted. Internationally, there have been many issues with establishing LED lights standards and regulations. There are very few countries other than the U.S. that lack such principles. The Global Lighting Association (GLA) is part of the International Commission on Illumination (CIE) network on energy efficient lighting and lighting qualities. Both, the GLA and CIE network work together to help promote international standards on LED lights while trying to solidify strict usage regulations. Figure 4, helps show the specific networks and places that have specific standards and regulations universally (Denneman, n.d.).

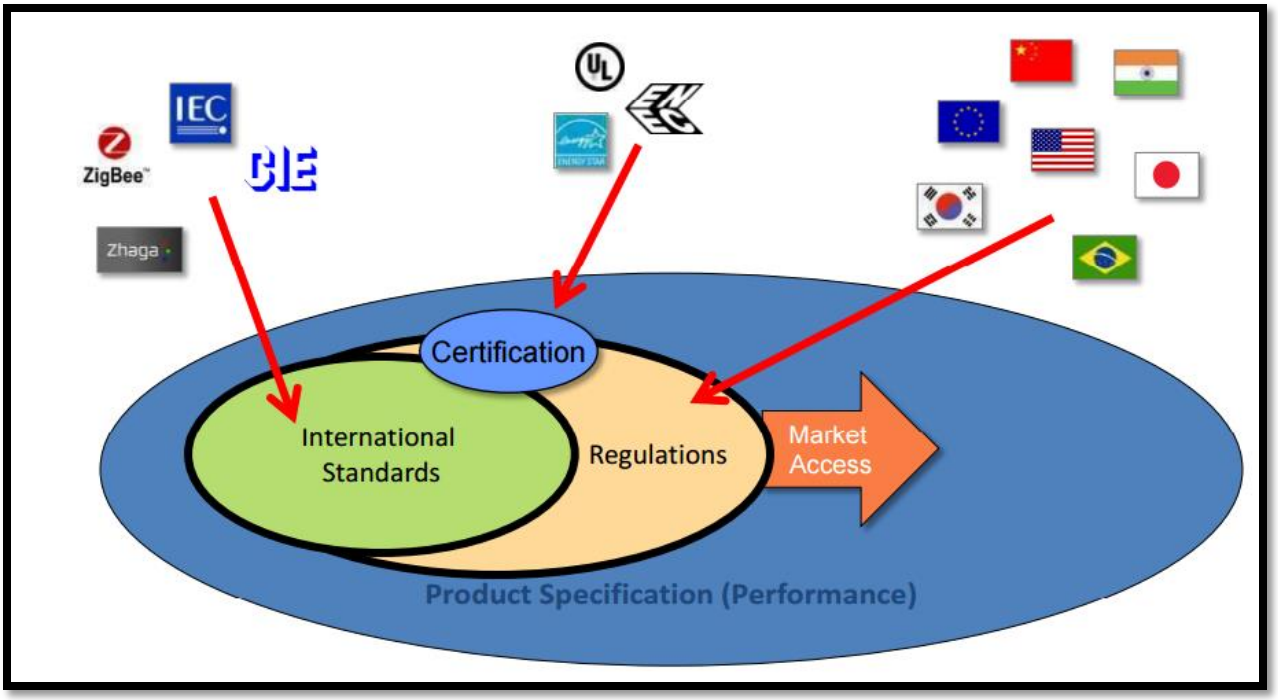

Figure 4: Standards and Regulations Overview
Photo By: J. Denneman, n.d.

Evidently, there are only six countries that specifically acquire regulations amongst LED lights. In addition, only four networks establish international standards but not regulations. The reinforcement elsewhere has yet to pick-up on the light industry and its relevance and significance.

LED SWOT Analysis

A SWOT Analysis is a process that identifies the strengths, weaknesses, opportunities and threats of a given topic. Below, is a SWOT analysis of new companies entering the industrial lighting industry. Based on our background research on LED technology and the industry, we completed the following SWOT Analysis.

SWOT Analysis

Strengths	Weaknesses	Opportunities	Threats
• Innovation = technical advantages of Discrete technology • High performance, high reliability, • Price = lower than existing high-end products in the market • Overall market size for LEDs • Consumer attitude for environmentally friendly alternatives • Before 2013 there were no LED sources or luminaries on the market	• Bad color revivification • Single LED's power is still low • Short illumination range • "Yellow ring" phenomenon • Heat dissipation • Industrial scale spaces lit 24/7/365 • Halogen lights will still hold more than 50% of the market by 2021 • LED lights share will increase from $2.6 billion to $7 billion by 2021	• Spaces predominantly lit with halogen lamps rated at > 400W energy consumption. • Gov. Regulations for energy efficiency • "Go Green" Strive • Regulations on Greenhouse admissions • Increasing Energy Prices / Innovative technology • Long-term savings • Lighting market expected to expand up to 70% in the next decade • Application LED luminaires save 40% energy used for lighting spaces	• Current successful LED companies • Pricing/affordability amongst competitors • Efficiency of current LED products • Ceramic conversion in product • Entering well-developed industry • Customers willingness to pay • Quality of technology

Figure 5: LED Industry SWOT Analysis

The strengths play relatively large part in the analysis of the lighting industry with individuals striving to be environmentally friendly want more energy efficient in order to reduce their carbon foot print LED technology is a growing market. Many stores and wear houses are converting to using LED Technology to light their stores and storage facilities. Also many distributors of lighting product are only selling LED bulbs and products. Weaknesses of the LED industry are relative to the product itself. There is high initial cost for implementing LED technology, which deters customers. There are also very few market shares that are not controlled by large companies. On the other hand opportunities are abundant in entering the industrial lighting market with LED technology as long as all aspects are considered. Competition is also high in regards to creating new innovations for industrial LEDs. Overall the lighting market is a market

in which a product like led technology is currently in its growth stage. There are several barriers to entry however the market can be penetrated by new entrants. In the next years to come LED technology will grow significantly leaving opportunities for innovation and improvement on the lighting technology.

LED Benefits

The growth and development of LEDs have flourished in the last decade, making LEDs a popular market choice. There are several contributing factors as to why LEDs are such a popular choice in the market amongst other lighting competitors. The first reason is that is last up to 10 times as long as compact fluorescents and other incandescent lighting fixtures. The structure of LEDs is a large component to its durability and its ability to remain cool as opposed to heating up when plugged in (Eartheasy, 2014).There are other contributing factors leading to LEDs success. They are more energy efficient. They solely use 2-17 watts of electricity comparative to Incandescent of CFL lighting, which generally use one third of electricity. Not only do LEDs use less energy, it last ten to fifteen times longer than incandescent bulbs (Eartheasy, 2014). LEDs are not only energy efficient, but cost effective. The initial cost of LEDs is more expensive than incandescent bulbs; however, the durability of LEDs causes them to be more cost effective.

Major Stakeholders

Stakeholders are a vital part of any organization. They take sincere interest in a variety of aspects of the organization. All companies and organizations have stakeholders, whether they are investors, employees or even customers. The amount of stakeholders per company fluctuates based on the organization itself and where stakeholders are necessary.

For our project, there are two major stakeholders. Our first major stakeholders are individuals and businesses who are interested in entering the lighting industry. These particular

individuals could potentially utilize our information presented in order to gain a better understanding of the market. In addition, the provided information in our paper could help as guidance when entering a competitive and complicated industry. With the partnership with WPI, Mass Development has become a major stakeholder throughout our project as well. They have helped assist our project in educating us on their business as a whole and various lights, specifically LEDs. These two are currently playing a crucial role in determining the feasibilities of LEDs.

Bridging the Gap between LED Technologies and New Market Entries

There are many enclosed industrial scale spaces in the world that are lighted every day. These places vary amongst warehouses, parking garages, railway terminals and much more. Specifically, these locations are predominately lighted through halogen lamps. These particular lamps are rated at a temperature that is greater than 400W of energy consumption. However, LED lights would be a better fit for such locations. If implemented, LED luminaries could approximately save 40% of energy. Before 2013, LED sources and Luminaries were not out in the market and barely ranked 100% suitable for such settings.

Today, however, LEDs would become the new alternative solution for specific dwellings. Consequently, LED lights are continuously growing throughout the market. As a result, they are constantly taking the place of existing lighting sources. More and more businesses today are converting or constructing buildings with LEDs specifically. Entering such a competitive market consists of understanding the LED technology itself (i.e. bulbs vs. chip), the advantages and disadvantages and the top competitors in the field.

Comparing LED Technologies

Within the LED light spectrum there are several different kinds of LEDs. Just like any emerging technology, LED's have evolved throughout the years and different more advanced technologies have come to life. The LED packaging evolution has four different options, the Dual in Line Package (DIP), Surface Mount Device (SMD), Chip on Board (COB) and Multiple Chips on Board (MCOB). The DIP technology stands for Dual in Line Package and is the most commonly used LED package for medium and small scale circuits. SMD or surface mount device LEDs are more efficient than DIP and are used for general purpose lighting. COB or Chip on Board LEDs Chip on board technology packages LED chips that are mounted directly onto a printed circuit board allowing more area to be illuminated. MCOB or Multiple Chips on Board has many small chips that are on one single large chip. MCOB's are used primarily for large tunnel and flood lights and high bay overhead lighting.

Light Industry Lead Competitors

LED prices have recently declined in the market where as all sectors (commercial industrial and residential) are using this technology. LEDS are becoming the leading choice for environmentally friendly consumers looking to save money with a better economical alternative. Originally, early adopters turned to LEDS for unique features such as improved efficiency, improved operations in climate environments, and controllability. All sectors view a boost in the use of LED lights including vehicle headlights. The fall in LED prices are opening up opportunities for companies within the lighting industry; however there are several issues arising with price wars. There are continued patent disputes as inventors, owners, and many more fight to protect intellectual property. Between 2015 and 2024, LED lamps and modules are expected to increase at a compound annual growth rate (CARG) of 17%-19% (ReportLinker, 2015).

Cost-reductions of LED manufacturing processes (packaging and optimization) should improve the LED wholesale prices allowing Led lighting to gain global market acceptance in the next few years, while a boosting global industry sales turnover is highly expected. Market forecasts predict and immediate impact of fast paced growth in the LED industry as, lower prices will benefit the supply chains from manufacturers, to wholesale distributors and commercial end consumers. The LED Industry has recently been receiving optimistic reviews, "LED lights are becoming known as the light way of the future." LED market value has reported a jump in $100 billion in annual sales within the next decade increasing from a previous $15 billion that it is currently estimated at. Purchasing LED for public and private places is the most cost-efficient and energy-conserving investments (Tenningas, 2013).

Currently the global market is underpenetrated by the LEDs. Other technologies currently maintained are dominantly presence in the light industry. Currently low LED market penetration can be attributed to the use of fluorescent lights. LED market penetrations are less than 10% for this reason. Originally, high price was the reason for competition with fluorescent lights but at the price of LEDs drops the factors restraining LED lights growth. Currently government regulations worldwide have banned incandescent lamps, where LEDs are expected to obtain the market shares of incandescent lamps in the next few years (Transparency, 2013).

As a group, we all wanted to gain a better understanding of the LED market rather than primarily focusing on market research. As a result, we decided to connect with people who were involved with the LED industry in some way or form. Furthermore, this allowed us to better grasp the lighting industry as a whole. In the end, we hope that our dedication and research not only helps us but also provides a better comprehension of the overall industry itself. The lighting

industry is a complicated one as it is, but this project is intended to simplify its complexities. Consequently, our results go more in depth about our premature research and proof various sectors of the lighting industry. We developed and executed several methods to find sufficient results. In the following chapter we thoroughly explain the steps taken to identify our results.

Methodology

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n joint diode, which produces light when activated. This project will study LED technology by investigating its disadvantages and advantages. In addition, it will examine the possible marketing opportunities for LEDs. Consequently, it will examine LED technology as a whole to determine the feasibility of LEDs to help new market entries. In order to accomplish this goal; we completed the following objectives:

1. Identified LED technology and market opportunities (B2B, B2C, B2G) of LED lights
2. Identified disadvantages and advantages (i.e. SWOT, Four P's) of LED lights domestically and globally
3. Completed a cost benefit analysis of Industrial LEDs
4. Evaluated the feasibility of new products entering the Industrial LED market

In this chapter, we will discuss the steps that were taken to determine the feasibility of a new product entering the Industrial LED market. An overall economic analysis of LEDs versus other lights along with the four P's of marketing (product, price, placement, and promotion) was conducted to better understand if an opportunity exists for a new player to enter this market. This helped us evaluate the existing economic issues and feasibilities of utilizing LED lights. An

evaluation of the current light industry was created in order to reveal gaps that could be mended throughout the lighting industry.

Identify LED technology & market opportunities (B2B, B2C, B2G)

In order to evaluate LED technology and its marketing opportunities utilizing (B2B, B2C, B2G), we first completed research on the topic. As a result, we learned how LEDs work, their major components, and market gains. Companies use market analysis to study and estimate the amount of opportunities and attractiveness of a market within a certain industry. Our report used data and market trends to provide information on how lucrative implementing new LED technology is in entering the commercial lighting industry. The purpose of this section was to gain a better understanding for the process of determining factors, conditions, and characteristics of the lighting market within commercial industries. We gained an in depth understanding of the commercial lighting industry and the relativity of LED lighting modules and technologies.

Identify disadvantages and advantages of LED lights

LED lighting is a growing market throughout the United States and overseas. The technology and innovation is being further developed, causing LEDs to become a more popular choice of lighting. Though LED products are being purchased, there are several advantages and disadvantages on the matter. To determine the advantages and disadvantages of LEDs we completed secondary research.

Secondary Research

While we continually gathered primary data, secondary data was already collected and available from other sources. There are many advantages of secondary data. For example, secondary data is readily available and economical. In addition, we are able to compare and

contrast secondary data to our primary data and fill in gaps and deficiencies thus, allowing us to interpret information that needs to still be drawn. In addition, secondary data also allows us to improve the understanding of the information. Looking at different viewpoints allows for an unbiased opinion and it provides a basis for comparison for the data that is collected by another research at a previous point in time.

When evaluating whether secondary data serves useful or not, our group decided to look at the four major parameters of secondary data that was created by Robert W. Joselyn: Availability, Relevance, Accuracy, and Sufficiency (Joselyn, 1971, P. 109). The information must be easily available, it should be relevant to the topic at hand, the margin of error and dependability to the source must be examined, and adequate data should be available.

Research conducted with secondary data can be seen in many organizations today. For example, the WSIB (Workplace Safety & Insurance Board), an independent trust agency that administers compensation for workplaces, obtains information about employee compensation claims and insurance premiums to help them save time and money compared to direct surveying or interviewing (WSIB, 2016). Another example of this is the insurance company Zurich, who conducted a secondary study with some industry data. Market researcher, Nielsen, found that the majority of Internet users rely on online communities to recommend products or services. It was clear to Zurich that the secondary data concluded that their website needed to be more of a communication vehicle. Other examples of secondary data being used in a corporate setting include censuses, weather reports, organizational reports and accounting documents. "…secondary data can be examined over a longer period of time. For example, you can look at a company's lost-time rates over several years to see at trends" (Institute for Work & Health, 2008, P. 5).

Perform a cost benefit analysis

A cost benefit analysis is a systematic approach to determine the strengths and weaknesses of a company, business or any situation to better understand the entirety of it to help reach a conclusion. To determine the feasibility of new market entries for LEDs, a cost benefit analysis was extremely useful. We created an analysis that focused on the price, economic impact, energy efficiency, energy cost and environmental impact of LEDs versus Incandescent lighting and compact fluorescent lighting. To gather suitable data on each of these fixtures, we utilized the WPI Gordon Library database, Google scholar as well as other online sources. We also contacted experienced individuals in the lighting industries from two primary places; Osram Sylvania and Mass Development. We applied their experience and knowledge of LEDs and retail, manufacturing and affiliation industries into our cost benefit analysis (OSRAM SYLVANIA, 2016).

Cost Benefit Analysis

	Incandescent	Compact Fluorescents (CFLs)	LEDs
Life Span (avg)	1,200	8,00 hours	50,000
Watts of Electricity Used	60 Watts	13-15 Watts	6-8 Watts
Kilowatts of Electricity Used	3,285 KWh/yr	767 KWh/yr	329 KWh/yr
Annual Operating Costs	$328.59/yr	$76.65/yr	$32.85/yr
Operating Cots per 60,000 Hours	$821.72	$191.73	$82.17
Initial Costs	$1.38	$2.95	$45.99
Carbon Footprint	40 bulbs	6 bulbs	1 bulb

Table 1: Lighting Industry Cost Benefit Analysis

The cost benefit analysis above shows that LED lights have a higher upfront cost than Incandescent and CFL's. This high upfront cost hurts the LED because the average Joe consumer is looking to buy a relatively cheap bulb. They do not realize that over a longer period of time the LED will end up saving them money. The main benefits of the LED shown by this cost benefit analysis are the long term savings as well as the environmental impact. The long term savings come from the energy efficiency as seen by the total wattage of electricity used. 6-8 watts for LEDs is far less than CFLs at 13-15 watts. Less energy used will save money in the long run as well as not have as big of an impact on the environment. Carbon footprint, which is the total amount of greenhouse gasses emitted by a product is 6x less for LEDs than CFLs and 40x less than incandescent. This means that LED lights are also the environmentally friendly option.

Evaluate the feasibility of a product entering the lighting market

In order to evaluate LED technology and its marketing opportunities utilizing (B2B, B2C, B2G), we first completed research. From our research we were able to understand how LEDs work, what their main components were and what market gains they had. Conducting interviews was the most credible source of data we retrieved for this project.

Conducting Interviews

In depth, we collected our data from the public and our project stakeholders through conducting interviews. Interviews allowed us to comprehend LED lights and refute LED stereotypes. Conducting a focus group was considered; however, we determined that interviews permitted more direct responses. Our interview process consisted of 11 questions, which can be found in Appendix A. We conducted a total of 7 interviews, which were recorded, ranging from retailers such as Home Depot, manufacturers such as, Osram Sylvania and industry affiliates

such as Mass Development. In addition, we contacted 5 businesses (i.e. retailers, manufacturers, affiliates) to find out what specific places currently utilize LEDs throughout their facilities.

This process helped us gather more credible information about LEDs and its marketing entry levels. The answers to our questions determined the distribution paths each company is involved in. In addition, this procedure determined whether a middle man was needed or if it is directly business to customer (B2C). All interviews were summarized in order to answer our projects main question: Are LEDs feasible? Lastly, a behavioral analysis was conducted on the answers given in order to determine possible trends in our data. This helped us determine whether or not a second survey should take place based off of the observed patterns found.

Behavioral Analysis

After conducting interviews, we created a spreadsheet to analyze each of the interviews. To analyze, we listened to each of the recordings and then noted the important information that was given from the interview. We went through each interview individually so that all seven interviews were analyzed four times. Creating the spreadsheet, allowed us to see what common trends were noted throughout all interviews. Subsequently, we each went through the spreadsheet to find any themes from the interviews. This was then placed into a list to see the most important concepts to note when determining the feasibility of new markets entering the LED lighting industry. Below, Table 2: *Sample Description for Interviews* thoroughly breaks down how we organized our data and what we gained from each significant piece.

Sample Description for Interviews

Subject	Job Title	Expert (Y/N)	(R) Retailer/(M)Manufacturer/(A)Affiliate	Use LEDs (Y/N)
1	Head Project Manager	Y	M/R	Y
2	Product Marketing Manager II	Y	M/R	Y
3	Vice President, Manufacturing Initiatives	Y	A	N
4	Program Manager, Growth & Innovation	N	A	N
5	Electrician	Y	R	N
6	General Manager	N	R	Y
7	Supervisor, Structural Maintenance	N	R	Y

Table 2: Sample Description for Interviews

In addition, Table 3: *Local Industry Analysis* shows what specific places we interviewed commonly use LED lights and where specifically these places use them throughout one's establishment.

Local Industry Analysis

Subject	(R) Retailer/(M)Manufacturer/(A)Affiliate	Use LEDs (Y/N)	(P)Parking Lots/(F)Freezers/(B)Building
1	R	Y	P
2	R	Y	P/F
3	R	Y	F
4	R	Y	F
5	R	Y	B
6	R	Y	B

Table 3: Local Industry Analysis

Results

Retailers are the sale of commodities or goods in small quantities to ultimate consumers. On the other hand, manufacturers are subdivisions of productions and trade based on the fabrication, processing, or preparation of products from raw materials and commodities. This includes all refined metals and minerals derived from extracted ores. Consequently, affiliates are officially attached or connected (a subsidiary group or a person) to an organization. These three categories help identify all possible lighting industry components. Throughout this project retailers, manufacturers and affiliates describe our data collection substantially.

LED Industry

Upon conducting our research for this project, we were highly motivated to determine what the lighting industry atmosphere looked like for LED technologies. We also wanted to find out what the competition, distribution, and feasibility was for new players to enter the market. From our interviews we were able to conclude that the lighting industry market is a highly competitive place, making market entry difficult for smaller firms or innovators to succeed in penetrating the market. “Despite this difficulty, there are several new firms entering the lighting industry everyday” said, the Vice President of Manufacturing initiatives. In general the market is dominated by major companies who control a majority of the market share within the industry (i.e. General Electric, Siemens, and Philips.) These firms have hundreds of innovators working to improve and develop new LED and lighting technologies daily.

Competition within the lighting market does not only encompass the LED sector of the industry. Industry competition includes other alternative forms of lighting technologies available in the market. Incentives from the government have made LED technology more appealing to users. LED technologies help to save money and energy as countries strive to be more eco-

friendly. The biggest competition faced in the industry has been the affordability of the technology. Based on our interviews several companies are working on cutting the price of LED technology by shortening the shelf-life of the bulb. Distribution of LED's are being seen on everyday shelves of local produces retail stores groceries etc. Some large retailers actually use LED in their facilities, particular large groceries store holders (implement the technology in their refrigerators.) A general manager said "They've done away with regular light bulbs, people still demand them, LEDs will be all you're able to buy". LEDs are making a major impact in the lighting industry.

We were able to conclude from all of our research that the LED industry is no longer in its introductory phase of the product cycle; it has now entered the growth phase. As more individuals adopt the technology the industry should expand. With LED technology entering the growth phase of its product life cycle we should see new innovations and further development of LED technologies. This allows us to understand just where LED technology is currently in relevance to its product life cycle. There is still major room for growth within this industry, as technologies (i.e. batteries, wiring, and platforms) that support LED light bulbs and fixture improve, LED's themselves will be able to become more advanced and efficient, LED's have a bright future within the lighting industry.

Product, Price, Promotion, Place

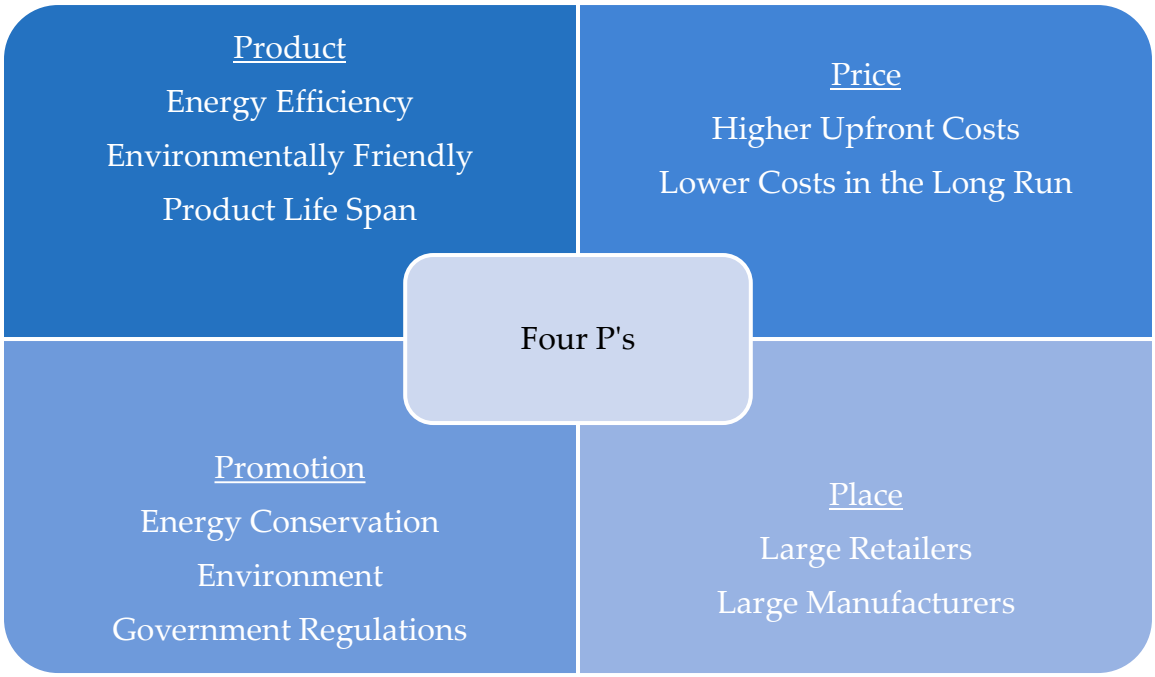

Figure 6: Product, Price, Promotion & Place

LED lights have three main qualities that make the so attractive to companies and the consumer. The first quality is that they are energy efficient. Energy efficiency can save a person a great deal of money because the LED light is using less power to work. Energy efficiency is a major key in the product of LEDs as well as the promotion. Customers who are looking to save money in the long run would implement LEDs due to the energy efficiency. This is why it has to do with 3 of the 4 P's, product, price, and promotion. The second key differentiator to an LED vs. other light bulbs is that LEDs are environmentally friendly. The environment is a major issue in today's society. People and companies are becoming more and more environmentally cautious which makes LED lights more attractive than other less environmentally friendly options. The last major differentiator that LEDs have is their life span. LED lights last longer than CFLs and Incandescent lights which means they do not have to be replaced as much. Major retail stores

such as Wal-Mart and Home Depot carry and distribute LEDs and major manufacturers such as Cree and Osram Sylvania make and innovate LED lights to be distributed by the retailers.

Benefits/use of LEDs

Throughout our research about LED bulbs and LED light fixtures our group found that there are several benefits to the use of LEDs. One well known benefit of LED bulbs is that they are more energy efficient than incandescent and CFLs. The LED bulbs use less energy to generate light, which not only is beneficial to the environment, but it also saves companies money in the long run. One subject, who is part of the manufacturing LED industry, stated that businesses are weary of implementing LEDs into their facilities because of the initial upfront costs. Many of them do not know that in the long run the money that is saved on conversion costs and energy efficiency costs makes LED the cheaper option compared to other forms of lighting. Another major benefit of using LEDs is that there are government incentives on saving energy. A company could get rewarded for saving energy by switching to LED bulbs.

There is a wide range of use for LEDs varying from single bulbs in homes to larger light fixtures in office buildings. According to a Head Project Manager, "LED lamps by 2018 could grow to a $10 Billion dollar industry." This growth of LED lamps shows that the desire for LED lamps is increasing. LED lamps are just a small segment of the LED market. As explained by the VP for manufacturing Initiatives the LED bulb and the LED fixtures are two completely different industries. Businesses such as airports and retail stores are starting to switch to LED lights throughout their facilities. For example, even the company, OSRAM Sylvania is changing its name to LEDVance. This name change signifies a change in the company's direction to focus strictly on LED technology. It is a significant change because it shows that OSRAM sees a future

for LEDs and the LED market. It shows that they see other forms of light being completely phased out by LEDs, which is why they are refocusing their entire attention to LED technology.

The industry experts that we interviewed agreed that LED technology is the best form of lighting that we have today. The benefits in the long run far outweigh the initial costs that come with LEDs. In today's society where we are worried about global warming and the environment as a whole, people are starting to switch to LEDs because of its energy efficiency. From our research and interviews we have concluded that the benefits of LED lights are greater than the costs.

Challenges

Beginning this project, we set out to determine the feasibility of new entries into the industrial LED market. We took the time to interview several individuals who had experience in the industry. Amongst all of the interviews that took place, we found a common trend throughout each interview, and that was challenges with LEDs. There were four main challenges: 1) - packaging and recycling 2) - installations 3) - price and consumer understanding of LEDs.

While conducting our interviews, we learned more about other components of LEDs such as the recycling process. As we knew converting to LEDs is a challenge especially within older buildings, but we found that recycling them is a detailed, structured process. To recycle LEDs the bulbs must first be packaged correctly and after being packaged they must be placed in a dated bin. The lights in the bins must be sealed at all times and are inspected monthly. If requirements are not met the party recycling LEDs will be fined. A General Manager we spoke with stated, "They are annoying to recycle because they have to be packaged correctly."

LEDs are the popular lighting to choose and are growing in the market; however, we found that there is a setback when purchasing LEDs and that is due to the installation.

Converting to LEDs is not as simple task, especially when larger buildings are looking to convert the lighting in their building. The reason behind this is because established buildings that were built 10-30 years ago were designed specifically for incandescent and fluorescent lighting fixtures. To install LEDs is a significant process due to the expense of converting the fixture as well as the cost to have it installed. Discussing with several companies, we found that there is a desire to convert buildings to LEDs, but the installation is creating a setback. When speaking with a Vice President of Manufacturing Initiatives, they stated one challenge was "changing the fixtures versus changing bulbs." We found that the actual procedure of converting an entire building to LEDs is desired, but not quite plausible, because of the installation cost and process.

A common word we discovered throughout our interviews was "price." Arguably one of the biggest challenges LEDs have is the initial cost of them. In the long run, LEDs save you a lot of money, but there is a lot of hesitation when purchasing LEDs and that is because of the initial cost of them. Since LEDs are so new in the last few decades, consumers do not have a full understanding of the benefits LEDs provide. This creates another challenge because when seeing the initial cost of LEDs, one will choose to purchase a cheaper lighting fixture, due to the lack of understanding the benefits of LEDs. We spoke to a Head Project Manager who claimed one challenge was "the consumer understanding the value of LED technology. The energy savings, along with lifetime improvements make LEDs very attractive. But, consumers do not want to pay for this benefit." We found that with a lack of understanding the benefits and technology of LEDs consumers choose to pay for a cheaper lighting fixture, causing a lower number in LED conversion. We spoke to a Product Marketing Manager II who emphasized the challenge of the price of LEDs, they stated "LED light bulb technology has hit a plateau with few new development breakthroughs in the coming years. LED light bulbs are more expensive than other

technologies such as Compact Fluorescent or halogen." Though, LEDs are more favorable in the long run, having little understanding of its benefits cause a hesitation in converting to LEDs due to the initial cost of them.

Future for LEDs

While discussing the future of LED lights, a Product Marketing Manager II, retailer and manufacturer, stated, that his "Company maintains more than $6 billion and is ranked the 2nd largest company in the lighting industry." Evidently, his company is in great standing throughout the lighting industry and has acquired the right technological equipment to sustain its position in the market and allots advancement. As the conversation progressed, he proclaimed the projected prospect of LEDs, stating, "Lighting in all technologies is worth $82 billion, specifically LEDs in 2015 made up 31% however by 2020 they will increase to about 70%." The Head Project Manager chimed in affirming that, "By 2022 the LED market will be worth $165.91 billion especially since the lighting industry roughly increases by $10 billion yearly." One can interpret such information as LEDs are becoming more dominant throughout the lighting industry. In addition, the cost for them is increasing yearly, moving them higher and higher in rankings.

The future for LED lights looks very bright for all retailers, manufacturers and industry affiliates. "Most definitely, everything will be LED one day, unless they come up with something better," The Supervisor of Structural Maintenance, a retailer, enthusiastically stated. LED lights have become a commodity amongst many businesses. They are being viewed as more useful than the average lighting sources used today. He also described the upsurge of LEDs as, "the answer" unless we go back candles. In addition, a general manager of a retailer declared that, "They've done away with regular light bulbs, people still demand them, and LED will be all you're able to buy." As previously stated in the beginning of this project, regulations on various lighting sources were mentioned. In that particular section we discussed how new regulations on

today's lights outcast primarily used lights today. This includes incandescent and fluorescent lights. LEDs possess the right equipment and features that coincide with such regulations. As a result, our project agrees with an electrician, a retailer, statement, "everything will be LEDs 100%, it's a no brainer." Even with the rise of LED technology, there are many aspects that effect new and improvement merchandises.

Room for Improvement

As the LED market steadily develops, large retailers, manufacturers and industry affiliates are starting to identify and acknowledge LED technology disadvantages. After conversing with various industry professionals, a retailer stated, "There's always room for improvement no matter what we are talking about." Clearly, retailers are noticing the defects of LED lights and take a backlash when selling such products in comparison to others. However, with growing new products there are always highs and lows.

Thorough research helped us effectively understand where some areas of improvements were. "I would not call the LED market mature there is room to grow. The LED business will totally change when batteries get better and wiring is not an issue," a Program Manager of Growth & Innovation, an affiliate, stated. LED batteries and wiring has become a weakness of LED technologies. Thus, problems main fester if not addressed and resolved for all future endeavors. This can help prosper LED lights even further than projected. In addition, the Vice President of Manufacturing Initiatives, an affiliate, confirmed that, "Yes, there is always room for improvement certainly, energy efficiency and cost, making them bulbs not fixture." Another room for improvement is the energy and cost of LED technology. Many industry connoisseurs have stated that these two aspects in everything play a huge role in almost every product in a market. If a product could be introduced into a market with low costs and high energy efficiency then nothing could compare. However, the question is, how do we get LEDs to fall under this

category. The future for LEDs is a bright one for sure, but adhering to minors glitches all LED imminent undertakings will be at an all-time high.

Conclusion

Collectively, our data helped us identify 5 major topics: the lighting industry, benefits/use of LEDs, challenges, the future of LEDs and room for improvement with respect to LED technology. Throughout the lighting industry new market entries can face rough times. This primarily occurs because already established businesses (i.e. competitors, distributors) have currently introduced themselves to the public. Due to this, the world already categorizes such companies with a product. For example, when the fast food chain, McDonald's first established everyone worldwide identified the chain with fast food. Thus, it was hard for other fast food chains to first enter the market. However, when entering such a market one must do their homework on the specific industry themselves. It is imperative, for a new market enterer to find or create something that will make them stand out from the rest. Our research showed that LEDs are continuously growing in market but price plays a huge role in its utilization. However, its distribution channels are primarily being applied to grocery store refrigerator lighting systems. Consequently, methods such as these coincide with ascertaining the benefits and use of specific products: LEDs.

It is quite clear that the benefits of LEDs are that they are energy efficient and in the long-run save money. Specifically, there are many government incentives for utilizing LEDs that help with saving money. Today, there are many companies who are taking advantage of such remunerations. For example, *SYLVANIA OSRAM*, the second largest lighting/distributor company, is changing its name to *LEDVance.* Even with LED advancements and benefits there are always challenges for any product. The best way to successfully elongate product profits is to

face such challenges head-on. Recognizing weaknesses and fixing those weaknesses are exactly what make products better than the rest. LEDs have three main challenges: 1) - LED packaging & recycling, 2) - LED installation and as previously mentioned 3) - price. Full comprehension of these challenges should be noted and addressed. In doing so, new market entries can affect the future of LEDs. In today's society everyone now-a-days need light. According to the Supervisor of Structural of Maintenance, the "upsurge of LEDs is, "the answer" unless we go back to candles.

Our group listed the major themes that were apparent from our interviews of individuals involved in the LED market. We compiled a database of the interviews and sifted through it to compile a list of reoccurring themes in the interviews. We found that there were several ideas that came up time and time again in each interview. The first theme that we noticed as a group is that the people that we interviewed all have at least 5 years of experience in the lighting industry. This was important to us because these people have seen and used other forms of lighting in the past, such as incandescent and CFL lights. The use of several different types of lights allowed them to really state that LEDs are the best form of lighting that we have today.

One of the major themes that we noticed throughout the interviews is that there is a huge future for LEDs. Individuals from retailers, manufacturers, distributors and affiliates all believe that LED lights are the future of the lighting industry. "LEDs are making up 31% of the lighting in all technologies in 2015. In 2020 it is projected to make up 70 %" (OSRAM SYLVANIIA, 2016). The future for the LED industry is bright and companies are starting to move more towards implementing LED technology more throughout their businesses.

Another major theme we found and the reason why companies are starting to lean more towards LEDs over other lighting options is that LED lights are more environmentally friendly

and more energy efficient than the competition. An electrician we interviewed stated, “We can save 80 to 85% in energy costs and the bulb can last for 20 years!” The money that an LED light can save a company due to the energy efficiency is what draws several retailers such as retailers to a product. The last major theme is that there are several challenges regarding LED lights in regards to installation and consumer knowledge. We will elaborate more on these challenges in the next section.

Based on our results and the data we have collect we predict the LED industry is going to experience vast growth in the next 10 years. We were able to gather information on the industry, the benefits, the challenges, the improvements, and the future of LED technology. After analyzing all the data we collected while conducting this project we were able to predict that the LED industry is growing for the better. We learned from several industry experts and mangers within lighting companies, that the industry is certainly expanding. This makes for a lot of opportunity for further innovation and improvement of LED technology and implementation of LED products. Our research allowed us to understand in depth the benefits offered by implementing LED technology. LEDs use less energy and help to save money in the long run, however currently they are expensive in upfront short term initial cost. Several companies are shifting their focus on LED technology, as it is becoming a more desired product by both businesses and consumers. LED technology is the best form of lighting technology we have today, and the benefits of LED implementation is far larger than the money it saves the user.

New Market Entries Guidelines

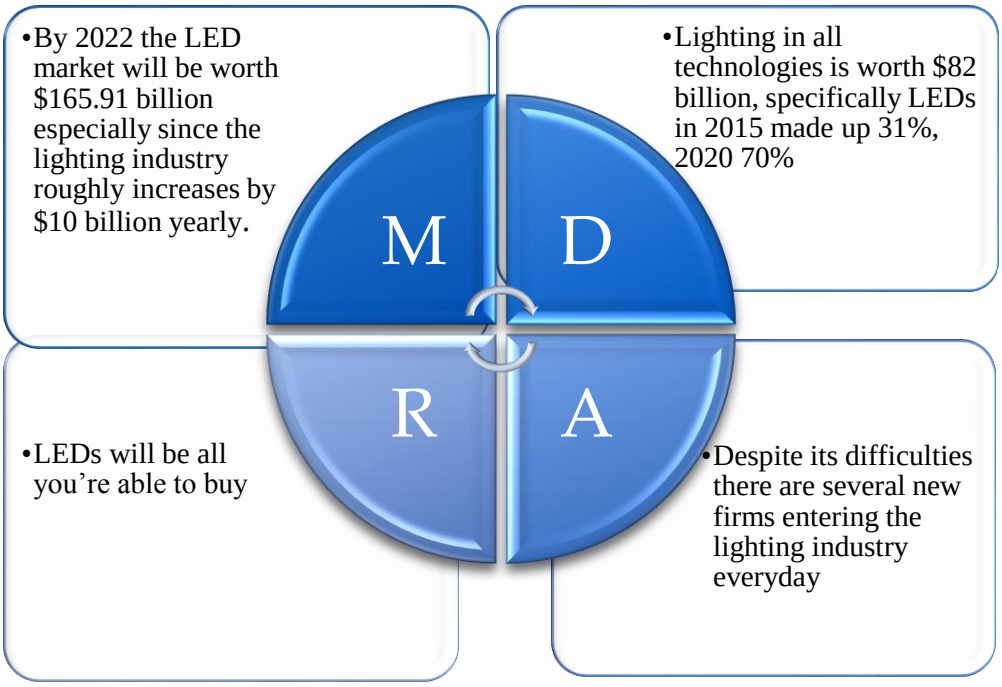

Figure 7: New Market Entries Guidelines

In order to help new market enterers, we constructed a graphical image to define the four major pathways in entering the lighting market. As previously mentioned, our data primarily focused on manufacturers, distributors, retailers and industry affiliates, which closely represent the lighting industry subsections. New Market entries could potentially gain a better understanding on how to enter or who to connect when contemplating on entering or not entering such a competitive and growing field. Consequently, it sheds light on the projected future of LEDs and gives a more in depth overview of LED stabilities.

Although there are numerous benefits to using LED technology and it is proposed at the lighting technology of the future there are still several challenges involved in converting full to LED technology. Our research allowed us to identify three main challenges: packaging & recycling, installations and price. We found that companies are already trying to address these

issues in order to make the implementation of LED more universally feasible. We predict that with the development of parts and technology that help support LED technology, LED's will be able to overcome these challenges and make their way into our everyday lives. By improving the technology that supports LED such as platforms, wires, batteries and much more, LED capabilities will grow while heightening its feasibility of use.

The future of LED is looking good; we found that several light bulb retailers are only going to be offering LED bulbs as options to purchase. Also several retailers' factories and warehouses are implementing the Led technologies in stores and warehouses, which allow them to cut down cost on electricity in the long run. After discussing the industry with several experts in the next 7-10 years the industry is expected to grow by billions of dollars. We predict that in the next s7-10 years LED technology will be a part of everyone everyday life no matter what the use is.

From our findings we can conclude that there are three main challenges in the LED market. The first challenge we found was disposing LEDs. There is a strict procedure that must be followed and if requirements are not met fines are given. A second challenge we determined from analyzing the common themes from the conducted interviews was the installation cost and conversion. We found that to change halogen and fluorescent fixtures to LED bulbs is challenging because everything must be converted. The third challenge we determined from the interviews was the initial cost of LEDs and value of LEDs. We found that there is a lack of understanding the value of LEDs amongst consumers causing a hesitation in converting to LEDs. Because there is a lack of understanding the advantages of LEDs and having a higher initial cost than other lighting fixtures creates a challenge for LEDs in causing consumers to convert to them.

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Appendixes

Appendix A: Interview Questions

1. Please tell us your role at (Company's name) and your experience with the LED industry.
2. What is your company's role in the LED industry/market?
3. Who are your competitors? What is your specialty?
4. How long have you been working in the lighting industry?
5. What is the most your company would be willing to pay for an innovation on LEDs?
6. What do you think is the projected market forecast for industrial LEDs in the next 10 years? 20 years?
7. What challenges do you foresee with LEDs becoming more predominantly used in the lighting industry?
8. Are than any new innovations that could enhance the quality and efficiency of LEDs?
9. Do you think there is opportunity for new market entries for LEDs?
10. What do you think are the biggest factors when purchasing industrial LEDs?
11. Do you think that there is room for improvement with respect to technology and use within the industrial LED market?

Appendix B: Result Compilations

Sam's Club, Worcester MA	
Questions	**Responses**
1. Please tell us your role at (Company's name) and your experience with the LED industry.	general manager, LED sell it, grown over the years, have plan with National grid subsidize cost of light bulbs, have out in parking lot, in the club have fluorescent, have LEDs in the freezers around the doors
2. What is your company's role in the LED industry/market?	sell LEDs, looking to be as efficient as possible, looking to change out indoor lights within next 6 months, environmentally concerned
3. Who are your competitors? What is your specialty?	anyone sells light bulbs is competitors, specialty: wholesale, compet: bj, whitechs, costco,
4. How long have you been working in the lighting industry	11 years
5. What is the most your company would be willing to pay for an innovation on LEDs?	n/a
6. What do you think is the projected market forecast for industrial LEDs in the next 10 years? 20 years?	they've done away with regular light bulbs, people still demand them, LED all you'll be able to buy
7. What challenges do you foresee with LEDs becoming more predominantly used in the lighting industry?	they're annoying to recycle, have to package correctly, have to be in a dated bin, has to be sealed at all times, could get fined if not done correctly, 100%, inspected every month
8. Are than any new innovations that could enhance the quality and efficiency of LEDs?	sell lightbulb that works with smoke detector light turns red when the alarm goes off, Nest
9. Do you think there is opportunity for new market entries for LEDs?	yes for commercial side
10. What do you think are the biggest factors when purchasing industrial LEDs?	cost, installation, doing with old bulbs
11. Do you think that there is room for improvement with respect to technology and use within the industrial LED market?	changing with colors, but not too sure

Worcester Airport, Worcester Ma	
Questions	**Responses**
1. Please tell us your role at (Company's name) and your experience with the LED industry.	Kevin Duffy, Supervisor Structural Maintenance, No experience with LED industry, trying to convert, trying to talk to Massport into converting to all LEDs. We've got about 8 different lights, 8 different lightbulbs in the building that are all a problem, all expensive. LEDs are initally expensive but good in the long run for not replacing like metal highlights and flouscent lights
2. What is your company's role in the LED industry/market?	No Idea
3. Who are your competitors? What is your specialty?	Do not have competitors, it's an airport, Logan, TF green
4. How long have you been working in the lighting industry	Working with lights for 20 years
5. What is the most your company would be willing to pay for an innovation on LEDs?	Could not say
6. What do you think is the projected market forecast for industrial LEDs in the next 10 years? 20 years?	Astronomical, It has to be, common sense, if you know anything about LEDs, Better than other lights
7. What challenges do you foresee with LEDs becoming more predominantly used in the lighting industry?	I don't see any challenges, what challenges would there be, 40 years being a maintenance man and LED is the answer unless we go back to candles. **Installing LED bulbs vs Others:** didn't have to change an LED bulb yet but others were a pain, had to change other bulbs probably 10-20 times a month but you have to remember this a big building and have there's lot of lights
8. Are than any new innovations that could enhance the quality and efficiency of LEDs?	Idk, you answered that when you looked at that and said it's bright
9. Do you think there is opportunity for new market entries for LEDs?	Most definitely, everything will be LED one day, unless they come up with something better
10. What do you think are the biggest factors when purchasing industrial LEDs?	Lifetime, lifespan, that's it
11. Do you think that there is room for improvement with respect to technology and use within the industrial LED market?	There's always room for improvement no matter what we are talking about.

Peter Russo	
Questions	**Responses**
What is MMEP and what does it do?	A non profit organization, Mass MEP runs off the belief that there is some element of everything in (?) in Massachusetts that can provide growth and innovation.If people know what that element is but don't know how to leverage it, MMEPhelps them and if they don't know the element MMEP heps them discover it and then execute on it. MMEP also provides experiencial learning for corporations. For the service industry MMEP provides spot solutions (ISO certification). Half of the funds comes from state and federal based on MMEP's economic impact on the state of MA and the other half comes from fees that MMEP charges.
What is your role within Mass Development?	I am the program manager for growth and innovation.
What is it like to have a start up company in a well developed industry?	One of the key ways to get into a new market or a market that is established is to either come up with a new technology or with a new belief statement that you deliver in a new way. One new way to enter the market is to find a different place within the supply chain. Another way to enter a channel is to offer a different service level. The absolute worst way to enter an established market is on price.
Can you tell us anything you know about the development of LEDS?	I would not call the LED market mature there is room to grow. The LED business will totally change when batteries get better and wiring is not an issue

Veda Clark	
Questions	**Responses**
1. Please tell us your role at (Company's name) and your experience with the LED industry.	1.) Vice President VP, Manufacturing initiatives, Mass Development CEO of Lighting Company, Linear architectural company
2. What is your company's role in the LED industry/market?	2.) Manufacturer of lights LED bulbs Fixtures
3. Who are your competitors? What is your specialty?	3.) Phillips, General Electric, Sylvannia, Lythonia, Aqutie
4. How long have you been working in the lighting industry	4.) 20 years
5. What is the most your company would be willing to pay for an innovation on LEDs?	5.) n/a $75 reg fluorescent, LED $125
6. What do you think is the projected market forecast for industrial LEDs in the next 10 years? 20 years?	6.) 2015-19 $5B à $22B LED fixture market
7. What challenges do you foresee with LEDs becoming more predominantly used in the lighting industry?	7.) Initial costs, feasibility- difficult to change fixture opposed to bulbs
8. Are than any new innovations that could enhance the quality and efficiency of LEDs?	8.) The are constantly new entries in the market there is always room for improvement with the technology
9. Do you think there is opportunity for new market entries for LEDs?	9.) Yes there are constant new entries into the market
10. What do you think are the biggest factors when purchasing industrial LEDs?	10.) Initial costs, conversion costs, energy efficiency, incentives on energy
11. Do you think that there is room for improvement with respect to technology and use within the industrial LED market?	11.) Yes, there is always room for improvement certainly, energy efficiency and cost, making them bulbs not fixture

Peter Karalis (OSRAM)	
Questions	**Responses**
1. Please tell us your role at Osram Sylvania and your experience with the LED indus	My role at Osram (soon to be LEDVance) is Project Management head for the Americas. I have been working in the LED industry for 5 years in this role. In my role I work with cross funcional teams to specify, develop and deliver new lighting products (all with LEDS).
2. What is your company's role in the LED industry/market?	Our main role is to develip and delivery lighting products using LEDS. We specify the requirementsfor these new products, and then we work with design and manufacture houses to develop, test, manufacture, and ship these new products.
3. Who are your competitors? What is your specialty?	Philips Lighting, Cree, Nitchia Corporation. Our specialty is finished lighting products that we sell to trade and retail markets.
4. What is the most your company would be willing to pay for an innovation on LEDs?	This is a tough question, and it depends on the type of innovation and payback. Our market is extremely cost sensitive, so the innovation would have to be either cheaper LEDS (which does not seem viable, most LEDS are just now pennies to buy), or a technology and feature
at do you think is the projected market forecast for industrial LEDs in the next 10 years? 20 ye	I know the LED lighting industry is expected to grow signifigantly. LED lamps by 2018 could grow to a 10Billion dollar industry. I have also seen reports that the Industrial and Commercial LED Lighting Market Worth $165.91 Billion by 2022.
t challenges do you foresee with LEDs becoming more predominantly used in the lighting indu	The consumer understanding the value of LED technology. The energy savings, along with lifetime improvements make LEDs very attractive. But, consumers do not want to pay for this benefit. Our developments focus on the cost and making LED products look like the
7. Are than any new innovations that could enhance the quality and efficiency of LEDs?	The biggest issue I see right now is thermal management of LEDs. Customers want smaller form factor lighting, and with that we lose thermal control. Innovation in thermal management would reduce a lot of risk.
8. Do you think there is opportunity for new market entries for LEDs?	This seems like a challenge to me. LEDs are becoming a commodity and with the costs dropping every six months, entry into the market seems to be a challenge.
9. What do you think are the biggest factors when purchasing industrial LEDs?	From my perspective the biggest factor is cost. Our market is extremely cost competitive. Most suppliers are meeting the color temperatures requested, and the quality of the LED's dpes not seem to be a problem.
10. Do you think that there is room for improvement with respect to technology and use withi	Yes, there is always room for improvement. Cost reduction will always be a factor, but continuing to improve energy savings is critical. LED manufacturing, improved processes and materials, are developing LEDs with superior light output, energy savings, and smaller sizes.

Peter Stratemeyer (OSRAM)	
Questions	**Responses**
1. Please tell us your role at Osram Sylvania and your experience with the LED industry	My role at Osram is Product Marketing Management for Classical LED lamp. My portfolio includes Classical lightbulb shapes driven by LED's including A, B, and G shape. I have been in the lighting industry for 6 years all in LED lighting.
2. What is your company's role in the LED industry/market?	Osram Sylvania is the second largest global lighting company that designs, develops and manufactures all forms of lighting products. We have many subsidiaries and divisions, including Automotive lighting, LED lightbulbs, Ballasts, fluorescent lamps and our opwn semiconductors including LED chip. We are a powerhouse in leading lighting technology and in leading
3. Who are your competitors? What is your specialty?	Philips Lighting, GE, TCP and Feit are our major competitors. Osram Sylvania supports all lighting application with a current focus on LED light bulbs, LED fixtures, and LED wireless lighting products.
4. What is the most your company would be willing to pay for an innovation on LEDs?	Osram Sylvania leads in innovation, so we would most likely not pay for innovation. We have more than 400 engineers globally and product managers that are constantly monitoring the lighting world for market trends and new product ideas.
hat do you think is the projected market forecast for industrial LEDs in the next 10 years? 20 yea	Lighting in all technologies is an $82 Billion dollar global business, with LED making up 31% in 2015 and a projection to hit 70% by 2020. OSRAM maintains more than $6 Billion of lighting share globally.
hat challenges do you foresee with LEDs becoming more predominantly used in the lighting indus	LED lightbulb technology has hit a plateau with few new development breakthroughs in the coming years. LED lightbulbs are more expensive than other technologies, such as Compact Fluorescent or halogen. The lighting industry has turned to reducing features to reduce costs, such as shorter life to make the products more attractive to
r. Are than any new innovations that could enhance the quality and efficiency of LEDs?	There is a tremendous amount of work being done on LED chips to increase the Color Rendering Index (CRI) and maintain high levels of efficacy (lumens per watt). Higher CRI LEDs require more power to produce the same lumen output of a lower CRI chip. This increases cost and makes the energy savings less favorable to the consumer.