

**USING THE OUTCOME-DRIVEN INNOVATION
APPROACH TO DEVELOP A CUSTOMER VALUE
MODEL FOR LIGHTING**

by

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ABSTRACT

LED technology is on the cusp of disrupting the entire lighting industry if the industry can develop new lighting products that customers will want to use and purchase. Understanding what customers value from their lighting products is an open question for the industry. To answer this question and to provide a deeper understanding of customer's needs, I have applied the outcome driven innovation approach. Through this approach the customer value model was developed, which identifies customers needs and product evaluation metrics for lighting. In this analysis it is revealed that customers will value lighting products that meet both their functional and non-functional requirements. Finally, I have presented a new product development process which integrates the customer value model into all process activities from inception to product launch.

Keywords: light emitting diodes; solid state lighting; outcome driven innovation; customers

Subject Terms: new product development; disruptive innovation; customer led innovation

DEDICATION

For Chris, who provided unconditional support and ensured my coffee cup was never empty throughout this entire academic adventure.

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TABLE OF CONTENTS

Approval	ii
Abstract	iii
Dedication	iv
Acknowledgements	v
Table of Contents	vi
List of Figures	viii
List of Tables	ix
Glossary	x
1: Introduction	1
1.1 Purpose and Scope of Analysis	1
1.2 The Lighting Industry.....	2
1.2.1 Industry Growth Trends	4
1.2.2 Light Technology	5
1.2.3 Demand for Energy Efficient Lighting Technologies.....	6
1.2.4 Banning of Inefficient Incandescent Light Bulbs.....	7
1.3 Light Emitting Diodes	7
1.3.1 LED Technology	8
1.3.2 Disruption to the General Lighting Industry Value Chain	9
1.3.3 Comparative Advantages of SSL over Traditional Technologies.....	12
1.3.4 Applications of SSL Technology outside General Lighting	16
1.3.5 General Illumination Market Successes	17
1.3.6 General Illumination Market Introduction Challenges.....	18
1.3.7 SSL Innovation Opportunities.....	21
2: Customer Driven Innovation Literature Review	24
2.1 Customer Driven Innovation	24
2.1.1 Identifying What Customer Value.....	28
2.1.2 Applying the Jobs-to-be-done Approach.....	29
3: Research Methodology	33
3.1 Capturing Customer Inputs For Lighting	34
3.2 Phase 1: “Jobs to be Done”	35
3.2.1 Categorizing the Types of Jobs	40
3.2.2 Creating the Process Job Map	42
3.3 Phase 2: “Desired Outcomes”	44

3.3.1	Developing a Desired Outcome Statement.....	44
3.3.2	Collecting Customer’s Desired Outcomes	46
4:	Results.....	50
4.1	Types of Jobs that Customers Accomplish with Lighting	50
4.2	Job Map	54
4.3	Customer – Desired Outcomes.....	58
4.3.1	Desired Outcome Statements for the Functional Job of Lighting	59
4.3.2	Desired Outcomes for the Consumption Chain Jobs of Lighting.....	73
5:	Discussion and Recommendations	82
5.1	Interpretation of the Customer Value Model	83
5.1.1	Understanding the Core Functional Jobs to be Done by Lighting	83
5.1.2	Other Functional Jobs.....	84
5.1.3	Unidentified Functional Job of Lighting	87
5.1.4	Emotional Jobs of Lighting	88
5.1.5	Variability of Jobs by User.....	89
5.1.6	Interpretation the Job Map.....	90
5.1.7	Interpretation of Desired Outcomes	92
5.1.8	Summary of the Customer Value Model for Lighting	93
5.2	Incorporating Outcome Driven Innovation into LED Product Development.....	94
5.2.1	Standards for LED Development Processes.....	94
5.2.2	Integrating Outcome Driven Innovation into the Product Development Process.....	95
5.3	Future Research Recommendations	100
5.4	Conclusion.....	101
5.4.1	Assessment of the ODI Methodology	102
Appendices.....		104
Appendix 1:	Light Efficacy Based on Energy Usage.....	104
Appendix 2:	Comparison of Overall Lighting Operation Costs.....	105
Appendix 3:	Colour Saturation Efficiency	106
Reference List.....		107

LIST OF FIGURES

Figure 1: Relative Market Share of Lighting Application Segments within the General Lighting Market.....	4
Figure 2: Comparison of performance attributes of SSL and incumbent lighting technologies.....	16
Figure 3: Haitz Law	21
Figure 4: Structure of a Job Statement.....	37
Figure 5: Structure of a Desired Outcome Statement.....	45
Figure 6: Customer Value Model, the Job Map for seeing an area with insufficient light	56
Figure 7: Customer desired outcomes statements when identifying when light is required	60
Figure 8: Customer desired outcomes for locating which light to turn on	62
Figure 9: Customer desired outcomes for locating a light switch	63
Figure 10: Customer desired outcomes for turning on a light	65
Figure 11: Customer desired outcomes for using light to see when performing an activity.....	68
Figure 12: Customer desired outcomes for adjusting the light.....	71
Figure 13: Customer desired outcomes for turning off the light	72
Figure 14: Customer desired outcomes for installing and/or replacing the light bulb.....	74
Figure 15: Customer desired outcomes for purchasing a light bulb	76
Figure 16: Customer desired outcomes for installing and/or replacing the light fixture	78
Figure 17: Customer desired outcomes for purchasing a light fixture.....	80
Figure 18: Outcome-Driven Innovation Product Development Process	96
Figure 19: Product Feature Evaluation Matrix Template	99

LIST OF TABLES

Table 1: Summary of the 8 functional steps of a Job, where products can create value and examples of product successes.	43
Table 2: Jobs customers are attempting to achieve with residential lighting	52
Table 3: Directly related functional jobs of lights, excerpted from Table 2.	85
Table 4: Indirectly related functional jobs, users want to achieve with lights.....	86

GLOSSARY

Compact Fluorescent lamp (CFL)	Fluorescent lights are gas-discharge lamps that use electricity. A compact fluorescent light typically has bent tubes to reduce the size of the light bulb.
General lighting	The largest market for lighting products, it includes lighting applications used in offices, homes, industrial, retail spaces, the hospitality sector, outdoors and architectural design.
Incandescent Bulb	The most commonly used light source in residential settings and are a very inefficient light source. These types of bulbs produce light from a filament, that glows when heated by an electrical current.
Light Emitting Diodes (LED)	Light emitting diode is a semiconductor device that emits visible light with an electric current is passed through it
Outcome driven innovation (ODI)	Developed by Ulwick (2005), this is an innovation methodology, which defines the customer's needs first. The needs are defined following a rigorous approach to collecting customer need statements, which are can be used to generate and validate new product ideas and opportunities.
Residential Lighting	The largest of seven market segments within the general lighting market segment. Residential lighting includes both permanent and portable light fixtures that are used in the home.
Semiconductors	A controlled conductive device that has the ability to conduct an electric current. Semiconductors used in LEDs are a p-n junction diode that acts as a light emitter.
Solid State Lighting (SSL)	Lighting from solid state semiconductor devices such as light emitting diodes

1: INTRODUCTION

1.1 Purpose and Scope of Analysis

Solid state lighting (SSL) has long been prophesized to revolutionize the lighting industry with promised energy and economic savings. The successful adoption of SSL, or more specifically Light Emitting Diodes (LED), by consumers for general illumination will result in a complete industry disruption, ending a more than 100 year domination of the incumbent technology, incandescent bulbs. LED technology has steadily improving since the first LEDs were developed in the 1960s, however it is only with recent technological advances that the vision of SSL has become a technically viable solution for general illumination market. Up until recently, SSL developers key concerns were solving technological problems such as light efficacy, colour and reliability, but as these challenges are being overcome the industry is now faced with a bigger question of what end-products will be most successful with customers. Companies have therefore, become increasingly interested in how they can better meet customers needs by adding value to a market that has been relatively stagnant since the invention of the light bulb.

The purpose of this project is to identify customers' needs and performance metrics for lighting, which can then be used to identify what products and features will deliver the most value to customers. In terms of the lighting industry, the scope of this study is limited to residential lighting. Using the techniques described by Ulwick (2005), a qualitative approach towards analysing outcome driven innovation, will be deployed to specifically identify how residential customers use lighting products in their homes and

how they evaluate whether the product successfully meets their needs. This method aims to uncover customers' latent needs and to build a deep understanding of the customers. It is an essential first step in new product development process and provides insights that are used to inform strategy.

In the remainder of Chapter one, I will provide an overview of the lighting industry, LED technology and a summary of how LED lighting is poised to disrupt the general illumination market. In Chapter two, I will review customer driven innovation approaches used to ensure that new product are developed successfully. Chapter three will outline the methodology used to define customer's needs and values for lighting. Chapter four presents a summary of the research results. Finally in Chapter five, I will discuss how this data can be used to define development and marketing strategy, as well as introduce a template to measure success in the development of new products.

1.2 The Lighting Industry

The global lighting market is estimated to have revenues of approximately \$70 billion USD, which is expected to grow to \$159 billion by 2020 (McKinsey & Company, 2011). The three largest sectors within the industry are general lighting, followed by automotive and backlighting, making up 75%, 20%, and 6% of market size respectively (McKinsey & Company, 2011). Of these three primary sectors, the general lighting segment is predicted to have the fastest growth over the next decade, with an expected increase of \$53 billion dollars forecast by 2020, and an overall increased market share of 80% (McKinsey & Company, 2011). The remaining 10% of the market consists of sign display, medical lighting, light sources for projectors, optical devices, signal light and

sensors for other electronics, however this segment is projected to remain relatively the same size over the next 10 years (McKinsey & Company, 2011).

The general lighting market, the largest and fastest growing sector, is further segmented by seven sub-markets, based on the unique requirements and purchasing decisions required for each application. The seven sub-markets within the general lighting market are residential, office, commercial/retail, architectural, hospitality, outdoor, and industrial, of which the largest is the residential market making up 40% of the entire general lighting market (Figure 1). The residential market is also the largest consumer for incandescent lighting and is predicted to undergo significant technology changes in the next few years as consumers and governments look to reduce energy consumption.

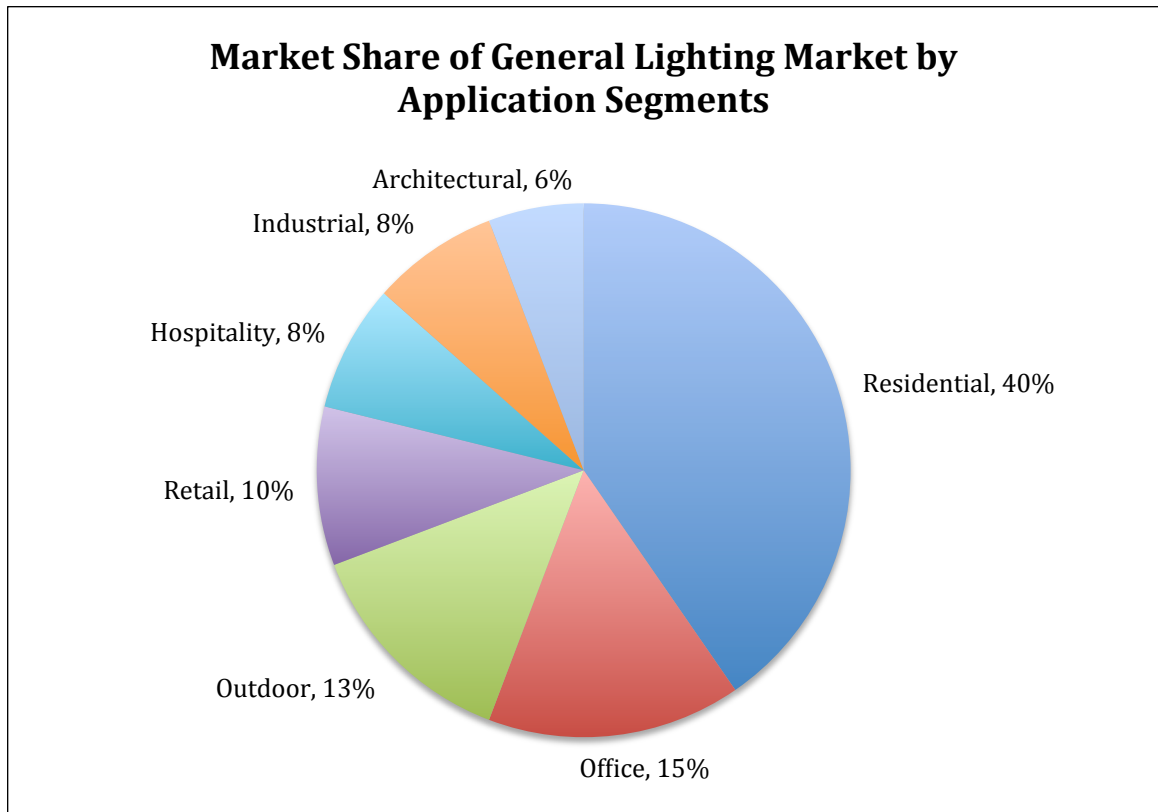


Figure 1: Relative Market Share of Lighting Application Segments within the General Lighting Market. Adapted from *Lighting the Way: Perspectives of the Global Lighting Market* by McKinsey and Company, 2011, p. 29.

1.2.1 Industry Growth Trends

According to McKinsey & Company (2011), over the next decade, demands for lighting are expected to continue to grow at a rate of 3-5% due to three key trends:

1. Population growth, primarily in developing countries, is a fundamental driver for demand for lighting. Asia and India are expected to have the fastest growing demand for lighting products, not only in the general lighting market but also throughout the lighting industry.

2. Increasing global urbanization will directly impact demand for lighting products because urbanized cities use more light than rural areas.
3. Increasing energy costs, and global efforts to reduce CO2 emissions will increase demand for energy efficient lighting products, thereby driving the development and commercialization of more energy efficient lighting technologies.

1.2.2 Light Technology

The lighting industry is a mature industry, having existed since the commercialization of the light bulb over 100 years ago. Surprisingly for a technology-based industry, there have been relatively few industry changing innovations, and original incandescent bulb technology is still the dominant product sold today. In the general lighting market, incandescent bulbs on a per unit basis represent 64% of the products sold. The industry's primary incumbent light source technologies are incandescent (traditional filament light bulbs and halogen lights), gas-discharge (neon and high intensity discharge lights) and electric arc lighting (fluorescent lighting such as compact fluorescent light). Within these three technologies, technological advancement has tended to be incremental throughout the past century (Sanderson et al., 2008). The fourth and newest light source technology are Light Emitting Diodes (LED). LED technology is forecast to grow in market share over the next decade primarily by replacing the energy inefficient incandescent lighting (Kickham, 2011). Currently, incandescent lighting holds by far the greatest market share in terms of units sold, however the other technologies due to higher prices hold proportionally more of the market share in terms of revenues (McKinsey & Company, 2011; Sanderson et al., 2008).

In the next couple years, compact fluorescent lamps (CFL) are expected to steadily increase in market share (Freedonia Group, 2009), however in the longer term LED technologies are forecast to be the primarily replacement technology for incandescent lighting (McKinsey & Company, 2011).

1.2.3 Demand for Energy Efficient Lighting Technologies

Improved energy efficiency is one of two dominant trends driving technological innovation in the lighting industry. Incandescent light bulbs, the dominant incumbent technology for residential and commercial use, is extremely energy inefficient. The US Department of Energy estimates that lighting consumes 22% of all electrical energy produced in the United States (Ashe et al., 2012). Within the general lighting sector, residential and commercial lighting are the largest consumers of energy, using approximately 78% of the energy consumed by lighting (Ashe et al., 2012). Due to the high percentage of energy consumed, the lighting industry has become a primary target in efforts to help nations reduce their total green-house emissions. Not only is there increased emphasis on developing more efficient lighting solutions, but also in ensuring consumers purchase and use these more energy efficient solutions. Solid-state lighting is being primed as major technology in the industry because it is extremely energy efficient. In the U.S. for example, SSL has the potential to reduce lighting energy usage by nearly one half, which would play a key role in their to climate change solutions (U.S. Department of Energy: Energy Efficiency & Renewable Energy, 2012).

1.2.4 Banning of Inefficient Incandescent Light Bulbs

Canada is one of many countries, including the United States, the European Union, Australia and India who are participating in the global trend to ban inefficient incandescent lighting and to define efficiency standards for lighting. Australia was one of the first countries to ban incandescent bulbs, beginning their phase out process in 2009 (Department of Climate Change and Energy Efficiency, Australian Government, 2011). Canada, like many countries is taking a phased approach to the ban starting with the least efficient light bulbs, specifically the higher wattage bulbs. Although originally scheduled for 2012, Canada's will be phasing out 75 and 100 watt bulbs in January 2014, to be followed by bans on 40 and 60 watt bulbs by December 31, 2014 (Natural Resources Canada, 2011). For Canada this ban is predicted to help reduce greenhouse emissions by more than 6 million tonnes a year, with an estimated savings of \$60 annually for end consumers in their electricity costs (CBC, 2009). Although the motive behind this ban is to reduce green-house emissions, the ban is also a key driver in the adoption of new lighting technologies.

1.3 Light Emitting Diodes

Solid-state lighting (SSL) technology was first developed in the 1960s and since those early days their overall performance has rapidly improved. Fundamentally, SSL technologies are a radical departure from existing lighting technologies. SSL devices use semiconductors to convert energy into light, which is unlike traditional lighting technologies where light is created within a glass bulb using either a filament (incandescent) or gas (fluorescent), this new method is highly efficient. However, SSL devices are not just replacements for existing technology, they are capable of creating

entirely new lighting applications. As such, many industry experts forecast large revenue sales from SSL devices as they replace many of the incumbent technologies (McKinsey & Company, 2011; NanoMarkets, 2005; Strategies Unlimited, 2005). Why do SSL devices, which are a radical departure from traditional lighting technologies, show such promise for the lighting industry? This question is likely best answered by looking at two primary reasons; first they have several performance advantages over traditional technologies and second they have a very broad range of applications.

In the following sections I will discuss provide an overview of the broad range of LED applications, the advantages of SSL devices have over traditional devices, the technology and why it is a disruptive technology, and finally the current market for LEDs.

1.3.1 LED Technology

Solid state lighting devices consist of semiconductors that convert energy into light. The basic light generating elements of a SSL system include an electronic-carrying n-layer and a hole-carrying p-layer. When voltage is applied to this structure, electrons are injected into each layer causing them to radiatively recombine. The result of this process is the emission of a photon, which is the basic element of light (Arpad et al., 2001). Adjusting the energy levels of the electrons and holes enable developers to control this photon's colour and wavelength. The SSL's light source is therefore derived from a solid block of semiconductors. The semiconductors can either be light-emitting diodes (LED), organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED) to emit light. In a SSL system, the LEDs are controlled by a digital control that can be linked to a computer, thus enabling the LEDs to be fully integrated with other systems.

LED and OLED are the dominant semiconductor technologies in the industry, however LED technologies have been further developed and are the growing SSL technology in the general lighting market.

1.3.2 Disruption to the General Lighting Industry Value Chain

With the advent of general market SSL solutions the lighting industry is beginning to undergo a significant transformation from a vacuum tube based technology to a solid state semiconductor lighting technology. This transition is equivalent to other industries that have undergone the transition from analog to digital, such as LP records to compact discs to MP3 for music storage. Like similar transitions in other industries, if successful, SSL technology is poised to completely disrupt the industry likely pushing the incandescent light bulb we know today into obsolescence. With this disruption, every stage of the value chain will undergo significant changes from new production methods upstream to a rapidly growing fixtures market downstream (McKinsey & Company, 2011).

Upstream, as the new production industry develops, new entrants to the general lighting industry are expected to come from other segments. This is because production differs significantly for LEDs. The new entrants, although not new to LEDs as their focus was in other LED applications such as backlights, are looking to gain a share in the lucrative general lighting market. Their background in LED production makes them ideally situated to compete with the longstanding companies that currently dominate this industry. Fortunately for the incumbents, they hold some competitive advantage because LEDs for the general lighting market require a more sophisticated technology and a wider variety of application know-how (McKinsey & Company, 2011). Given the long lead

time for the growth in general lighting LEDs, incumbents have an opportunity to shift and develop new technical capabilities to compete. Even further upstream, providers of raw materials, such as Dow Corning are already researching how they can play an important role in the components for LED lighting (LED lighting: Will history repeat itself?2008).

Midstream, 60 to 70 percent of the lighting market share is controlled by three companies Philips, GE and Osram (McKinsey & Company, 2011; Viertler et al., 2009). These companies focus on light sources, which have well defined standards making products virtually interchangeable. Currently, traditional light sources have become a commodity. In fact the growing LED market lacks clearly defined standards, as traditional standards have been disrupted by LEDs' new value proposition of longer life spans and high energy efficiency. Although each of these companies is expected to perform strongly in the LED market, changing production methods are driving new entrants into this market (McKinsey & Company, 2011). There is the potential for the midstream to become greatly fragmented as LEDs become customized for light fixtures, where light producers would need to align their production with fixture producers.

Upstream presents the most value-added potential within the LED market as it's possible to exploit the additional functionality of LEDs to create new opportunities (Viertler et al., 2009). Many companies are seeking growth through value chain expansion, for example, fixture companies are expanding into the system/solutions market by creating new solutions for different applications (McKinsey & Company, 2011), which is in contrast to existing upstream producers who must cater their fixture designs to lamp standards. Philips for example, is now focusing on developing lighting

solutions for distinct applications from creating vibrant commercial spaces to relaxing home environments (Phillips, n.d.).

From a technology standpoint, when SSL technology matures, SSL promises to provide the most energy efficient lighting solution on the market. Thereby enabling a larger population of less wealthy individuals access. Because SSL systems are incredibly energy efficient, they will be attractive to developing countries that have regular power outages due to overuse of insufficient electrical grids. Cuba has already moved to replace incandescent bulbs with compact fluorescents, which use 20 percent of the electricity that standard bulbs do, for this very reason and the fact that longer life spans of newer lighting technologies require less replacement and maintenance (United Nations Environment Programme, 2012). Venezuela and Chile have since followed Cuba's example. Therefore this is expected to lead to growth in the overall market size of general lighting.

However, before the participants in the LED value chain are rewarded, LEDs need to be adopted by consumers. Cost is one of the key challenges facing LEDs because their initial higher costs are a sharp departure from the cheap commoditized incandescent light bulbs. SSL systems are more expensive, and total revenues would increase within the revenue, however consumers will likely find the higher price tag a deterrent to purchase. However, the upfront expense can be negated by the overall costs savings resulting from longer life-spans and lower energy usage of LEDs. Market demand is likely to be generated from government legislations being put in place as countries strive to find ways decrease their greenhouse gas emissions. Government legislation is important to SSL technology because it is anticipated to be the catalyst for SSL adoption in the commercial and residential markets. From an industry perspective, the regulations

help to equally impact all lighting technologies developers as their margins will be affected in the same way as they are all forced to convert their technologies to more efficient lighting systems. It also provides limits any one companies competitive advantage as incumbent producers will be prevented from selling older but cheaper technology with higher margins.

1.3.3 Comparative Advantages of SSL over Traditional Technologies

There are several key performance attributes that provide SSL an advantage over traditional lighting technologies. These specific attributes are determining factors in performance for multiple lighting market segments. This section describes each of the key attributes and why they are relevant to SSL's comparative advantage over traditional technologies.

High Energy Efficiency – LED lamps have very low power consumption because their conversion process of energy into light is highly efficient. By 2030, it is projected that LEDs efficacy will improve to more than 200 lm/W, which is approximately 15 times more efficient than standard incandescent bulbs (U.S. Department of Energy, 2012). This improvement in efficiency is projected to decrease energy consumption by lights in the United States by more than half (Ashe et al., 2012). Energy efficiency will be a key driver for the adoption of SSL systems as the countries strive to reduce their energy consumption to save money and meet current and forthcoming environmental standards. LEDs achieve more than 90 percent conversion efficiencies in turning electricity into light and as a result do not waste energy in the form of heat. SSL systems clearly outperform almost every other competing technology with only high-intensity discharge lights competing on the same level of efficiency (see Appendix 1 for details). With

energy also comes usage savings as presented in Appendix 2.

Long Lasting – the operational lifespan of an LED is considerably longer than it's contemporaries. A white LED for general lighting applications can last 30,000 to 50,000 hours (approximately 5-10 years), whereas incandescent bulbs typically last 1000 hours and a fluorescent bulb is expected to have between 8000 to 10,000 hours of use (U.S. Department of Energy, 2012). Long-term forecasts have LED lasting up to 100,000 hours, however this has yet to be achieved in the field (NanoMarkets, 2005). A long lifespan decreases the long-term costs of maintaining a lighting system and LEDs, as part of a SSL system can achieve just that. The "useful life" – a quantified measure of time a light lasts before burning/fading out. Unlike most traditional light sources, LEDs slowly decrease in light output over time and will gradually fade, instead of burning out suddenly. This has important value added implications for decorative or architectural lighting where a sudden burnout would severely damage the aesthetics of the design. One note about life-span is that LED's promised 100,000 hours have only been realized in a lab, and have not been proven in the field.

Multiple Colour Variations – LEDs are available in a variety of colours ranging across the full visible spectrum. Perhaps the most unique characteristic of LEDs is the ability to change the colour output through control of the lighting mechanism itself, therefore making it possible to transition from bright white light for some activities to dimmer warm light for other activities. It is possible to program a red, green and blue (RGB) array to produce almost any color and because light is not being filtered or absorbed the result is a deeper saturation of the color. This also applies to individual LED colors such as red that is produced directly and not by filtering out all of the blue, green,

and yellow present in the light source. Traditional lighting does not have this range of versatility (Appendix 3). Note that SSL has not yet been able to achieve all ranges it claims to be able to produce.

Fast Response Times – LEDs have what is called a ‘snap transition’ from off to on states, which occurs in Nano seconds rather than milliseconds as in traditional lights (NanoMarkets, 2005). This transition makes them very useful in high-speed applications. This fast response time is also not effected by environment temperature as found in many incumbent technologies. While there are lamps available that are resistant to low temperatures (metal halide and other HID lights), others, particularly fluorescents, do not perform well in cold weather. HID lights are not useful for all outdoor applications, such as motion detectors, because they take up to 10 minutes to turn on.

No Cooling Needed - LEDs use a lower wattage of light, and unlike traditional bulbs they remain cool to the touch. The lack of heat produced from LEDs, permits their use in a wider variety of spaces and for smaller fixtures without the additional need for a cooling system. As a result their overall safety is higher than existing products as overheating surfaces or causing burns is significantly reduced.

Robust Physical Characteristics – Without the filament found in traditional bulbs, LEDs are not easily damaged. The lack of delicate parts allows for rugged applications such as in vehicles. LEDs are resistant to vibrations and this robustness in their design gives them a clear advantage over traditional lighting technologies that use fragile glass and filaments. Because fluorescent and halogen lights use gases in their design, breakage also results in the release of toxic elements, requiring special disposal and clean up.

Ease of Integration – LEDs are easy to integrate with controlling systems like

computer systems, phone networks, or wireless protocol as they allow for digital control and optical control. Integration adaptability makes LEDs suitable for adoption by a wide range of applications. This advantage is essential in allowing SSL systems to enter multiple markets. As digital control and applications grow, it becomes increasingly important that lighting become integrated into that infrastructure. SSL is already a digital system that can be interfaced with other systems or precisely controlled to achieve maximum performance. This makes it a more suitable solution for “smart” homes and buildings. Optical systems in SSL systems can be designed to control the light with extremely high efficiency, resulting in less light being required to perform a certain function, which in turn increases the energy efficiency of the system. Current SSL systems generally operate on low voltage DC power, making them very safe to install and operate. However, they also require an adaptor to be suitable for current electrical voltage standards.

It is the combination of these individual advantages mentioned above that provides SSL devices a comparative advantage over traditional light technologies (Figure 2). When comparing the overall performance in all key performance attributes, we see that SSL consistently outperforms the incumbent technologies and is therefore superior from a technological viewpoint. However not all attributes presented are an advantage, as cost is still very high for SSL products. If cost were a weighted attribute, it would likely be a primary attribute as the high price point of current SSL’s continues to challenge adoption, as consumers are not able to justify the high cost despite the numerous advantages.

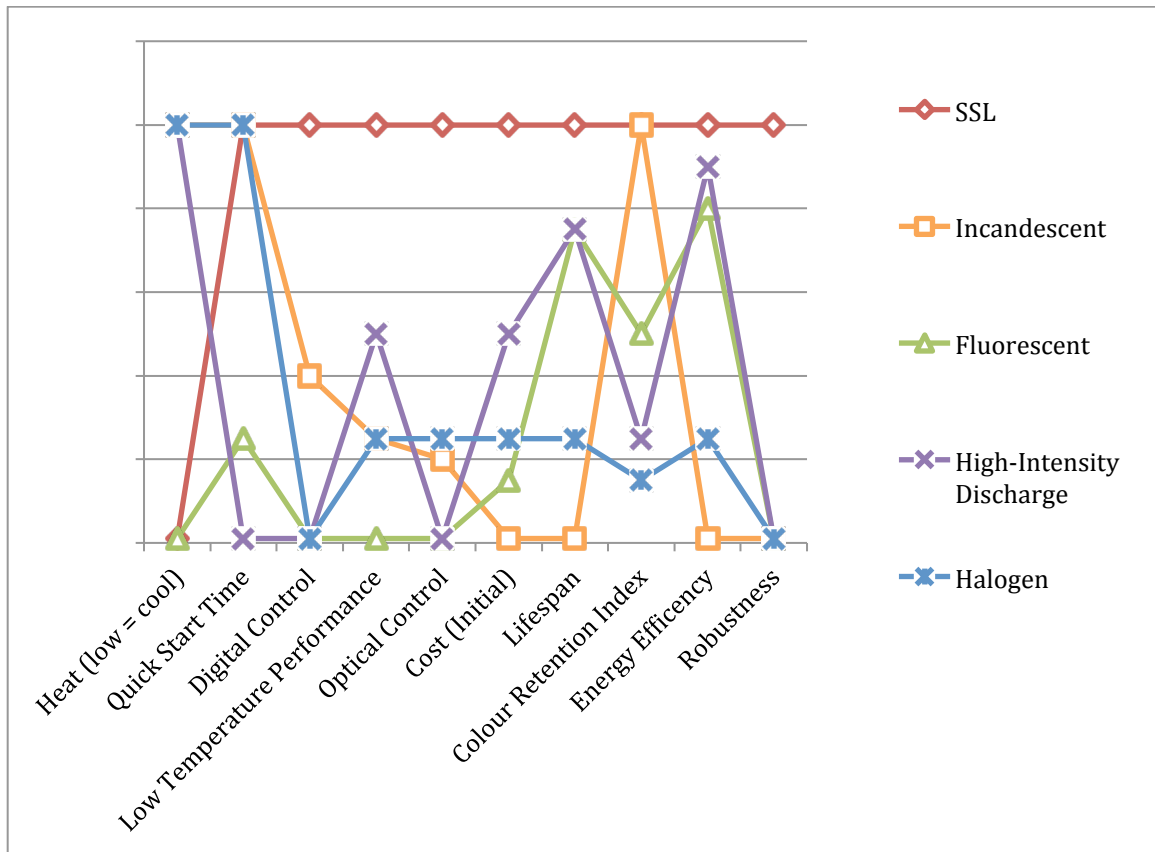


Figure 2: Comparison of performance attributes of SSL and incumbent lighting technologies. Line Chart created by author, compiled from the following sources: (EERE, 2012a; EERE, 2012b; EnergyStar, n.d.; Lingard et al., 2008; Paget et al., 2008)

1.3.4 Applications of SSL Technology outside General Lighting

With multiple distinct advantages over traditional lights, LEDs are finding increasing usage in a wide variety of applications. These include applications previously reliant on traditional light technologies as well as new innovative applications that are able to take advantage of the unique properties of LEDs. The main areas where LEDs are used include:

- Backlighting of mobile displays (i.e. Mobile phones)

- LCD backlighting (television, computer screens and signage)
- Automotive tail lights and interior lights
- Traffic lights
- Electronic equipment displays (i.e. indicator lights)

Backlighting for mobile phone displays, television, computers, and signage are primary drivers for growth in the LED industry as market demand for these products is also growing (NanoMarkets, 2005). The share of LED in the backlighting market is predicted to be close to 100 percent by 2016, where analysts predict the market will begin to shift from LCD TV to OLED TV which does not use backlighting (McKinsey & Company, 2011). In the automotive industry LEDs still have significant room to grow to gain the dominant market share. As of 2010, the market share of LED in the automotive sector was 12 percent, however with increased usage of LEDs in daytime running lights that are mandated for new car production in the EU, market share is forecast to grow to 64% by 2020 ((McKinsey & Company, 2011). However, despite these market successes, the general illumination industry still represents the '*holy grail*' for the LED industry, as it comprises of approximately 75% of the total lighting industry (McKinsey & Company, 2011).

1.3.5 General Illumination Market Successes

LED technology has become widely used in several market segments such as indicator lights in electronics, traffic lights, and more recently television sets and backlighting for mobile phones. Despite these successes, it has only been with the advent of certain advancements of the technology that has allowed LEDs to be suitable for use in

general illumination. Today the market share of LEDs in general lighting is still relatively low at approximately 7 percent (McKinsey & Company, 2011). However, a closer look at the general lighting sub-markets reveals that this adoption has been primarily in the niche general lighting architectural application. LEDs make up close to 40 percent of the architectural market share, which has been a leading early adopter for LEDs. By 2016, the LED market share within the architectural segment is expected to grow to 74 percent (McKinsey & Company, 2011).

The architectural segment applies to a wide variety of lighting applications, including building facades, theatres, retail outlets, hotels, casinos, restaurants, theme parks and other commercial venues that use lighting effects as an element of their public appeal. The biggest advantage of LED in the architectural segment the ability to easily control and change light colours to create lighting effects (Strategies Unlimited, 2005). Traditional lights use filters and a colour wheel or multiple bulbs are required to change light colours resulting in high maintenance costs. LEDs are however ideally suited for this application, as LED light colour is controlled by inputs into the RGB control mechanism permitting a single LED light to produce multiple different colours. This ability to generate colours leads to very low maintenance costs for LEDs.

1.3.6 General Illumination Market Introduction Challenges

Despite promising significant improvements over traditional technologies, LEDs must first demonstrate a compelling value to buyers before they can be expected to meet the optimistic market forecasts in the next ten years. In the past decade, significant development advances of white LEDs required for general illumination have helped to bring the possibility of LEDs closer to reality, however they are still in their adoption

infancy from the market perspective. Before winning over the market, LEDs still have several issues to resolve before gaining a sizeable market share and displacing the current technologies. Many buyers, distributors and retailers are still uncertain that LEDs will hold up to the promises they make, which is not unexpected considering the relative failure of the introduction of CFLs to the market (Brodrick, 2007). The industry is well aware of the issues it faces to bring LEDs to market, particularly in outstanding technical challenges that need to be resolved. Key technical challenges include luminous efficacy, light colour, and product complexity. Beyond these technical challenges, there are also several market challenges such as pricing and bringing products to market that customers will understand and want. In this section I will outline these issues and describe what the industry is doing to overcome these challenges.

Without a doubt, ensuring that technically LEDs can achieve their promises of high energy-efficiency, long life spans, and high quality light have been a focus of the industry. Although improving rapidly, LEDs today offer energy-efficiency approximately that is comparable to a CFL, and some commercially available products are even less efficient (BC Hydro, 2012). For LEDs to be cost-effective and market-ready the industry's goal is an efficacy of 160 lumens per watt, currently warm light LEDs are measured at 90 lumens per watt (U.S. Department of Energy, 2012). Further complicating the energy-efficiency challenge is that the fixture itself impacts efficiency of the LED. What this means, is that regardless of the advertised efficacy of a LED bulb, it can only be as good as it's fixture, which is problematic from a market perspective as the claims of efficiency become exaggerated and will lead to consumer mistrust. In terms of life-span, the promise of the 100,000-hour life span has not yet been achieved, which is key in

terms of the return on investment customers make upfront with a more expensive light. Finally colour is one of the biggest technological challenges, particularly white light as this is a key requirement of the general illumination market. Unlike traditional light sources, LEDs do not naturally produce white light, and producing the right type of white is proving to be challenging. Starting in 2003, the U.S. Department of Energy (DOE), began running a comprehensive program to accelerate the research and development of LEDs to advance the commercialization of LEDs. In addition to funding several development programs, the DOE SSL program is addressing challenges such as lack of standards to ensure that when LED enter the market they are represented accurately.

In addition to the technical challenges, the initial product cost is a main obstacle for LED acceptance by consumers. A LED lighting systems on the market today cost more than 500 times the comparable incandescent lamp and 90 times more than a CFL (Wiggins et al., 2010). However, costs are projected to continue to decrease. Since the 1960's LED's pricing and lumen output have been following a Haitz's law similar to Moore's Law, which forecasts that every 10 years the amount of light generated by an LED increases by a factor of 20, while the cost per lumen (unit of useful light emitted) falls by a factor of 10 (Figure 3). These advances can be linked the parallel development of other semiconductor technologies and advances in optics. Although the decrease costs will make LEDs more appealing to consumers, they will still be more expensive than traditional bulbs in 2015.

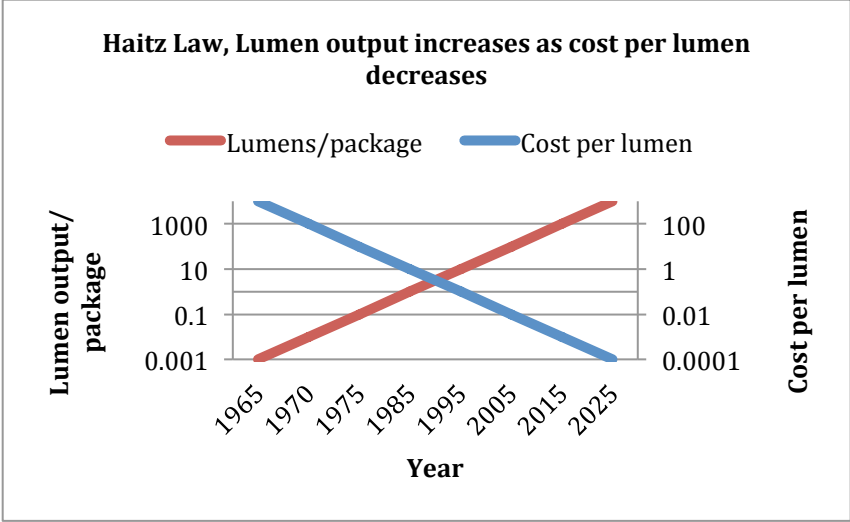


Figure 3: Haitz Law

Ultimately success of LED products will be determined by customers willingness to purchase LEDs. The market is wary of products that potentially exaggerate their performance following the failed introduction of CFLs to the market two decades ago. CFLs initially had shorter life-spans, had poor colour rendering, and performed poorly (Brodrick, 2007). Learning from CFL’s market introduction, it is clear that understanding how the market perceives new products will be key. Furthermore, with a radical new technology like LEDs, where functionality is not constrained by existing functionality, developers have the opportunity to redefine the industry. To achieve this, understanding how LED can better serve customers existing and latent needs will be essential to drive product development strategy.

1.3.7 SSL Innovation Opportunities

To date the lighting industry has been focused on overcoming known SSL technological barriers such as light colour and efficiency, lowering product costs, and

developing industry measurement standards. However, with this radical new technology there are many opportunities to redefine the industry, especially how consumers use and perceive lighting for their homes. In the past few years there has been a number of exciting innovative product concepts introduced. Developers are presenting many innovative prototypes that redefine how we think of lighting – no more are lights simply individual fixture and light bulb . Some of the innovative designs include:

- LED lighting systems that combine the fixture and the bulb into a single unit that redefine the traditional lamp structure, such the Andromeda lamp designed by Ross Lovegrove (Yamagiwa, n.d.)
- LED products with adjustable colour such as lights that can change light colour based on the user's activity being performed. Panasonic recently demonstrated a light for a dining area that provided cool whiter light for breakfast and lunch, warmer light for dinner, and even softer warmer light for after dinner drinks (Wright, 2012)
- LED lights that mimic traditional incandescent-like lights, such as those being developed and sold by Philips (Philips, 2012)

The key question for industry incumbents and start-ups alike, who are seeking to gain market share, is not what unique and novel ways they can innovate with SSL, but instead what opportunities and ideas may prove to be more valuable to customers that take advantage of the unique attributes of this radical new technology. As SSL is introduced to the lighting industry, companies have the opportunity to redefine what customers expect from general lighting for what has been a relatively static industry for the past 100 years. To choose which are the best opportunities that the technology lends

itself to, companies need to ensure they have a thorough understanding of what customers value. Companies need to specifically focus on gathering insights that are technology-neutral to reduce the probability that today's incumbent technologies limit their ideation and identification of concepts. This step requires going back to the basic market research for residential lighting, and uncovering customers technology-neutral needs.

Increasingly, customer-driven innovation has become one such tool to ensure that innovative products will be market successes. In the next chapter I provide an overview of customer-driven innovation and techniques that can be applied to drive innovation, and then in the following chapters apply a specific customer innovation driven innovation methodology to identify opportunities for lighting.

2: CUSTOMER DRIVEN INNOVATION LITERATURE REVIEW

The objective of this chapter is not meant to provide an exhaustive theoretical review of the published literature on innovation approaches, but instead to provide a practical review of key approaches for identifying customers' needs to drive successful disruptive technological innovation. Within this chapter, I will discuss how customer insights are vital to innovation despite the inherent risks of listening too closely your customers, the practical innovation strategies for understanding and identifying customer's needs, and finally an outline of the methodology used for identifying customer needs and values for lighting in this project.

2.1 Customer Driven Innovation

Today, the opportunity and competitive advantages for new product innovation is seemingly limitless. A company's ability to successfully innovate is linked directly to their long-term viability as failure to innovate can potentially lead to the companies demise (Blundell et al., 1999; Utterback, 1996). Companies who continually and successfully innovate commercially viable new products are more likely to establish a competitive advantage within their industry, which leads to the companies' long term sustainability through higher profit margins and growth of their existing market share (Christensen & Raynor, 2003). Therefore, it comes as little surprise that most companies are perpetually looking at ways to not only improve existing products but to create the next innovative product for their market. However, innovation comes with its own set of

risks. Innovation activities are costly because, despite their best efforts, most companies struggle to develop even one successful new product. Failure rates and costs for new products are astronomically high, with approximately 3 out of 4 new products failing and the costs exceeding 50% of all corporate resources spent on these failures (Cooper & Kleinschmidt, 1987). Given these high rates of failure, successful new product development remains elusive for many companies.

Product innovation failure has devastating consequences for companies due to the expensive and labour intensive nature of new product development. Choosing not to innovate however is not a sound strategy for companies. By not innovating, existing products with incremental innovation become increasingly commoditized and are rapidly replaced by new technologies that meet the needs of future customers (Bower & Christensen, 1995). When product commoditization occurs, product margins decrease and a company begins to lose their market share to newer and more radical products, which provide more value to customers than existing products and to similar cheaper products. Therefore, the forces pushing many companies to innovate are stronger than the risks of new product failure, which is why we see billions of dollars annually invested into the research and development of new products.

To reduce the risk of failure companies need to understand two key points; first, why products fail and second what makes a product successful. When companies examine the processes that lead to creating successful versus unsuccessful products, it helps them to identify key factors to reduce the risk of new product failure. Pinpointing why individual products fail is challenging because there are always unique variables contributing to every new product's failure. In fact, product failure may not have

anything to do with the quality of the product itself, and it's failure may be attributed to poor pricing strategies and weak positioning to insufficient sales channels and even rival competitors products which better meet the markets' need. However, looking at product failure in general terms, researchers have identified two common reasons behind new products failure. The first reason products commonly fail is when companies create new products as an ad-hoc reaction to their competitive environment. For example an ad-hoc reaction would include adding new features to a product simply because their competitors offer the same feature. The second reason behind a product failure occurs when future customer needs are not met by the new product (Cooper and Kleinschmidt, 2003). Therefore, to reduce the risk of failure it becomes essential for companies to avoid the knee-jerk response to match their competitors products feature for feature, instead they must ensure that projects are initiated with a clear understanding of their customer's needs with a clear definition of the problems the new product will be solving.

Increasingly, to improve product success, many companies are looking towards using customer or market-driven innovation processes upfront to guide their own product development and innovation initiatives. Companies are looking to identify the current, latent and future customer needs to help them identify new markets and preferences for their new products. Unfortunately, it is much easier to demonstrate that a failed product was not something a customer valued than to actually determine those values upfront. The actual process of determining customer values is challenging because customers do not naturally reveal their needs (Ulwick, 2005, Slater & Mohr, 2006). The key problem is that customers do not know what they want out of an innovative product as their present needs are confined by their knowledge of existing products (Bower & Christensen, 1995).

The question remains, on how do companies understand their customers to create new products? Christensen (1997) identified three key principles of innovating.

1. Successful products must fill customers' needs – If a product does not fulfil a need, it does not have any value to a customer.
2. Customers are unlikely to know why they need new products – This is especially true of new and unfamiliar technologies that the customer is unable to understand or envision how it can be implemented to meet their needs. It is the innovator's job to define what that new product will be and how they can embrace new technologies to develop new innovative products that satisfy their customers.
3. Innovators must be careful not to follow their customers into failure – By focusing on only product attributes and features expressed by their customers, innovators can not expand how they can meet customers' needs. By focusing on the articulated needs of customers, it's possible to incrementally innovate along existing product dimensions, while other opportunities for innovation are ignored.

Given these principals, by identifying customers' needs a primary dilemma evolves. By following their customers too closely, companies risk not being innovative enough to capture new market space or future customers. However, if they don't listen to their existing customers there is always the risk they may lose these customers in the future in addition to not capturing future customers. A successful innovator's goal is to find a balance that works for their product and their company and to translate customers' unknown 'wants' to identify unmet needs in the market (Christensen, 1997).

2.1.1 Identifying What Customer Value

Stevens and Burley (1997) found that for one single successful innovation a company requires as many as 3000 ideas. Given the immense number of ideas to be evaluated, how does a company pick the winning idea? To effectively make these decisions, companies require a framework in which they can consistently and successfully evaluate product ideas against what customers value. Integrating customers into the innovation process appears to be a key success factor (Rejeb et al., 2011). As a result, there are a number processes discussed in the literature where customers are integrated into the new product development process from User-Oriented Design (Veryzer et al., 2005) to the Lead-User theory (von Hippel, 1986). These methods have proven to be successful both in the identification of new ideas and particularly in evaluating products through the development process. However, both Ulwick (2002) and Christensen (1997) argue that customer's expressed opinions have limited impact on breakthrough innovations and therefore companies need to abstract customer needs from any particular solution. Instead they advocate the jobs-to-be-done approach.

The jobs-to-be-done approach avoids focusing on the features and customer attributes and instead provides understanding of the circumstances that customers buy or use products (Christensen & Raynor, 2003; Ulwick, 2002). This approach identifies how customers perceive objects in relation to the possible actions that can be performed instead of the product features. The jobs-to-be-done approach is not a new concept, but one that is based on a marketing concept identified in the 1960s (Levitt, 2004). Alternately, this method is also referred to as the theory of affordances, first described by Gibson (1977), in the field of perceptual psychology. Affordance-based design, or rather

the jobs to be done approach has been influencing product development for the past 30 years (Maier & Fadel, 2009).

The Jobs-to-be done approach allows companies to identify what customers value through the solution-neutral identification of what tasks customers are trying to achieve with a product (Christensen & Raynor, 2003). The focus of the approach is to identify the job that customer's hire a product to perform. Customers may hire a number of products to achieve the same goal. For example, to remove unwanted hair, Men may hire a razor and shaving cream to remove facial hair or they may hire an electric razor for the same job. In addition to the primary job of removing unwanted hair, each product excels at a number of sub-jobs. For example the razor enables the customer to have a smooth finish, where as the electric razor is better at enabling the customer to perform the task quickly and without the need for other products. These represent the sub-jobs, and customers make decisions based to purchase a product based not only on the primary job they wish to achieve but also on several sub-jobs. By understanding what a product is hired to do, and better yet what jobs are not being satisfied by current products developers can better fuse together their technological knowledge with customer's needs to provide customers with better products that help them achieve more jobs, faster and easier before (Christensen & Raynor, 2003; Ulwick 2005).

2.1.2 Applying the Jobs-to-be-done Approach

Ulwick's (2005) Outcome-Driven Innovation (ODI) and Maier and Fadel's (2009) Affordance-based Design, are similar methodologies that apply the jobs-to-be-done approach to innovation. Both describe a multi-step process that starts with the identification of solution-neutral customer's needs, a prioritization of the needs identified,

and then the development of products that are evaluated against these prioritized needs. Unlike Maier and Fadel (2009), Ulwick (2005) provides a more structured approach using contextual interviews and applying the desired-outcome technique. This technique uses precise syntax to define customer's needs that ensures a format that can be universally applied to any technology and reduce the risk of misinterpretation by developers. This syntax is described in the following Chapter. Maier and Fadel's (2009) approach, by comparison provides developers with methods for designing for specific customer needs to ensure that positive needs are met and negative detractors are not introduced. However, from the initial customer needs identification Ulwick's ODI approach provides clearer guideline of what information must be collected from customers to ensure companies can develop strategies, identify new product opportunities, and bring new products to market.

The ODI approach is based on the identification of jobs to be done and the identification of metrics that customers use to evaluate how well a product enables them to get that job done (Ulwick, 2005). This approach has been applied with a high degree of success for a number of companies (Bumpas, 2010; Kavanagh et al., 2011; Ulwick, 2002), but empirical review of the ODI success rate is lacking in the literature. There are however a number of case studies where companies found success through applying the ODI process. For example, Cochlear, a medical device company used this approach to discover and validate user needs for innovation purposes. They found that this process enabled them to shift their innovation practice from being largely intuitively based to a more predictable and efficient process because they were able to closely align their development efforts with prioritized customer needs (Kavanagh et al., 2011). Further,

they found that by becoming more customer focused they were able to better identify unmet needs within the market which could be used for ideation, rather than focusing on technical functionality. For example, they found that parents of cochlear implant users attributed a high importance to the job “to know when my child is not hearing well”. Through the identification of this need, Cochlear’s innovation team was able to respond with a remote monitoring assistant which provided parents with the status of the implant’s function (Kavanagh et al., 2011). Product innovation success using this method was also realized by Cordis Corporation, who grew their company from a less than 1% market share to a market leader position. Cordis applied the ODI methodology, by conducting outcome based interviews of their customers. Specifically they interviewed cardiologists, nurses and other laboratory personnel, where they focused not on the features they wanted to see but instead the results or outcomes they expected (Ulwick, 2002). With the outcome-based data they collected, Cordis concluded which products in their innovation pipeline were likely to fail, and also were able to recognize the potential value to customers a particular device would have (Ulwick, 2002). This device was the stent, which became the fastest-growing medical device in history, reaching \$1 billion in revenue its first year (Ulwick, 2002). Successful application of the ODI approach is not limited to medical devices. Ulwick (2012) has found success in industries from software development to Power Tools.

In the following chapters I will apply Ulwick’s Outcome Driven Innovation Approach to lighting products to identify the job’s that customer’s are trying to get done in addition to the what metrics they use to evaluate product performance. In the next

Chapter, I will detail how the ODI approach was applied using the methodology described by Ulwick (2005).

3: RESEARCH METHODOLOGY

To identify what customers value in lighting, I have followed the outcome driven innovation (ODI) approach outlined by Ulwick (2005) to create the customer value model. The ODI approach enables companies to better identify underserved customer needs and focusing their innovation activities on these product opportunities that can be universally applied (Ulwick, 2005). Furthermore, this method focuses on uncovering non-solution specific customer needs, and therefore avoids the trap of listening too close to customers for only collecting product specific attributes, requirements or features, which lead only to incremental improvements of existing products. Ulwick's (2002, 2005) method can be applied to any industry as the information collected is not solution specific. To develop the customer value model for lighting, I will capture the following two customer inputs for lighting:

1. **Jobs to be Done:** What people are trying to achieve when using lighting, the “jobs to be done”. These jobs are the customer’s needs, and help define which innovation strategy best matches the new product growth options.
2. **Desired Outcomes:** What metrics people use to evaluate the success of a lighting product in completing the job they have hired to product to complete. These metrics are the desired outcomes and provide a systematic tool for measuring how new products can successfully meet the customer’s needs.

In this chapter I will describe the methodology I used to capture these inputs to create the customer value model using the process outlined by Ulwick (2005).

3.1 Capturing Customer Inputs For Lighting

The ODI approach to capturing customer's needs and desired outcomes requires a qualitative discovery phase where you must avoid focusing on solutions or design specific requirement gathering (A. W. Ulwick & Bettencourt, 2008). The inputs collected in this phase provide the building blocks for a companies innovation strategy, product development prioritization, development and marketing. Ulwick and Bettencourt (2008) suggest a number of qualitative techniques from personal interviews, ethnographic/observational interviews, focus groups, and lead user analysis. However, they emphasise that it is not the qualitative technique specifically that is important, but instead the data collected.

To capture customer inputs for lighting, I used a series of 21 depth interviews. I wanted to ensure that I captured the maximum amount of inputs before the laws of diminishing returns prevailed, which is typically between 10 to 30 interviews based on the complexity of the subject matter and the experience of the researcher (Griffin & Hauser, 1993). I separated the discovery phase into two distinct phases based on how I needed to collect the information. Phase 1 focused on collecting customers needs, jobs-to-be-done, and the interviews were primarily observational in nature. The data collected in phase one was also used to dissect the primary job itself into its process steps to create the Job Map. Phase 2 research consisted of semi-structured interviews utilizing the Job Map to understand how customers evaluated success at each process step. Between the phases, the interviews broke down as follows, 6 interviews in Phase 1 and 15 interviews

in Phase 2. In the remainder of this chapter, I will outline the specific methodology used in each phase of this study.

3.2 Phase 1: “Jobs to be Done”

In Phase 1, the objective was to identify what jobs customers are trying to get done with lighting and the context that the jobs are being performed. A job is defined as the functional goal a customer is trying to accomplish or problem a customer is attempting to resolve within a particular situation (Bettencourt and Ulwick, 2008). I have specifically focused my research on identifying the jobs customers are trying to achieve with lighting in a residential environment. The rationale for selecting this segment is twofold. First, lighting has many applications and the jobs between each segment are greatly varied; therefore, I wanted to focus on only one segment. Second, residential lighting is a high growth opportunity market for LEDs for which developers are currently working to develop new products for, therefore the information collected is timely.

To identify the jobs and to identify the process steps, I conducted six personal interviews, each took approximately one to two hours in length. All Phase 1 interviews were conducted in the interviewees’ home, allowing for my observation of the tasks the interviewees were trying to complete when using their own lights. These interviews were conducted in the evening to better observe the use of lights when needed. This timing was particularly important as it identified sub-conscious use of house lights out of necessity, allowing me to bring these actions to the interviewees’ attention for further discussion. The interviewees were recruited from people whom I knew, representing a wide demographic sample of men and women from ages 26 to 67. There was also a mix of homeowners and renters. However, because I wanted to capture real life usage of an

‘average’ customer I did not seek out interviewees who possess specialized lighting knowledge. In so doing, the approach helps to ensure the language used was more likely similar to the general population.

To start off the interview process the interviewee was asked to provide a tour of their home. As we walked through each room, I observed the lights that were on, being turned on, how many lights were in the room with the goal of creating “day in the life” scenarios. During the interview, as we entered each room I asked questions about what activities were performed in that room and what actions took to complete those activities. The interviewee discussed and often demonstrated when and why each light was used in a particular room. In each room they would describe what activities took place there, how many lights were there and what lights they were likely to turn on for a particular activity. I found that the details of how customers use their lights was to some degree subconscious; therefore, to determine how people were truly using their lights required a combination of discussion and observation. However, for the most part the interviewees led the conversation and were only prompted from time to time to expand upon a task, or why they choose a particular light to use over another. For example, one interviewee pointed out built-in lights that were never used. When I asked why, the interviewee said the light was a fluorescent tube light that created an ugly hue to the room. From this response we were able to define a job statement that the other lights were performing, which was to make the room attractive. In this case, although the fluorescent light provided light that enabled her to see, it performed a secondary job so poorly that the interviewee found they were unable to use the light.

Each job statement developed followed a specific structure and format to ensure it was specifying an action for which a solution is needed. Ulwick (2005) outlines that the job statement structure at minimum must include a verb to introduce the job and the object of the verb that defines the job to be done. Additionally, the statement can include a contextual clarifier that describes the circumstances under which the job needs to get done (Figure 4). For example, a sample job statement is shown below.

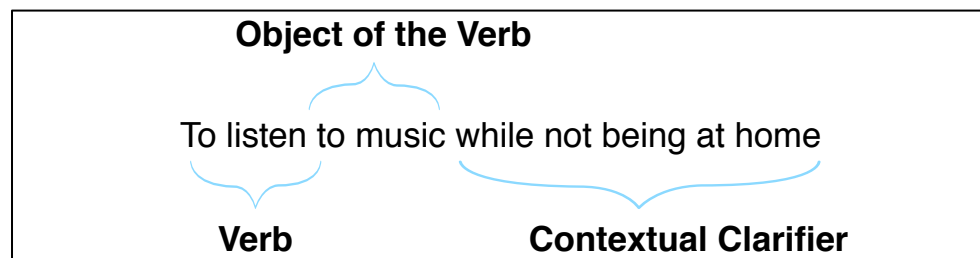


Figure 4: Structure of a Job Statement. Source: Ulwick and Bettencourt, 2008. This job statement is the customer job that led Sony to innovate the Sony Walkman (Christensen and Raynor, 2003).

By standardizing each job statement in this format we can avoid introducing solution biases, such as specifying product feature requirements. Without limiting the statement to a specific technology and by focusing on the action, this ensures that the job statement can be universally applied across multiple technologies (Ulwick & Bettencourt, 2008). For example the statement in Figure 4 applies equally to a walkman and a portable mp3 player. The job statement is what companies can then use focus their ideation to develop products that provide a solution to help customers achieve the job.

Following each interview, I typed up my notes with room-by-room descriptions and compiled the job statements identified. For example:

Interviewee 3: Male, 36, Renter

Room: Office/Den

Uses: Computer Work, hobbies, TV/Movie watching

Lights: Overhead light, operated with a switch at the door, standing floor lamp, desk lamp.

Observations/Discussion: The interviewee enters the room and turns on the overhead light with the switch by the door. He talked about how his family liked to watch TV here, but found the overhead light too bright so they used a separate lamp. They didn't turn off all the lights because this caused eyestrain and made it hard to move around the room. This light also reduced glare on the screen, and provided enough light for ambient room light. As the interviewee described the scenario he walked over to the light that was located behind a sofa. After turning on the light, he walked back to the light switch for the overhead light, tripping slightly over the chair between the lamp and the switch. He mentioned that the light was annoying to access, especially because they needed to turn on all lights to safely walk in the room to turn it on, and then come back to turn off the overhead light.

He also mentioned that the floor light was frequently left on when they weren't at home, as it provided security by giving the impression that someone was home.

The floor light uses a halogen bulb, which he mentioned he had never had to change. He said he would likely buy a new light fixture and bulb when this one died.

Job Statements:

- To improve security of the home by creating the impression that the home/room is occupied
- To watch TV without causing eye strain if the room is too dark
- To see when there is insufficient natural light
- To find objects in the room
- To navigate in the room with insufficient natural light
- To read when there is insufficient natural light

Interviewee 2: Female, 50s, Homeowner

Room: Formal dining area

Uses: Entertaining, eating

Lights: Elaborate 9-bulb chandelier

Observations/Discussion: The interviewee was excited to show off their chandelier and its features as she felt it was attractive and added to the overall appeal of her home. She acknowledged without prompting that she did not think it was very energy efficient, but felt that the appearance was more important. She also really liked that the fixture was dimmable and could be set the mood for the space that was important for entertaining. She preferred a warm light for entertaining because she felt it was more welcoming, that people were more attractive and the food looked better

I also observed that the fixture and the light helped to define the dining area in an open concept home.

Job Statements:

- To be perceived as having good taste in home décor and styling
- To create a warm and attractive area
- To be perceived as having a welcoming home
- To make food appear appetizing
- To make people appear attractive
- To see people and objects in a room

Room: Formal Living Room

Lights: Two table lamps, track lighting on the ceiling, Accent lighting on the ceiling

Observations/Discussion: The two table lamps are on a timer. The timer ensures there are lights on when it gets dark outside, particularly in the winter. By having the lights on a timer it gives the impression that someone is home, and creates a warm and welcoming environment for the owner to come home to. These table lamps provide sufficient lighting to pass through the room without blinding a person but ensure enough light to prevent tripping, therefore it provides a safety element. The owner finds that having these lights on makes her feel less lonely when home alone.

Other lights in the room, which were not turned on included track lighting in the ceiling and accent lighting to highlight architectural design of the room. When the interviewee was asked when she might use them the responses were as follows:

- The ceiling track lighting is never used because it is too bright, and does not contribute to the comfortable mood of the room.
- The Accent lighting is never used because it is fluorescent lighting that gives the room cold feeling and makes the colours on the wall unattractive.

Job Statements:

- To see to perform activities in a room
- To feel warm and comfortable in the room
- To easily navigate the room when there is insufficient natural light
- To feel less lonely when home alone

3.2.1 Categorizing the Types of Jobs

Prior to categorizing the job statements I reviewed all statements to identify duplicates. For example, two different interviewees produced the following two statements:

1. To increase home security by creating the appearance that the house was occupied when empty
2. To improve home security while not home

These statements are duplicates worded slightly differently, therefore I combined and counted them as a single statement. Once the list of job statements was compiled, I categorized the jobs identified into job categories and sub-jobs as defined by Ulwick (2005). The job categories are as follows:

- **Core Functional Job:** the primary task that customers are trying to accomplish with the product. This job can be broken out into process steps, where each process step has a set of metrics people use to measure the successful execution of the job. For example, the core functional job of a toothbrush is to clean your teeth. Understanding this job's process steps and metrics allow you to add desired function to a product.
- **Other Functional Jobs:** secondary jobs that the customer is trying to achieve while executing the core functional job. Understanding these jobs helps to add desired function to the product.
 - **Directly related jobs:** Jobs that the customer is trying to get done while executing the core functional job, which are directly related to the core job. For example, directly related jobs to brushing your

teeth are to whiten your teeth and to prevent cavities (Ulwick, 2005).

- **Indirectly related jobs:** Jobs that the customer would like to get done. In the toothbrush example, an indirect job related to oral health would be to straighten teeth. Although this is not a job a toothbrush can be used for, it provides insight into jobs where a solution might be possible (Ulwick, 2005).
- **Emotional Jobs:** These are non-functional tasks a customer may use to purchase a product. Ulwick (2005) is explicit that emotional jobs should not be confused with functional jobs as emotional jobs do not create function, but rather they help to understand how a company should position a product in the market.
 - **Personal Jobs:** These jobs explain how people want to feel about a product given a specific circumstance. For example, a luxury car owner may want to feel successful when driving the car.
 - **Social Jobs:** These jobs explain how people want to be perceived by others when using the product. For example, a sports car owner wants the car to make them be perceived as attractive.

3.2.2 Creating the Process Job Map

The objective of creating a job map is to uncover what a customer is trying to get done at different points in the process of executing a job (Bettencourt & Ulwick, 2008). A job map is not the same as a process map because the process map focuses on what people are currently doing whereas the job map focuses on what people are trying to get done. This distinction is important because by focusing on what people are trying to get done, it shifts attention away from how an existing product is used and how it can be improved, which is limiting for innovation. (Bettencourt & Ulwick, 2008). The job map helps form the basis of the customer value model, which is completed by uncovering the desired outcomes at each step (Ulwick, 2005). For each job, typically a universal structure of eight distinct steps can be applied where a product can create value for a customer (Bettencourt & Ulwick, 2008). In Table 1 below, I've outlined each of the steps, standard ways that value can be delivered and the product innovations that have been created based on improvements to that step using this methodology.

To create the job map for lighting, I started with the execution task and worked out the previous and subsequent steps. In the case of lighting, I found that eight distinct steps could not be identified. Specifically step 4, confirmation was not required as lighting is typically pre-existing in a residential setting, for example a ceiling light, so that users do not re-confirm that the setup is there each time they execute the job. Not having all eight steps is not uncommon. In Ulwick's (2005) work with Bosch and research into the job performed by a circular saw they found only 6 steps.

Table 1: Summary of the 8 functional steps of a Job, where products can create value and examples of product successes. Summary table created by author based on the process steps defined by Bettencourt and Ulwick, 2008

Job Process Step	How Products Can Create Value within this Step	Examples
1. Define what is required to complete the job	<ul style="list-style-type: none"> • Simplify resource planning • Help customer understand objectives 	Weight watchers helps it's customers to lose weight by helping the dieter select appropriate foods without having to count calories (Ulwick and Bettencourt, 2008).
2. Identifying and locating inputs	<ul style="list-style-type: none"> • Streamlining the process of gathering tangible inputs • Eliminating the need for some inputs 	Apple's mp3 players not only play music but also provide a music management system where music can be purchased, organized and stored (Kavanagh <i>et al.</i> , 2011).
3. Preparing the components and physical environment	<ul style="list-style-type: none"> • Simplify the setup/preparation process 	Bosch added built in common bevel adjustments to it's circular saw with adjustable levers to reduce the time needed to cut wood and to improve accuracy (Ulwick, 2005)
4. Confirming that everything is ready	<ul style="list-style-type: none"> • Help customers gain access to the information needed to confirm readiness • Find ways to combine with the previous step to reduce time spent 	Oracle's ProfitLogic, merchandising optimization software, confirms the timing and percentage of markdowns, thereby removing the responsibility from the merchandiser (Ulwick and Bettencourt, 2008).
5. Executing the task	<ul style="list-style-type: none"> • Help customers to avoid problems or delays • Help customers to achieve optimal results 	Roche's Accu-Chek Comfort Curve blood glucose monitoring test kit eliminated the need for accurate blood placement and made it easier to place the strip on the device as these steps frequently lead to failure of executing in similar products (Ulwick, 2005).
6. Monitoring the results	<ul style="list-style-type: none"> • Provide diagnostic feedback to improve overall job execution 	A cochlear implant company developed a remote device for parents to make them aware of issues such as low battery charge in their child's implant (Kavanagh <i>et al.</i> , 2011).
7. Making Modifications	<ul style="list-style-type: none"> • Offer ways to get the execution task back on track for success • Eliminate this step for the customer 	Microsoft introduced automatic updates to help customers easily modify their computer operating systems against security threats. This practice is now commonplace within the industry (Ulwick and Bettencourt, 2008).
8. Concluding the Job	<ul style="list-style-type: none"> • Simply the process so it feels less burdensome for customers • For cyclical jobs ensure concluding activities connect to the starting point of the new job cycle. 	3M developed a self-adherent wound dressing, which is not only to apply, but is easy to remove because it doesn't stick to skin. This product helps to moves the conclusion into an early step of the process as the self-adherence, which makes it easy to apply, also makes it easy to remove (Ulwick and Bettencourt, 2008).

3.3 Phase 2: “Desired Outcomes”

The next step in completing the customer value model, started with the Job Map, is to identify customer’s performance metrics for each step of the job (Ulwick, 2005). These performance metrics are called the desired outcomes, and it is this collective set of outcomes that represents the customer’s value model in the Outcome Driven Innovation. The desired outcome is a metric used by customers to measure the success of getting a job done (Ulwick, 2002). Each job has multiple desired outcomes, which are specific to each process step in the job map, and that can be prioritized. Desired outcomes combined with the jobs represent the customer’s need, and based on how a product fulfils this need, a customer will choose to purchase a product as the solution (Bettencourt, 2009). For each job, and job step there are multiple outcome statements. Ulwick’s (2005) research finds that an average job typically has between 50 to 150 desired outcomes. As a researcher it is essential to identify all of the desired outcomes statements to ensure that companies can identify underserved needs (Ulwick, 2005). Once the outcome statements are defined, developers and marketers can use these to guide each step of the innovation process from early product inception to bringing a product to market. Throughout the product development process companies use the outcome statements to identify and bring value to their customers. The focus of innovation is not only to help customers accomplish a multiple jobs, but to ensure that customers execute these jobs successfully based on the customer’s own performance metrics.

3.3.1 Developing a Desired Outcome Statement

An effective outcome statement must not reference the solution itself, i.e. how to satisfy the job, as this limits universality of the application of the statement to a specific

product and solution (Ulwick, 2002). The outcome statement must also use unambiguous language to ensure that the statement is interpreted equally by different people and to ensure that it remains stable over time (Ulwick, 2005). For example, a desired outcome statement for people brushing their teeth would be that they want to “decrease the time it takes to remove food stuck in their teeth”. This statement is equally valid for all solutions from flossing to electric toothbrushes, and it has remained the same throughout time (Ulwick, 2005). Thus a good outcome statement does not include language such as “easy to use”, “durable”, “better”, “cheaper”, “faster”, “eliminate”, “prevent” as these terms can be subjective to the user and not quantifiable (Ulwick, 2005). Defining desired outcome statements with language that is unambiguous is essential to ensure that they cannot be subjectively interpreted, as this prevents developers from making assumptions about what the customer means. Ulwick (2005) prescribes a very specific structure for each statement. The outcome statement consists of three parts; a direction for improvement (i.e. minimize or increase), a unit of measurement (number, time, frequency, likelihood) and the desired outcome (Figure 5).

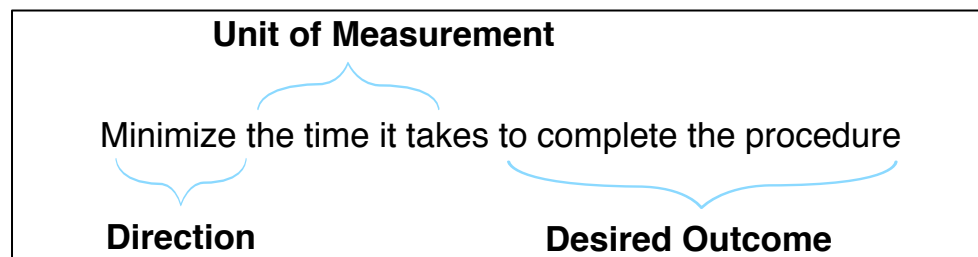


Figure 5: Structure of a Desired Outcome Statement. Source: Ulwick and Bettencourt, 2008. This statement is from the list of outcome statements identified by Cordis’s research into cardiologists needs for unblocking clogged arteries. Source: Ulwick, 2002.

For the terminology used for the outcome statements for lighting, I have limited the words for the direction to be either minimize or maximize because Ulwick (2002) has found that using different words that mean the same such as “increase” and “decrease”, impact how customers rate the importance of the statements in later quantitative work. Therefore, I wanted to ensure the statements were consistent with each other.

3.3.2 Collecting Customer’s Desired Outcomes

The desired outcome must be defined in the customer’s own words and not by the researcher or company as this leads to needs statements that reflect the researcher or company development priorities (Ulwick, 2005). However, as customers do not naturally talk in terms of the metrics they use to evaluate a product, researchers must therefore engage customers in a conversation that is designed to extract the desired outcomes from the customer (Ulwick, 2005). To collect the desired outcome statements, Ulwick (2005) finds that a number of different qualitative techniques can be effectively used from personal interviews to focus groups as long as the interviewer extracts the desired outcome in the correct format. Typically a one-hour personal interview will generate 20 to 30 outcome statements, and in a study with Cordis they were able to extract 96% of outcome statements for a given job in three focus groups (Ulwick, 2002). Other studies use Griffin and Hauser’s (1993) suggested numbers of requirement of 20 to 30 interviews to ensure all the data is collect without suffering from diminishing returns (Kavanagh et al., 2011).

Regardless of the qualitative technique used, attention must be given to selecting which customers to interview because too wide a group can lead to extraneous information that complicates research efforts (Ulwick, 2002). Ulwick (2002)

recommends selecting a target group that can judge a product from a user perspective. For Phase 2, I selected users of lighting who had frequent experience in designing lighting scenarios for residential settings. I assumed that these users would have a high degree of successful and unsuccessful user experiences because of the frequency that they used lights in new scenarios. The interviewees selected were a mix of interior design professionals and individuals with experience in residential lighting in multiple settings such as home stagers, and contractors. I further found that by choosing specialists, they are better able to articulate their answers due to their experience in applying lighting to different settings, their understanding of lighting design and theory and their frequent application of lighting new situations. This aspect differed from Phase 1, where I observed that the interviewees who had little experience with lighting struggled to explain or even recall when and how they used their lights.

The interviews in Phase 2, were semi-structured. To start each interview I began by describing the process and the precise format of the desired outcome. I provided a few examples at the beginning of the interview to help the interviewee to clearly see how the outcome statement was constructed. I presented each interviewee with the job map to guide the interview, which we referred to regularly throughout the interview to ensure we covered each step in our discussion. From the beginning, I also made it very clear that I was not looking for feature requirements for lights, and that I was attempting to capture how they personally determined the success of a lighting application in the form of a desired outcome. In total, 16 people were interviewed for Phase 2. Each interview took approximately one hour and was designed to capture the customers' metrics for measuring the success of using lights to achieve their tasks.

To guide the conversation and to collect the outcome statements, I asked the interviewees to think about how they themselves used lighting and what they were trying to achieve when lighting an area, turning on lights, adjusting lights and the steps used to carry out these actions. Depending on the discussion and their description of the job, the interviewee was asked questions such as, “what makes one type of light in this scenario better than another and why? How would you describe the ideal light scenario for this activity? What is inefficient or inconvenient about the execution of lighting and an area? What trends may affect how people light their homes in the future?” By focusing the discussion in this direction, I was able to prompt the interviewee to reveal desired outcomes without directly even asking what they valued in lighting, which is a significantly more challenging question to answer. From the interviewees answers to these questions, we were able to develop the desired outcome statements for each step of the job.

In the course of a natural discussion, the interviewee would not automatically state their desired outcome in the prescribed desired outcome format (Figure 5). Therefore, when a possible outcome was mentioned I would ask more questions to help us to arrive at the standard format that matched what the interviewee was saying. For example, the interviewee might say, “I really hate forgetting that I left the kitchen lights on after getting into bed”. Upon hearing this statement my response might be to say, “Could this situation be improved if you had minimized the likelihood of inadvertently leaving your lights on when you left a room.” The interviewee might say that this was exactly right, and this statement would be used as the outcome statement, or they might disagree and emphasize not having to get out of bed to turn off lights. In this case we

would revise the outcome statement, which could end up being to “maximize the number of locations where lights can be controlled from in your house”. The interview would continue until all functional steps within the job had been discussed.

To ensure completeness and accuracy, each outcome statement was documented in real-time with the interviewee, thus reducing the risk of paraphrasing later. During the interview I recorded the desired outcome statements directly into my laptop and verified the wording with the interviewee at that time to ensure I did not make assumptions later about their true meaning. Upon completion of all the interviews, I created lists of all the outcomes for each process step. At this time, duplicates were identified and consolidated.

Together, the Job Map and the desired outcome statements form the customer value model for lighting following the outcome driven innovation approach (Ulwick, 2005). In the following chapter I will present the results of the interviews and the subsequent customer value model for lighting.

4: RESULTS

This chapter summarizes the qualitative results of the Phase 1 and Phase 2 interviews. First, I will present the job statements identified along with their categorization based on whether they were either functional or emotional jobs. These job statements reflect what customers needs are for lighting products. Then I will present the job map I developed to describe the steps customers navigate to successfully use lighting products. Finally, I will present the desired outcome statements that were uncovered in the Phase 2 interviews. These desired outcome statements combined with the job reflect the customer value model for lighting (Ulwick, 2005).

4.1 Types of Jobs that Customers Accomplish with Lighting

Following Ulwick's (2005, 2008) outcome driven innovation methodology, the first step in identifying customer's needs is to identify the jobs customers are trying to get done when they use a product. A job is defined as a goal a customer is trying to accomplished or problem a customer is attempting to resolve within a particular situation (Bettencourt & Ulwick, 2008). A product is purely a means to help customers get the job done. However, not all jobs are functional in nature, as mentioned previously in Chapter 3, jobs can be functional or emotional (Ulwick, 2005). Breakthrough products fulfil more customer needs by helping users to achieve several additional related jobs in addition to the core functional job. Understanding the distinctions between the types of jobs is important. For example, the primary job of a bottled drink is to satisfy thirst, however related functional jobs including staying focused, recovering from exercise, and staying

awake, which are jobs met by a growing market segment of energy and health drinks that include beverage producers such as Red Bull Energy Drink, Vitamin Water (Ulwick, 2005).

From the Phase 1 interviews, I identified 22 jobs statements that customers were trying to get done when using lights in their homes (Table 2). Eleven of these jobs are functional jobs that define the tasks that people want to accomplish with the product. From these 11 jobs, I identified a single core functional job, which is “to see an area when there is insufficient light”. I have defined this as the core functional job as it is the one job that is mutually exclusive of the other jobs, and given the scenario where no other job can be achieved this core functional job satisfies the user’s needs at the most basic level. The other functional jobs are related and often supporting to the core job. For example, a user may turn on a light to see a room that dark, however the light is not required to navigate the room safely if they are familiar with the room layout and can use other sensory perceptions. Perhaps the most interesting of the functional jobs are the four indirectly related functional jobs (Table 2):

- To improve security of the home by creating the impression that the home/room is occupied
- To create a specific mood, environment or feeling in the room (e.g. warm, cozy, intimate, stimulating)
- To make people, objects and food appear more attractive
- To create a space within the multiple uses at any time of day (e.g. TV watching, entertaining and reading).

Table 2: Jobs customers are attempting to achieve with residential lighting

Customer Input Type		Identified Jobs
Core Functional Job		To see an area clearly when there is insufficient light
Other Functional Jobs	Directly Related Functional Jobs	To reduce eyestrain when performing specific tasks (i.e. reading, knitting, cooking, etc.).
		To highlight specific objects, artwork or architectural features of a room
		To navigate through a room while reducing the possibility of injury from objects within the room
		To find objects
		To perform activities (e.g. reading, knitting, painting, TV watching)
		To distinguish between closely related coloured objects.
	Indirectly Related Functional Jobs	To improve security of the home by creating the impression that the home/room is occupied
		To create a specific mood, environment or feeling in the room (e.g. warm, cozy, intimate, stimulating)
		To make people, objects and food appear more attractive.
		To create a space with multiple uses at any time of day (e.g. TV Watching, entertaining, reading)
Emotional Jobs	Personal Jobs	To feel warm, cozy and comfortable in a room
		To reduce feeling alone or isolated in a room or house
		To feel safe and secure from intruders
		To feel like their home is attractive and inviting to others
		To feel happy
		To feel awake in the morning, even if it is dark outside
	Social Jobs	To be perceived as having good taste in home décor and styling
		To have others perceive the room as occupied to increase security
		To have guests perceive dark areas of the home as off limits
		To be perceived as having a warm, attractive and cozy home
To have others see the home as inviting and welcoming		
Consumption Chain Jobs		Purchasing Fixtures, Installing/Replacing fixtures, Purchasing light bulbs, Installing/Replacing Light bulbs, Disposing of Old lights, maintain the light and fixture

The four indirectly related functional jobs are the simultaneous tasks customers are trying to complete, and potentially represent areas of greatest opportunity for satisfying multiple needs of customers. What I found interesting is that the majority of people interviewed mentioned security as a function of lighting, as they used their lights to give the impression that someone was home. This presents an opportunity, both in terms of energy efficient products to help reduce the cost of use for this job, but perhaps new ways of using lights to make a room appear occupied and providing customers with greater control of when lights are turned on.

The remaining 11 job statements identified are the emotional jobs users look for lights to perform. These emotional jobs not only provide key insights into how new products can better satisfy customer's needs but are useful in marketing a new product. Specifically by understanding these customer's needs a company can use these jobs to determine product messaging as many purchasing decisions are not purely feature or cost based. For example, customer's purchase luxury cars both for the features and for how customers feel about how other people perceive them in their car, they are a symbol of status. In the emotional jobs category for lighting, there were six personal jobs identified and five social jobs (Table 2).

It is a well established fact that light has both psychological and physiological impact on people; light is linked to vitamin D production, seasonal affective disorder, productivity and much more (Edwards & Torcellini, 2002). Therefore, it is not surprising that four of the six personal jobs are related to the general feelings of well-being and health. These four jobs; to feel happy, to feel awake, to feel warm and comfortable, to feel secure are interesting for what was not identified to increase productivity which has

also been linked to lighting (Edwards & Torcellini, 2002). The two remaining personal jobs are to feel secure and to feel attractive. The personal job of feeling secure is similar to the functional job of providing security, which appears to indicate that users have a strong need to feel secure in their own homes, and although current products do not functionally make a home more secure users attempt to use products in this manner. The sixth personal job where the user wants to feel attractive, can be very subjective, however this is an area where previous product introductions have failed and the market has not been receptive, therefore this is an important job for lights. Specifically, a key reason for compact fluorescent lights failing was that due to poor colour rendering of the light resulted in unattractive light (Brodrick, 2007).

Finally, I have added an additional category of jobs, called the consumption chain jobs. These jobs reflect the additional steps that feed into the primary job, such as purchasing light bulbs, fixtures and their disposal. I found it necessary to include these jobs because in each discussion they played a key role in the lifecycle of the product and how the user interacted with the product.

4.2 Job Map

Before capturing the desired outcome statements, it is important to dissect the job into its process steps, thereby creating the job map. The job map provides insight into how in the process of using a product customers evaluate the performance of a product to accomplish a job (Ulwick, 2005). The job map provides a clear depiction of the customer value model, and provides dissection of the 'job' so that companies can better target specific aspects of the job to create products that improve the overall process of a job's execution (Ulwick, 2005). From the observational aspect of the interviews in Phase 1, I

deconstructed the core functional job of lighting into the steps need to get this job done. Using the standard eight steps defined by Bettencourt and Ulwick (2008) as a guideline, I looked at what the customer is trying to achieve at different steps in executing a job and what must happen at each juncture in order for the job to be carried out successfully. I then validated each step to ensure applied universally for any customer executing the step or if it was specific to one customer. For example, an invalid step might be to “call a supplier to place an order”, where the act of calling the supplier is unique to some customers as other may order from a website. A valid step in this scenario would be simply to “place an order” (Bettencourt & Ulwick, 2008). In the scenario for lighting, an invalid step would be to “Use a switch to turn on a light” because some customer may use motion sensors or timers to turn on a light, therefore the switch is no universally applicable. These are the process steps of how the product is used to get the job done to achieve what the customer wants (Bettencourt & Ulwick, 2008).

For the core functional job of lighting, to see an area clearly when there is insufficient light, I identified seven key process steps lighting (Figure 6). Unlike the generic job process that consists of eight steps, I found that lighting did not include all 8 steps. Absent was the confirmation step, where a customer verifies that preparations are complete. Bettencourt and Ulwick (2008) find that this step is critical in for jobs where delay can cause loss of money, time or health such as the preparation of a patient for survey or preparation of taxes for submission. However, in the job of lighting this step in not critical and has been eliminated by existing lights that are permanently set up in a room to be readily available when required. The process steps outlined in Figure 6, are

also generic to the job itself and can be applied to lighting an entire room or a small area such as a desk.

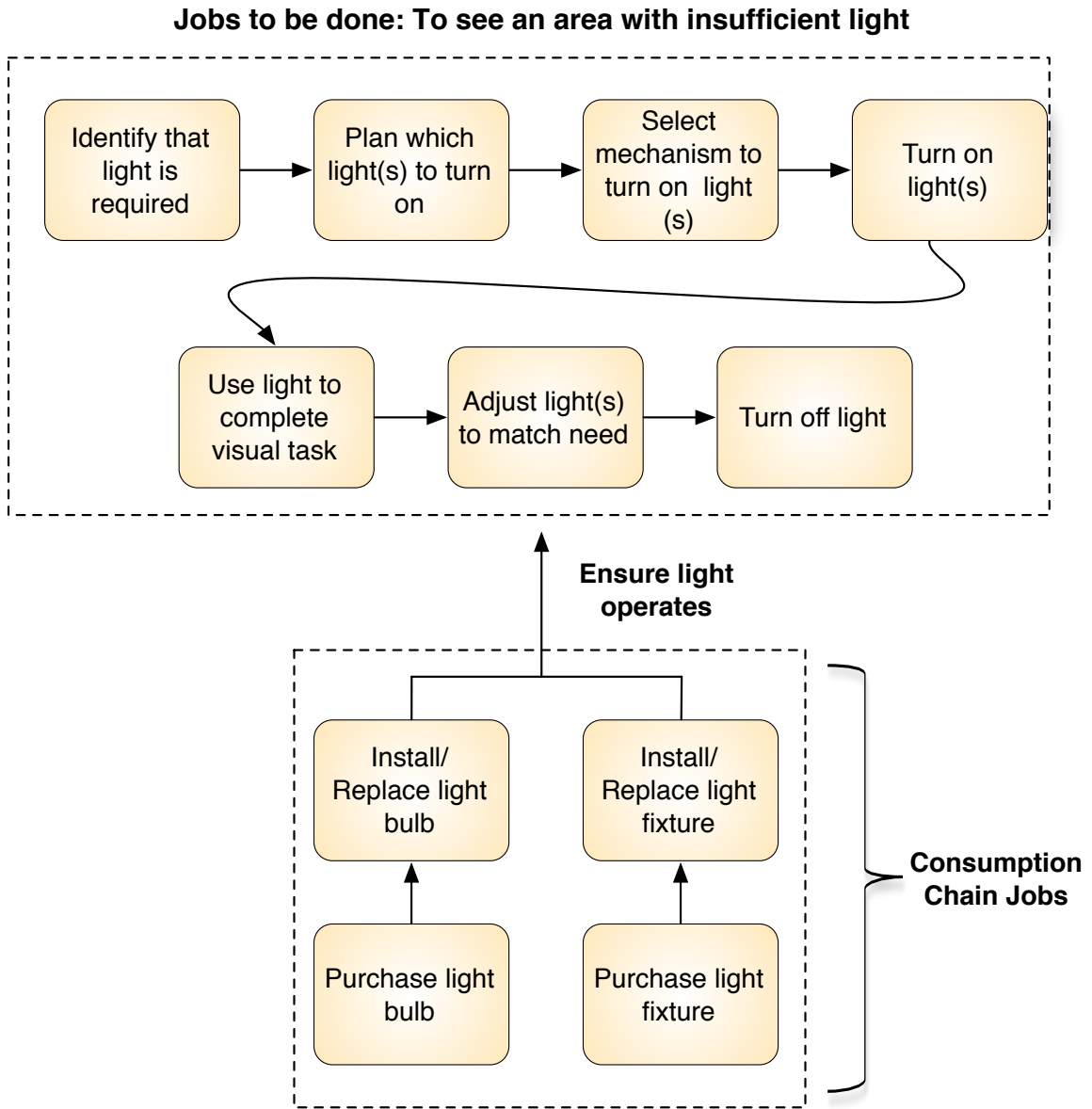


Figure 6: Customer Value Model, the Job Map for seeing an area with insufficient light

I found that in addition to the main process steps, customers must also ensure that the light operates as at any stage in the process, as the job is at risk of failing if the light bulb, fixture, or power source fails. If the light does not operate, then the job of lighting an area fails to execute successfully. The failure of the light bulb, power source or fixture can occur at any point within the process, therefore I have identified this as a continuous process that takes place outside the step-by-step process of lighting an area.

Throughout the interviews, all the interviewees made special note of the fixtures and the light bulbs involved, and were unable to separate the purchasing and replacing of these items from their tasks. One could argue that the step of purchasing or replacing a light bulb are part of the preparation aspect of the job itself, however I see these steps as sitting outside the main job steps due to the infrequency of their occurrence. For example, it's not uncommon for a customer to never replace a fixture such as a ceiling light, which is built into their home and requires some basic electrical knowledge to be replaced. I instead see the jobs of purchasing a fixture, installing a fixture, purchasing a light bulb and installing a light bulb as consumption chain jobs, which customers directly associate with ensuring the light operates properly. As the interviewees had frequently mentioned these jobs, and outcomes were developed in the interviews, I have added the consumption chain jobs as external jobs to this process for they play a large role in the customer's perspective of the functional job of lighting (Figure 6).

Within the job map, two key areas stand out as potentially underserved needs of customers, which if better met could improve a customer's overall success of performing a job. The first is found in the monitoring and modifying steps of using the light and adjust the light. I found that people frequently would not notice that the artificial light

needed to be increased or decreased due to changes in natural light conditions as they would become absorbed in a task. This can lead to increased energy waste if lights are left on longer than required, and can lead to eye-strain if lights are not turned on soon enough. By either eliminating the need to monitor the changes of light levels customer's need could be better served in this area. The second potential opportunity is linked to the modification step, and that is the conclusion step. The conclusion step of turning off a light is often poorly performed, and is easily forgotten, leading to wasted energy and potential bulb failure that makes the execution of the job unsuccessful the next time light is required. Preventing customers from failing at this step could be a good opportunity to improve existing functionality.

4.3 Customer – Desired Outcomes

The following section presents the desired outcome statements for each step in the job to see an area with insufficient light that were collected in Phase 2. These outcome statements combined with the job map, present the customer value model for lighting in addition to presenting the metrics that customers use to measure the performance of a product at executing the job of lighting.

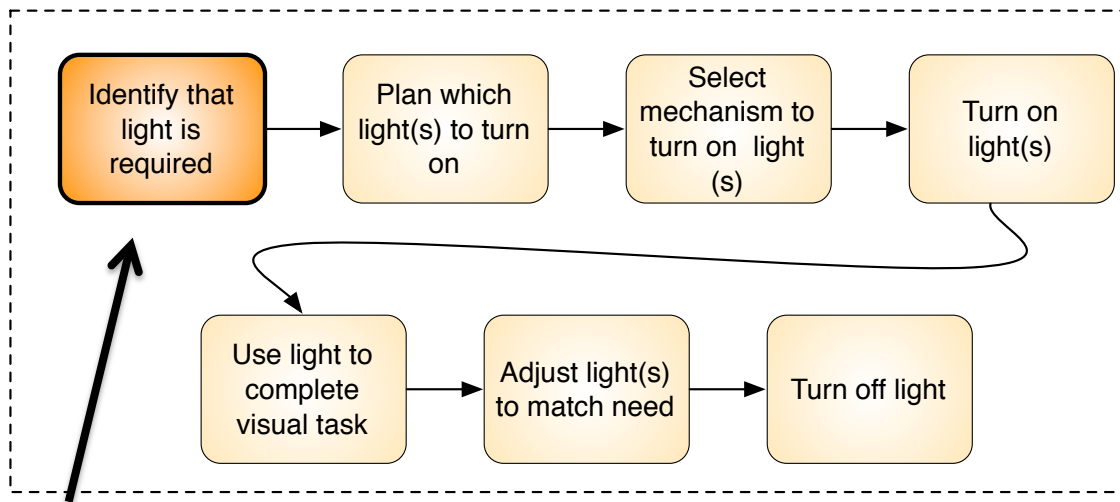
In total, I identified 115 desired outcomes statements for the core functional job and consumption jobs of lighting. I collected outcome statements for both the functional job as well as the consumption jobs included in the job map (Figure 6). Outcome statements for the consumption jobs were included as in the interviewees saw these as integral to the overall successful execution of the job. These 115 outcome statements are therefore split with 78 unique outcome statements for the functional job of lighting, and 37 unique outcome statements for lighting purchasing, installing and replacing fixtures

and bulbs. In the following two sections, I will present each of the 115 outcome statements as they were identified and the frequency that mentioned with each process step within the customer value model for the functional and consumption chain jobs (Figure 7 to Figure 17).

4.3.1 Desired Outcome Statements for the Functional Job of Lighting

In this section I will present the desired outcome statements for each step of the customer value model for lighting. Specifically these outcome statements reflect how customers measure the performance of products at each process step of the execution of the job of using a product to see in an area with insufficient lighting. The desired outcomes are presented for each job step in Figure 7 to Figure 13.

Job Step & Outcome Statements for identifying when light is required



Desired Outcome Statements	Frequency
Minimize the number of times the user is interrupted from a task to adjust artificial lighting as natural light levels change	2
Minimize the frequency the user finds themselves walking through a dark room	10
Minimize the frequency when room light becomes too dim, causing eye strain, while working on a visual task	3
Minimize the frequency a user is surprised by a catastrophic failure of the light source and is left in darkness	4
Minimize the likelihood that rooms will appear empty when no one is home leading to a decrease in the security of the home	1
Minimize the likelihood of injury caused by moving through a poorly lit or unlit room	6

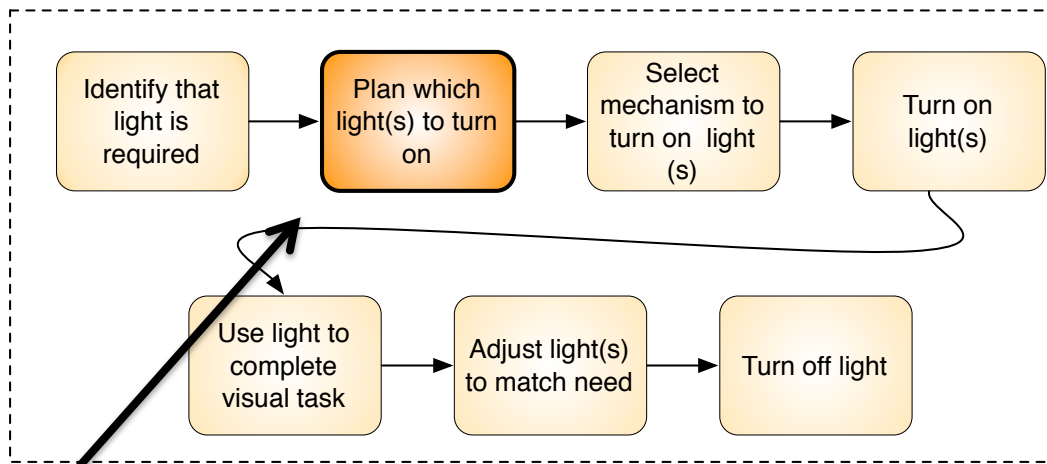
Figure 7: Customer desired outcomes statements when identifying when light is required

A common theme in the outcome statements for the first job step is that in many cases the act of identifying that light is required in an area is resulting from the disruption of other activities that a user is performing (Figure 7). This is most likely due to the fact that seeing is supplemental to another activity. The identification typically occurs after light levels are too low, and thus becomes reactive rather than proactive to task. This is a problematic step for many of the users as indicated by the high frequency for which the

outcome statement “Minimize the frequency the users find themselves walking through a dark room” came up in the discussion.

A second interesting outcome set is the first statement “minimize the number of times the user is interrupted from a task to adjust artificial lighting as natural light levels change”. At first glance this outcome seems more related to the modification of light following execution. However, when considering that it is directly linked to changes in natural light levels, this is a outcome related to defining when artificial lights should be turned on. Like the most frequently stated outcome, this outcome shows a preference of users to be able to have products that are more proactive in the management of their room light settings.

Job Step & Outcome Statements for planning which lights to use

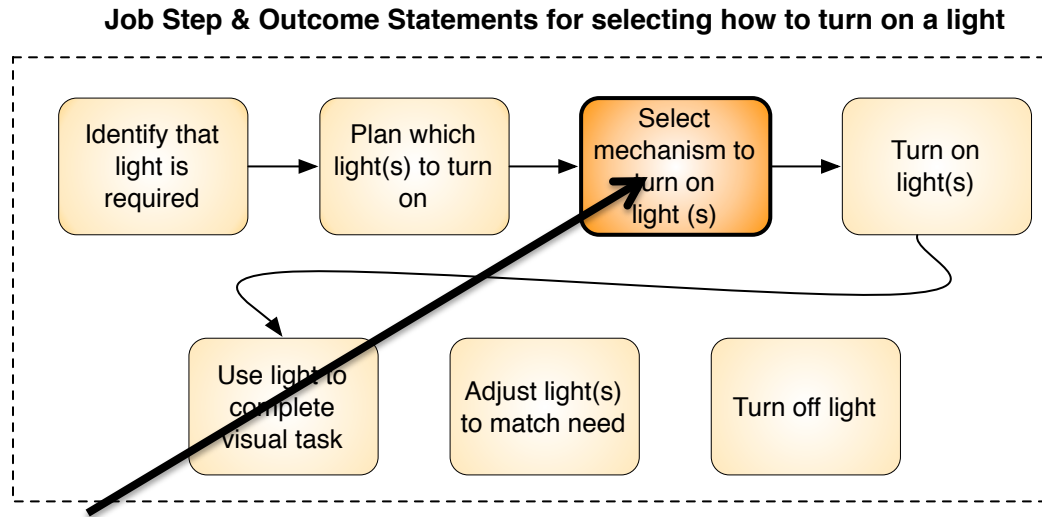


Outcomes	Frequency
Maximize the likelihood that a user can select a single light for multiple situations (e.g. warm colours entertaining, cooler colours for visual tasks)	7
Minimize the time required to choose which lights to use for a particular activity (eating and entertaining vs. working at that same table)	6
Minimize the likelihood that the user will be uncertain about which lights will work best for their needs for different room activities (e.g. entertaining vs. visual tasks)	3
Minimize the likelihood that the user will have to test different room lights to find a setup that works best for a visual task	5
Minimize the number of lights required to establish multiple room lighting scenarios. For example, one type of light is only useful for creating a bright room, but is not useful when trying to create a environment for entertaining	1
Maximize the likelihood that users can choose a natural light scenario	5
Maximize the likelihood that users can customize light set ups and fixtures to match their personal style and unique requirements	11
Maximize the likelihood that users will be able to select natural light-like for visual tasks	13
Maximize the number of ways light can be arranged and rearranged around the space as desired by the users can choose where they want lights to be turned (.e. e.g. users can adjust lights if they rearrange furniture)	3
Minimize the number of lights required to light a room which the user can turn on or off without being in the room for security purposes	5

Figure 8: Customer desired outcomes for locating which light to turn on

Users find the location step of selecting lights to turn on complicated when they are required to choose to light for a specific activity when multiple choices are available

(Figure 8). What is surprising is that user frustrations are most likely to occur when they do not have the lights available to meet their needs, such as creating a lighting scenario for performing a specific task due to insufficient lights or brightness in the room. The ability to mimic natural light within a space was also strongly preferred.



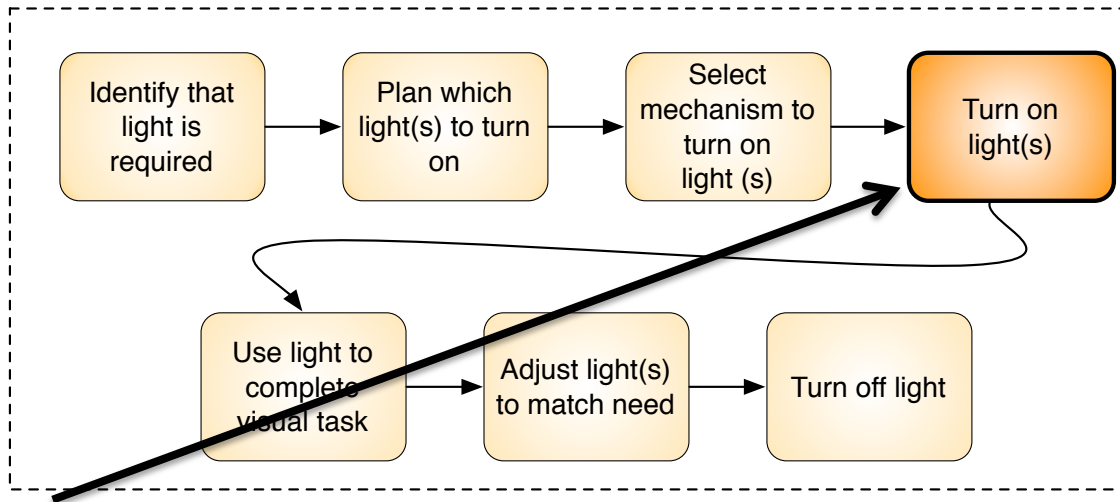
Outcomes	Frequency
Maximize the likelihood that lights can be turned on or off regardless of whether or not the user is in the room	3
Minimize the distance the user is required to travel in the room to turn on lights	7
Maximize the number of places a light can be turned on from	3
Minimize the likelihood that light switches are inaccessible to the user due to their positioning of fixtures or other room furniture	1
Minimize the likelihood that the user will inadvertently use the wrong switch to attempt to turn on a light	4
Minimize the likelihood that a user will find the location of light switches awkward to turn on because they are difficult to reach. (E.g. floor lamps placed behind furniture that the user has to climb over to turn on)	8
Minimize the total area of the light switch panels on the wall so that they are less intrusive and distracting from the room design	5

Figure 9: Customer desired outcomes for locating a light switch

In all the interviews conducted, users tended to refer to locating switches to prepare for turning on a light (Figure 9). This was surprising as there are other options

available such as motion detectors and timers, however for the most part these are not widely used and therefore not considered an option by users. Two key themes arose as potentially poorly served customer needs. The first was the access to mechanisms for turning on lights, as the placement of the mechanism often caused users to proceed further than desired into a poorly lit environment which disrupted the living tasks they were performing. Second, a number of users found that the switch mechanisms used were often obtrusive in a room and limited wall space for hanging pictures or other décor items. This is important to keep in mind, as it implies the solution to improving access to switch mechanisms isn't simply to add more switches as this would lead to user frustration in lost wall space and impact on the room design as most people found switches and interruption to the overall interior design of a space.

Job Step & Outcome Statements for turning on a light



Outcomes	Frequency
Maximize the total brightness of lights to reduce the number of lights that the user is required to turn on to get the desired brightness level	2
Maximize the likelihood that lights can be turned on when a custom is not in the room for added security	1
Minimize the likelihood of any electrical interference caused by switching a light on (e.g. such as radio interference, or buzzing noises)	1
Minimize the likelihood that a person will have to walk across a dark room and risk tripping or injury to turn on a light	1
Minimize the likelihood that in the evening that lights in living spaces will trigger a daylight effect and prevent the user from falling sleep	1
Minimize the likelihood that the user will turn on a light and discover that the light does not work	9
Minimize the likelihood that when lights are turned on that the user is temporarily blinded until their eyes adjust to the new light levels	4
Minimize the number of switches the user is required to use to get the desired lighting effect	2
Minimize the total distance the user is required to travel to turn on the light	1
Minimize the total time from when the switch is turned on and the light operates at its maximum brightness	6

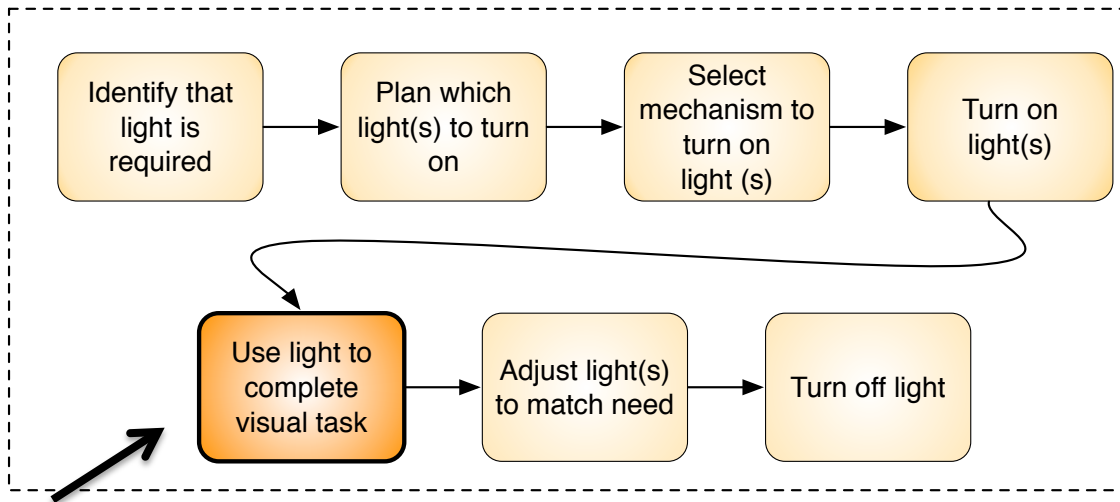
Figure 10: Customer desired outcomes for turning on a light

For this fourth job step in the job process map, ensuring a light works creates the greatest point of failure for users (Figure 10). More than half of the users interviewed wanted to minimize the potentially of turning on a light only to discover it doesn't work

because at this stage it is too late and user's must stop all other activities. The knowledge that a light will not work prior to turning it on could help users to execute the job as correct this issue prior to executing the job of turning on the light.

The desired outcome statement to “minimize the total time it takes for a light to reach it's maximum brightness” is interesting as it reflects a failure in new lighting technologies to meet customer needs. Depending on the quality of the light bulb and the room temperature compact fluorescent light bulbs turn on and then slowly reach their maximum brightness. Although the change is subtle, it is significant enough to be noticed by users, and to be identified as problematic. New technologies should therefore address this in terms of their performance and the time it takes to reach brightness capacity. If light is perceived to be instantaneous, then this outcome would likely be prioritized lower in importance and may not even be considered.

Job Step & Outcome Statements for using a light to see



Outcomes	Frequency
Maximize the likelihood that the user feels as if the light is generated from natural sources for living spaces during the day and for completing visual tasks	5
Maximize the accuracy of colour rendering of the light, to ensure colours will appear the same under artificial light as in natural light	14
Minimize the likelihood that the light will suddenly burn out leaving the user in complete darkness	4
Maximize the likelihood that people, objects and food will appear attractive in the light. (For example green hues in the light tend to make skin tones look unattractive)	2
Maximize the likelihood that lights will contribute to creating a warm, cozy and relaxing environment when turned on	6
Minimize the likelihood that the user would be distracted or annoyed by direct light glare, or glare reflecting off surfaces such as TV screens, or bright spots on surfaces	3
Maximize the distance that the light is dispersed away from the bulb so that light is more evenly dispersed throughout a space. (For example, the intensity of light does not sharply drop off as the user moves a metre or two away from the light)	1
Minimize the likelihood the user will trip over unseen objects hidden by dark shadows	1
Minimize the amount of background sound created by lights that could distract and/or annoy the user	3
Minimize the likelihood that the user will not be able to see colours accurately. For example mistaking navy blue socks for black socks resulting in wearing a mismatched set, or their socks not matching their pants	4
Minimize the likelihood that the light will cause objects such as paintings or fabrics to fade over time	1
Figure 11 continued on following page...	

Figure 11 Continued...	Frequency
Maximize the overall uniformity of light dispersal when the user is completing visual tasks. For example, reduce bright spots that may be distracting or make it difficult for the user to complete their task	2
Minimize the total cost of electricity used when a light is used	4
Minimize the total energy consumed when a light is being used	4
Minimize the likelihood that sleeping people in the room will be disturbed when a light is on	2
Minimize the likelihood of a person being injured from touching the light when in use	9
Minimize the likelihood that the light will heat up the surrounding physical space and require that the user install additional cooling systems	7
Minimize potential heat damage on nearby objects and when a light is on	6
Minimize any sounds generated when the light and fixture are in use	1
Minimize the visual impact lights (fixture and bulbs) have on a space if they are not a design feature	2

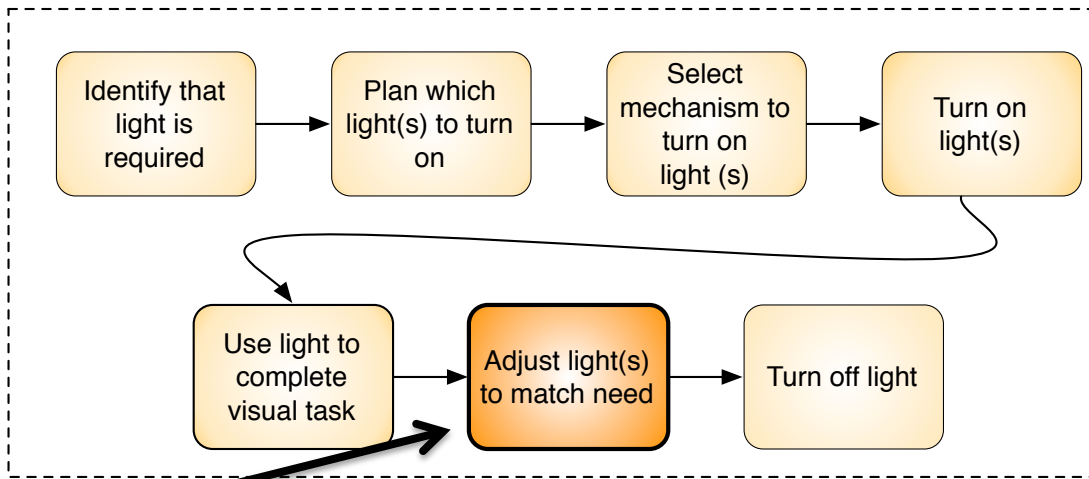
Figure 11: Customer desired outcomes for using light to see when performing an activity

The fifth process step is where people physically using the light generated by a light source and where users are monitoring the effectiveness of that product (Figure 11). The most common desired outcome stated was related to being able to see colours accurately, including distinguishing between blue and black socks and applying appropriate make-up colours to viewing paintings or other articles. I believe that this is closely linked to the metric that users measure quality of light by using natural light as their benchmark. What is interesting is that another important performance metric included the light's ability to maximize the attractiveness of people, specifically their skin tones. In discussions users preferred warmer light hues that can ultimately impact colour rendering. I therefore believe that these two desire outcomes are dependant on the specific task for which a user requires light in a room.

Four outcome statements in this fifth process step were related to a side effect of traditional light technologies, which is heat generation. In all cases, the users found that

heat generation negatively impacted the light's performance from potentially causing injury, damage to fixtures, and overheating spaces or objects. LEDs are known to be highly efficient at converting energy into light thus the side effect of heat production can be significantly reduced. Although the frequency of mentions of these desired outcomes does not reflect how users would prioritize these statements against the other outcome statements, their frequency does indicate to some extent how heat generation is top of mind for many users, possibly due to past damage or on-going safety concerns.

Job Step & Outcome Statements for modifying a light source



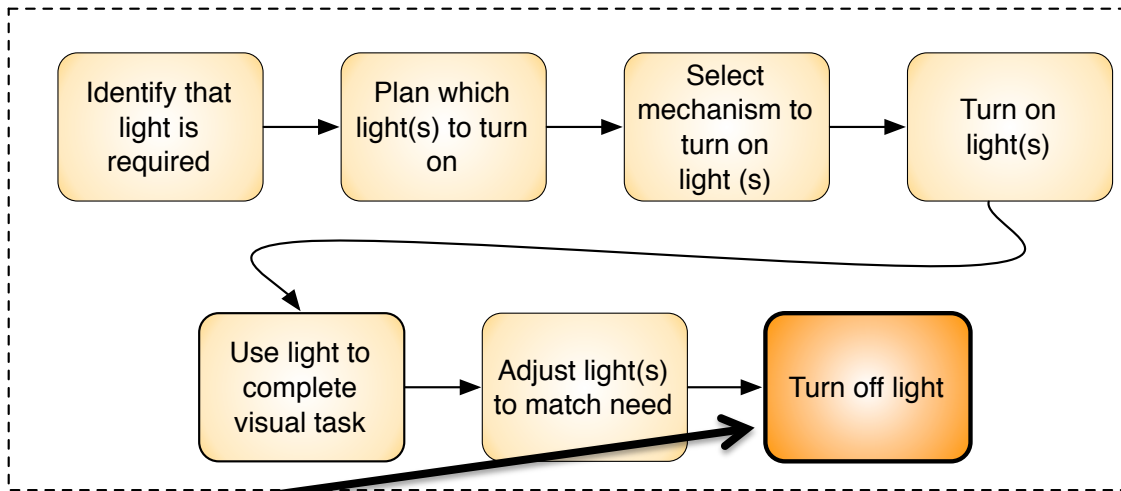
Outcomes	Frequency
Maximize the number of light settings that the user can create in a room. For example, a single space can be used for reading, watching TV, entertaining each with individual lighting requirements	8
Maximize the total adjustable brightness range that a light can be adjusted to, so that the user can dim lights for one purpose or make them brighter for another	3
Minimize the number of times the user is required to change light settings in the room as the natural light changes throughout the day	2
Minimize the likelihood that lights are accidentally left on when not required during light transition periods. For example from early to mid-morning	4
Maximize the number of choices of light's colour temperature so that the user can use the same light for different situations such as cool light for visual tasks and warm light for living spaces, where the same space has multiple uses	3
Minimize the time it takes to adjust light levels for specific light settings. For example reading, eating, entertaining, applying make up	2
Maximize the number of ways a user can focus a light depending on their task and/or how the space is used. For example, if the user primarily uses a space for living they may want to create a more layered affect in the room with bright areas and dimmer areas, but other activities may require the light to be evenly diffused throughout the room	2
Minimize the likelihood that the user will require special training to understand how to best adjust light in the room to meet their needs	1
Maximize the likelihood that customers can easily adjust where the light is positioned	1
Minimize the number of settings the user must attempt to find the right setting	1
Minimize the number of lights the user needs to individually adjust to acquire the appropriate level of light within a room	1
Figure 12 continued on following page	

Figure 12 Continued	Frequency
Maximize the likelihood that the user can dim or brighten a light depending on how they want to use a room	10
Maximize the number of locations where light sources can be placed to suit individual needs	5
Maximize the colour temperatures available for different activities. For example, low warm light for a relaxing bath vs. cool light for applying makeup.	2

Figure 12: Customer desired outcomes for adjusting the light

In the sixth step of executing the job for lighting, customers evaluate the effectiveness of the job execution and determine how they can modify a product to better achieve a result (Figure 12). Unique to the task of lighting, is that the user's purpose for using a light may change midway through executing the job because the activities being performed by the user have changed. For example, a user may initially turn light on in a room to set-up a dining room for a dinner party. Once set-up is complete the lighting needs to be modified to set the mood of the room and potentially increase the attractiveness of the food and guests by limiting overhead light and dimming the overall brightness of the room. The act of modifying due to changing needs is quite different from other products. For example, a user would not stop using a circular saw midway through the cut because they want to make another cut or being sanding the cut. As user needs change in the process of using lighting, modifying how the lights function is an important step. This is reflected in the number of outcomes looking at minimizing the time it takes to modify the settings as well as maximizing the options available from dimming to creating focal points.

Job Step & Outcome Statements for concluding the use of a light



Outcomes	Frequency
Minimize the likelihood that a light is left on when the user is not in the room	16
Minimize that the likelihood that the user will discover that they need to turn off artificial light sources as natural light levels increase in a room	7
Minimize the distance the user is required to travel to turn off a light	3
Maximize the number of locations from where a light can be controlled	2
Minimize the amount of “phantom drain” (energy drain) that occurs when the light is off	1
Minimize the cost of the on-going maintenance of lights and fixtures	2
Minimize the likelihood that the user will turn off the wrong light before finding the correct switch to turn off the light	3
Minimize the likelihood that the user will realize that they left lights on in another room after they have gotten into bed	3

Figure 13: Customer desired outcomes for turning off the light

In the final step of using a light to complete the functional job of being able to see in an area with insufficient light, there was one outcome statement that was repeated by each interviewee (Figure 13). “Minimize the likelihood that a light is left on when the user is not in the room”, was universally stated. Further questioning about why this was important to user is that they did not want to waste energy. In addition to this outcome statement, other statements alluded to the importance of energy conservation such as minimizing phantom drain from lighting fixtures. The cost of leaving lights on was also

related to inconvenience of the user. For example, having to stop another activity to return to a room to turn off a light. This inconvenience was an irritation point for users. Developers who work on solutions to assist in the conclusion of light use could potentially meet multiple customer needs that would be highly valued by users.

4.3.2 Desired Outcomes for the Consumption Chain Jobs of Lighting

In this section I will present the desired outcome statements identified for the consumption chain jobs of lighting (Figures 14 to 17). Specifically these are the metrics that customers use to evaluate the success of replacing and purchasing both fixtures and light bulbs.

Customers' Desired Outcomes when Installing/Replacing the Light Bulb

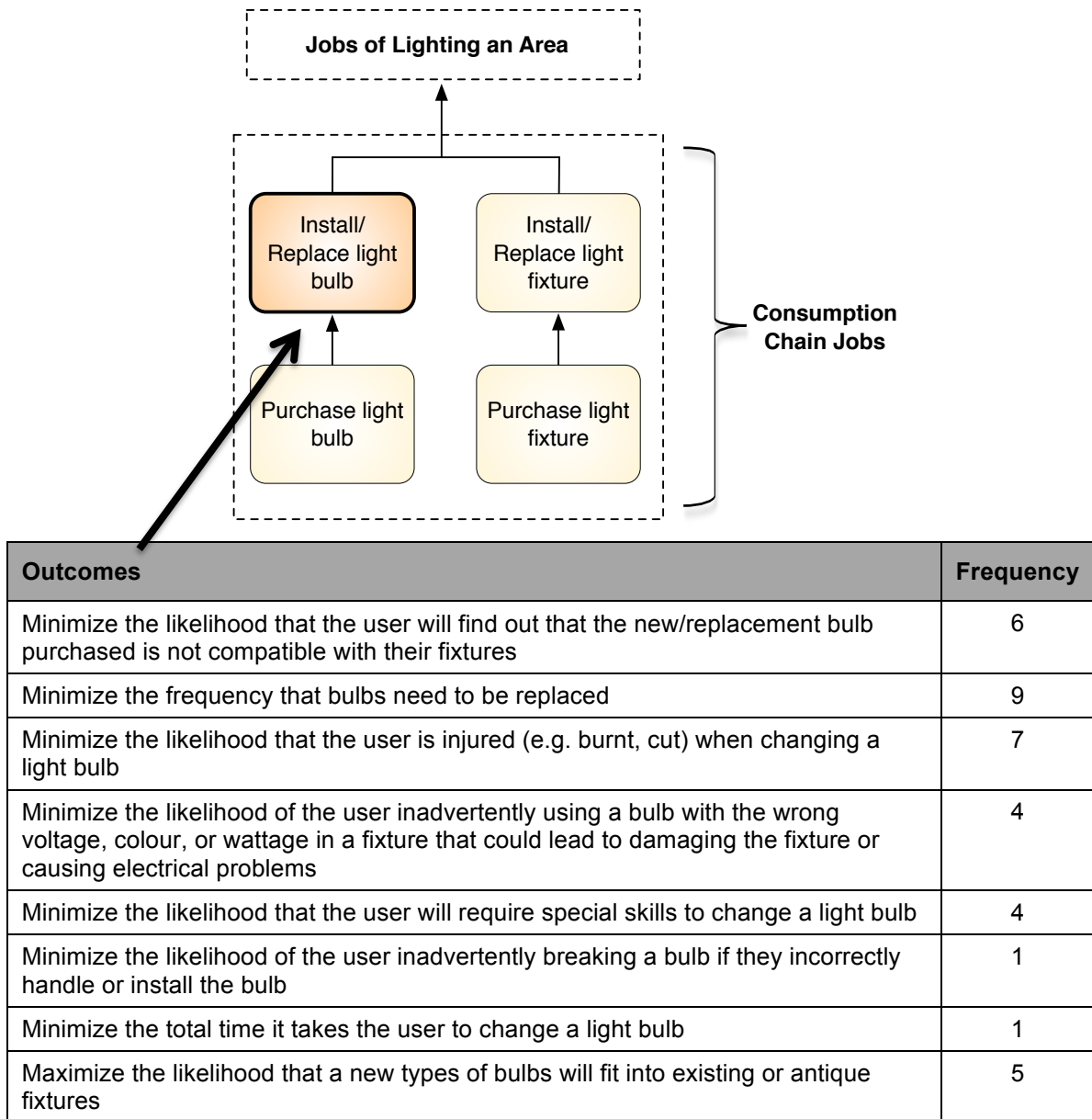


Figure 14: Customer desired outcomes for installing and/or replacing the light bulb

For the consumption chain job step of installing and/or replacing a light bulb a number of desired outcome statements are identified (Figure 14). This step when combined with the functional steps typically occurs at the beginning of using light when the materials needed are prepared, located and confirmed. However, this is not a step that is performed by the user each time a light performs its job. It comes as no surprise that

the outcome to “minimize the frequency that bulbs need to be replaced” was mentioned multiple times as this step is a disruption to the normal flow of the functional job. Each time this step occurs, it typically costs users money, time, and effort while preventing them from carrying out their regular tasks. As expected failing to succeed at this task, such as making a mistake with the type of light bulb required is something customers hope to minimize. The estimated long life span of LEDs could potentially help to better meet customer’s desire to reduce the time and frequency that this step requires with modern lighting technology.

Customers' Desired Outcomes when Purchasing a Light Bulb

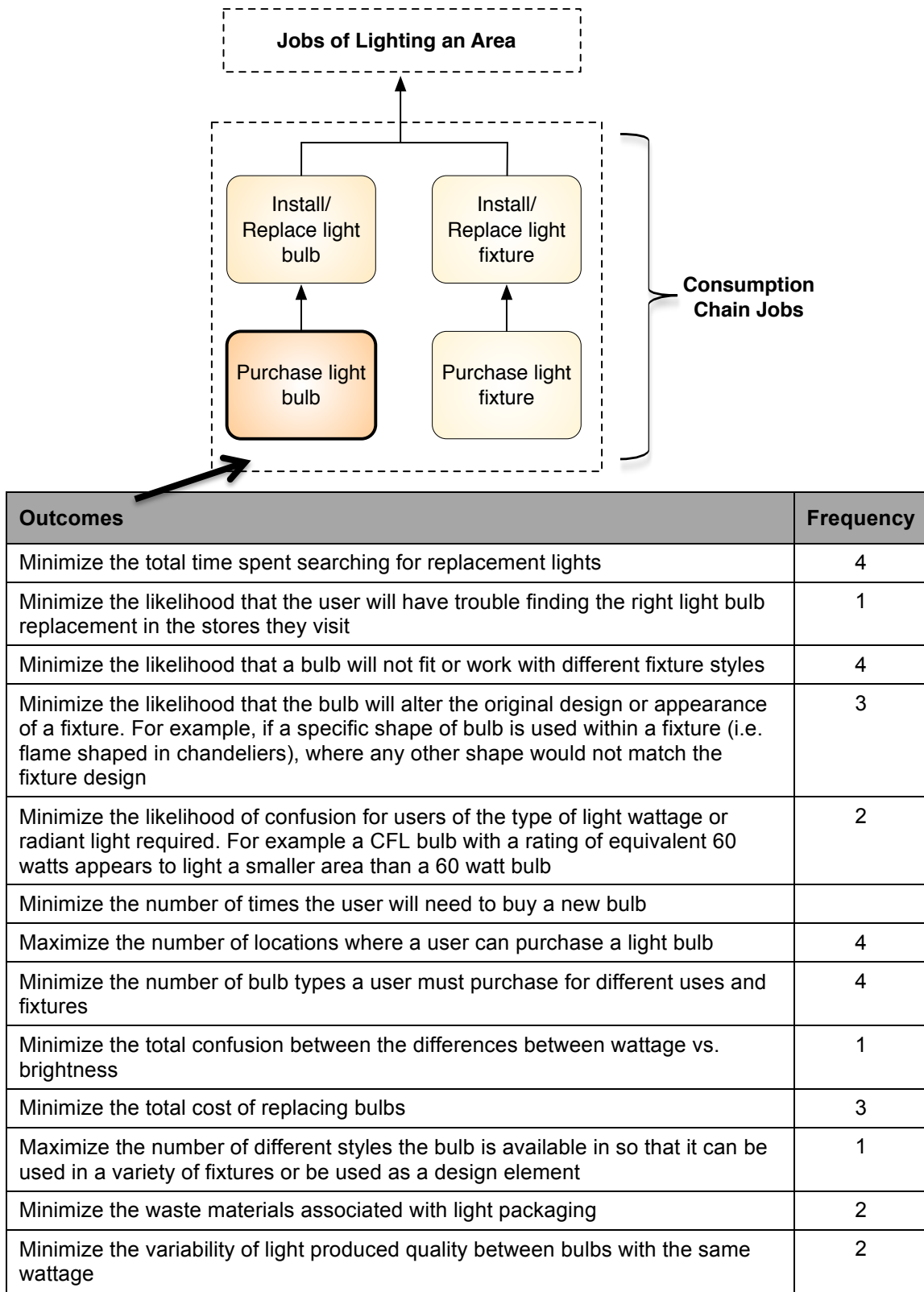


Figure 15: Customer desired outcomes for purchasing a light bulb

In the consumption job step of purchasing a light a number of desired outcomes were identified (Figure 15). I would have predicted that the outcomes would be based on availability and cost, however there are multiple metrics that user consider when purchasing their lighting product from packaging waste, style, and understanding light output. What was also interesting is that there was no single outcome statement that came up universally across the interviews. I suspect that part of the low frequencies was due to our focus of the interviews on the functional jobs of lighting, which could also indicate that there are several more uncovered needs for this particular task. The purchasing needs of customers have an indirect impact on development from decisions made on pricing, helping customer better understand new technologies, and providing products that can be used with existing infrastructure such as lighting fixtures.

Customers' Desired Outcomes when Installing/Replacing a Light Fixture

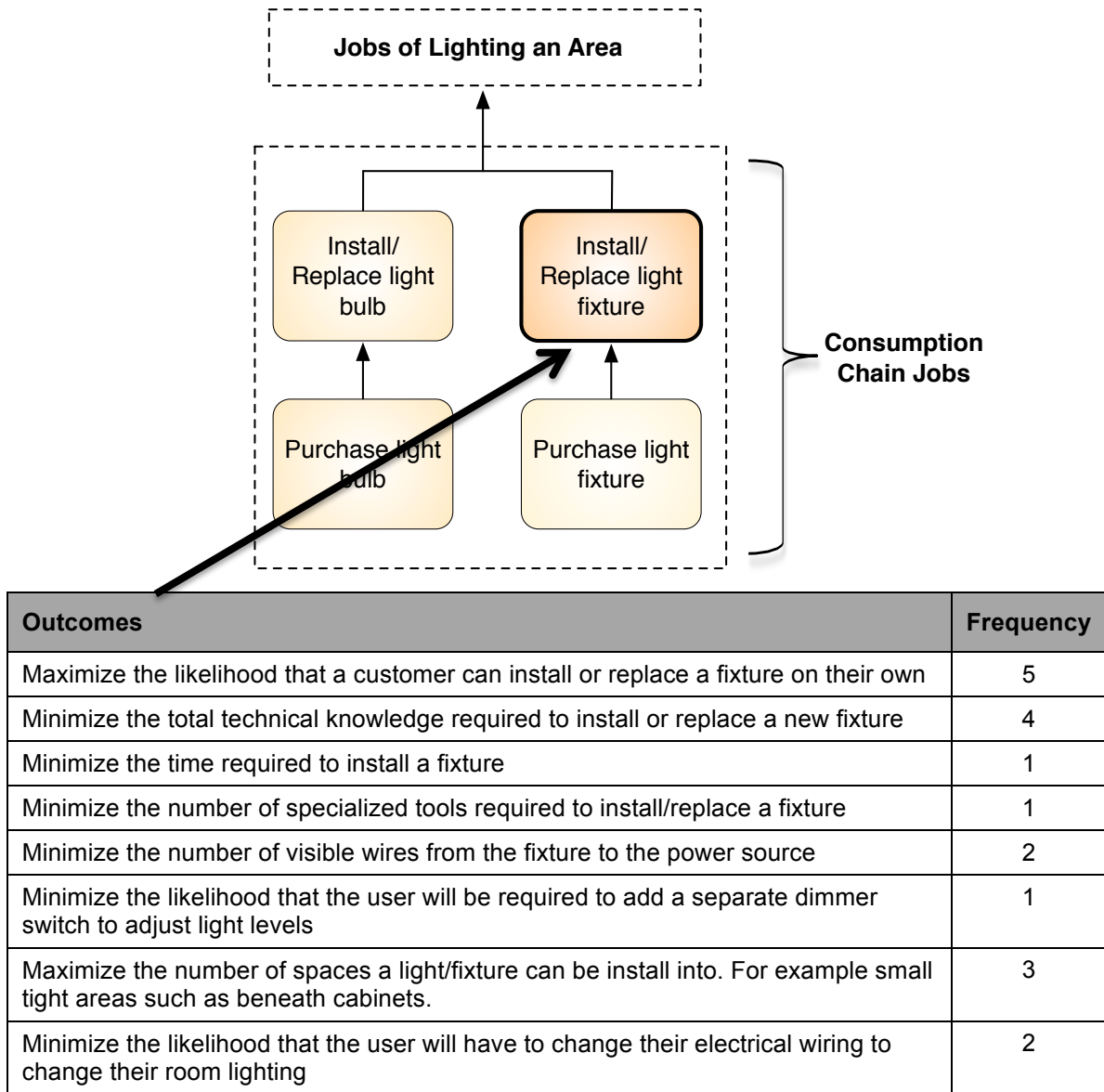


Figure 16: Customer desired outcomes for installing and/or replacing the light fixture

In the consumption job step of installing a fixtures users identified a number of outcomes for which they measure the successful execution of this step (Figure 16). This particular task tends to be infrequent in nature, for example, users often purchase built in fixtures such as ceiling lights with their homes. Although people often want to change these fixtures to better suit the design aesthetic of a room, they are limited by their own

technical skills as changing a built in fixture requires some knowledge of electrical systems. Often the only flexibility they have in installing new lamps in their home is using freestanding lamps to match their decor. In the case of LED lighting where the lamp and fixture can be the same unit, will need to insure that replacement and installation is simple otherwise customer's satisfaction with these products could be used based on the desired outcomes.

Customers' Desired Outcomes when Purchasing a Light Fixture

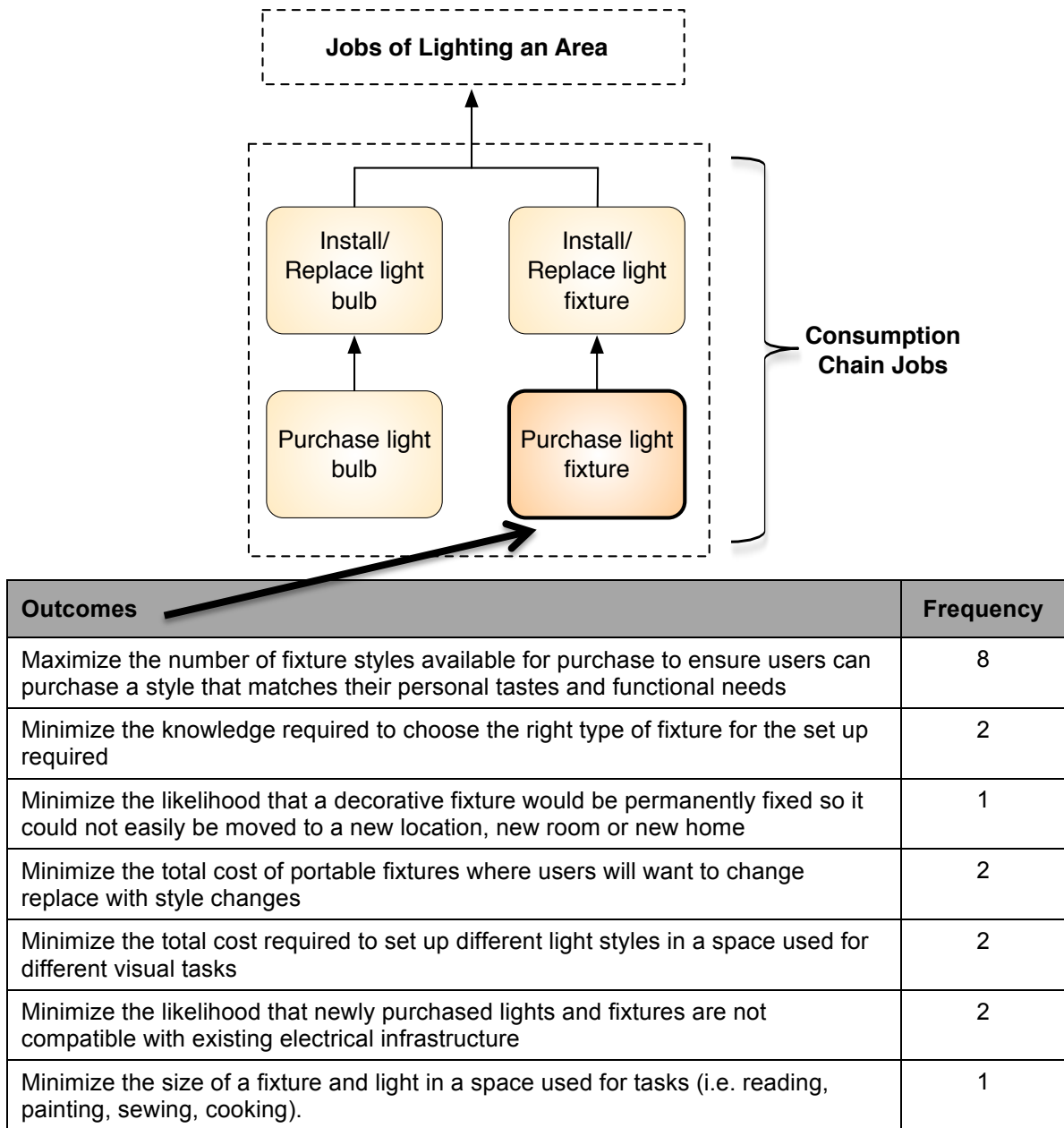


Figure 17: Customer desired outcomes for purchasing a light fixture

In the consumption job step of purchasing fixtures users identified a number of outcomes for which they measure the successful execution of this step (Figure 17). As expected a number of the metrics used are related to the cost of purchasing. However, there was also a lot of focus on purchasing fixtures that matched users personal aesthetic.

Style was the most frequently cited outcome statement because users want to have a wide variety of styles to ensure they can purchase a fixture that not only meets their needs but appeals to their design sense. I suspect that as the step of purchasing fixtures was not a focus of the interviews that there are more desired outcomes related to this step, which could further help marketers identify why customers make specific buying decisions for their fixtures.

5: DISCUSSION AND RECOMMENDATIONS

LED lighting sits on the precipice of replacing traditional lighting systems, specifically incandescent light bulbs. A key driver for change in the lighting industry is pressure for consumers and legislation to switch to more sustainable and efficient lighting products for which LEDs are ideally suited. In recent years, technological advances have opened up the doors for LED applications in general lighting, and the list of potential innovations seem limitless. However, the big question remains as to which product innovations will be most successful and readily adopted by consumers in the over-served residential lighting market.

Using Ulwick's outcome-driven innovation approach to uncover customer needs, I have identified the key tasks and activities (jobs) customers want to achieve with lights, as well as the metrics (desired outcome statements) customers use to measure the success of using lighting products. Together the jobs and outcomes statements form the customer value model for lighting, which can be used to formulate the strategic approach, drive ideation, build product requirements for new lighting products, and finally position and deliver the new product to the market. In this chapter I will present the key themes identified from the customer value model and potential implications for LED innovation, design a workflow structure on how incorporate the customer value model into innovation development processes, provide a template for a scorecard using the desired outcomes to evaluate new product development, and finally make some recommendations for future research.

5.1 Interpretation of the Customer Value Model

The Customer Value Model for lighting (Figures 7 through 17), outlines each step that a user must complete to successfully execute a job, and provides the metrics for which a customer evaluates the successful execution of that job (Ulwick, 2005). This model provides key performance metrics in the form of desired outcome statements. In this section I will provide insights into common themes, trends and applicability to LED innovation.

5.1.1 Understanding the Core Functional Jobs to be Done by Lighting

Customers purchase lighting products to use to perform multiple jobs (Table 2). Bettencourt and Ulwick (2008) describe this process of selecting and using a product as “hiring” a product to get a “job” done. Lighting as a product, is somewhat different than many products, as most customers use lights in conjunction with accomplishing other tasks and using other products. Unlike many products, such as a cell phone or a toothbrush, where users consciously make a decision to use the product to complete a specific task; customers tend to use lights more subconsciously while they simultaneously perform other tasks. As a result, customers tend to think about light in terms of how it relates to additional unrelated products. This also means that customers only notice the job that lights are performing when the light is unsuccessful at meeting their needs. From a product development perspective this becomes interesting, because instead of focusing on simply creating light, products could bundle their solution into solving multiple jobs, and therefore making their products more about helping customers meet their safety, lifestyle and health needs.

Despite being possible to create solutions that target multiple customer jobs for lighting, it is important not to lose focus of the “core functional job,” i.e. to see when there is insufficient light. This job is the primary reason customers purchase lighting products and how they initially evaluate the effectiveness of LEDs as they introduce them to their homes. One key requirement of the core functional job is that only exists due to a lack of other light sources, typically natural light sources. The requirement of the job means that customers will be comparing LED technology not only to the incumbent lighting technologies but also evaluating it against natural light. For example, as natural daylight decreases late in the day, most people tend to turn on lights in their home to continue living their lives and performing various activities. Often those activities require additional lighting for specific tasks such as reading when the ambient artificial room light is insufficient whether it’s daylight or not.

5.1.2 Other Functional Jobs

Beyond the core functional job, consumers ‘hire’ lighting to complete between one to eight additional tasks (Table 2). These additional functional jobs perhaps provide the greatest opportunity for LEDs. Five of these tasks are directly related functional jobs, in that they are tasks that lighting products are specifically designed to accomplish. The remaining three jobs are indirectly related, in that customers are using lights as a solution to accomplish tasks that lighting products are not specifically designed to perform.

The directly related jobs are all jobs that the user is trying to execute in addition to the core functional job (Table 3). In each example, users are using lighting products to help them perform other tasks such as reading, finding objects, distinguishing between colours in items such as socks. There is one exception and that is the job of highlighting

specific objects, artwork or architecture features of this room. This task is very specific for a light and the user does not typically expect to perform other tasks with this lighting products. Although used in residential lighting, this job is closely aligned with the architectural lighting application in general lighting, but on a smaller scale. As LEDs have had relative success in this niche markets (McKinsey & Company, 2011), it is plausible that they could also quickly adapt existing products to fulfil this need, thereby quickly introducing LED products to homes where the opportunity is available.

Table 3: Directly related functional jobs of lights, excerpted from Table 2.

Directly Related Functional Jobs
To reduce eyestrain when performing specific tasks (i.e. reading, knitting, cooking, etc.).
To highlight specific objects, artwork or architectural features of a room
To reduce the possibility of injury when moving in a room
To see and find objects
To find and distinguish between closely related coloured objects.

The indirect functional jobs that user look to lighting products to perform, though they are not implicitly designed for this function, are listed in Table 4. I have categorized these jobs into three broad categories of security, design and finally environment. I created these sub-categories because each has a unique set up and expectation from the users.

Table 4: Indirectly related functional jobs, users want to achieve with lights

Indirectly Related Functional Jobs	
Security	To improve home security (e.g. turned on lights give the impression that people are home and therefore deter break-ins)
Environment	To create a specific mood, environment or feeling in the room (e.g. warm and cozy)
Design	To define the functional use of different spaces within a room, or define multiple uses for the same space regardless of time of day (e.g. TV watching, entertaining, reading a book)

The job of providing security was mentioned by several interviewees in Phase 1 as they frequently left lights on in their home that were visible from the outside to give the impression that someone was home. The concept of creating an illusion that a home is not unique, and it is often a recommended security precaution (Vancouver Police Department, n.d.). Unfortunately, this practice of using residential lights for security is counter-intuitive to global initiatives to be more energy efficient. LED lighting promises high energy efficiency, and with additional features of programmability to control when lights are on and which colours are used, LED producers could target this job specifically. However, research would be required to determine if there was demand for such a product, and if LED lights used for general illumination could not perform this secondary task equally well.

The interviewees also frequently mentioned the subcategory of environment, where users are looking to create a specific mood or feeling for a room, such as “warm and cozy”. Creating a specific environment in a room is something that can be controlled by colour temperature of a light. Warm colour temperatures, which closely mimic incandescent lights are typically associated with creating warm or happy feelings in a room. In the past CFL lighting failed when initially introduced to the market because they

tended to produce colder greenish light that people found unappealing (Brodrick, 2007). LED lights can potentially excel in helping users to easily accomplish this job, because they can generate different colours. This indirect job of lighting, is potentially a key job that LED lights can help users to achieve in addition to the core functional job and therefore drive the success of this product..

Finally, users create non-physical divisions between spaces to indicate how the space should be used with lights. For example lighting an open plan space with a desk lamp to work at a desk, and lighting around a sitting area for entertaining. This use of light can be classified as a design function. I have classed this as an indirect functional job because lights are not inherently designed to delineate spaces within a room. However, with control over focal points and brightness, LED lights could potentially be more effective in helping interior designers and design enthusiasts accomplish this task. However, this indirect job is likely not one that seems to be underserved as fixtures for incandescent and CFLs provide sufficient control.

5.1.3 Unidentified Functional Job of Lighting

Interestingly there is one functional job that I believe that was not identified during the interview process. That job is to promote the well being and health of the user. By this, I am referring to the aspect of lighting that affects people's health. It is well documented that light can impact sleep patterns, productivity, and mental health (Boyce, 2010; Knisley, 2005; Linda, 2004). The emotional and social jobs alluded to this functional job of lighting, such as to feel happy, but it did not come out during the interviews as a clear functional job. It is possible that this was missed because most people think of using light for specific healthcare reasons, like seasonal affective disorder

as a specialized function requiring specialized lighting equipment or because the people interviewed did not personally identify with this job. Hence, such issue did not come out as a job their standard residential lighting would perform. Still, from a product development perspective, there is no reason that this job should be ignored in what can be achieved with LEDs.

5.1.4 Emotional Jobs of Lighting

Beyond the functional jobs of lighting there are the emotional jobs of lighting that are important to customers. These are categorized as personal jobs, how people want to feel when using the product, and social jobs, how people want to be perceived by others that are important to customers (Ulwick, 2005). During the interviews, each interviewee frequently highlighted emotional jobs such as “to feel cozy” as a primary job despite it not being directly related to the function of the light. For example, people may use warm coloured light to make a room feel cozy, however they would not use that light if the room was always brightly lit from natural sources. When looking at past lighting products such as CFLs and juxtaposing these emotional jobs, it is easy to see why CFLs were poorly received when they were first introduced because they did not serve these jobs well. For example, the light output of early CFLs tended to have a greenish hue, which makes people unattractive and provide little colour warmth as a traditional incandescent bulb. For LED lights, these emotional jobs provide not only insight into customers, needs that must be met, but also insight into how new products can be marketed.

5.1.5 Variability of Jobs by User

After the first few Phase 1 interviews, I found that for the most part core jobs were consistent across all interviewees with one exception. The exception was with an interviewee, who was a recent immigrant to Canada from a non “western” country. Although the process of how they performed the core functional job was identical to all other interviewees, they did not identify any emotional jobs observed with the other interviewees. From my observations of their home and through discussions, it was very clear that lights were only used when it was dark for the purpose of allowing them to see. The interviewee was not concerned with colour, appearance, or how attractive light made their home. Unlike the other homes I had visited, this interviewee was using only the bare minimum of lights. There were no decorative fixtures, and all bulbs in the basic fixtures were CFLs.

Although there was a slight language barrier during the interview, I suspect that the differences found were more directly related to cultural differences in the usage of light. For example, the interviewee asked questions such as “Why do people in Canada leave their lights on all the time?” and “Why do people have so many lights in their homes?” When asked these questions, I mentioned some of the emotional and functional jobs identified in previous interviews. What was interesting was the interviewee’s response to my explanation, which was “But it costs too much to use so many lights.” This statement indicated that for the interviewee, the key metric that they used to measure the successful performance of a light was the cost of using and purchasing lights. The interviewee then explained that in Asia, electricity was expensive, and that most people only used lights in their homes as needed. It is important to note that this interviewee is

from a large metropolitan area and was a successful professional business person both in Canada and in Asia. What was significant about this interview was that it indicates that there are likely strong cultural difference in both the priority of how users measure the success of a light and how a light must be positioned in international markets. Although the features of the light could be the same, marketing would need to be specific to each market where the product is sold.

5.1.6 Interpretation the Job Map

In analysing the job map (Figure 6), an interesting attribute is that the job requires multiple products to be fulfilled. Users must have fixtures, light bulbs and switches at a bare minimum to achieve the job. Often fixtures and switches are combined for stand alone lamps, however all built-in lights separate out these products. From a commercial perspective each of these products is unique and must be purchased separately. For example, a fixture like a dining room chandelier is designed, manufactured, marketed and sold separate from the bulbs that it requires to function. Given that multiple products are required to complete the job, it is therefore logical to ask from a product development standpoint why must a single job require multiple products to achieve a simple task? A reasonable explanation is that currently these products are sold separately due to existing manufacturing, distribution, installation practices within the value chain. Furthermore, the life span of each product is variable. For example, an incandescent light bulb may only last a year, whereas a fixture may last a decade before the user becomes dissatisfied with its style, and a switch will last several decades LEDs have the potential to change this model because LED projected lifespans are expected to be increased significantly in the next 10 years. Furthermore, when fixture development occurs in conjunction with

LED light development developers can ensure maximum energy efficiency (U.S. Department of Energy, 2012). Although the process for completing the job does not change, LED developers can provide a more comprehensive solution to customers to fulfil the job. This simplification would add value to customers by reducing the number of steps and frequency within the consumption chain. For example, if the lifespan potential of LED bulbs is realized, there's no reason why the fixture and the light couldn't be produced and sold as a single unit. This ultimately will result in changes to how people perceive lights as being something that requires high maintenance and regular replacement, to a more permanent appliance in their home.

Further analysis of the job map reveals other opportunities where LED could look to add value to customers by simplifying the job process steps. Specifically the steps that could be improvised are as follows:

- Reduce the frequency of consumption chain jobs, particularly in the replacement of bulbs. This step will reduce the effort and cost required for light maintenance.
- Reduce the need to adjust. Particularly due to changes in other light settings. LEDs can be integrated into a control system that can be self-monitoring and adjust lighting to program levels automatically eliminating the need for users to perform this step.
- Simplify the planning step for creating multiple lighting environments in the same space. Similar to the automatic adjustment, the advantage of LEDs being integrated into control systems allows for programmable settings for how much light and what colours are displayed from a device.

For example, the same LED could display bright, uniform white light for performing tasks, and then be switched to a dimmer, warmer light colour for entertaining when the same room is used for both functions.

One final aspect of job process that can significantly disrupt users is the on going task of ensuring that a light works. Failure of a light results in the complete disruption of any activity that the user requires an additional light. LEDs offer a unique feature, where unlike traditional lights that have sudden “catastrophic” failures as they burn out, LEDs fade over time. Therefore, monitoring overall brightness will become a step of monitoring the LED performance.

5.1.7 Interpretation of Desired Outcomes

The desired outcomes statements collected provided many clear insights into how customer’s measure the successful application of lighting products. Although the desired outcomes were collected based on customer’s perceptions of existing technology, such as incandescent and compact fluorescent lighting, they are technology neutral statements and therefore applicable to any lighting technology. There were several themes that materialized from the desired outcome statements identified. Although the task of lighting appears simple enough, the functionally that customer’s measure is vast as indicated through the more than 100 outcome statements identified in this analysis. Many of these outcome statements measure the success of personal and social jobs in addition to straight-forward functionality.

5.1.8 Summary of the Customer Value Model for Lighting

There were three themes identified in the customer value model that present opportunities for LED developers. From the model it is clear that lighting is not just about being able to see, and that cost is not the only metric customer use when purchasing a light. The three overall themes identified were as follows:

- Customers value lighting's ability to create an environmental ambiance to meet their lifestyle needs.
- Customers value the safety features of light, from both a security standpoint for their homes, but also in ensuring that they can safely perform activities in their home. For example, limiting eye strain.
- Customers value the positive impact of lighting on their health and the overall sense of well being and the effect their general health.

These themes offer insight into new market opportunities for additional growth within the lighting segment. By focusing LED innovation on these new opportunities, it is possible to conceive new products and product categories that better exploit the product advantages of LEDs and does not limit development to incremental improvements over existing lighting technologies. In the next section I will discuss how the customer value model can be incorporated into the innovation process to enable companies to exploit these new opportunities.

5.2 Incorporating Outcome Driven Innovation into LED Product Development

The customer value model provides companies with a powerful tool to develop innovation strategy, measure development success and plan successful go to market campaigns by deeply imbedding customer insight into their process. Without true customer insight, companies are at risk of inventing new products that are not valued by their customers and therefore fail in the marketplace because they have essentially created a product without a market (Newman, 2009). Furthermore, because the customer value model does not focus on customers articulated needs, such as specific feature requests, it provides companies with a tool to assess all forms of product development from incremental improvements to innovative new products. Ultimately, because the model itself is not tied to a specific solution and customer needs do not change over time, it allows companies to identify new market opportunities that will meet customers future needs. However, the question remains, once the insights are collected and the value model constructed, how do companies incorporate this into their own processes? In this section, I will discuss how and when the customer value model can be used throughout the new product development process.

5.2.1 Standards for LED Development Processes

Within the lighting industry many LED companies follow development processes that comply with the International Organization for the Standardization (ISO 9001:2008). Specifically, companies need to ensure that their processes follows a quality standard practice with the goal of consistently developing quality products that conform to market and customer requirements. Incorporating the customer value model into a companies

standard process can provide tools that will complement standard product life cycle processes. In the following section I will outline the outcome driven innovation process.

5.2.2 Integrating Outcome Driven Innovation into the Product Development Process

A company's ability to develop new products is a critical function, particularly for technology based firms because the success of development efforts is linked to the long-term viability and economic success of the company (Ulrich & Eppinger, 2004). There are many different processes employed by companies, and although each process used by a company is unique, there are common steps that can be identified (Smith & Morrow, 1999). At a basic level, the product development process is the practice of turning customer needs into a commercial product. Using these basic steps, a high level Outcome Driven Product Innovation Process (ODPIP) is depicted Figure 18 below.

ODPIP begins with the project initiation, which could be inspired by a need for an existing product redesign, a perceived market need or a new idea. It is expected that at this time the project schedules, costs, and marketing targets can be identified by the business operations of the company and provide this information to the engineers.

The first phase of ODPIP is to build the Customer Value Model (CVM) if one does not previously exist. It is possible that if a company has an on-going market and customer research the CVM has been previously developed, and even possibly motivated the project initiation. Designers at this stage should gather their customer inputs to identify the jobs to be done, the process job map, and finally the outcome statements. These three inputs create the CVM artefact for this first task. The CVM will then provide a tool for assessment, ideation, product testing and marketing in later steps.

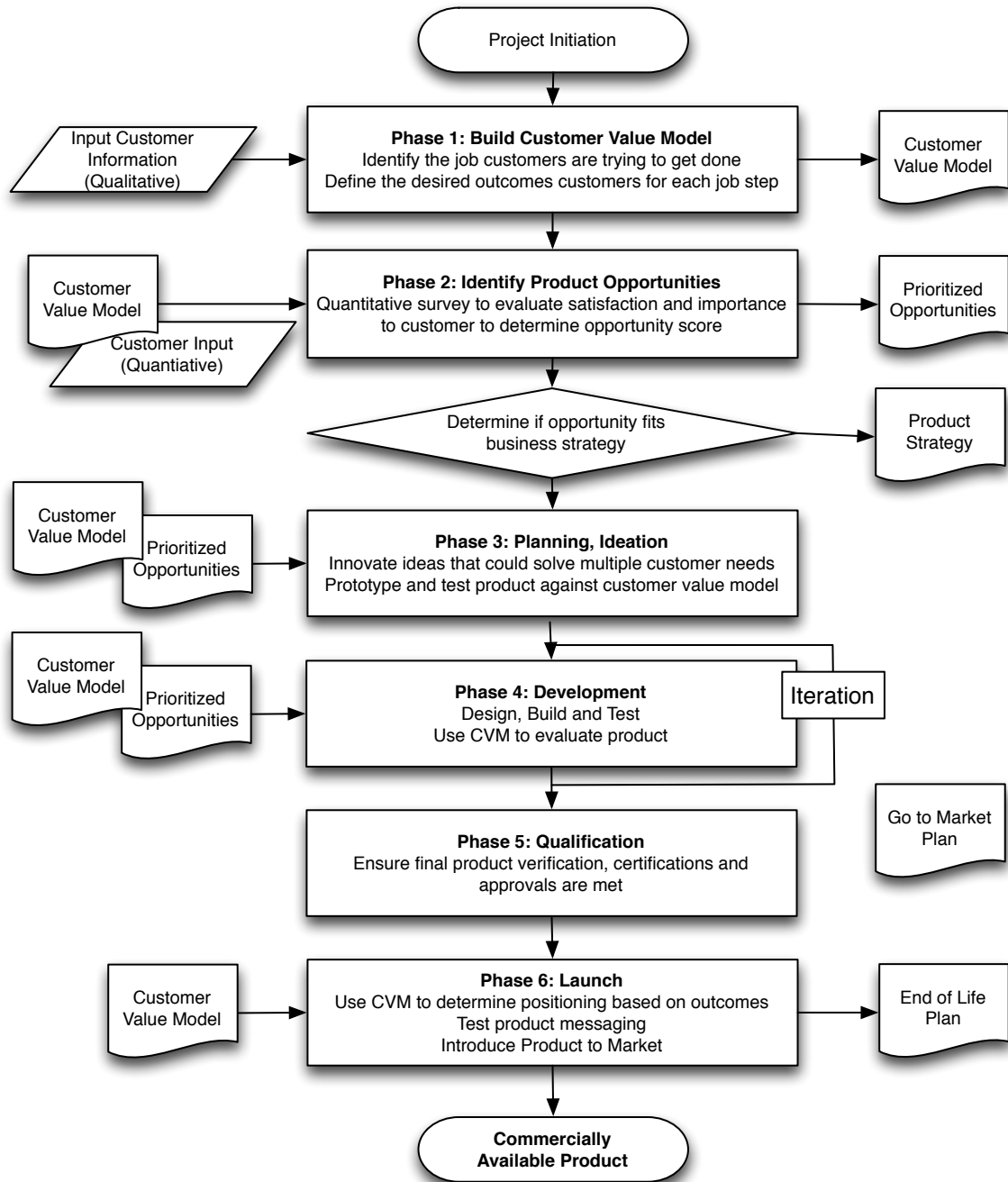


Figure 18: Outcome-Driven Innovation Product Development Process. Source: Created by author.

The ODPIP’s second phase is where the outcomes and jobs must be prioritized.

Ulwick (2005), provides one methodology that defines opportunity scores for each

outcome. This requires a survey where customers are asked to rate each outcome on a scale of one to 10 for importance, and one to 10 for satisfaction, where in both cases a one is low and ten is high. To calculate the opportunity score the algorithm Ulwick (2005) suggests is as follows:

$$\text{Opportunity} = \text{Importance} + \max(\text{Importance} - \text{Satisfaction})$$

Although lacking empirical evidence this simple algorithm appears to be effective at suppressing the unimportant outcomes while preserving important outcomes (Pinegar, 2006). The opportunity scores are then used to rank the outcomes from highest to lowest. However it is not critical that this specific methodology is applied as long as the outcomes are systematically prioritized using customer input at this phase. At the end of the second stage is where the key business decision of whether to proceed or not with a particular opportunity. The result will depend on how the business case for the opportunity fits within the companies business strategy and technological capabilities.

Phase 3 of the ODPIP is the planning phase. This phase is pivotal to the success of the development effort as at this stage the product definition in response to the opportunities is created. This is where the opportunity is transformed into a high level design concept that enables estimating, product cost, development cost, resourcing etc. In this phase the outcome and job statements identified in the CVM are used as drivers for ideation and product design, and each concept should be evaluated to determine how well it satisfies the outcomes identified as the opportunities. Within this phase designers will construct some early prototypes and outline the specific technologies that will be used in their product. By incorporating the CVM into the evaluation process, designers will quickly be able to identify concepts and ideas that customers will not value. This

information contributes to a business case that the business units external to the development team can use to determine if the project should proceed based on the estimates of the product ROI.

Phase 4 of the ODPIP is where the actual development occurs. This phase is not unlike the classic engineering development phase, but should also encompass the on going validation that the product is adding customer value based on the customer metrics of the CVM. Within this phase, based on feedback on the product design it may be necessary to iterate to ensure the key outcomes are achieved to fully develop an opportunity. It is possible for engineers to evaluate a product and all of its features using a simple product feature evaluation matrix presented in **Error! Reference source not found.** In the matrix the product features are presented along the columns and the outcome statements represent each of the rows. Each feature is then evaluated against the desired outcome statements, which represent the customer's performance metrics. Along the left, the scores are totalled and positive (green), neutral (blue) and negative (red) scores indicate which outcomes are not being successfully met. Based on the score, a decision is made to iterate or proceed to the next Phase.

Phase 5 is the one phase of the ODPIP that does not require inputs from the CVM. The objective of this phase is to obtain all final approval and acceptance of the product, including required certifications. The product may at this phase go into early beta, allowing for further validation of the product functionality and as an opportunity to garner customer feedback. However, at this stage if the CVM has been adequately incorporated throughout the process there should be no major surprises in the client feedback and the final decision to proceed can be made.

Desired Outcome Statements	Feature 1: Lighting Efficacy = 200lm/W		Feature 2: 50,000 hr lifespan of LED		Feature 3: Dimmable functionality		Feature 4: Remote control operated		Feature 5: Input Power 6W±5%		Feature 6: Customizable Colour		Total Improvement		Total Reduced Performance		Percentage Improvement		Percentage Difference		
Maximize the likelihood that lights can be turned on or off regardless of whether or not the user is in the room														1	1	2	50	50	0	0	
Maximize the likelihood that people, objects and food will appear attractive in the light. (For example green hues in the light tend to make skin tones look unattractive)														1	1	2	50	50	0	0	
Minimize the number of settings the user must attempt to find the right setting														1	1	2	50	50	0	0	
Maximize the number of places a light can be turned on from														1	0	1	100	0	100	0	100
Minimize the distance the user is required to travel in the room to turn on lights														1	1	2	50	50	0	0	
Minimize the frequency a user is surprised by a catastrophic failure of the light source and is left in darkness														1	0	1	100	0	100	0	100
Maximize the number of light settings that the user can create in a room. For example, a single space can be used for reading, watching TV, entertaining each with individual lighting requirements														3	0	3	100	0	100	0	100
Minimize the likelihood that the light will suddenly burn out leaving the user in complete darkness														1	0	1	100	0	100	0	100
Minimize the likelihood that the user will not be able to see colours accurately. For example mistaking navy blue socks for black socks resulting in wearing a mismatched set, or their socks not matching their pants.														1	1	2	50	50	0	0	
Minimize the total cost of electricity used when a light is used														3	1	4	75	25	50	50	
Minimize the total energy consumed when a light is being used														2	0	2	100	0	100	0	100
Minimize the likelihood that the user will find out that the new/replacement bulb purchased is not compatible with their fixtures														1	2	3	33	66.667	-33.3	-33.3	
Minimize the frequency that bulbs need to be replaced														1	0	1	100	0	100.0	0	100.0
Minimize the likelihood of the user inadvertently using a bulb with the wrong voltage, colour, or wattage in a fixture that could lead to damaging the fixture or causing electrical problems.														1	3	4	25	75	-50.0	-50.0	

Figure 19: Product Feature Evaluation Matrix Template. Source: Created by author

Phase 6 is of the ODPIP includes all the external launch activities of the product. The phase is where customers are introduced to the product in the methods outlined by the marketing and launch plans. To ensure that the messaging is aligned with the product, the CVM can be instrumental in defining the value statements for customers. The outcome of this phase is the commercially available product. Despite having a commercially viable product the OPDID does not end here. There are two remaining steps. First, on going evaluations of the product success and how customers value the product are required. This will further feed into product improvements for the next version of the product, and will kick-start the OPDID from the beginning. The second step is ensuring when required that there is an end of life plan, which outlines any on going support and notifications that customers require. This plan is the last phase of the product life cycle.

5.3 Future Research Recommendations

The development of the customer value model has highlighted areas requiring further research. These topics are as follows:

Identification of Variation in Outcomes due to Cultural Differences

As indicated in section 5.1.5 on page 89, there is the possibility that cultural differences directly influence the customer jobs and outcome statements. This difference implies that lighting opportunities differ by geographic location. Further analysis is required in order to better understand how cultural influences impact the customer value model.

The Consumption Chain

Further study of the consumption chain jobs to better understand how customers make decision for lighting purchases. This includes an analysis of the customer value chain. Although highlighted in this report, a thorough analysis was not completed as it was outside the scope of this project.

Prioritization of Outcome Statements

Quantities analysis of the outcome statements to prioritize and identify opportunities is the next step in the outcome driven innovation process. Although there exist several techniques to prioritize customer needs, Ulwick (2005) recommends one method, which asks customers to indicate their satisfaction and importance of each outcome statement.

5.4 Conclusion

LED technology is on the cusp of disrupting the lighting industry if the industry can develop new lighting products that customers will want to use and purchase. However, identifying which LED product opportunities will achieve success in the market is still an open question, which can be answered through the application of the outcome driven innovation process developed by Ulwick (2005). With this approach companies build a deep understanding of customers needs and how those same customers will evaluate their products. The outcome driven innovation approach provides a starting point for successful innovation, because without this understanding it is possible to

innovate new products, which are not desired by customers. Although there are several approaches to identifying and gathering customer needs, the outcome driven innovation approach provides a systematic and technology neutral approach to identify not only customer's current needs, but also latent and future needs. This structured approach, further enables companies to integrate the needs and values of their customer into their entire new product development process from product inception to delivery to market.

In applying the ODI to lighting products, several valuable insights have been uncovered. What is clear, is that customers expect more from their lighting products than simply providing light in a room both in terms of functional and non-functional requirements. New LED product developers can benefit from the customer value model identified within this project by using the outcome statements to influence the feature requirements designed and evaluate the outcomes. Furthermore, developers can use the core needs identified to drive product strategy as they can choose to focus on solutions that help customers achieve more of their needs more efficiently.

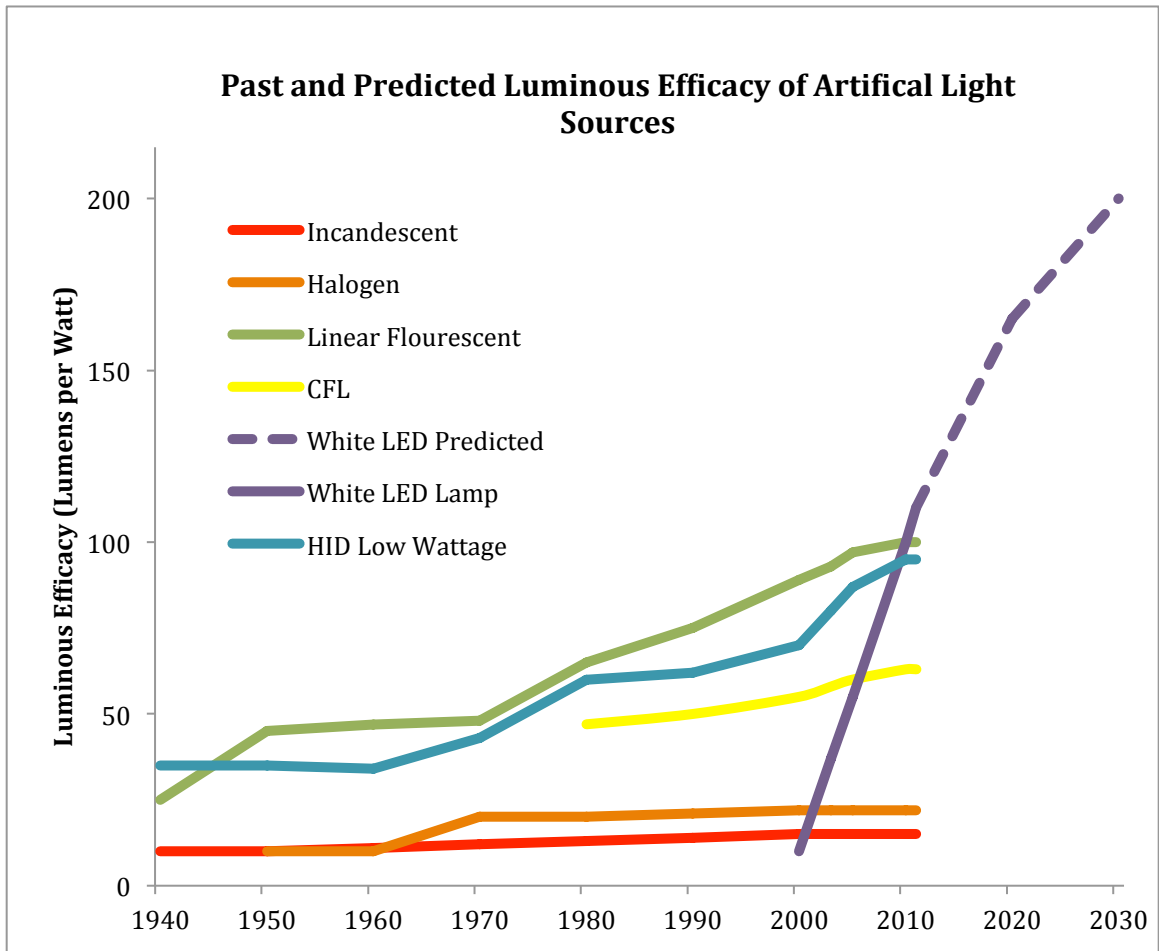
5.4.1 Assessment of the ODI Methodology

ODI is but one of many approaches for gathering customer insight at the front end of innovation. It's key strength is that it goes beyond simply uncovering user insights through interviews and it provides an actionable and rational framework which can be used throughout the entire new product development cycle to prioritize and measure product innovation. Specifically, ODI results in easily evaluated customer outcomes, providing both the business and development teams with metrics to evaluate their product development strategy and concepts. However, there is no single tool customer analysis tool that that has been empirically shown to identify all relevant influences required to

measure the potential for a disruptive technology (Reinhardt & Gurtner, 2011). ODI is successful in identifying current and potential customer needs, however it lacks analysis of relevant social and cultural trends, emerging markets, and exceeding customer needs. Reinhardt and Gurtner (2011) suggest that a combination of customer analysis methods should be used to gain a comprehensive understanding of customer needs and markets to detect disruptive opportunities and create the appropriate innovations. Therefore additional techniques such as Lead-User design or Consumer Idealized Design could complement ODI research by completing the market knowledge gaps. Ultimately, although the ODI method has been used to uncover a wide range of user needs for lighting, should not serve as the only form of customer analysis.

APPENDICES

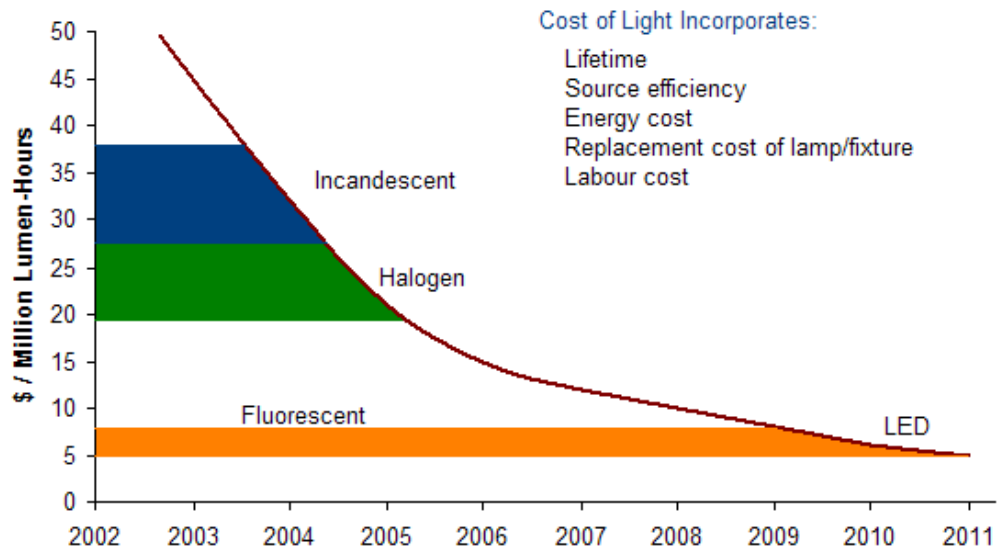
Appendix 1: Light Efficacy Based on Energy Usage



Note. Adapted from Solid-State Lighting Research and Development: Multi-Year Program Plan by the US Department of Energy, 2012

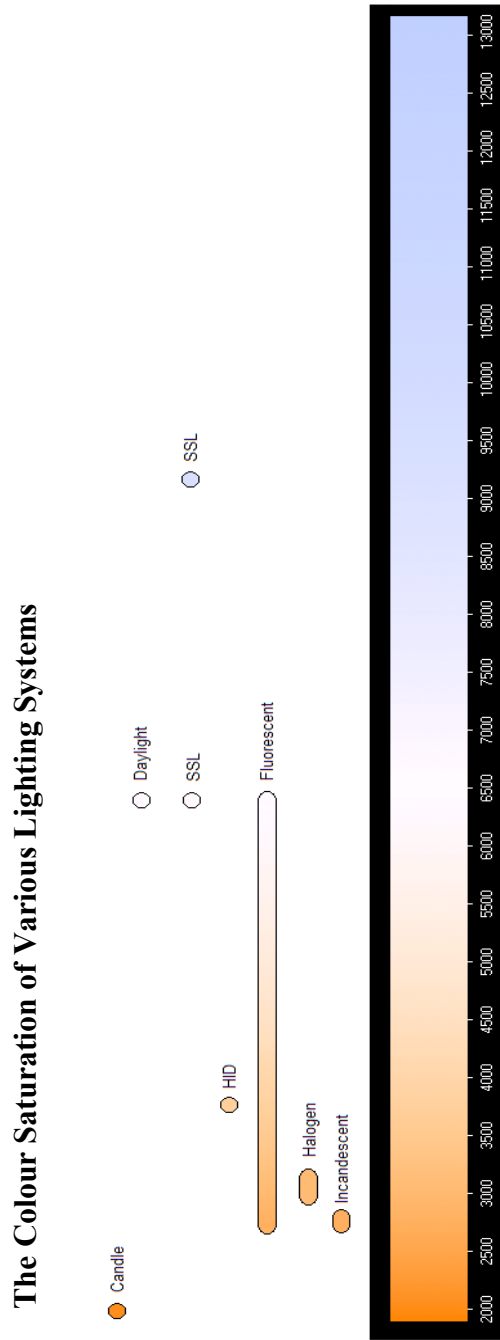
Appendix 2: Comparison of Overall Lighting Operation Costs

The Cost in Lumen-hours of Various Lighting Systems



Sources: Sanderson *et. al*, 2004, EERE 2012a, EERE 2012b

Appendix 3: Colour Saturation Efficiency



Data Sources: (EERE, 2012a; EERE, 2012b; EnergyStar, n.d.; Lingard et al., 2008; Paget et al., 2008)

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