ADVANCED LIGHTING MARKET INSIGHT: OVERVIEW & SEGMENTATION ANALYSIS

A Market Undergoing Radical Transformation

Lighting is a 100+ year old industry dominated by large incumbents who are almost as old as the industry itself. Indeed, just three companies – GE, Philips, and Osram – have a nearly 50% market share. The age of the industry and its domination by large incumbents has earned it a well-deserved reputation as stale and lacking in innovation. But Cleantech Group believes the next decade will be a time of unprecedented, radical change in the industry both on the "hardware" (materials, chips, packages and lamps) and "software" (control systems and services) side. This report:

- Outlines the key trends driving the industry's transformation
- Describes the key technology and business model decisions that differentiate vendors
- Provides an industry value chain and maps key vendors within this framework
- Presents a lifetime cost or total cost of ownership model that measures competing lighting types
- Relates payback periods to adoption rates
- Forecasts the key differences between current and future states of the lighting market
- Provides a framework for future vendor evaluation

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Total Venture Capital Raised:
2010: $350M
2009: $230M
2008: $220M

Top Venture-Backed Companies in Sector by funds raised:
1. Bridgelux
2. Luminus Devices
3. Lattice Power
4. Luxim
5. Lemnis Lighting

Tags:
Lighting, LED, CFL, Lighting Control Systems, Demand Response, Energy Efficiency, Building Management Systems

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Executive Summary and Keys to Vendor Success

Lighting opportunities fall into two key categories: hardware (materials, chips, packages and lamps) and software (control systems and services). On the hardware side, most opportunities are related to Light-Emitting Diode (LED) technology, which has only recently been commercialized at scale worldwide. On the software side, the opportunity is an installed lighting base that is 98% "dumb" or without controls. Even conservative assumptions about how much energy savings from improved hardware and software point to a market opportunity in the many hundreds of billions of dollars worldwide.

Vendors' Strategic Choices

Based on the key market opportunities described above, we believe lighting vendors make 3 key choices that determine their success:

1. *What lighting type do I address?*
2. *Do I sell hardware, software, or both?*
3. *On which communication system(s) does my software run?*

Lighting Types

We believe – in the long run – LEDs "win" as manufacturing scale and innovation rapidly bring down cost. The adoption of LEDs instead of Fluorescent or Compact Fluorescent (FL/CFL) shows a better long term return on investment, but requires a higher upfront capital cost. That cost differential is why we believe that there is plenty of room for FL/CFL-focused companies to grow targeting the retrofit market while LED costs decline.

Hardware vs. Software

We also believe software 'wins' for all but the largest of vendors because hardware lends itself to economies of scale, requires more capital, and is subject to intense pricing pressure. Hardware companies can win if they can truly differentiate on their hardware technology. However, that differentiation is very difficult to achieve since the pace of technical improvement is so fast, which is driven in part by large companies spending billions in R&D to drive these improvements. Without real differentiation, hardware becomes a game of "lowest cost wins." And such a cost competitive market lends itself to the largest vendors who can deliver economies of scale.

Software-centric companies, on the other hand, tend to be able to innovate more quickly and cheaper than their hardware brethren. Further, software is the tie that binds continued innovation in the "smart building" from the Building Management Systems (BMS) and Demand Response (DR) segments. We believe there will be plenty of hardware-centric success stories who grow and are acquired by larger OEM vendors. But we believe software players are built to last given their role enabling BMS and DR, and the smarter buildings that come with it.

Communication System(s)

Third, open software platforms also "win" for the same reason that software wins. Customers are already seeking integrated building management solutions,

and a wide variety of data points from our analysis suggests that integration between all the layers separating sources of energy demand from the utility – including lighting, HVAC, building management systems, and demand response – is occurring today (see p.13 for our diagram of this phenomenon). Open platforms present the opportunity to be the "tie that binds" these disparate systems. This opportunity is why it will be difficult for proprietary systems to be long-term winners unless they establish such a large install base that they become the de-facto standard.

Although we believe LED compatible, software-centric, open systems are long term winners amongst smaller vendors, the nascent and quickly evolving "smart lighting" market will provide plenty of opportunity in the intervening decade for vendors who do not fit this profile. Given the links between lighting startup management teams and their technology counterparts at large companies like Cisco and HP, we believe the next few years will see massive acquisition and consolidation before the LED compatible, software-centric, open systems model wins out. Further, we expect to see additional startup activity in this area for some time to come, given that the segment can be capital efficient (lending itself to VC investment) and software-focused, making a large pool of experienced entrepreneurs feel that this market is not, in fact, so new or different from the software world. In short, the lighting industry – often seen as staid, old and boring – will be an increasingly interesting segment for entrepreneurs, investors, utilities, and large companies alike in coming years.

Lighting Industry Market Overview

Background

Traditionally, lighting has been considered largely a functional or aesthetic issue. End consumers have questioned whether the quality, type and location of lights were conducive to worker productivity, an attractive home or office environment, and perhaps even a personal or corporate image. At the same time, producers viewed the lighting industry as a mature, industrial market. Keys to success were lowering manufacturing costs through large-scale production and low cost capital and labor inputs, while maintaining a strong position in relevant distribution channels. Less attention was paid to innovation or corporate research and development.

Now consumers, large-scale producers, and startups are increasingly aware that lighting is as much an energy issue as it is a matter of functionality or aesthetics. This change in the perception of lighting is not just a matter of semantics; it has brought about rapid and significant transformations in all parts of the industry, which we will describe in further detail below.

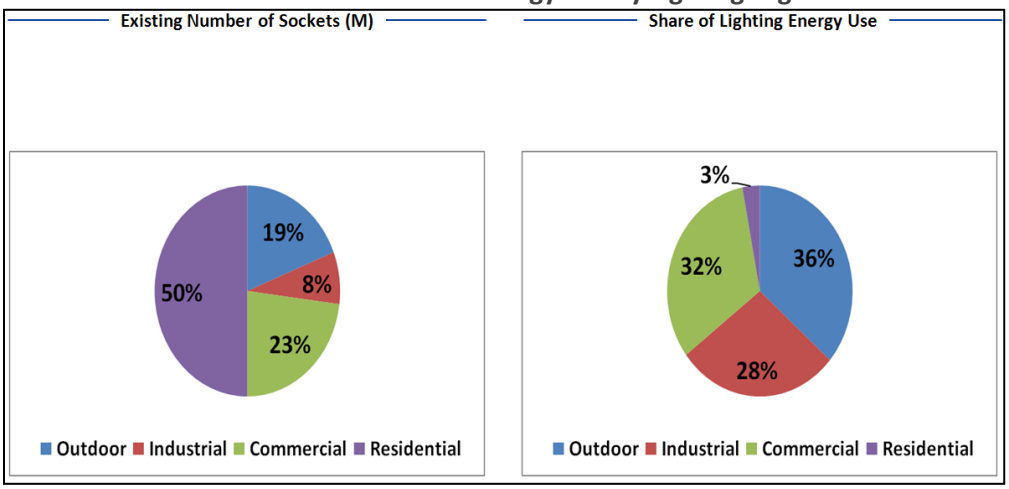
Why Lighting is an Energy Issue

Lighting in all segments (residential, commercial, industrial, and outdoor) consumes almost 20% of the energy in the built environment, internationally. [1] This energy is expended both in the electricity necessary to illuminate a given lightbulb, but also in cooling costs needed to counteract the heat produced by lighting fixtures. In fact, the heat produced by lighting alone contributes to 42% of the cooling load in U.S. buildings.[2] The energy used by lighting amounts to 1.2 Terawatts (equivalent to 1,200 Gigawatts or 1,200,000 Megawatts), 112 full-sized power plants, and 1.9 billion tons of annual carbon emissions.[3] If LEDs made up 45% of the world's lighting supply by 2020, we would forgo 5 trillion kWh of electricity, 559 full-sized power plants, and 8.4 billion tons of carbon emissions.[4]

Contrary to popular belief, lighting is not primarily a residential issue. As the graph below demonstrates, the residential market accounts for the largest share of the market if measured by the number of sockets but since each socket typically illuminates a much smaller space compared with industrial or commercial markets, it uses significantly less energy per socket, and therefore less energy overall.

[1] http://www.undp.org.cn/projects/00062179.pdf
[2] U.S. Department of Energy Buildings Energy Data Book, Sept. 2008
[3] Based on United States Energy Information Administration estimates.
[4] Ibid.

Global Number of Sockets and Energy Use by Lighting Segment

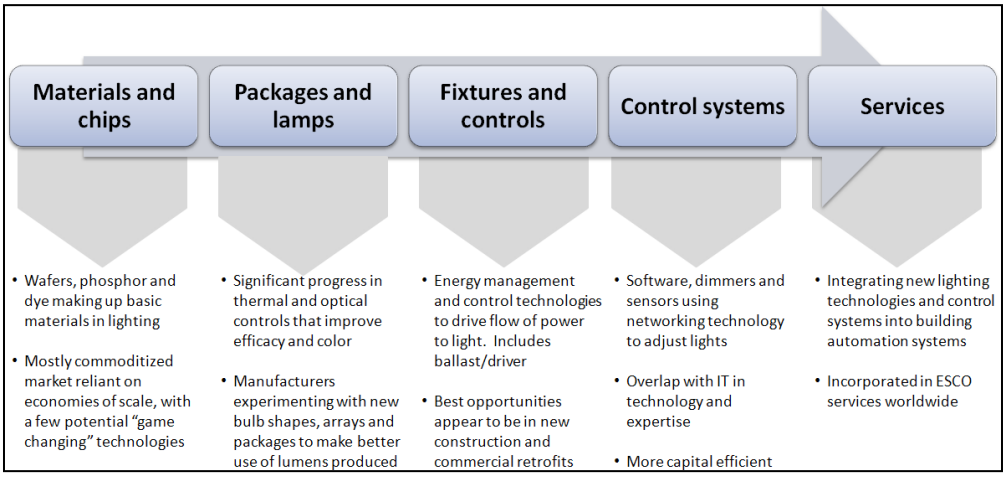


Source: Cleantech Group and Canaccord Genuity Analysis

Lighting Market Supply Chain

The 100+ year old lighting market is dominated by large incumbent players. GE, Osram, and Philips account for nearly 50% market share.[5] They exert great influence throughout distribution channels, as well as the supply chain, particularly at the materials and components level. Below we have segmented and classified the key elements of the lighting market:

Lighting Market Supply Chain



Source: Cleantech Group Analysis

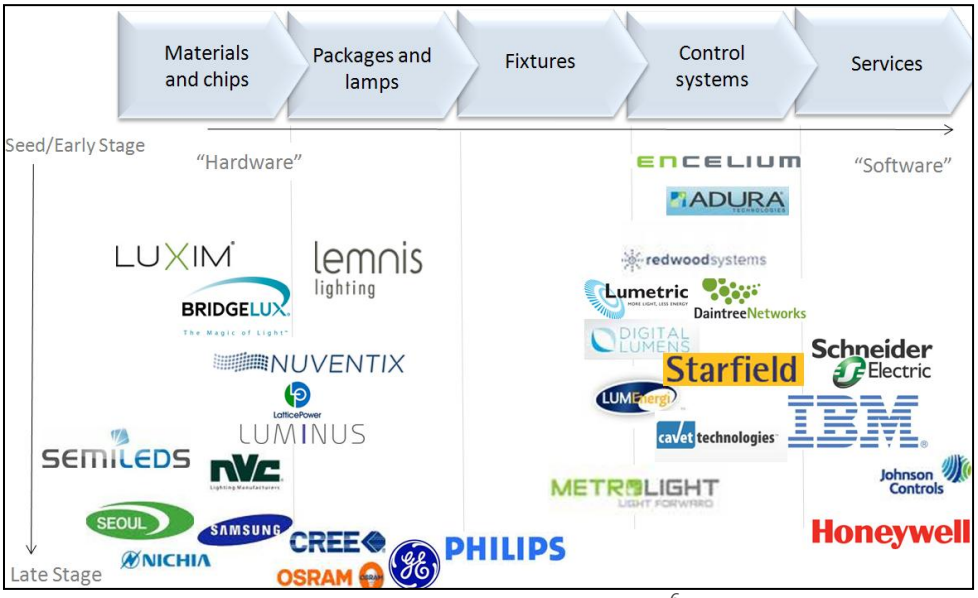
The earlier stages of the supply chain on the left-hand side are highly commoditized except for those vendors who can truly differentiate on technology. In this way, the LED lighting market is analogous to the semiconductor industry, especially when one considers the similar original components and manufacturing processes in the materials and chips, packages and lamps segments. The manufacturing process for lighting is similar to that for

[5] http://www.opera2015.org/Deliverables/D_4_3_CD-ROM_Wroclaw_Nieuw/5_Presentations/16_Brunner_LEDs_for_Lighting.pdf

semiconductors, and the price of components drops at a similar rate (while performance or efficiency improves at a corresponding rate). While there are opportunities for new innovations in the earlier segments of the supply chain, significant venture investing and startup activities in those segments going forward is unlikely due to the significant amounts of capital required for chips and packages to make it to market. Further, there is a higher "hurdle" rate to adopt innovation from startups in the early stages of the supply chain as large incumbent players are resistant to sourcing components from companies without a track record.

We believe that venture and startup activity will be much greater in the later stages of the supply chain, on the right-hand side of the chart depicted below. Innovations in control systems and services tend to be software (not hardware) intensive, capital efficient, and well-aligned with the traditional venture capital investment approach of small amounts of capital yielding, potentially, large returns. This dynamic – startups focusing on the latter stages of the supply chain while larger incumbents dominate the earlier stages – is borne out by our mapping of vendors by each stage of the supply chain.

Vendors by Stage & Market Segment



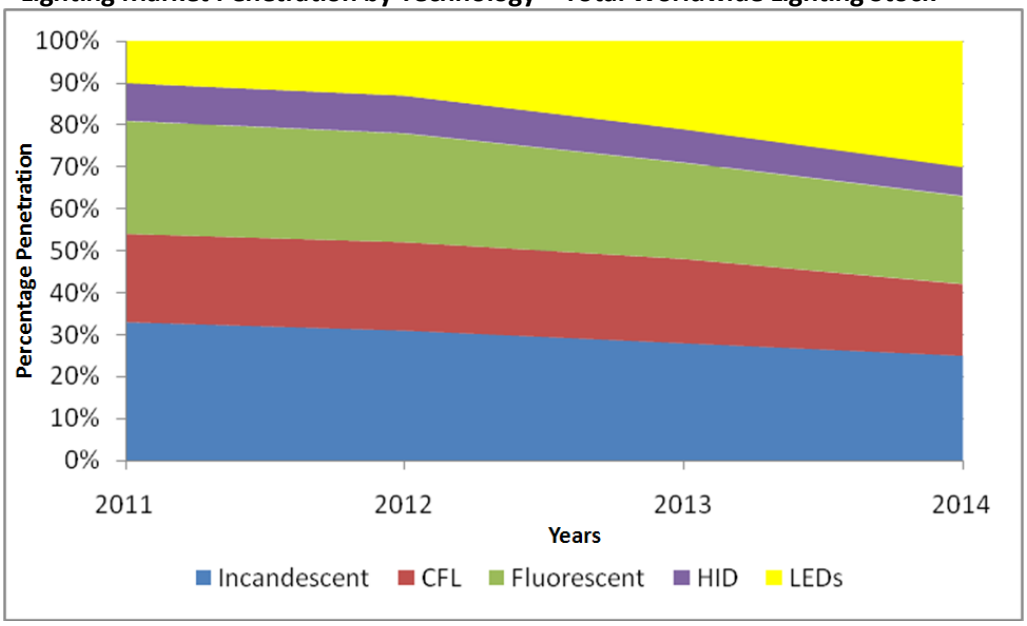
Source: Cleantech Group Analysis[6]

Factors Driving Adoption of Efficient Lighting

The lighting market is served by five competing technologies, listed in reverse order of energy efficiency: Incandescents, Compact Fluorescents (CFL), Fluorescents, High-Intensity Discharge (HID), and Light Emitting Diodes (LED). As the chart below demonstrates, the market is still largely dominated by the most inefficient technologies.

[6] Note: All major lighting players – such as GE, Philips, and Osram – conduct business in each segment of the value chain above but we have located them where they focus their core business.

Lighting Market Penetration by Technology – Total Worldwide Lighting Stock



Source: Cleantech Group and Canaccord Genuity Analysis

As the chart demonstrates, the more energy efficient technologies – and LEDs in particular – are forecast to register tremendous growth in the coming years. There are three key drivers for adoption: policy, high energy-use market segments and basic economics. We will examine each separately.

Policy

Governments around the world are banning older, inefficient lighting technologies, and subsidizing the retail price of more efficient types. Many countries have begun programs to phase out incandescent bulbs: The EU and Australia began programs in 2009, Russia and Canada will both ban incandescents by 2012, and regions in the U.S. have recently begun with a rolling compliance deadline of 2012 – 2014. While the details vary by country, by 2014, sales of incandescent bulbs will be banned in the entire developed world. In addition to incandescent bans, these countries have various forms of subsidies for more efficient lighting, including CFL, FL, HID and LEDs. Every program subsidizes the retail price of more efficient bulbs either through direct subsidies, or by after purchase tax credits. The programs tend to differ on two key elements: who is subsidizing the bulbs (government, utilities, or some combination thereof), and the amount of that subsidy.

High Energy-Use End Markets

The second key driver is high energy use market segments. To explain why high energy use market segments are early adopters, it's important to consider lighting as an asset with a lifetime cost of ownership as follows:

Total Cost of Ownership or Lifetime Cost of Lighting (LCOL)

Lifetime cost = S^1 (selling price) + O&M + R (Replacement costs)

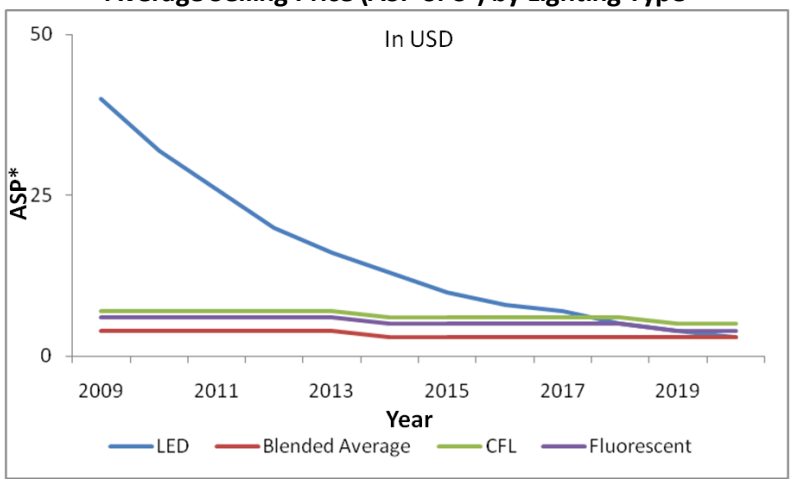
Where:

S^1=ASP – Average selling (or retail) price of a fixture

O=Operational cost (kW/h required to produce a given amount of lumens * $/kWh) + cooling offsets (kW/h required to cool heat produced by lighting * $/kWh)
M=Maintenance cost (replacement cost * # of replacements in 10 year operational life)
R= Replacement cost (S^2/T) where
S^2 = ASP at the time of replacement and
T = years elapsed from original purchase until replacement

Comparing retail price, the metric the general public and most industry commentators pay attention to, tells only part of the story. Indeed, if one were to focus only on the retail price, LEDs do not reach cost parity until 2020.

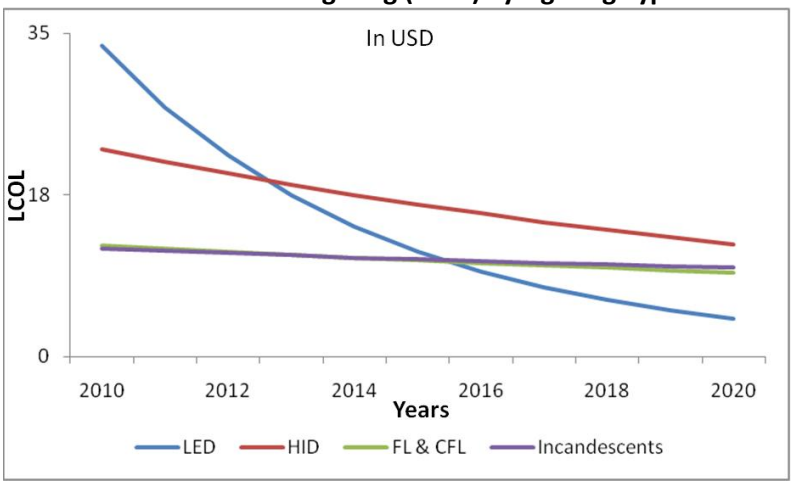
Average Selling Price (ASP or S^1) by Lighting Type



Source: Sterne Agee, US Department of Energy, and Cleantech Group Analysis[7]

On the other hand, if one compares the lifetime cost of lighting (LCOL), we believe LEDs are below all of its competitors by 2016.

Lifetime Cost of Lighting (LCOL) by Lighting Type

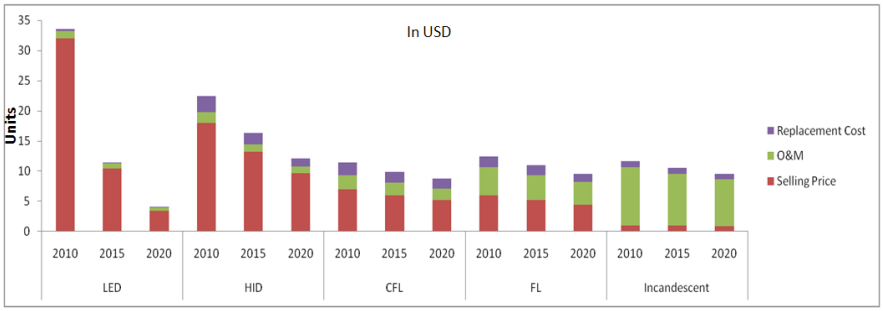


Source: Cleantech Group Analysis

[7] Where Average Selling Price (ASP)=Average retail price of a 60W bulb (1050 lumens)

Since ongoing O&M costs make up a significant component of lighting's lifetime cost (up to 80% of the lifetime cost in some cases), more efficient lighting types are even more attractive in high energy use segments and where energy is expensive. As the chart below makes clear, O&M costs differ quite dramatically between lighting types; from negligible for LEDs to nearly 80% for incandescents.

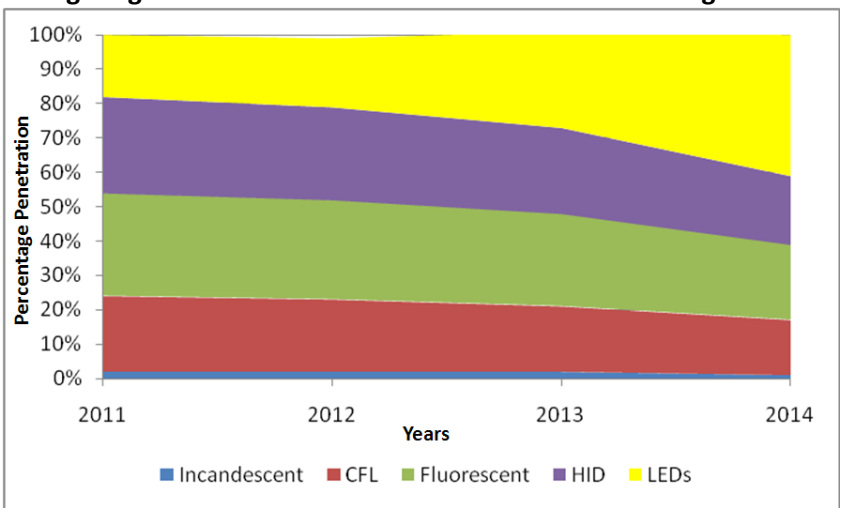
Lifetime Cost of Lighting (LCOL) by Variable



Source: Cleantech Group Analysis

Since O&M costs are more important for markets where energy use is higher, or where electricity is more expensive, customers in these segments are therefore more likely to adopt newer bulbs. Indeed, this logic is supported by projections of adoption in the high energy use segments, as displayed below.

Lighting Market Penetration in Industrial & Outdoor Segments



Source: Cleantech Group and Canaccord Genuity Analysis

Economies of Scale

Finally, there are some basic economic trends affecting LED adoption. One trend is the continuing decline of LED retail prices, dropping at a rate of 20-25% per year compared to incumbent technologies where prices are flat or are declining much more slowly.[8] A narrowing price differential between LEDs and more traditional forms of lighting is therefore slowly removing one of the key barriers to mass adoption. The other, related barrier is time to payback. Time to payback is the

[8] Cleantech Group Analysis

time necessary for an LED customer to break even on his/her investment in a more expensive LED bulb. Based on extensive research in Japan where energy prices are very high, thus lowering the time to payback for more efficient bulbs, customers have a 10% chance of adopting a technology if payback is two years, a 30% chance if payback is one year, and a 40% if payback is six months.[9] Therefore, the time to payback metric helps to predict LED adoption with some historical and empirical accuracy. Given that payback periods are shrinking along with LED retail prices, we can be confident of significant market penetration (50 %+) in the next decade.

Payback Period vs. Probability of Adoption

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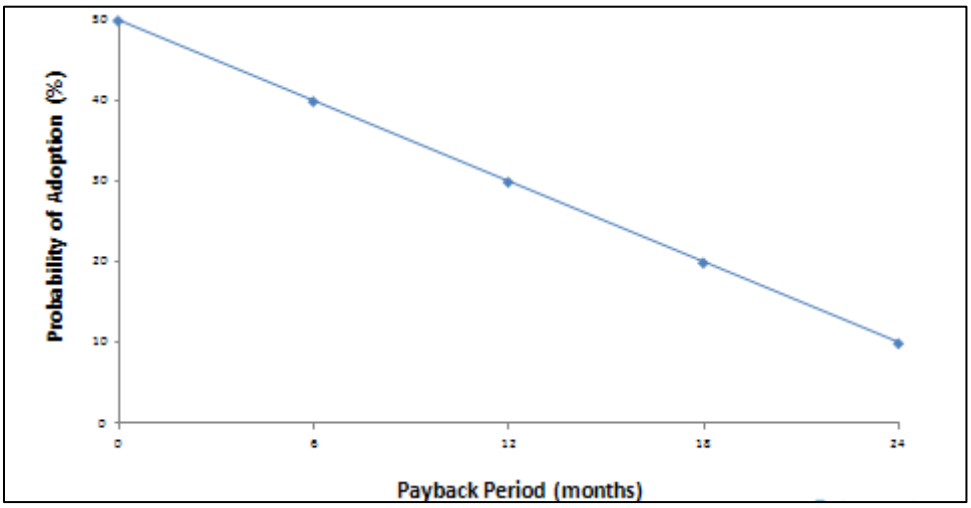


Source: Cleantech Group and Canaccord Genuity Analysis

[9] Canaccord Genuity Analysis and see Cleantech Group's, "Home Energy Management: Seeking Clarity Amidst the Hype."

Future Market Direction

Our key contention is that the lighting market will undergo radical change in coming years. Below, we describe the key changes and the trends driving those changes.

Hardware

The design and manufacture of chips for advanced lighting, lighting materials and fixtures, has been upended by the LED. LED manufacturing is similar to the semiconductor industry in two key respects. First, just as the semiconductor industry has innovated around the manufacturing devices and processes for chips, so has the lighting industry innovated around the production devices and processes necessary to produce LEDs. In the semiconductor industry this innovation has resulted in the famous "Moore's Law," where every 18-24 months sees a doubling of the transistors that can be put on a chip, while cost is reduced by half. While 20-25% annual LED retail price reductions do not quite meet Moore's Law, the path – and the associated R&D and manufacturing investments necessary to achieve it – is quite similar.

Second, both lighting and semiconductors are industries where scale matters. Manufacturing advanced lighting materials, chips and packages requires significant fixed costs and capital investment in the advanced machinery necessary to produce these devices. Variable costs – costs based on the number of devices produced – are relatively low, as are gross margins. Therefore, pure economic logic dictates that winners in these industries must produce and sell at global scale. This is why both industries are dominated by large incumbents with the capital required to produce at scale.

While there is room for "capital-light" innovation in hardware – focusing on the intellectual property around more efficient materials, devices and manufacturing processes – constructing supply chains and manufacturing facilities still requires many tens of millions of dollars. While we expect continued innovation in this space, we believe the semiconductor industry analogy is a good one – most "hardware" lighting start-ups will be acquired, or license their IP, as their capital requirements preclude construction at large scale.

Therefore, while incumbents will be required to innovate, invest in R&D, and make acquisitions, sheer scale – and its associated cost advantages – matters on the hardware side. That is why we expect the "household" lighting names to be major players in ten years time, though we also expect renewed challenges from Asia-based players. In short, while what manufacturers produce will change, and how they produce it will also change, we're likely to see a similar set of names continue to dominate lighting on the hardware side.

Software

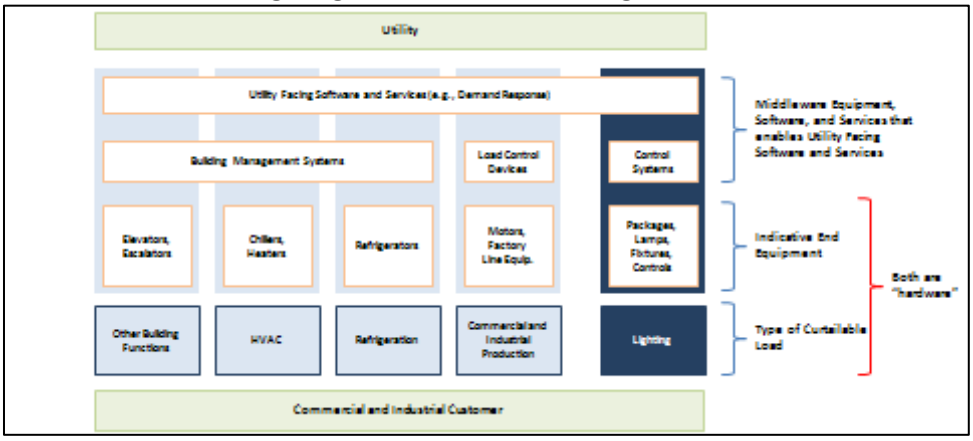
Before describing our take on the software side of the lighting market, it's important to first define what, exactly, we mean by software. One way to

describe this industry sub-segment is "intelligent lighting." In other words, these are the control devices, systems, data analytics, and software that enable lighting to be "smart." In addition to utilizing more efficient devices, smart lighting can respond to daylight, sense occupancy, adjust to the particular business, technical, or manufacturing requirements of building spaces, be managed and provide usage information remotely and – at its current boundaries – respond to time of use and demand response signals, even aggregating load to participate in the ancillary services market.

Lighting as Demand Side Management

The outer boundaries of today's intelligent lighting allude to where we believe the industry is headed. Lights are one of many sources of energy demand or curtailable load. Other sources – which originate from the same homes, offices, and factories as lights – include heating, ventilation and air conditioning (HVAC), refrigeration, commercial and industrial production, and what we broadly call IT (charging mobile devices, computers, servers, etc.). After all: a) Lighting is just one component of this demand b) The demand is originating from similar or shared locations and c) Supply is also originating from centralized sources like utilities and Independent Power Producers (IPPs). That is why vendors will seek to simplify demand-side curtailable load by aggregate all types of energy demand and blurring the distinction between demand response, building management systems, and smart lighting. We've depicted this idea in the graph below:

Lighting as Demand-Side Management



Source: Cleantech Group Analysis

In addition to the improved simplicity and larger addressable market involved in managing all sources of demand, our research indicates that customers are increasingly asking for integrated demand management solutions. While all customers are driven by the desire to save more money, different customer segments have other, secondary motivations. For instance, large corporations have expressed a desire to avoid evaluating a wide variety of vendors and solutions outside their core business and have expressed a market preference – through their relationships with "full service" players like IBM, Honeywell, or Johnson Controls – to select vendors who can provide as wide an array of services

as possible. From primary interviews and secondary research on industry "case studies," Cleantech Group has documented how and why different customer segments are pushing for integrated solutions in our chart below.

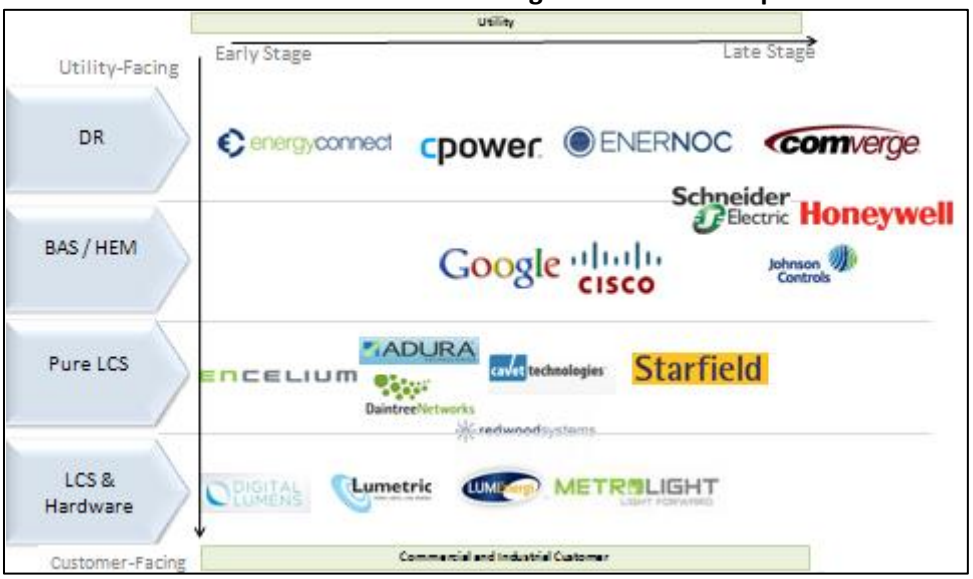
Customers Driving Demand-Side Solutions

Type of Customer	Reason for buying lighting controls & services	Reason for integrated solution
Corporations with multiple buildings	• Corporate sustainability goals • Energy savings	• No time, desire, or sophistication to sort through variety of vendors and/or solutions
REITs	• Cost savings • LEED certification	• "One stop shop" that can be deployed across portfolio
Government	• Federal or state mandates for GhG reductions • Energy efficiency savings	• Time savings • Scale • Reduced procurement beaucracry
Utilities	• Reducing overall & peak loads • Cost savings can be split w/ consumer	• Fewer vendors reduces time & cost of interaction / coordination
ESCOs / DR / BMS	• Improving lighting control system in proprietary BMS • Ability to offer customer integrated solution if it can't do so already	• See above – customers demanding integrated solutions

Source: Cleantech Group Analysis

Vendors, not surprisingly, are responding to their customer needs by broadening their product offering to include more elements of demand management. Traditional lighting vendors like Philips, Osram and GE are investing in R&D and making acquisitions to expand their software footprint, have partnerships with major building management vendors like JCI, and we expect further integration with building automation and even demand response vendors in the future. Building management players are interested in expanding their existing lighting partnerships to include control vendors, and have made "software" related acquisitions like Honeywell's purchase of Tridium and JCI's acquisition of National Energy Services. Demand response vendors are also trying to move further inside the building as evidenced by EnerNOC's string of acquisitions to fill out its "EfficiencySMART" suite of services. Even IT players – leveraging their core expertise in software and experience in managing data – have branched into lighting and building management as evidenced by Cisco's acquisition of Richards-Zeta in 2009, Google's expressed desire to use PowerMeter for lighting control systems, and a slew of rumors about in-house R&D moves from companies like HP and Juniper. In short, we expect that, in coming years, it will be increasingly difficult to distinguish between demand response, building automation, and lighting vendors as we have in the "current state" graph below.

Current State Demand Management Vendor Map



Source: Cleantech Group Analysis

In short, the "software" side of lighting is an industry that will be changed by the push towards integrated demand management, and consolidation from a flurry of vendor partnerships and acquisitions. Further – since the industry is so new (98% of lighting is still "dumb") – the software side of the industry is wide open territory compared to the hardware side which is dominated by large incumbents. Certainly there are large companies and lighting market incumbents who serve the control systems and services market – including names like Schneider Electric, IBM, Johnson Controls, Honeywell – but the segment is too new to claim that any player is yet truly dominant.

Vendor Evaluation Criteria

Our future lighting research will focus on profiling companies, particularly new and innovative vendors. To establish a consistent and concrete set of evaluation criteria, we identified eight key variables on which we evaluate and classify vendors: product offering and business model. We will use these criteria in our forthcoming lighting company profiles.

Key Variables

Product Offering

Lighting Type: Which of the available lighting types – incandescent, fluorescents/compact fluorescents, High-Intensity Discharge (HID), or Light-Emitting Diode (LED) – does the vendor's product address?

Communication Type: Does the control system run on proprietary software, ZigBee-based software, wired or wireless IP-based software, or some combination thereof?

Deployments: How many deployments has the vendor performed? We are using this as one of the proxies for the maturity of the company's product.

Average Payback: What is the average time to customer's payback on its investment in the company's product, assuming the customer is bearing all of the cost up-front?

Business Model

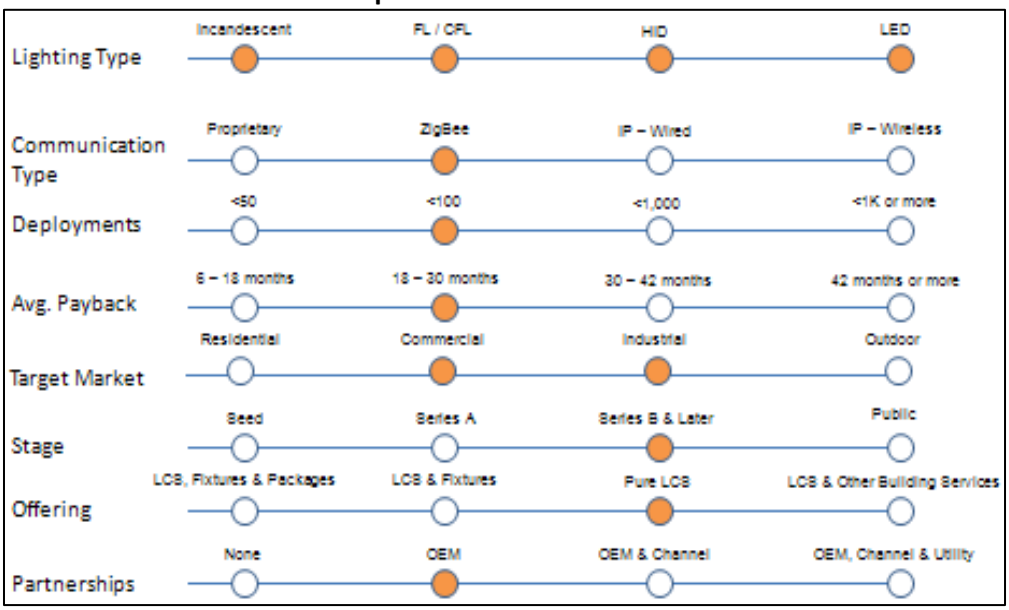
Target Market: Is the company targeting residential, commercial, industrial or outdoor segments? The target market will influence the company's product, pricing model, sales and distribution strategy.

Stage: This metric details how many rounds of fundraising a vendor has undergone and is another proxy of the company's maturity.

Offering: A company that sells purely lighting control systems, or pairs control systems with other fixtures or other services, changes a company's pricing model, need for capital, channel strategy, time to payback, and even the type of employee it hires.

Partnerships: Relationships with OEMs, various channel distributors and re-sellers, and utilities affects the size, range, and reach of the company's product.

Sample Vendor Evaluation



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