Speculative thinking about the future of LED and OLED lighting industries

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LED and OLED lighting markets are at different stages of maturity: LED is getting to scale. OLED lighting is just getting started and not yet included in most forecasts.

Source: A.T. Kearney, 2002 and HCL analysis
LED industry has grown in automotive and display markets, but with display demand falling, excess supply will spill over to general lighting.

- Display backlighting demand has driven LED so far, but this is changing.
- LED usage per TV is now decreasing and display panel makers have established their own sources/alliances:
  - AUO — Lextar
  - CMI — CMLT/ GIO
  - LGD — LG Innotek
  - Samsung — Samsung LED
- As a result, companies have put in place excess capacity and this will provide stimulus to the general lighting market.
- Chinese firms are beginning to pile in at all parts of the value chain, in what may be a replication of the dynamics of the photo-voltaic industry.

LED-lit Costs Will Be Lower

Rewind and Reshape the Value Chain

<table>
<thead>
<tr>
<th>TV Brand</th>
<th>Panel Maker</th>
<th>LED Supplier</th>
<th>Related JV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>Samsung LCD</td>
<td>Samsung LED</td>
<td>Samsung Micro.</td>
</tr>
<tr>
<td>LG</td>
<td>LG Display</td>
<td>LG Innotek</td>
<td>Wooree</td>
</tr>
<tr>
<td>TPV (OEM) AOC</td>
<td>AU Optronics</td>
<td>Lextar</td>
<td>Everlight, Epistar</td>
</tr>
<tr>
<td>Hon Hai (OEM)</td>
<td>Chimei Innolux</td>
<td>Formosa Epitaxy</td>
<td>AOT, Chi Lin</td>
</tr>
</tbody>
</table>

Source: Our consulting partner BizWitz LLC presentation to Strategies In Light, 2011
Patent filings also suggest that the LED technology development phase is over and now truly into “scaling up”

- Patent searches show that the peak of IP registrations was already back in 2006
- New patent registration now is around colour management, thermal management and lighting fixture control
- SEMI counts 77 LED fab projects underway in 2011 and it expects 72 new projects will get underway in 2012
- Current investments supported heavily by government policies (especially rebates for investments in wafer capacity in China)
- LED wafer capacity is already 93% in Asia with China becoming more and more important

Source: Innography, SEMI
LED market map and value chain: Selected players

- **Equipment**
  - AIXTRON
  - Veeco
  - Taiyo Nippon Sanso
  - Disco

- **Substrate & Phosphors**
  - GT Solar
  - Shin Etsu
  - Samsung Sumitomo
  - Kyocera
  - Mitsubishi C
  - Monocrystal
  - Rubicon
  - Denki Kagaku
  - Others

- **Epi/Chip**
  - Epistar
  - Formosa E
  - Genesis
  - Sanan Opto
  - GCL Poly

- **Package**
  - Philips incl Lumileds
  - OSRAM
  - Cree
  - Everlight
  - Seoul Semi
  - Liteon
  - Harvatek
  - Unity
  - Toyoda Gosei
  - Samsung LED
  - Lattice Power
  - GE lighting

- **Light engine, luminaire**
  - Ruud
  - Acuity
  - Zumbotel
  - Hubbell
  - Cooper
  - Panasonic EW

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- 2 main firms dominate the MOCVD business
- Strong economics based on barriers to entry. Long term regional copying of equipment may occur
- Medium barriers to entry and fairly high operating margins here have led to a number of new entrants
- Op margins 40% range but may fall with new entrants
- Fairly heavily IP protected
- Operating margins in the 25% range
- Players moving to scale rapidly but new Chinese also
- Fragmenting very rapidly and operating margins likely to fall
- Op margins in the 15% range
- Barriers to entry are not high but not many players have global reach and scale
- Op margins in the 10% range

Source: McKinsey, Taiwan government, company analyst reports, Nomura, Goldman Sachs, Canaccord, Strategies in Light
What is amazing is the speed of transformation of the LED industry in terms of players forming ventures and relationships:

Epistar illustrates JV development matrices in Greater China

Sharp illustrates display to LED to fixture value creation

Source: Recent announcements
# Key LED players: Selected companies

<table>
<thead>
<tr>
<th>Philips</th>
<th>OSRAM</th>
<th>Cree</th>
<th>Nichia</th>
<th>Epistar</th>
<th>Everlight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Profile</strong></td>
<td>The leader in the lighting industry but with large exposure to legacy technologies also</td>
<td>Subsidiary of Siemens that is being considered for IPO</td>
<td>US pure play LED player. Recent forward integration in to channel in USA</td>
<td>Mainly family owned old Japanese firm and one of the first players in LED</td>
<td>LED packaging firm in Taiwan with revenues of $600m</td>
</tr>
<tr>
<td><strong>Strategy</strong></td>
<td>Maintain global position during the transition</td>
<td>Technology leader in new lighting space</td>
<td>Forward integrating to help market development (Ruud acquisition)</td>
<td>Phosphors, nitride LEDs and fine chemicals</td>
<td>Customer intimacy based approach for lighting, backlighting and LED signboards</td>
</tr>
<tr>
<td><strong>Product line up for SSL</strong></td>
<td>LumiLEDs in house position plus purchased LEDs.</td>
<td>Have bets in both LED and OLED lighting. LED is the more serious position</td>
<td>LED only with emphasis on street lighting, retail and general lighting</td>
<td>LED only with recent move into BLU. One of the major IP leaders in the industry</td>
<td>Biggest InGaN chip maker in Taiwan. Balanced sales across market segments</td>
</tr>
<tr>
<td><strong>Technical and manufacturing capabilities</strong></td>
<td>Deep technical strengths in lighting but hollowed out in knowledge for Semi/OLEDs</td>
<td>Recent investment in OLED capacity in Germany and LED capacity in Panang</td>
<td>One of the technical leaders in LEDs</td>
<td>Deep competencies and IP in LED. High technology positioning</td>
<td>One of the leaders in direct red LEDs. Patents for AC LEDs</td>
</tr>
<tr>
<td><strong>Market position and customer base</strong></td>
<td>Dominant market position in luminaires globally</td>
<td>One of the stronger players in the market for now</td>
<td>Strong pure play LED player in the USA. Very profitable</td>
<td>Strong channels as one of the main established players. Pursues patent claims</td>
<td>Strong customer portfolio with focus on backlighting. Moving towards general lighting</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td>The elephant of the lighting industry but also trying to manage massive internal change</td>
<td>One of the innovators off the block</td>
<td>Potential regional leader. One of the most profitable players. Keeping up with capacity</td>
<td>One of the old standing leaders of the industry. Risks falling behind on capacity</td>
<td>Profitable leading Taiwanese chip maker. One of the faster movers to lighting</td>
</tr>
</tbody>
</table>

**Source:** Company websites, analyst reports, text searches
### Key LED players: Selected companies

<table>
<thead>
<tr>
<th></th>
<th>Seoul Semi</th>
<th>Samsung LED</th>
<th>LG Innotek</th>
<th>Lattice Power</th>
<th>Sanan Opto</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Profile</strong></td>
<td>Korean LED packaging company with strong lighting business</td>
<td>Joint venture of Samsung electronics and SEMCO</td>
<td>One of the LG group of companies. Focused on LEDs and components</td>
<td>Chinese recent player focused on epi/chip manufacturing</td>
<td>New player in China investing large amounts into chip/epi. Public company in China</td>
</tr>
<tr>
<td><strong>Strategy</strong></td>
<td>Focus on backlighting and general lighting. JV with POSCO for industrial lighting</td>
<td>3 market emphasis for now: Backlighting, automotive and general lighting</td>
<td>LG Innotek supports LG group companies in mobiles and related component</td>
<td>Commercialise silicon based GaN lighting LEDs delivered through high scale</td>
<td>One of the Chinese new entrants focusing on full colour HB LEDs</td>
</tr>
<tr>
<td><strong>Product line up for SSL</strong></td>
<td>LED packaging firm with chip/epi subsidiary Seoul Opto</td>
<td>Chip and packing LED set up. Different Samsung company is leader in AMOLED display</td>
<td>LED only at this point although have/had a mobile display business</td>
<td>LED chip/epi now but with plans to forward integrate into packaging</td>
<td>Includes blue and red LEDs. They believe their technology similar to Epistar</td>
</tr>
<tr>
<td><strong>Technical and manufacturing capabilities</strong></td>
<td>Ariche branded AC general lighting LEDs with strong efficiency</td>
<td>Samsung group has all the competencies needed to make a success</td>
<td>Broader capabilities than many LED companies given multi technology exposure</td>
<td>Working on GaN on Silicon as a technical approach</td>
<td>Aiming for 144 MOCVD reactors by end of 2011 and will move up sales ranks</td>
</tr>
<tr>
<td><strong>Market position and customer base</strong></td>
<td>Relationships with many Korean/Asia electronics players plus GE &amp; Philips</td>
<td>Clearly a very strong relationship with the Samsung group companies plus Acuity brands</td>
<td>Primary relationship with LG group companies which may limit growth</td>
<td>New Chinese entrant but with big plans</td>
<td>New entrant to LEDs but investing heavily. Also play in Solar</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td>Strong position in general lighting. One to watch</td>
<td>A very real threat to the current state of the market</td>
<td>Quite a capable firm and could be one to watch. LG group emphasis may limit growth</td>
<td>Chinese players in LED need to be monitored closely</td>
<td>Bullish investment plans make this one company to watch</td>
</tr>
</tbody>
</table>

**Source:** Company websites, analyst reports, text searches
OLED lighting by comparison has only just begun…

**Product offerings 2011**

<table>
<thead>
<tr>
<th>Company</th>
<th>Efficacy (lm/W)</th>
<th>Area (cm²)</th>
<th>Price (€)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philips Lumiblade</td>
<td>20</td>
<td>10 - 60</td>
<td>77-269</td>
<td>Various colors, sizes, shapes</td>
</tr>
<tr>
<td>Philips Lumiblade Plus</td>
<td>45</td>
<td>50</td>
<td>120</td>
<td>Highly efficient</td>
</tr>
<tr>
<td>Lumiotec 2011</td>
<td>11</td>
<td>100 - 300</td>
<td>115-350</td>
<td>Various colors, sizes, shapes</td>
</tr>
<tr>
<td>Osram Orbeo</td>
<td>23</td>
<td>50 (circular) 65</td>
<td>240</td>
<td>Various shapes Mirrored or Diffuse</td>
</tr>
<tr>
<td>LG Chem</td>
<td>46-60</td>
<td></td>
<td></td>
<td>Highly efficient; Q1 2012 Availability</td>
</tr>
<tr>
<td>Fraunhofer Tabola</td>
<td>25 - 115</td>
<td></td>
<td></td>
<td>Transparent version</td>
</tr>
<tr>
<td>Verbatim Veil</td>
<td>28</td>
<td>200</td>
<td></td>
<td>Color tunable</td>
</tr>
<tr>
<td>Kaneka</td>
<td>20</td>
<td></td>
<td></td>
<td>Various colors</td>
</tr>
</tbody>
</table>

- 4 companies shipping product already and 4 more coming to market soon
- The current lighting players are the first to market but the next round of players coming through are ones with no background in the lighting arena
- Companies like LG Chem and Verbatim OLED (given backing of Pioneer) are quite credible players for the market place
- However, worth saying that current investment levels are “a drop in the ocean” compared to investments in the flat panel industry that is spending €10m a day on capex for AMOLED displays in 2011
  - Investments by Philips, OSRAM and Moser Baer represent less than 2 weeks spending for AMOLED displays
  - Any threat of any entry by one of the AMOLED display players (SMD, LGD) must be taken very seriously

Source: Text searches, DOE, JP Morgan, our analysis
…and yet many players already (selected companies)

Source: Text searches
Arrows indicate commercial partnerships or equity venture shareholdings or research collaborations including licensing agreements

Substrate Barriers Research institution Parent company or other Lighting company Display or related co Materials/IP Equipment OLED light player

Source: HENDYCONSULTING DISPLAY, HIGHEST & MEDICAL IMAGING STRATEGY

10
# Key selected OLED lighting players

<table>
<thead>
<tr>
<th>Profile</th>
<th>GE</th>
<th>Philips</th>
<th>Konica Minolta</th>
<th>Moser Baer</th>
<th>Lumiotec</th>
</tr>
</thead>
<tbody>
<tr>
<td>The global number 3 in lighting solutions with strong USA position</td>
<td>The lead player in the global lighting industry</td>
<td>Imaging and film company with recent moves into barriers and OLED materials</td>
<td>Indian publicly quoted firm with history in optical storage, solar and entertainment</td>
<td>OLED lighting vehicle of 4 major Japanese co: Rohm, Mitsui, Toppan, Mitsubishi</td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
<td>GE lighting business was up for sale. GE playing catchup in LEDs</td>
<td>Manage the transition to new lighting technologies</td>
<td>See this as an investment into green technology</td>
<td>See OLED lighting as potential new growth area. Recent investment in NY state</td>
<td>Early leader into OLED lighting manufacturing (60k panels/day)</td>
</tr>
<tr>
<td>Product line up for SSL</td>
<td>Have R&amp;D in both LEDs and OLED lighting (on web). Behind on market traction</td>
<td>Both LED and OLED plays. One of the early players into OLED</td>
<td>Blue phosphor material and developments in barrier film</td>
<td>OLED lighting focus with relationship with UDC</td>
<td>5-10 different product sizes so far but at relatively lower efficiency</td>
</tr>
<tr>
<td>Technical and manufacturing capabilities</td>
<td>R&amp;D in OLED is one of the leaders but behind on LED traction</td>
<td>All of the lighting skills but emphasis on capex and on deposition/coating has declined</td>
<td>Have an interesting set of competencies for OLED lighting market</td>
<td>High tech electronics orientation given optical storage background</td>
<td>Japanese parents represent many of the important competencies</td>
</tr>
<tr>
<td>Market position and customer base</td>
<td>Strong channel access as one of the lighting majors</td>
<td>Strong market position as the lighting leader with many recent acquisitions</td>
<td>Do not have channel access. Have agreement with Philips</td>
<td>No channel access</td>
<td>Beginning to build profile and channel access. Also launched 2 luminaire products</td>
</tr>
<tr>
<td>Summary</td>
<td>Seem to be going through &quot;commitment&quot; issues</td>
<td>Trying to defend current position. Shyness to invest capex may become an issue</td>
<td>Interesting firm with some of the key competencies for this market</td>
<td>New entrant but securing DoE support through UDC</td>
<td>Parents are serious players if the competencies are correctly deployed</td>
</tr>
</tbody>
</table>

Source: Company websites, analyst reports, text searches
### Key selected OLED lighting players

<table>
<thead>
<tr>
<th>Profile</th>
<th>Verbatim OLED</th>
<th>LEDON OLED</th>
<th>Panasonic Idemitsu OLED (PIOL)</th>
<th>LG Chem</th>
<th>SMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration of Mitsubishi Chemical and Pioneer for LEDs and OLEDs</td>
<td>Established new venture by Zumtobel (in collaboration with Fraunhofer)</td>
<td>A joint venture of PEW (now Panasonic) and Idemitsu Kosan</td>
<td>Korean multinational with positions in display polarisers and glass IP</td>
<td>$3bn display company and the market leader for AMOLED displays</td>
<td></td>
</tr>
</tbody>
</table>

| Strategy | Colour tunable OLEDs for hospitality, auto and aviation as example segments | OLED lighting play | OLED lighting only venture | Claim to be entering the OLED lighting market in 2012 | Create the future in AMOLED displays |

| Product line up for OLED | 14x14cm OLED lighting squares. Positioned as colour tunable | OLED lighting | OLED lighting only venture | Claim to be entering the OLED lighting market in 2012 | Current OLED display leader with deep competencies |

| Technical and manufacturing capabilities | VELVE OLED lighting range moving to mass production in 2011 | Fraunhofer capabilities are reasonably strong but they are a research body | Capabilities of Panasonic and Idemitsu together are potentially strong | Between LGD and LG Chem this is a very strong force | The strongest technical position in OLED |

| Market position and customer base | Beginning to build up lighting channel access by touting new products | Relationship with Zumtobel/Thorn is important | Panasonic even has a current lighting business with strong Japanese position | No channel access into lighting channels as yet | No channel access into lighting channels so far |

| Summary | Pioneer strength at OLEDs brings credence to this partnership | Ability to move to mass production will be critical to determine success | A strong potential combination | Again another firm to watch very carefully | Perhaps even more so than LG Chem this is also a firm to watch |

Source: Company websites, analyst reports, text searches
Cost structure depends on many breakthroughs coming at the same time. LED estimates are credible. OLED estimates are aggressive.

- LED lighting already established on a cost reduction path based on markets that already exist.
- Current emphases on managing LED thermal packaging and improving phosphor uniformity.
- Integrated functional intelligence (into the chip) is under discussion; may need new socket specifications.

OLED lighting will not reach the targets shown here, since the DOE assumptions suggest that OLED lighting factories come on line very quickly after the equivalent first display lighting facility of equivalent size. This is possible theoretically but unlikely in practice.

The resulting business is a very materials-intensive business. “Dressed substrates” and other materials solutions (encapsulation) become critical factors.

Source: DOE workshops and cost analyses.
We assume the following givens in the 10 year outlook on solid state lighting:

- LED SSL has reached sufficient scale and trajectory to make us comfortable saying that it will become the leading source of light.
- Additional capacity that was targeted for the display backlighting arena will spill over into lighting applications, especially since the unit usage in backlighting is declining and TV demand is maturing.
- Economics for many parts of the LED supply chain will start to decline in the near future.
  - Most defensible positions may develop in material supply, which could have a global footprint.
  - Equipment supply may become regionalized over time but yields high margins in the meantime.
- Some leaders may continue to accrue value from their fundamental IP positions.
  - The first round of cross-licensing is nearly complete, benefitting Philips, OSRAM and Nichia in LED companies like Universal Display or Idemitsu in OLED.
  - The next round of negotiation/confrontation will concern control electronics and fixture systems.
- We assume government support for energy-saving SSL will be sustained or increased in most regions.
  - The key variable is the degree of support for R&D and industrial policies that drive investments in underlying parts of the value chain (fabrication, packaging, assembly, etcetera).
  - A second regional variable is regulatory flexibility that supports evolution of intelligent lighting systems and competitive construction-integration platforms (versus reactionary vested interests).
- Meaningful differentiation between LED and OLED value propositions remains uncertain, so far.
Overall industry roadmaps: Each market’s strategy themes will evolve

<table>
<thead>
<tr>
<th>LED Value proposition</th>
<th>Now</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy Replacement</td>
<td>Legacy Replacement</td>
<td>Fixture Enhancements</td>
<td>System Enhancements</td>
<td>Platform Upgrades</td>
</tr>
<tr>
<td>OLED TFT Gen 5.5 to Gen 8</td>
<td>OLED TFT Gen 8 to Gen 8</td>
<td>OLED TFT &gt; IGZO commoditization</td>
<td>Quantum Dot display?</td>
<td></td>
</tr>
<tr>
<td>Luminaire Innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED Tech Driver</td>
<td>Thermal &amp; Packaging</td>
<td>QD &amp; Colour Control</td>
<td>Functional Integration</td>
<td>Platform Architecture</td>
</tr>
<tr>
<td>LED Industry phase</td>
<td>Pre-shakeout Surge</td>
<td>Shake-out &amp; Leadership</td>
<td>Scale-Specialization</td>
<td>“Smile Curve”</td>
</tr>
<tr>
<td>LED Investment</td>
<td>4” Wafer transition</td>
<td>6” Wafer transition</td>
<td>Logic &amp; Integration</td>
<td>Regional Design</td>
</tr>
<tr>
<td>OLED Display</td>
<td>OLED TFT Gen 5.5 to Gen 8</td>
<td>OLED TFT &gt; IGZO commoditization</td>
<td>Quantum Dot display?</td>
<td></td>
</tr>
<tr>
<td>OLED SSL Value proposition</td>
<td>Luminaire Innovation</td>
<td>Surface Integration</td>
<td>Conformal-Flexible Transition</td>
<td></td>
</tr>
<tr>
<td>OLED SSL Tech driver</td>
<td>Emission Material Set</td>
<td>Light Management</td>
<td>Substrate-barrier Material Cost Reduction</td>
<td></td>
</tr>
<tr>
<td>OLED SSL Industry phase</td>
<td>New Entrants</td>
<td>Pre-shakeout Surge</td>
<td>Quest for Differentiated Scale Opportunities</td>
<td></td>
</tr>
<tr>
<td>OLED SSL Investment</td>
<td>Pilot Fabs</td>
<td>Larger Gen Scale-up</td>
<td>Transition to Web Process Integration</td>
<td></td>
</tr>
</tbody>
</table>

Source: Our outlook
Winners in OLED lighting manufacture will have core competencies in coating/deposition/printing, equipment management, electronics integration, capital risk taking and OLED materials. OSRAM, Philips and GE are not obvious winners based on competencies today. Others better positioned.

<table>
<thead>
<tr>
<th>Channel competency</th>
<th>Philips, GE, OSRAM</th>
<th>Konica Minolta</th>
<th>LG Chem (&amp; LG group)</th>
<th>SMD</th>
<th>Touch panel companies</th>
<th>Colour filter firms (JPN)</th>
<th>BLU &amp; Film firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating/Deposition</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>OLED materials</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronics integration</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital risk taking</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment management</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Winners in OLED lighting may be very different firms to today’s lighting majors.
Key uncertainties or risks that we see:

<table>
<thead>
<tr>
<th>Description of shock or uncertainty</th>
<th>How this changes the future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role of brand and channel in SSL</td>
<td>Channel structure and deployment by geography will remain risk factors: will current market structures persist (fragmented in Europe and consolidated in the USA, for example) or will new Asian brands become established through new structures?</td>
</tr>
<tr>
<td>Market penetration or differentiation of OLED</td>
<td>We believe that backlight-related technologies (e.g. Sharp's fixture) threatens a key point of differentiation for OLED SSL. The potential for conformable or flexible surfaces may become more important factors.</td>
</tr>
<tr>
<td>Government Policy</td>
<td>The material, tool and packaging systems for OLED may remain distinct from LED-based SSL. Thus there is potential for different policy preferences between governments that could foster local champions.</td>
</tr>
<tr>
<td>Technology Innovation</td>
<td>Substitution of quantum dots for conventional phosphors may change the value proposition of some material suppliers and ignite more IP battles between SSL firms. Transition to solution-based or other web processes could affect fixture design and system integration.</td>
</tr>
<tr>
<td>System Integration</td>
<td>Longer SSL operational lifetimes will make system-brands and feature upgrades key value drivers. This could lead to regional or global de facto standards that favor one brand (value chain, e.g. Apple).</td>
</tr>
</tbody>
</table>
## Our view of the LED and OLED lighting industry future: Scenarios

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Tech Race</th>
<th>Regional Regulation</th>
<th>Asian Games</th>
<th>Brand Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LED outlook</strong></td>
<td>LED penetration &gt;50% by 2020 in all segments (but lagging in offices)</td>
<td>LED and OLED each develop distinct value propositions</td>
<td>Government policies drive localisation and divide value chains by geography</td>
<td>China piles into LED as it did in PV, driving prices down and other regions out of business.</td>
<td>Massive investments in Asia commoditise lighting components. EU and US integrators have a field day.</td>
</tr>
<tr>
<td><strong>OLED outlook</strong></td>
<td>OLED lighting finds a niche in premium illumination products</td>
<td>OLED lighting creates a new market position for exciting light surfaces</td>
<td>Japanese, Taiwanese, Korean and Chinese policies back domestic OLED champions</td>
<td>OLED lighting fails to take off in the face of LED lighting expansion and cost reduction.</td>
<td>OLED lighting remains a specialty show-piece for a few global brands</td>
</tr>
<tr>
<td><strong>Impact on profits</strong></td>
<td>Value destroyed in many markets. Chip/epi licensing and OLED materials retain value</td>
<td>Pockets of high value shift back and forth between two distinct value chains</td>
<td>Profit pools move in line with the impact of the regulation. Poor profits for most?</td>
<td>Prices fall everywhere and consumers benefit. Some Chinese firms win with scale.</td>
<td>Channel partners take the lion share of the value. Everyone else suffers.</td>
</tr>
<tr>
<td><strong>Winners</strong></td>
<td>LED: Equipment (medium term), chip/epi mfg + licensing income. OLED: materials</td>
<td>Philips, OSRAM, Nichia, UDC as IP players; LG, Samsung or Sharp play in LED and OLED</td>
<td>Materials and substrates and channel players in consolidated markets</td>
<td>Materials and substrates; equipment players in medium term</td>
<td>Acuity, Cree, Cooper, Panasonic, Philips, Zumbotel, etc</td>
</tr>
</tbody>
</table>

**Source:** Our outlook
In the “**Base Case**” scenario: LED lighting moves to the mainstream and current lighting incumbents share with leading LED players. OLED lighting is there but a niche technology comparatively.

### Base case

<table>
<thead>
<tr>
<th>LED outlook</th>
<th>LED penetration &gt;50% by 2020 in all segments (but lagging in offices)</th>
</tr>
</thead>
<tbody>
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#### Impact on players
- Chinese epi/chip companies integrate forward to challenge Cree, Nichia, Philips

#### Impact on profits
- Value destroyed in many markets. Chip/epi, licensing and OLED materials retain value

#### Winners
- LED: Equipment (medium term), chip/epi mfg + licensing income. OLED: materials.

- **Market**: Growth for both LED and OLED lighting. OLED lighting is niche.
- **Investments**: Investments around Asia LED foundries but some additional investments in other geographies (balanced outlook).
- **Players**: Chinese LED players and some of the Koreans push forward. Cree, TG and Nichia lose ground to more aggressive players. LG Chem, SMD, Japanese OLED consortia and Taiwan touch panel companies challenge the starting positions of GE, Moser Baer and OSRAM in OLED lighting. IP holders cash in in the medium term.

#### Themes
- Regulation drives consumers who are forced to upgrade.
- Market structures remain broadly in tact from today, though some Korean and Taiwanese firms rise up the ranks and make channel agreements.
- Efficiency gains for both LED and OLED light.
- Technology innovation but in the background.
- Slow migration of today’s sockets and architectures to new formats.

#### Prices
- Continue to decline at 15-20% per year.

#### Winners
- LG Chem, UDC, Panasonic Idemitsu, Veeco.

#### Losers
- GE, Moser Baer and Japanese LED players in general who lose out to Korean, Taiwanese and Chinese competition.

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Source: Our outlook
In the scenario 2 “Tech race”: Innovation in light lifts many boats and creates opportunities in many parts of the value chain. Only consumers pay suffer through regulation into new higher price lighting technologies.

<table>
<thead>
<tr>
<th>Tech race</th>
<th>LED</th>
<th>OLED lighting</th>
<th>Impact on players</th>
<th>Impact on profits</th>
<th>Winners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LED</td>
<td>OLED lighting</td>
<td>Market turmoil: new channels and disruptive products. Demand limits price erosion in places.</td>
<td>Pockets of high value shift back and forth between two distinct value chains</td>
<td>Philips, OSRAM, Nichia, UDC as IP players; LG, Samsung or Sharp play in LED and OLED</td>
</tr>
</tbody>
</table>

- Market: Market booms with new lighting offerings and the ability to create new occasions and new moods for lighting. Government legislation supports conversion to new technologies.
- Investments: Continue in MOCVD for LEDs but also in OLED fabs. OLED fabs are sheet fed leading to web-based fabs for OLED lighting later.
- Players: Players in all parts of the value chain make investments and are buoyed up by the overall growth in the market. Konica Minolta and Japanese/Taiwanese touch/colour filter players enter the OLED lighting market and battles among phosphorescent and fluorescent materials players intensify.
- New technologies appear for colour shifting (e.g. quantum dots), for heat management (LED) and outcoupling of OLED lighting. New architectures for smart lighting appear.
- Themes:
  - Creating light; Planar light through use of optical films and light conversion from point sources to planar
  - Experimentation with colour
  - New technology in all parts of the value chain
  - Smart lighting with new control approaches
- Winners: Materials and substrate companies are constant winners in all our scenarios. IP holders also do well in growth markets. Equipment companies do fine also. Konica Minolta, LG Chem and SMD may also do well in OLED lighting.
- Losers: Prices on the whole a little higher so consumers end up paying more.

Source: Our outlook
Scenario 3: “Regional Regulation” would lead to distinctly different markets in each geography with local players for each technology

<table>
<thead>
<tr>
<th>Regional Regulation</th>
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<tbody>
<tr>
<td><strong>LED</strong></td>
</tr>
<tr>
<td>Government policies drive localisation and divide value chains by geography</td>
</tr>
<tr>
<td><strong>OLED</strong></td>
</tr>
<tr>
<td>Japanese, Taiwanese, Korean and Chinese policies back domestic OLED champions</td>
</tr>
</tbody>
</table>

### Impact on players
- **Chanel players win in consolidated geographies. Materials suppliers may become localized**

### Impact on profits
- **Profit pools move in line with the impact of the regulation. Poor profits for most?**

### Winners
- **Materials and substrates and channel players in consolidated markets**

- **Market:** Develops differently in each geography with regional differences in market regulation driving more regional value chains
- **Investments:** Become heavily directed by regional and governmental policies and local product standards
- **Players:** Cree invests and builds up a strong position with Acuity and Hubbell in the USA, GE strengthens its USA business but loses in other geographies. Philips and OSRAM dominate Europe and Zumtobel plays number 3. Korean, Taiwanese, Japanese firms dominate their respective countries
- **OLED lighting** is important only in geographies with strong governmental support. Korea, China and Japan are potential examples based on regulatory behaviours we have seen in the past

### Themes:
- “USA consumers forced to adopt new energy saving light technology. California legislation drives higher efficiency lighting”
- **Buy local**

### Winners:
- Companies that are strong in their respective geographies. Some space for new companies to be important given today’s global market structure

### Losers:
- Consumers, and many of the players in the manufacturing chains. Global lighting companies will see their footprints shrunk back to strong regional positions and will lose some scale advantage as a result

Source: Our outlook
Scenario 4: “**Asian games**” represents a massive change to the status quo but a believable outcome (similar to PV) where massive oversupply drives collapse of all players not in China and we begin to see the emergence of Asian global brands.

<table>
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<th><strong>Asian Games</strong></th>
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<tbody>
<tr>
<td>LED</td>
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<tr>
<td>OLED</td>
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</tbody>
</table>

### Impact on players
- Chinese companies become B2C and B2B brands and displace today’s majors.

### Impact on profits
- Prices fall everywhere and consumers benefit. Some Chinese firms win with scale.

### Winners
- Materials and substrates; equipment players in medium term

### Market:
- Over investment by China in the LED value chain destroys value for the market place. Big winners are consumers. A number of Chinese firms have dominant scale and make some small economic value. OLED lighting fails to make it to scale.

### Investments:
- Chinese LED companies put in place huge investments in LED packaging supported by additional investments in chip capacity. As a result economics in all these sectors decline.

### Players:
- Companies like Lattice Power and Sanan Opto make massive investments, other Chinese players too and build global brands which begin to get traction through distributors in all markets.

### Themes:
- Lattice power, Seoul Semi (“Ariche”), Neo Neon are the hot new brands for LED lighting
- Light is cheaply and mass available

### Pricing:
- Collapses rapidly

### Winners and losers:
- MOCVD reactor makers win, consumers win, the few large Chinese firms win. Some IP owners will make returns but their businesses will become more about the IP streams than about the manufacturing that goes with it.

### Losers:
- Investors in the OLED lighting value chain, today’s global lighting majors. Western and Japanese LED companies

*Source: Our outlook*
Scenario 5: “**Brand values**” represents mass commoditisation of lighting componentry, chips, packages and OLED modules. Only lighting brands with strong channels win

<table>
<thead>
<tr>
<th>Brand Values</th>
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<tbody>
<tr>
<td>Massive investments in Asia commoditise lighting components. EU and US integrators have a field day.</td>
</tr>
<tr>
<td>OLED lighting remains a specialty show-piece for a few global brands.</td>
</tr>
</tbody>
</table>

### Impact on players

- **LED**: Chip/epi and packaging players lose value; channel players gain value.
- **OLED**: Channel partners take the lion share of the value. Everyone else suffers.

### Impact on profits

- Acuity, Cree, Cooper, Panasonic, Philips, Zumtobel, etc

### Impact on winners

- Market: Asian players make massive investments in LED capacity and OLED lighting as a result fails to achieve any scale and dies away. In this scenario though, local brand and channel companies reap the rewards of the low component pricing.
- Investments: Massive investments in LED Chip and packaging lead to radical fall in component cost.
- Players: Philips, OSRAM, GE, Acuity, Zumtobel and others reap the major rewards in this scenario.
- Themes:
  - Managing light systems is key competence
  - “All about the luminaire”
  - Adaptive light and new light uses
  - Specific channel knowledge including regulation critical
- Pricing: Component pricing collapses so only the companies with brand and channel make a decent return.
- Winners: Acuity brands, Philips, Zumtobel, Cooper, Hubbell. Some IP owners may also make returns but their businesses may become increasingly reliant on the IP moneys.
- Losers: Investors in the OLED lighting value chain, LED chip and package makers.

Source: Our outlook
Summary and implications:

- The lighting industry is about to experience massive change as it moves from incandescent and compact fluorescent to new forms of solid state lighting.

- The rules of the game and the key competencies needed to play are different: semiconductor prowess, understanding of capital and equipment deployment, phosphors, coatings and new digital architectures.
  - A replacement game becomes potentially a PC-like platform game where consumers need to be convinced every few years of the new need to upgrade.

- At this early stage, being definitive about the outcome is difficult. We believe that scenario analysis is a very powerful tool in talking about the future.
  - Companies can then seek to look at their strategy decisions in each case.

- Throughout this thinking the parallels with the PC, photovoltaic and display industries are inferred: we believe it is important for lighting companies to learn lessons from high technology behaviours in other similar markets.
Our services:

<table>
<thead>
<tr>
<th>Growth strategy</th>
<th>Performance improvement</th>
<th>Equipment and Capex</th>
<th>Sourcing strategy (Purchasing)</th>
</tr>
</thead>
</table>
| • Market entry strategy  
  • Business unit strategy  
  • Growth strategies for new technologies | • Product portfolio management  
  • Cost reduction  
  • Price strategies | • LCD/OLED factory capex decisions  
  • Investment decisions for new technologies  
  • Strategies for equipment makers | • Sourcing strategies, especially LCD and medical detectors  
  • Make/buy decisions |
| Technology strategy and technology assessment | Partnering and alliances | Professional advisory and business planning | Strategies for materials providers |
| • Market and commercial strategies for new technology businesses  
  • Market tracking services for corporates monitoring technology | • M&A candidates and assessments  
  • Alliance formation support  
  • Post merger integration planning | • Specialist insights for bankers, equity investors and other consultancies  
  • Reviews of business plans and models | • Strategy support for materials providers in the FPD, SSL, and PV markets  
  • IP and pricing plans |

Recent projects in AMOLED equipment and IGZO processes