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Solid State Lighting Market Overview

Summary

The adoption of LED lighting is poised to be one of the great growth stories of the 2010s decade. From near zero at the beginning of the decade, nearly 1 billion sockets will be filled with LED for general lighting purposes in 2014. Average market penetration is still only around 25% and most expect LED to have the lion's share of the market by 2020.

The investment outlook is not as clear as the outlook for growth in the sector. As with any rapid secular growth trend, valuations have been raised aggressively. There are relatively few investable names, and most of those are cannibalizing their own conventional technology with their rapidly growing LED segments. Pure plays higher up the supply chain are struggling with excess capacity, demonstrating that there are few technological bottlenecks or barriers to entry that might lead to extraordinary profits. In a sense, the market has already paid for the growth, and the onus is now on the companies to deliver.

We see near-term challenges emerging for the industry to maintain growth and margins. First, new penetration must be won from tougher segments of the market. Earlier penetration was gained from segments that had the most expensive conventional technologies, were not as price sensitive or that highly valued the controllability and design possibilities of digital lighting. Future penetration will have to come more from commercial segments using cheap and efficient fluorescent lighting or from price sensitive low margin retail consumers. Furthermore, we are not convinced that the industry will be able to continue to lower costs at the 20%-25% per annum rate of recent years without significant margin deterioration.

Of the companies exposed to LED lighting that we highlight at the end of this report, we are most favourably disposed to pure plays CREE and Epistar, but don't believe current prices represent attractive entry points. Austria-based Zumtobel, while not a pure play, may have more upside that its larger peers and be a possible acquisition target.

Technology and Definition

- Solid state lighting is semiconductor-based electroluminescence as opposed to conventional lighting which achieves luminescence from heating a filament or introducing electric charge to a material such as plasma or gas
    - Semiconductors that emit light when electric charge is introduced are called light emitting diodes (LEDs)
    - Most LEDs use electroluminescent material based on combinations of one or more of gallium, arsenic, indium, and aluminium
        - Phosphorous is combined with these materials to down shift from white or ultraviolet light to softer colours

- Organic LEDs (OLEDs) include carbon in their electroluminescent material
    - Still significantly more expensive than LEDs and less durable
- Polymer LEDs (PLEDs) are a thin-film light-emitting coating using petroleum based polymers in addition to LED materials
    - Not yet commercialized

Components and Manufacturing Processes

- LED chips consist of electroluminescent material that is layered on to a supporting substrate
    - Substrates in current use are synthetic sapphire (aluminum oxide) and silicon carbide (SiC)
        - Substrates are grown into large boules from 'seed' crystals in furnaces similar to the process for creating semiconductors
        - Wafers are sliced from the boule to create the thin substrate layer
    - Electroluminescent material (e.g. GaN) is deposed from gaseous form onto the substrate using metal organic chemical vapor deposition (MOCVD) machines
    - Electric wiring is etched onto electroluminescent material
    - Wafer is cut into individual chips
- Chips are assembled into packages with desired output capacity, which constitute the light engine for final assembly
- Packages are combined with power management (AC/DC conversion, surge protection, drivers), heat management, connectivity and controls, wiring, and aesthetic finishing

Technology Developments and Impact on Costs

- LED industry players, as with most semiconductor-based technology, look for a Moore's law analog in their space
    - Moore's law was the Intel chairman's rule of thumb that processor capacity doubled every six months
- The LED analog is Haitz's law, where lumens per standardized LED package doubled every two years
    - In the last decade, the rate of doubling has accelerated to every 18 months
- As some efficiency gains in lumens per package are achieved with higher-cost technology, costs do not decline at the same rate as productivity grows
    - ASPs in the past couple of years have been declining at a great than 25% rate
        - Biggest driver of this decline has been migration from 50 mm to 100 mm wafers
            - Larger wafer diameter means smaller percentage is cut off as waste around the edges, other scale economies

        - Also some margin compression in upstream businesses (materials, chips, packages) has led to prices falling faster than costs
- Industry players generally consistent in expecting a 20%-25% rate of annual cost / ASP decline for the rest of the decade
    - Room for luminous efficiency to increase
        - Technical maximum is 400 lumens per Watt, phosphor conversion reduces maximum to 220-240
        - Current output is 120 lumens per Watt
        - Higher efficiencies have been demonstrated at lab scale, no indication that they are hitting a ceiling yet
        - More efficient chips means smaller packages for same lumen output, less packaging, fewer drivers, less heat to be managed, leads to multi-faceted cost reductions
            - Heat management and package size are currently biggest cost obstacles to reducing costs for replacement lamps with small sockets
    - Wafer size currently being upgraded to 150 mm at leading players, industry will follow
- Some technology changes that could help reduce costs / improve efficiencies
    - Improved or new substrates
        - Substrates have lattice mismatch (essentially relatively poor fit of crystalline structures) with the different electroluminescent material, that has the effect of reducing the brightness of the glow produced by the final product
        - 90% of blue LEDs produces are on sapphire substrate
        - 10% of blue LEDs are on silicon carbide (all produced by CREE)
            - Sapphire has higher lattice mismatch than silicon carbide
            - Sapphire is an insulator, interferes with conductivity to electroluminescent material, is often removed in later production stages
            - Silicon carbide (SiC) is opaque, blocks some light emitted by electroluminescent material
        - New substrate materials are in development, but none appear ready to make an impact on the commercial market
            - GaN on GaN (developed by California-based private Sora'a), no lattice mismatch, still in research stage, still very expensive
            - ZnO, even earlier stage than GaN
            - Silicon, lower price, but significantly higher lattice mismatch, low-brightness chips

        - Improving transparency of SiC or reducing lattice mismatch in sapphire are the main areas for improving substrate performance
    - Improved phosphor reduction converts the blue light produced by high-power LEDs to warmer colours appealing to the human eye
        - Lumileds (owned by Philips) is a leader in high-brightness phosphor conversion
    - AC chips would reduce the need for drivers
    - Better light capture with mirrors, other adaptations in housing
- We are somewhat skeptical that 20%-25% price declines will continue without substantial margin erosion among producers
    - Some suggestion that decline rate already leveling off in recent months
    - Chip efficiency approaching maximums asymptotically

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Market Size, Share and Growth

- LEDs today already dominate the electronic device market and are now rapidly penetrating the general lighting and automotive market
    - General lighting is by far the biggest market demanding the greatest lumen output (one lumen is equal to the luminous output of one candle in a specific direction)
        - According to McKinsey, a €55 billion market in 2011
        - LED share of general lighting is roughly 25% today, expected to be greater than 50% by 2017
    - Electronic device attaches more value to the display technologies than the light source as lumen requirements are relatively low
        - A €4 billion market in 2011, expected to shrink even as volumes grow as the backlighting LEDs get further commoditized
        - LED share of electronic device backlighting is greater than 90%
    - The automotive market is dominated by headlights (2/3 of total market), which in turn are still dominated by halogen technology
        - A €14 billion market, almost entirely dependent on new vehicle production
        - LED share of automotive market still only 15% expected to be adopted more slowly than general lighting as OEMs are slower to make changes in design and pay the component premium
- Assuming by 2017 LED reaches 50% penetration of general lighting market (by dollar value) that grows 3% annually, implied 3-year CAGR for technology would be:
    - 47% for LED-based lighting
    - -12% for conventional technologies being supplanted by LED
- LED-based unit count in 2012 was 140m, expectation for 2015 is 1.2b
    - Equals a 3-year unit CAGR of more than 100%
- Philips pegs LED growth rate between now and 2016 at 35%, with conventional declining at a 6% rate
- Growth rates slowing as base gets larger
- Dollar growth rates are slower than unit growth rates as unit prices continue to decline

Regulatory Support for LED conversion

- Most major jurisdictions globally have phase-out regulations in place for incandescent bulbs
    - As of beginning 2014, EU, US, Japan, China, Brazil and Canada have all banned sale of standard incandescent bulbs 60W or higher
        - Some lower Wattage bulbs still being sold
        - Also some jurisdictions allowing ‘high-efficiency incandescents’

- EU has also banned low-voltage halogen lamps as well
- Many jurisdictions have regulations in place for overall energy efficiency of new construction buildings and LED is one of the most economical ways to meet these requirements
    - Lighting is 11% of primary energy use in residential buildings and 25% in commercial buildings
- Incentives are in place in many US states that knock $2 or more off the cost of LED replacement bulbs
- Generally regulatory bans have played a secondary role to economic incentives, both regulatory and free-market
    - Greatest LED penetration has been in outdoor and architectural lighting, areas where bans are not even in place

Current Economics of LED vs. Alternatives

- LEDs still sell at a significant premium to other lighting technologies in all markets, but prices have come down rapidly and are expected to continue to do so
    - Standard A-series lamp socket replacement bulbs sell for $10 to $15 in Canada, under $10 in the US
    - Halogen floodlight replacements sell for $25 and higher
    - LED assemblies to replace 2x4 fluorescent troffers sell for roughly $100, though some companies (Cooper-Eaton, e.g.) are claiming new generation product selling for significantly less
    - LED replacements for outdoor high-intensity discharge (HID) incandescent floodlights sell for $150 or more
- Prices are highly variable, fluctuating due to changing marketing strategies, jurisdictional incentive schemes, and different assumptions about the Wattage required to replace conventional technology
    - Directional capability of LEDs (focused on a specific angle vs. 360^0 diffusion of incandescent or fluorescent tubes) allows for effective lighting equivalence even with lower lumen output
        - Conventional technology light loss can be reduced with reflective housing and other techniques, but still does not approach directionality possible with LED
- Savings that offset the up-front premium of bulb cost are primarily due to lower electricity consumption, but also due to reduced supply and labour due to less frequent switching of bulbs in more difficult locations
    - Labour costs and replacement logistics are an important input for commercial / industrial / municipal buyers
    - Outdoor lighting, where accessibility poses the biggest challenges, is seeing the quickest switch from conventional to LED technology

- LED can also be programmed to reduce intensity in periods of lower need (e.g. parking lot between midnight and 5:00 am), further increasing energy savings

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	Case 1		Case 2		Case 3		Case 4	
	Resi. Incan.	Resi. A-series LED	Resi. Halogen Flood	Resi.l LED Flood	T5 2x4 Fluor. Troffer	LED 2x4 Panel	Outdoor HID Flood	Outdoor LED Flood
Watts	60	10	60	10	70	50	100	70
Bulb Cost	$0.50	$10.00	$3.00	$25.00	$30.00	$100.00	$30.00	$150.00
Lifetime	1000 hr	40000 hr	1000 hr	40000 hr	25000 hr	40000 hr	10000 hr	40000 hr
Daily use	3 hrs	3 hrs	3 hrs	3 hrs	12 hrs	12 hrs	11 hrs	11 hrs
10-yr bulbs	11	0.3	11	0.3	1.8	1.1	4	1
KWh per year	66	11	66	11	307	219	402	281
Elect. Price	$0.12 per kWh	$0.12 per kWh	$0.12 per kWh	$0.12 per kWh	$0.12 per kWh	$0.12 per kWh	$0.12 per kWh	$0.12 per kWh
Replace labour					15 min	15 min	60 min	60 min
Labour rate					$50 / hr	$50 / hr	$50 / hr	$50 / hr
Total 10 yr cost	**$84.32**	**$23.14**	**$111.69**	**$38.14**	**$442.38**	**$385.99**	**$803.00**	**$538.01**
Cost reduct'n		**$61.18 (73%)**		**$73.55 (66%)**		**$56.39 (13%)**		**$264.99 (33%)**
Bulbs		**-$4.53**		**$7.85**		**-$56.94**		**-$30.11**
Energy		**$65.7**		**$65.7**		**$105.12**		**$144.54**
Labour						**$8.21**		**$150.56**

- Four comparisons in the table above show that, based on certain assumptions, LED offers savings versus all conventional technologies in all end markets even with current bulb premiums
    - Savings are highest in percentage terms in residential markets
        - Non-residential markets already use more efficient lighting that is more competitive with LED (fluorescent, HID)
    - Lower electricity use for LED is generally the major contributor to savings
    - Maintenance (bulb-switching) labour can become more important depending on assumptions about labour all-in costs
        - This is most pronounced for outdoor applications that require a ladder at minimum, truck roll in the more expensive case
    - Savings do not take into account cost of capital (savings are delayed, premium must be paid up front) so on balance are slightly less attractive than they appear

        - Residential buyers most sensitive to sticker price shock, but commercial-industrial also reluctant to pay high premiums
        - Municipal street lighting has been slower to take up LED than other outdoor due to issues regarding financing up-front costs
            - Likely higher municipal labour rates would make savings more attractive for this class of buyer
    - Savings estimates are most sensitive to electricity price assumption, followed by lifetime and all-in switching cost
- Quality still needs to improve to penetrate residential interior lighting
    - While LED quality has improved tremendously in recent years, some bulbs on the market today still do not replicate the warm quality of incandescent light and do not handle dimming well

LED Investment Opportunities

- Despite LEDs representing a nearly $20 billion market today, the investable universe is fairly small since it is dominated by the large lighting industry oligopoly of GE, Osram (formally Siemens), and Philips
- **Retail bulbs and luminaires**
    - Major players include **Philips**, **Osram**, **GE**, **Eaton** (Cooper), **CREE** and **Acuity**
    - All of these companies (with the exception of CREE) are cannibalizing conventional sales as their LED sales grow, so overall growth profile does not necessarily improve with the switch to LED
    - GE, Eaton, and Philips dilute their exposure to lighting, and LED specifically, with other non-lighting divisions
        - Lighting is approximately 1/3 of Philips sales
        - Lighting is less than 10% of Eaton sales
        - Lighting is less than 5% of GE sales
    - **GE (market cap $250b)** has very little LED business and is often rumoured as a potential acquirer of CREE
    - **Philips ($32b)** is a leader in LED, its position solidified with the 2010 acquisition of Lumileds
        - LED constitutes nearly 25% of lighting revenues
        - Margins have improved lately, sales growth generally low to mid-single digits
    - **Osram (Euro 4.5b)**, recently spun out from Siemens has successfully restructured the company and improved margins as a stand-alone operation
        - Company claims LED already approaching 30% of revenues
            - Driven in part by high-end automotive headlights for German high-end OEMs

        - Sells retail replacement bulbs in North America under Sylvania brand, #3 to GE and Philips
    - **Acuity ($5.3b)** is a leader in North American professional lighting
        - Commercial, architectural new build
        - Primarily driven by relationships with independent representatives
        - Company has enjoyed increasing margins in recent years but growth is generally a proxy for US new construction, approximately 10% in recent years
        - Multiples of 30x earnings and free cash flow are hard to justify with margins at peak levels and little reason to believe growth can accelerate
    - **Zumtobel (Euro 700m)** is like a European Acuity, though smaller, with lower market share and lower margins
        - At 20x free cash flow and with the potential for margin upside, appears a better bet than Acuity so long as European and American economies don't materially diverge
    - **Eaton ($34b)** competes with Acuity and Philips in the professional lighting market
        - They were the most optimistic general lighting company on LED
        - Already 30% of their sales are in LED
        - Seeing biggest gains in outdoor
        - Launched a product called WaveStream to compete with fluorescent in commercial / institutional space, claim high take-up, 30%-40% efficiency advantage
        - Exposure to lighting very low, 20x multiples for single digit growth and peak margins
    - **CREE ($7.2b)** is the only pure-play, LED-only publicly-traded lighting company
        - Some non-LED business in Ruud, a downstream company that competes with Acuity, Philips, and Eaton, but CREE is more than 90% LED
        - CREE owns the technology and patents for SiC substrates
        - CREE has looked to aggressively penetrate the retail bulb market with the first sub-$10 bulbs on US big box store shelves
            - Margins have been hit initially, but the company is building brand recognition and claiming shelf space
        - CREE faces long-term risks that the market somehow standardizes around sapphire and it becomes challenging for designers to integrate SiC-based chips (i.e. SiC is like Betamax and sapphire like VHS)
            - This is unlikely since CREE has so far managed to be a cost leader with less scale than bigger competitors
            - VHS / Betamax analog doesn't exactly fit since there are no consumer interoperability issues

        - CREE will likely be challenged to maintain industry-leading margins, especially as it has to fight to defend expiring patent position in the early 20s
        - Valuation is aggressive for CREE stock, at 50x free cash flow and 40x earnings
            - However CREE has more sustainable growth upside than any other general lighting company and is also always a potential acquisition target
            - If CREE can hold margins it may grow into its valuation
    - **Dialight (GBP 250m)** is a UK-based niche specialty lighting company in areas like automotive, traffic, and marine
        - Limited visibility into very small markets
        - LED still less than half total sales
        - Stock was priced highly due to scarcity of lighting pure plays
        - Recent lumpiness in orders has led to small shortfalls, enough to drop the stock by nearly half from highs in mid-2013
        - Even after the drop, share price is more than 20x free cash flow and 16x earnings, growth in low double digits
- **Upstream suppliers of tools, chips, and packages**
    - Two public companies manufacture MOCVD machines, Aixtron and Veeco
    - In the supply of sapphire substrate, one public company supplies furnaces (GT Advanced Technologies) while a second supplies the actual material (Rubicon)
    - Major players in LED chips (besides CREE) include Samsung, Japanese private company Nichia, and Taiwanese foundry Epistar
    - In lower value-added packaging, Taiwanese-based Everlight Electronics is a pure play, while Samsung, Nichia, and CREE are all vertically integrated and able to package for themselves or external customers
    - **Aixtron (Euro 1.2b)** and **Veeco ($1.5b)**share the MOCVD market roughly equally between them
        - Sales are running at a level around 1/3 of what was achieved in 2010-2011 when Chinese start-ups tried to take over the growing LED market in a fashion similar to the way they took over solar
        - LED has proved more complex and the lighting sales channel more oligopolistic than the case for solar, and most of the Chinese start-ups have failed
        - Many machines ordered during 2010-2011 boom have barely been used, some damaged
            - There is an active market for used machines
        - Overall market remains oversupplied
            - Less than 1,000 machines could make 4b bulbs per year

        - There are 2,400 machines in the market, not all usable and not all for sale but still significant overcapacity
    - Companies are in cost-cutting mode, still EBITDA negative with the large drop in sales
- A similar China-driven oversupply exists with furnaces for sapphire manufacturing
    - However, sapphire is undergoing a shift in demand drivers from LED substrates to use in mobile phones
        - First as home button (Apple has committed for the iPhone and has a contract with GT Advanced Technologies)
        - Possibly further as replacement for all cover glass (replacing current Gorilla Glass made by Corning)
            - Price for glass must still come down by more than half to make full cover glass replacement a reasonable option
    - **GT Advanced Technologies ($1.4b)** sells furnaces for solar-grade silicon and for synthetic sapphire
        - Margins and prospects for Apple business are uncertain, but contract lends some credibility to the company and the stock
        - History of booking large cash advances and unearned revenue has made cash flows appear more attractive than they actually are over full business cycle
        - Margins remain depressed, stock trades on optimism that $100m-$200m free cash flows of 2009-2011 can be realized again with LED and solar growth and Apple providing new market
    - **Rubicon Technology** ($280m) competes with private Russian and Asian suppliers in the sapphire market
        - Rubicon was spun out from a Russian parent that now competes with it and has a lower cost profile
        - Sapphire has been very cyclical with margins swinging from +50% in 2010 to -50% in 2013
        - As a higher-cost competitor in a very cyclical industry, only cover glass-related rising tide would be likely to drive sustained upside in the stock
- **Epistar (USD $2b)** and **Everlight (USD $1b)** are qualitatively different Taiwanese LED companies at different stages in the supply chain
    - Epistar is relatively well-managed foundry with excess capacity available for outsourcing production
        - Analogous to TSMC in the semiconductor industry
        - Might be one of the best available public-market plays on LED volume surge

        - Currently utilization is low and consequently so are margins (15% compared to 35% two years ago)
        - Stock has not suffered commensurate with margins so valuation appears aggressive (more than 20x free cash flow)
        - Reporting is mostly in Mandarin, due diligence difficult
    - Everlight packages chips into diodes, has a reputation for shady quality and ignoring IP rights
        - Margins have also fallen, though not by as much as Epistar
        - Valuation at less than 15x free cash flow more reasonable, reflecting qualitative concerns