LEDs:
ILLUMINATING THE PATH FROM EAST TO WEST

A Market Leaning East

The world of solid state lighting is vast, ranging from materials required to produce luminaires to the services needed to integrate them. The accelerated development of the lighting market is a result of the continued innovation of materials and services in conjunction with more energy efficient forms of lighting.

This brief takes a case-study approach, profiling three Asia-based LED lighting businesses seeking opportunities in the Western market. The companies' technology, business models and unique perspectives are covered.

In its entirety, this report:

- Explains why lighting is relevant in an Asian context
- Describes the key trends driving industry transformation
- Profiles the technology and business model of three Asia-based vendors including:
  - LiquidLEDs
  - NeoPac Lighting Group
  - Lattice Power

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Companies Featured:
LiquidLEDs, NeoPac Lighting Group, Philips, BroadAir, Bayer, International Finance Corporation (IFC), Mayfield Fund, AIXTRON, Lattice Power

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, China, Energy Efficiency, Asia, Materials, Manufacturing

Related Recent Research:
Advanced Lighting Market Insight: Overview & Segmentation Analysis, April 2011
NeoPac Lighting Group Company Insight, April 2011
Liquid LEDs Company Insight, April 2011
Digital Lumens Company Insight, April 2011
Why Lighting Controls are Hot, September, 2010

Introduction

Lighting Market

Lighting represents a tremendous opportunity for reducing energy consumption, as it accounts for over 20% of the energy used in the built environment.[1] One of the innovations with the greatest potential savings and long term benefits are light-emitting diodes (LEDs).

LEDs are energy efficient lights that use up to 90% less energy than an incandescent bulb and 50% less energy than a CFL. They are more resistant to extreme weather conditions and do not use toxic materials such as mercury, a necessary component of fluorescent bulbs. Within the past few years, LED technology has also improved significantly with respect to brightness, energy efficiency, and colour quality and consistency.

LEDs have been significantly more expensive than traditional forms of lighting but costs have been declining due to improved production and manufacturing techniques, continued innovation in materials, and economies of scale. With declining costs, and a long operational life (up to 30 years), LEDs are becoming more appealing to consumers and businesses alike.

Asia

Asia plays an important role as a force driving LED adoption. Traditionally, the region has been overlooked as a technology innovator, with many viewing the continent as predominantly a manufacturing force. However, we have recently witnessed growing technology innovation in the region alongside the rapid development of the Asian "Tiger" economies, with China paving the way. With manufacturing and production infrastructure already in place, local innovation means Asia can compete with western technologies at lower prices.

This report takes an in depth look at three Asia-based LED companies. It presents each company's product innovations, investment history, business strategy/sales channels, and key western relationships. It also outlines some of the opportunities and challenges that LED companies in Asia encounter in the evolving global lighting market.

Key Takeaways

Some of the key takeaways from our report include:

A) Asian companies are in a strong position to capitalize on new opportunities in the lighting market due to a growing level of technological innovation as well as existing manufacturing capability.

B) While Asian companies are producing new lighting technologies, many of the strongest policy regulations are driving opportunities in the West. Asian companies, therefore, need to develop a Western business strategy.

[1] *Cleantech Group Analysis: Advanced Lighting Market Insight: Overview & Segmentation Analysis*

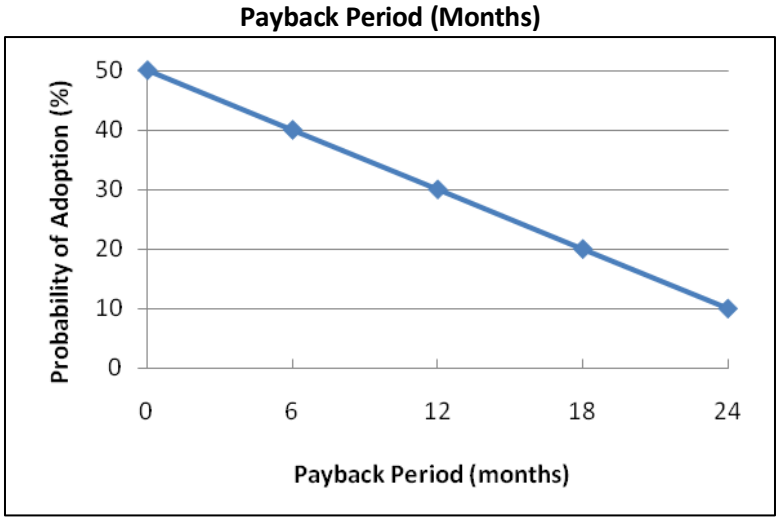
C) Asian LED developers are also looking to expand first in western regions where electricity prices are highest, such as Europe, in order to capitalize on faster payback periods for LED adoption.

D) Relationships between Asian LED developers and large Western corporations will play an important role in East-to-West strategies. Establishing business relationships with large corporations provides Asian LED developers with a foundation to enter new western markets.

Market Drivers in Lighting

Policy-makers and governments around the world are gradually phasing out incandescent light bulbs. The EU and Australia began such programs in 2009, both Russia and Canada will ban incandescent lights by 2012, and the U.S. has recently begun with a rolling compliance deadline of 2012-2014. In addition to incandescent bans, countries will provide subsidies for more efficient lighting, including compact fluorescent bulbs (CFL), fluorescent light bulbs (FL), high intensity lamps (HID), and LEDs. Most programs subsidize the retail price of more efficient bulbs either through direct subsidies, or by after purchase tax credits.

As LEDs are produced at scale, and LED-related innovations are adopted, retail prices have dropped at a rate of 20-25% per year.[2] A narrowing price differential between LEDs and other forms of lighting is slowly removing the cost barrier to mass adoption. One such cost barrier is the time to payback, or the amount of time for an LED owner to break even on their investment in a more expensive LED light bulb. Below is a chart using research data from Japan to estimate the probability of adoption based on the payback period. Japan has very high energy prices, so a country with lower energy prices would see a longer payback period and lower adoption percentages.

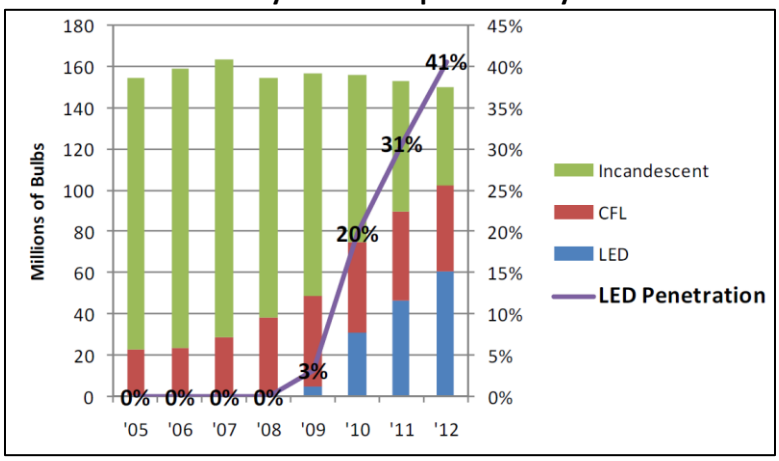


Source: Cleantech Group and Canaccord Genuity Analysis

With payback periods shrinking in tandem with LED retail prices, Cleantech Group estimates that we will see a market penetration of 40%+ in the next 2 years.

[2] *Cleantech Group Analysis: Advanced Lighting Market Insight: Overview & Segmentation Analysis*

Probability of LED Adoption vs. Payback

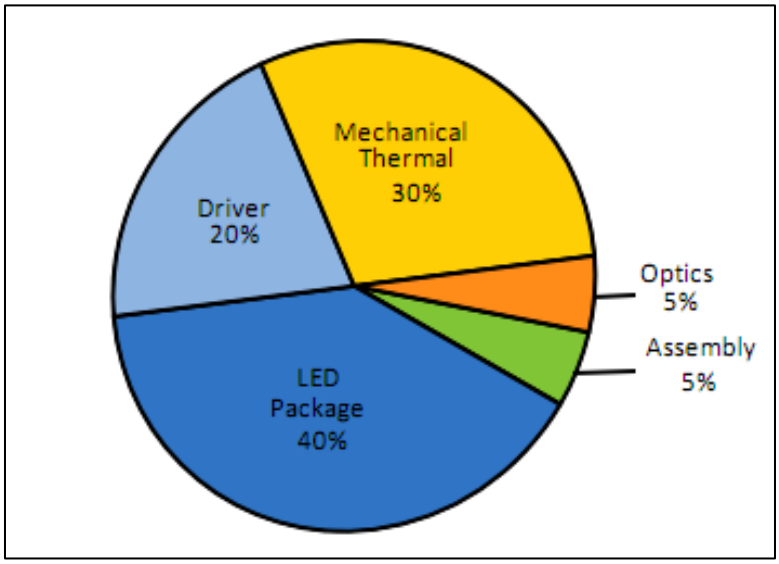


Source: Stern Agee and Cleantech Group Analysis

LED Potential in Asia

The greatest potential for cost reduction in LED production is in materials, also known as LED packages. In addition to packages, the cost of remaining components such as optics, mechanical/thermal controls, and assembly will also need to decrease. Power supply cost reductions will come from standardizing LED power requirements, which will lead to savings from higher volume manufacture of fewer subsystems. Advanced manufacturing techniques, including automation, can also lower the costs. Improved testing and inspection, and higher levels of component integration, are some of the other methods that reduce cost in the manufacturing process.

Approximate cost breakdown for LEDs



Source: Cree LED Lighting

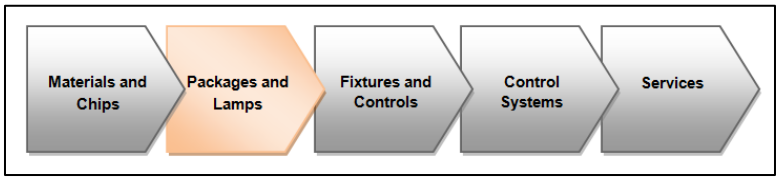
Asia is a materials and manufacturing powerhouse. However in recent years, we have also noticed the continent's growing prowess in technological innovation

and R&D. Coupled with manufacturing and production capacities, this represents an attractive combination of offerings that Asian companies can offer to customers around the world. Since high price is a barrier to mass adoption, Asia's cost advantage over North America and Europe could be key to accelerating LED adoption.

Company Profiles

In this section, we describe in more detail the technological innovations and business strategies of three Asia-based LED companies. All three companies fall under the packages and lamps section of the lighting market supply chain where significant progress in thermal and optical controls are able to improve energy efficiency and quality of light.

Lighting Market Supply Chain



Source: Cleantech Group Analysis

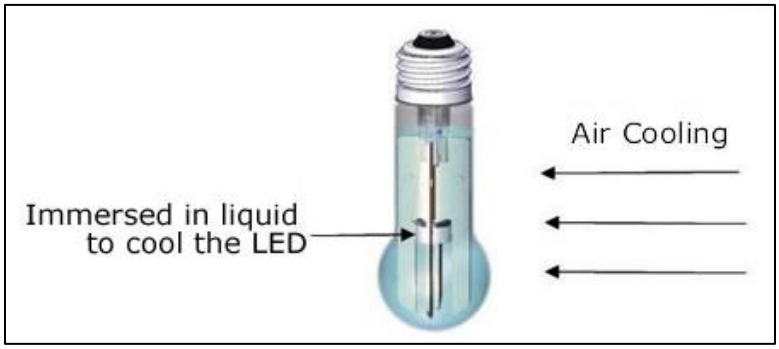
LiquidLEDs

Technology & Innovations

Taiwan-based LiquidLEDs specializes in LED research and development. The company's original technology is the Liquid Immersed Thermal Management Solution (LITMS), a vacuum-sealed liquid that maximizes heat dissipation, enhancing the efficiency of LED thermal management. Most conventional LED-based lights radiate excessive heat, reduce lighting intensity, and degrade the quality of lumen output over time. The problems of thermal energy build-up and the directional limitation of light remain challenges for many LED manufacturers.

The liquid-cooled bulbs utilize both liquid and metal conductors inside the bulb to achieve optimal heat dissipation. Both the LED module and metal conductors are immersed in liquid to dissipate heat from the entire glass surface. LITMS avoids user-exposed heat sinks which may be inefficient, dangerously hot and costly.

LiquidLEDs Thermal Management Solution



Source: LiquidLEDs

However, due to safety concerns related to the liquid technology, LiquidLEDs have also developed an LED filament bulb product, using a modified air circulation within the light bulb to balance thermal energy build up. The bulb can be

operated on AC power without the need of a DC converter. It is also fully dimmable, allowing consumers to control the brightness of the light, a feature commonly missing from CFLs and other LED light producers.

Investors

LiquidLEDs' principal investor is Taiwan-based ID Innovation. The company has also received funding from Taiwan-based Venture Tech Alliance and California-based Acorn Campus Ventures. The company's current CEO was a venture capital partner at iD Innovation previous to his post at LiquidLEDs.

Strategy/Sales Channel

For now, the company's current product line focuses on the segment of 40w and below LED light bulbs. Future products will incorporate higher lumen products.

Liquid LEDs sells their products directly to consumers through their online website system or through channel partners such as supermarkets and hardware stores, which then sell directly to consumers. The company's customers in Asia are predominantly located in Taiwan, and in June 2010, LiquidLEDs light bulbs were launched in Japan.

Key Western Relationships

Germany, Spain, France, UK, and Australia are countries in which LiquidLEDs have distribution channels. The main western focus of the company is Europe due to the continent's significantly higher electricity costs relative to other potential countries such as the U.S.A. The company recently has also diversified operations to Australia in 2010.

LiquidLEDs' largest western customers are based in Germany. Conrad, an online electronics shop, is the company's biggest distributor. Chemical and pharmaceutical giant Bayer uses LiquidLEDs light bulbs to light up its landmark Bayer Cross in Leverkusen, using 1710 bulbs. The company has used this relationship as a point of entry into the German market.

NeoPac Lighting

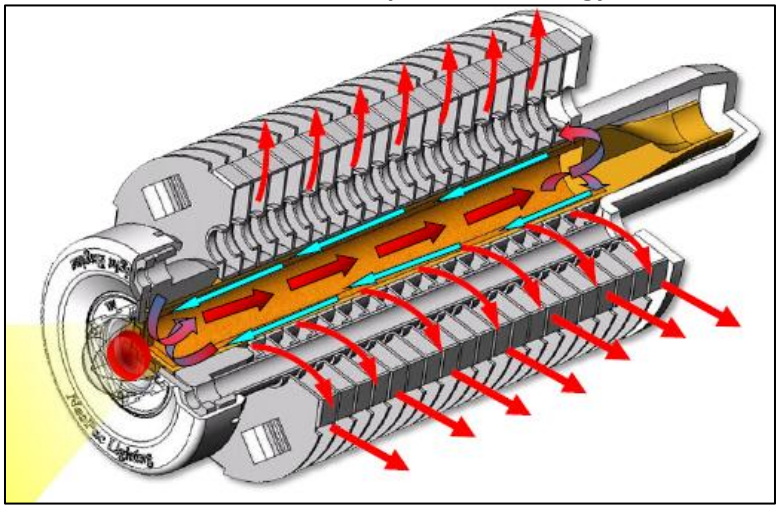
Technology & Innovations

Taiwan-based NeoPac is a developer of LED products and services. The core of its technology revolves around an efficient heat dissipation technology called a 'heat pipe' which maintains the junction temperature of the positive and negative electrodes of LED chips within a narrow range. A consistent temperature provides a longer useful life and less illumination degradation due to heat. The heat pipe manages heat by dissipating it from the LED lamp, similar to PC heat-dissipation technology.

NeoPac's heat pipe consists of an aluminum tube surrounded by stacked aluminum heat dissipation fins. It measures 50-120 mm in length, making it

adaptable to various sizes of lighting fixtures. The heat dissipation technology allows it to mount a cluster of high-power chips on its emitter module. The company's recently developed technology is an eight inch silicon-based wafer level package (WLP), a semiconductor process in which LED chips can be directly mounted along with a phosphor coating, wire bonding, and packaging processes on a whole silicon wafer.

NeoPac Heat Dissipation Technology



Source: NeoPac Lighting

In addition to light bulbs, the company's NeoPac Universal Platform (NUP) intends to cope with the rapidly changing nature of LED production. The NUP aims to develop a universal technology platform as an infrastructure upon which LED lights are created. Such a platform provides specifications including design rules for LED chips, packaging, assembly formulations, and a standardized way to measure key parameters. All of this is necessary to solve a lack of standardization that results in significant losses of inventory and profit.

Investors

The majority of NeoPac's investment is attributed to venture capitalists and listed companies in Taiwan. The company's western VC investor is San Francisco-based WI Harper.

Strategy/Sales Channel

NeoPac offers development services based on their Universal Platform to other lighting brands as well as their lighting products (NeoBulb), to distributors or lighting system integrators.

The company also has agreements and orders from the Chinese regional governments of Guangdong, Beijing, Shenyang and Shanghai to install NeoPac's 1270-lumen streetlights on some of the main roads in those regions.

Key Western Relationships

Philips is a known customer of NeoPac, and the company landed orders from 88 countries including mainland China, South Korea, Germany, Japan, the United States, Latin American nations and Taiwan.

An important relationship, indirectly western, is a partnership with China-based BroadAir. BroadAir began as a producer of energy efficient air conditioning systems, but has evolved to become a sustainable building developer with offices worldwide serving a global customer base. NeoPac has partnered with BroadAir to provide LED lighting in BroadAir-affiliated buildings. This allows NeoPac access to a large global network of new customers, while BroadAir is able to integrate LED lighting into their services and offerings.

Lattice Power

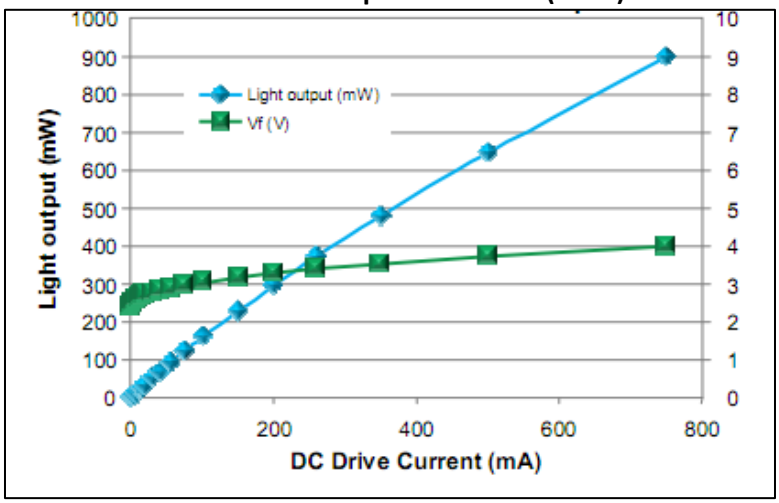
Technology & Innovations

China-based Lattice Power is a developer of high-output white LEDs based on gallium nitride (GAN) die fabricated on silicon substrates. The company has demonstrated lab results of cool-white LEDs with an output exceeding 100 lumens at 350mA from a 1x1 mm LED chip. The production capacity of Lattice Power has reached 14 billion chips, and with the addition of the new MOCVD installations, it is predicted to reach 24 billion in 2011.

Currently, almost all GaN-based LEDs are fabricated on sapphire substrates, a proven technology that dominates the business, but sapphire can be expensive and very difficult to scale down to 6 inch wafers. Silicon substrates are traditionally less expensive and a more flexible material, but also lower quality so that material stress can result in lattice mismatch and cracking of the films needed by high-power LEDs.

By using patterned substrates that isolate the stress caused by cracking, and a special AlGaN/AlGaN (aluminium gallium nitride) multilayer buffer structure that manages internal strain, Lattice Power is able to create GaN on silicon structures that yield high performance LEDs with minimal cracks. With this approach it is possible to produce a manufacturing yield of more than 95 percent of chips without cracking, for a chip size of1mm or smaller. The company's high performance, silicon-based LED chips could be a key factor in scaling and lowering the cost to LED adoption.

Lattice Power Chip Performance (1mm)



Source: Lattice Power

Investors

Investors in the company include: The IFC, California-based Mayfield Fund, Singapore-based Temasek Holdings, China-based AsiaVest Partners, China-based GSR Ventures, China-based Keytone Ventures. The IFC invested $55 million in LatticePower in December 2010.

Strategy/Sales Channel

Lattice Power generates revenue by manufacturing and selling GaN chips. It currently has a chip production capacity of 3 billion per year. The company's business plan can be broken down into three phases. In Phase 1, it aims to build capacity of 10 billion chips with a total investment of $99 million. In phase 2, Lattice Power will require an additional investment of $200 million to $300 million to allow it to obtain revenues of between $300 million to $400 million and solidify itself as one of the global leading LED chip suppliers. In phase 3, it plans to build LED application systems and to attract solid state lighting companies from all over the globe to Nanchang for the LED and solid state lighting industrial cluster establishment.

The CEO of Lattice Power, Sonny Wu, has 8 years of experience in developing high tech enterprises in China since 1993. He has strong industrial and financial networks in both the US and China. Sonny developed the original business plan for LatticePower with founders of the company and recruited a world class team from US and Taiwan. He was formerly founder and managing director of GSR Ventures.

Key Western Relationships

Lattice Power has formed a partnership with Germany-based AIXTRON, a provider of deposition equipment to the semiconductor industry. AIXTRON received an order for several MOCVD production systems from Lattice Power in Feb 2010. This was the largest single order from China that AIXTRON had received to date.

Conclusions

The mass adoption of LEDs is no small task; it will require full integration of retrofit lamps into current systems, accelerated renovation of the current installed base, and new building and infrastructure projects. Due to policy and governmental pressures, this change needs to happen at a quicker rate than we may expect. The projected fifty percent adoption in the next five years requires emerging LED technology developers to compete with incumbent players for market share in the lighting industry.

In this brief, we investigated Asia-based companies that have differentiated LED technology and western business strategies. As Asia is recognized for its innovation and R&D capacities, opportunities are opening for western companies and consumers to take advantage of these developments at a lower cost. If western companies are able to embrace Asia's technical and industry expertise in lighting, they will help "pave a path from the East to the West," facilitating future business relationships, partnerships and joint ventures that benefit both regions.

As more Asian LED developers position their strategies toward the western market, they may very well present a formidable challenge to western LED developers contributing an array of technological innovations, standardized supply chains, and advanced manufacturing techniques. The companies that are able to provide value in quality, consistency, and scale will be in the best position to secure a share of the burgeoning LED market.

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