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2014 Update on the Status of LED market

Georges Zissis
Paolo Bertoldi

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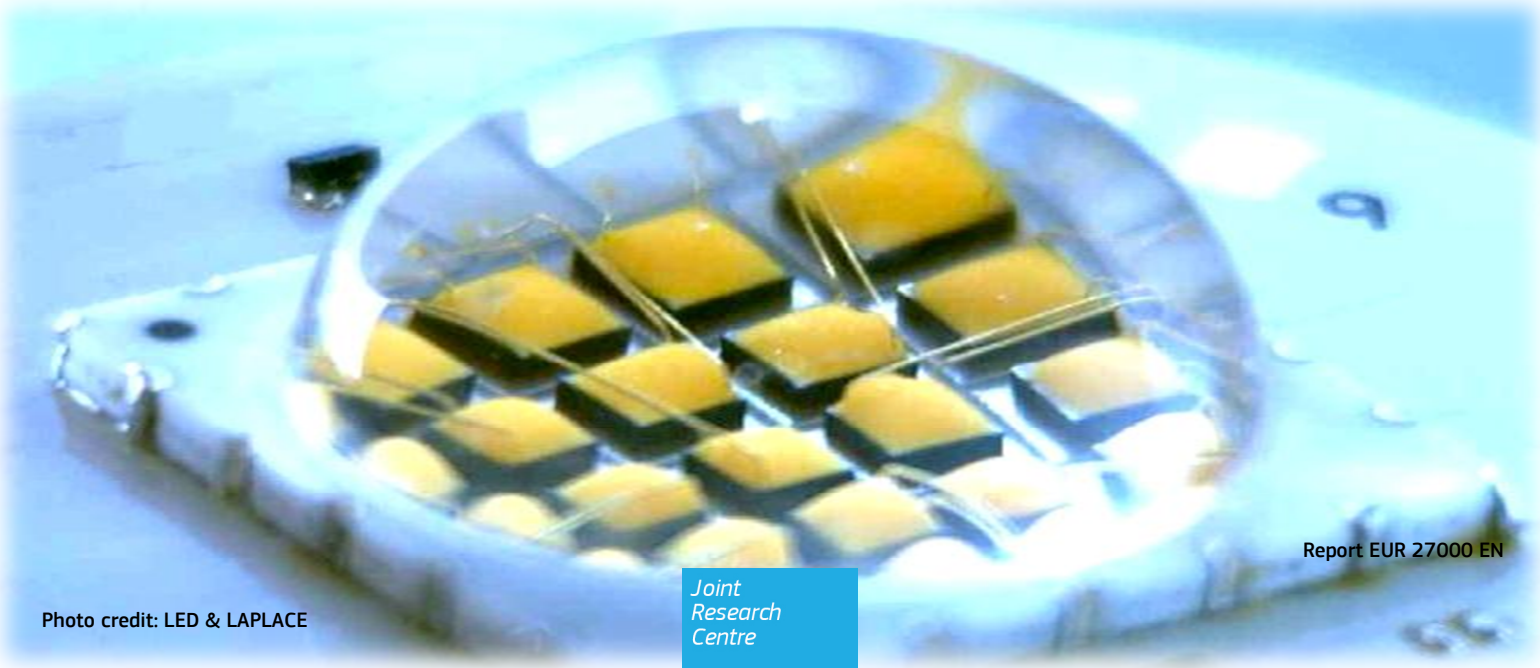

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Abstract

Light-emitting diodes (LEDs), a type of solid-state lighting (SSL), are revolutionizing the lighting market.
In just the last few years, LED performance has accelerated quickly and a wave of new commercial, industrial and institutional LED fixtures has been introduced. LED technology is fulfilling its promise of offering the market the most efficient means of converting electrons into photons.. The present report contains information on the latest technological developments concerning LED lighting. The report covers also in details the latest development in the LED markets in Europe and other key countries.

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Light-emitting diodes (LEDs), a type of solid-state lighting (SSL), are revolutionizing the lighting market.
In just the last few years, LED performance has accelerated quickly and a wave of new commercial, industrial and institutional LED fixtures has been introduced. LED technology is fulfilling its promise of offering the market the most efficient means of converting electrons into photons. LEDs have thus surpassed many conventional lighting technologies in terms of energy efficiency, lifetime, versatility, and colour quality, and due to their increasing cost competitiveness are beginning to successfully compete in a variety of lighting applications. Therefore, LED lighting is no longer "around the corner" it is here and has a solid market foothold. Performance is improving and costs are coming down. Today, high-performance products offer added value beyond efficacy. However, as any new or emerging technology, SSL products should be proven to be at least as safe as the products they intend to replace. Also, in new lighting applications where older technologies could not be employed, the safety of SSL products should be assessed considering new or unusual conditions of usage.
Major governments and corporations are important drivers for the early LED market, but there is great variation between lighting managers' levels of awareness: from recognizing energy saving as an issue; being alert to the current state of LED technology; and to understanding how to proceed in procuring well-designed LED solutions. With LED technology changing so rapidly, keeping up to date can be challenging [LCR-12].

Recent LED technological achievements and targets

Since 2000, light emitting diode performances increased to an almost exponential way and cost of packaged LEDs dropped rapidly within the same period. Figure 1 from T. Morrow's talk shows that evolution [MOR-12]. The question is where are the limits?

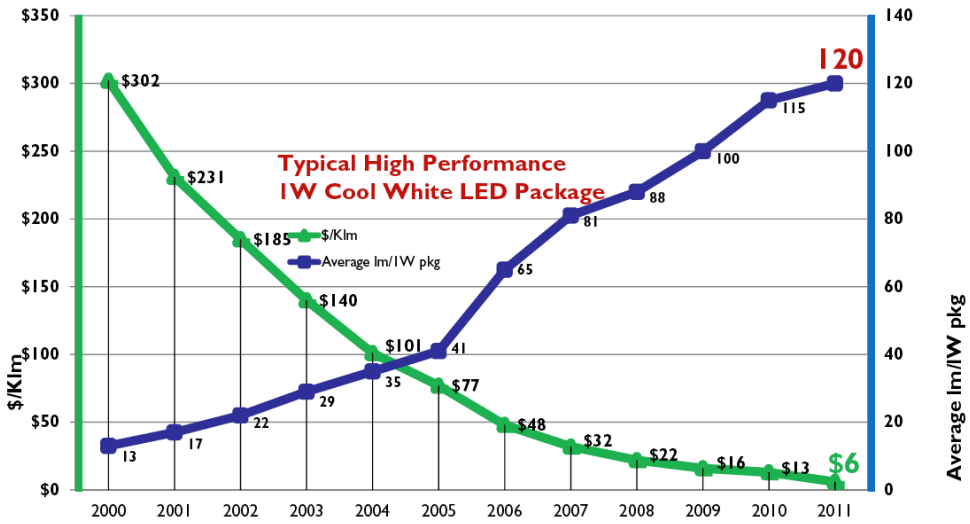


Figure 1: Evolution of LED performance and cost [MOR-12]

To answer that question, a starting point is the theoretical maximum efficacies of an SSL product given perfect conversion of electricity to light. This ideal performance is characterized by the luminous efficacy of radiation (LER), which is the amount of light, measured in lumens, obtained from a given spectrum per watt. Simulation work by

Yoshi Ohno and Wendy Davis at the National Institute of Standards and Technology (NIST) has shown that LED emission spectra with good colour quality and LER values in the range of 350 to 450 lm/$W_{optical}$ can be achieved [OHN-05]. The NIST model shows that this LER depends strongly on the Correlated Colour Temperature (CCT) and the Colour Rendering Index (CRI) of the light source. Both are critical for the quality of the light. The table T1 bellow indicates the maximal luminous efficacy of radiation as function of these two critical parameters.

Table T1: Maximal luminous efficacy of radiation for LEDs as function of CCT and CRI [MPP-13]

CCT (K)	Maximum LER (lm/W)		
	CRI 70	CRI 85	CRI 90
5000	380	365	356
3800	407	389	379
2700	428	407	394

In 2010, LED efficacy exceeded 200 lm/W in the laboratory, and leading researchers projected a future efficacy of between 250 to 280 lm/W [IEE-10]. At the device-level, these prototype laboratory LEDs have more than double the efficacy of LEDs being used in lamps today. Furthermore, white-light LED packages operating in excess of 200 lm/W are starting to become commercially available [CRE-12].
On the research side, a variety of techniques are being pursued to raise the efficacy of LED luminaires toward achievable levels of 200 lm/W [HAS-13]. Examples are:

- Improvements in epitaxial growth to enable more precise control of the P and N type materials to improve efficiency and colour consistency;
- Use of mixed red, green, and amber LEDs along with blue to produce white light without phosphors;
- Good phosphors are critical to ensuring that consistent, quality white light is available for general illumination Luminescent ceramic converter, an alternative embodiment of phosphors with improved conversion efficiency;
- Optical improvements to increase the fraction of the light emitted by the source that is emitted by the LED device. Packaged light extraction is currently at 80% efficiency and we believe another 15% can be achieved through roughening, high-reflectors, exotic structures and shapes, photonic crystals, and other extraction efficiency structures.
- Efficiency droop – LED internal quantum efficiency declines as current increases[1], or, in other words, LEDs tend to be most efficient when operating at low-currents. The cause of this reduction in efficiency is not yet fully understood but is believed to be caused primarily by Auger recombination and Shockley–Read–Hall or other non-radiative recombination and defects.
- Thermal droop – heat in the LED chip also causes a reduction in efficacy. When LEDs are operating in a fixture, the junction temperature can get very hot - 120°C – and the efficiency can drop by 20 or 30%. More research is needed to fully understand this phenomenon, but it is believed that part of this problem is caused by Auger recombination. Researchers have

[1] Tests have shown that the efficiencies can drop from 150 lm/W to as low as 70 lm/W at higher current densities

found that some of the negative impact can be mitigated through good thermal management in the chip packaging.

- LED ballast[2] technologies, there are very rapidly improving and efficacies are increasing. Thus, the best DC-drivers for LED lamps are 92 to 93% efficient. Researchers are working on a new set of drivers, and several companies are working on "driverless" lamps that are directly driven by AC. Experts estimate AC-driver efficiencies upward of 98% or higher can be achieved.

However, when LEDs are integrated in luminaries and lamps the overall luminous efficacy is dropping. The table T2 bellow shows the baseline for luminous efficacy achieved in2013 by different lighting technologies as given in [MPP-13].

Table T2: SSL performance compared to other lighting technologies

Product Type	Luminous Efficacy (lm/W)	CCT (K)	L_{70} (hours)
LED A19 Lamp (Warm-White)[1]	94	2700	30,000
LED PAR38 Lamp (Warm-White)[2]	78	3000	50,000
LED Troffer 1' x 4' (Warm-White)[3]	118	3500	75,000
LED High/Low-Bay Fixture (Warm-White)[4]	119	3500	75,000
OLED Luminaire[5]	52	3500	15,000
HID (High Watt) System[6]	115	3100	15,000
Linear Fluorescent System[6]	108	4100	25,000
HID (Low Watt) System[6]	104	3000	15,000
CFL	73	2700	12,000
Halogen	20	2750	8,400
Incandescent	15	2760	1,000

Notes:
1. Based on Philips' L Prize winning A19 lamp.
2. Based on Lighting Facts data label for Cree LRP38-10L-30K lamp.
3. Based on Lighting Facts data label for Cree CS14-40LHE-35K luminaire.
4. Based on Lighting Facts data label for Cree CS18-80LHE-35K luminaire.
5. Based on Acuity Brands luminaires.
6. Includes ballast losses.

The US DoE estimated that the average overall LED lighting system efficacy for warm white will reach by 2030 203 lm/W. The table T3 shows the DoE Multiyear Programme Plan (MYPP) projections given in 2012.

Table T3: DoE projections for overall LED warm-white lighting system luminous efficacy [MPP-12]

Year	2010	2015	2020	2025	2030
Overall luminous efficacy (lm/W)	50	120	180	195	203

Through research on these and other aspects of LED technology, improvement is occurring at a rapid pace, as shown in the figure 2 below. This diagram is taken from the US Department of Energy's MYPP for Solid-State Lighting, 2012 [MPP-12] The focus of DOE's report is on LEDs for general illumination, and this diagram shows the commercially available products as well as laboratory prototypes, and the projection for energy performance improvement in the coming years.

[2] CIE vocabulary advice to use rather "ballast" than "driver"

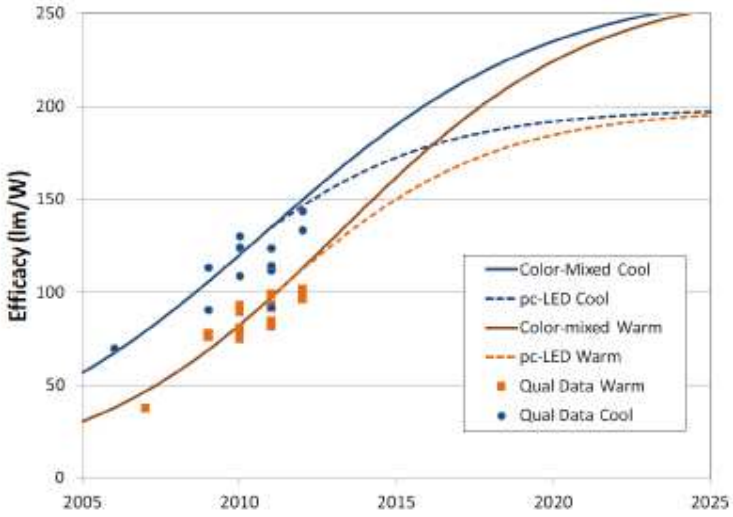


Figure 2: White Light LED Package Efficacy Projections for Commercial Products from [MPP-12]

Today the large majority of High-Brightness white LEDs (HN-LED) are using the principle of phosphor down conversion to generate white light. This type of LED called here "pc-LED" dominates the lighting market. It is possible obtain white light by colour mixing. This technology, called in this report "cm-LED", is today rather used for dynamic lighting systems than for general lighting due to CRI issues. However, assume a red, green, blue, amber (RGBA) configuration with each LED having a moderate full width at half maximum emission spectrum of approximately 20 nm. Under these conditions, the analysis suggests that warm-white cm-LEDs could have higher efficacies than cooler ones. Future white LEDs for lighting might use cm-LED technology and in that case as shown in the above figure the package efficacy could reach 250 lm/W value when pc-LED is limited to 200 lm/W.

Beyond projections, at the component level, in March 2013, CREE announced that the white LED light efficiency reach a highest record in the industry, testing on conditions of colour temperature of 4 401 K and 350 mA drive current, the observational LED luminous efficiency is 276 lm/W [CRE-13a].

Furthermore, in April 2013, Royal Philips Electronics NV has announced it has produced the most energy efficient LED tube (TLED) suitable for general lighting reaching 200 lm/W. The 200lm/W TLED lamp is expected to be available on the market in 2015 for office and industry applications before being offered for domestic use. [EET-13]

Lighting market update

The lighting usually industry sector includes lamps, luminaires and lighting controls. The global lighting market is benefiting from a "Perfect Storm" of solid-state technology development, high-energy prices, economic turmoil and social factors coinciding. The market for luminaires, lamps and lighting controls is forecast to reach US$ 108 billion in 2016 as consumers and industry increasingly pay more up-front for efficient, controllable lighting solutions (Figure 3). This market expansion will be largely driven by growth in demand for LEDs as their prices decline.

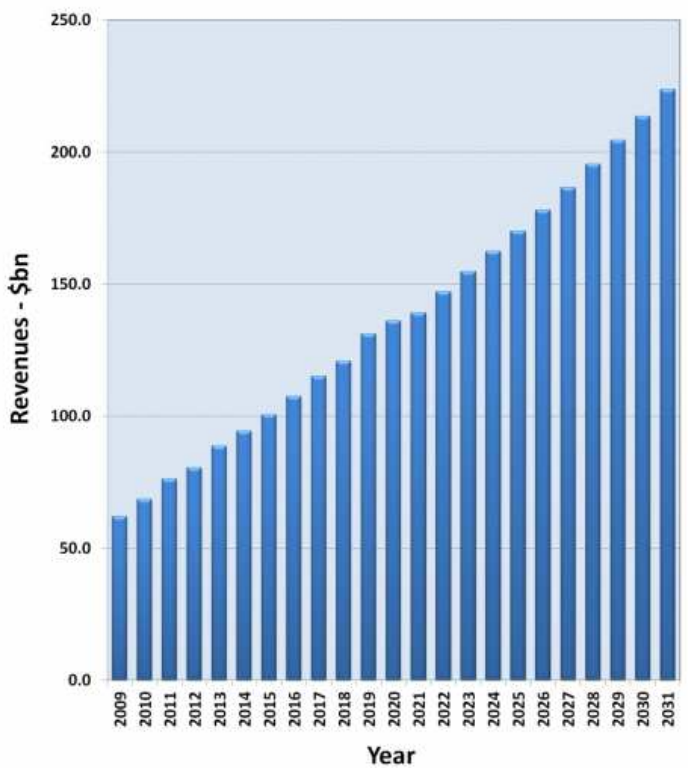
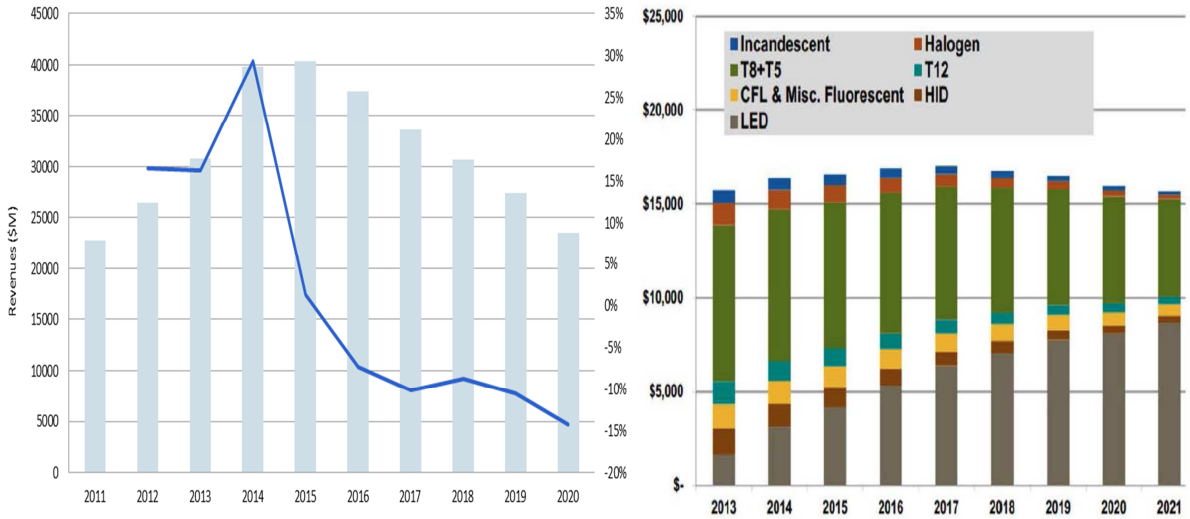


Figure 3: World Lighting market (luminaires, lamps and lighting controls) forecast [DAT-12]

In more details, the world lamp market is forecast to grow with 15% CAGR through 2015. Figure 4a shows that, from approximately US$ 23 billion in 2011 peaking at US$ 41 billion in 2015 is projected to fall steadily to around US$ 24 billion in 2020 [TAO-12]. This market saturation and decline is also reported by N. Bardsley (based on Navigant study) [BAR-13]. Figure 4b, shows this saturation and decline for different lamp technologies. It should be noticed here, that even if between the two studies, the tendencies are similar the absolute values are rather different (there is a factor of 2 between the two studies). Values reported by Bardsley seem to be more reasonable.



(a) (b)

Figure 4: (a) World lamp market revenue for lamps (all technologies) and CAGR (solid line) forecasts [TAO-12] (b) lamp market size by technology [BAR-13]

As shown in Figure 5, in 2011 for residential sector, incandescent lamps made up 65% of shipments, by 2020; this number is expected to decrease to 20% in 2020. Due to price sensitivity in less developed regions CFL shipments will begin leading in 2015 with 43% of all shipments, by 2019 LEDs will lead with shipments with 35%. Globally, it is forecasted that LED lighting will represent over 75% of all lighting sales by 2030 [TAO-12].

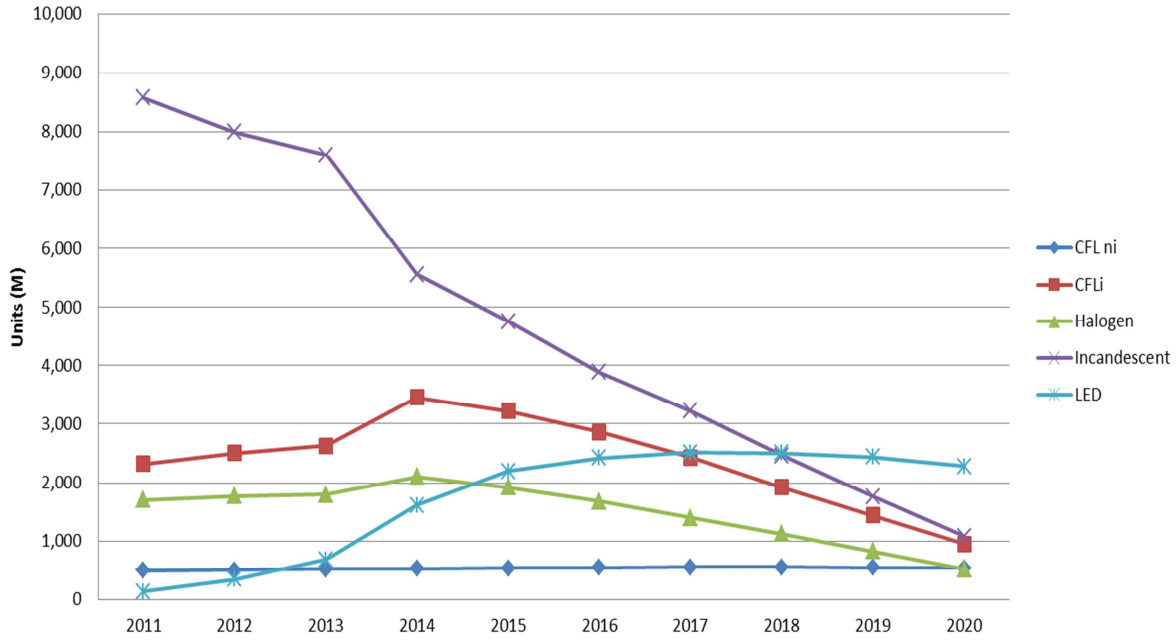


Figure 5: Lamp shipments forecast split by technology [TAO-12] in million units (Residential sector).

Europe is a world leader in the field of lighting, including in Solid State Lighting, having a share of 30% of the global market. In Europe, with 14 major lighting companies and several SMEs, the sector is driven by high innovation potential, accounts for an estimated €17-20 billion turnover, and represents over 150 000 jobs. The European lighting industry is highly fragmented and made up of a few large companies (global players), many 'mid-sized' ones, and thousands of SMEs. The lighting industry in Europe is and always has been a sector that is SME driven when it comes to the production of luminaires and of high value products. This SME culture within the industry is the most crucial precondition to provide the market with highly decorative, innovative, and sustainable products [LIE-13].
In the only case of USA, following the report [GUE-12] during the last decade, the US$11,4 billion US-lighting market has grown slowly, with the overall market landscape remaining unchanged. General Electric, Philips and Sylvania continue to dominate the ballast and lamp component market, based on a standardized set of interchangeable products. Enterprise customers have come to understand an established set of lighting products, vendors and distributors and today consider most products as commodities. China lighting industry has maintained a rapid, sustainable and steady development trend for more than ten years. Today, china is the largest lighting production country in the world. According, CALI there are over 10 000 lighting manufacturers in China. These manufactures are mainly distributed in China's southeastern coastal areas, including Guangdong, Fujian, Jiangsu, Zhejiang and Shanghai. Folowing Y.Yansheng (CALI), the sales volume of lighting products was US$ 55,6 billion in 2011. The export volume of

lighting products from China was US$ 22,34 billion, which set an historical record[3]. The lighting products made in China have been exported to over 200 countries. CFL and Christmas lights have occupied 80% of the global market. Export of luminaires has occupied 30% of the global luminaires trade market in 2011 [YAN-12].

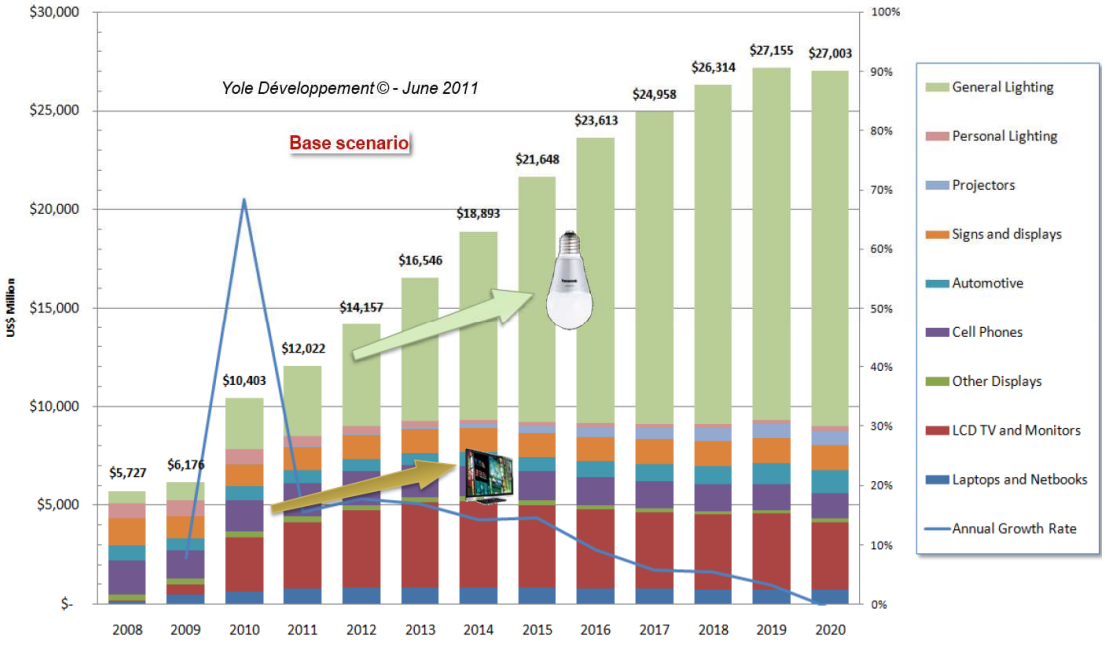
LED industry market update

The base scenario elaborated by YOLE Development, presented by J.Perkins in ECTC-12, for packaged LED industry revenue growth though 2020 predicts US $14,2 billion revenue for the full sector [PER-12] for 2012. Furthermore, E.Shum, director of the LED practice at Strategies Unlimited, reported also in [SHU-12] that the global market for packaged LEDs in 2012-totalled US$ 13,7 billion[4]. In an IMS Research study related by T.Morrow [MOR-12] the revenue for 2012 is estimated at US$ 10 billion, but only GaN type packaged LEDs are taken into account. All the above figures are in good agreement. Assuming that Packaged LEDs revenue in 2012 was US$ 14 billion this represents 4,6 % of the global revenue of semiconductor industry [MRG-12].[5]
Following YOLE, the CAGR of the sector is estimated at around 17% in 2012 and is decreasing due to the fact that past major LED targets are clearly saturated (figure 1). This is coherent with PY.Lesaicherre's (CEO Lumileds) talk relating in 2012 a 15% CAGR for the sector trough 2016 [LES-12]. As can be seen also in figure 6a [PER-12], lighting will be the only growing market segment and will drive the full sector from 2012-13. In fact, for the first time in 2012, general lighting became the largest market for packaged LEDs globally at US$ 3,1 billions [SHU-12] and in 2013 LED-General Lighting segment will represent 39% of the sector's revenue (Figure 6b) [YOL-13]. According PY. Lesaicherre (CEO Lumileds) for the period 2012-15 high power LEDs represents 67% of the global packaged LED market size [LES-12]. Furthermore, Strategies Unlimited segments the market six ways with 2012 sales broken down by SSL at 23%, backlights for TVs and monitors at 22%, mobile at 19%, signage at 13%, automotive at 10%, and other at 13% (see Figure 7).

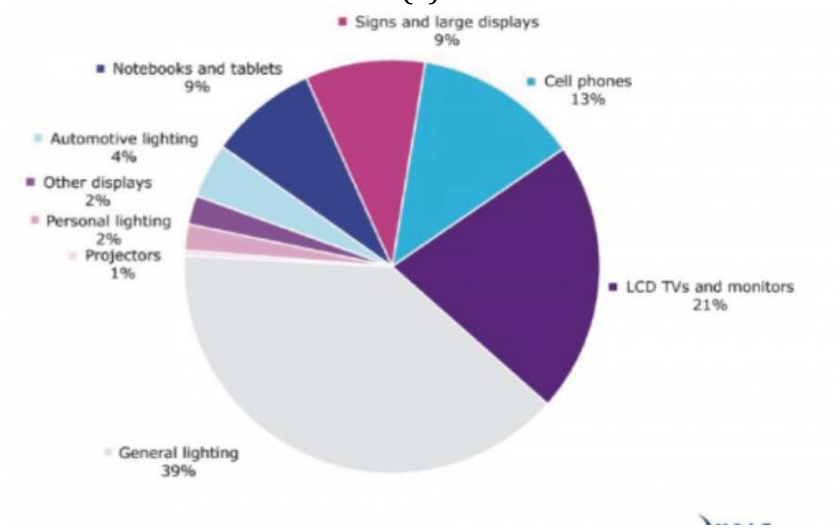
[3] At the same year (2011) the Chinese import volume of lighting products reached US$ 2,94 billion

[4] The number does not include the sale of bare die or modular lighting products but solely package LEDs whether the product in question is a single-emitter LED or a chip-on-board (COB) LED array

[5] Global revenue of semiconductor industry US$ 305 billion in 2012 [SIA-11]



(a)



(b)

Figure 6: (a) Packaged LED revenue forecast (bars) for major market segments and the CAGR of the global sector (solid line) [PER-12] (b) Packaged LED revenue split in 2013 [YOL-13]

The lighting segment experienced tremendous growth from just over US$1,5 billion in 2011. There was moderate growth or declines in the other segments that are largely are fully saturated at this point. More especially a recent market slowdown due to weaker demand for LCD panels and less LEDs per panel occurred. Following R. Chu from LEDInside, this decline may amplify during the next years. This is especially true for backlighting applications; the CAGR is expected to be in the order of -9,5% for the period from 2012 to 2016 [CHU-12].

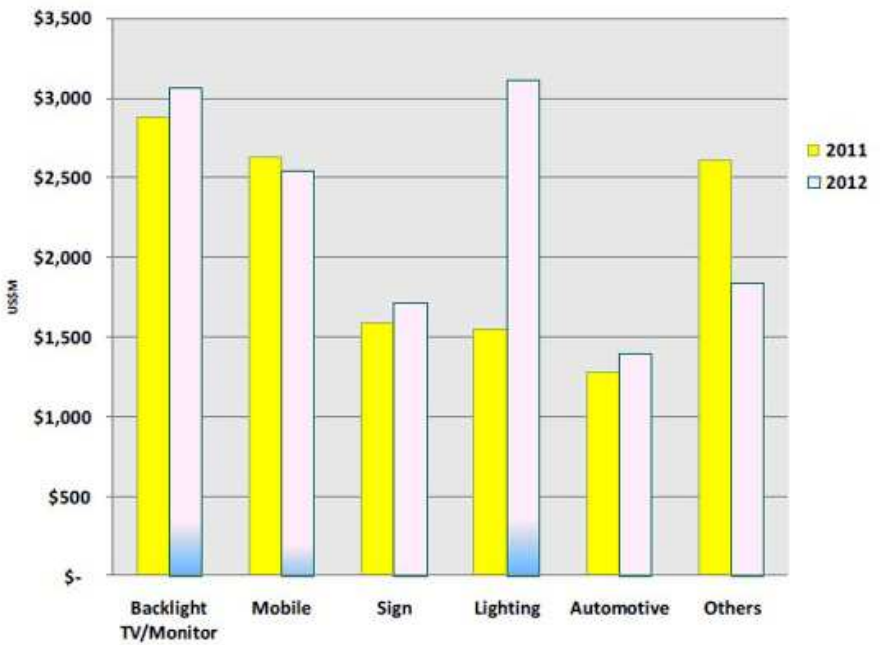


Figure 7: Packaged-LED sector revenue (in US$ million) variation from 2011 to 2012 split among 6 segments as identified by Strategies Unlimited [SHU-12]

Furthermore, E. Shum (Strategies Unlimited) estimates that the packaged LED market will grow to US$15 billion by 2017 with SSL being the largest driver. That reflects a CAGR of 1,8% which is coherent with YOLE predictions [PER-12]. Looking closer to the packaged LED lighting segment, figure 8 from PY. Lesaicherre's talk, according to Strategies Unlimited data, illustrates the revenue shares of High, Medium and Low Power packaged LEDs for the only lighting market [LES-12].

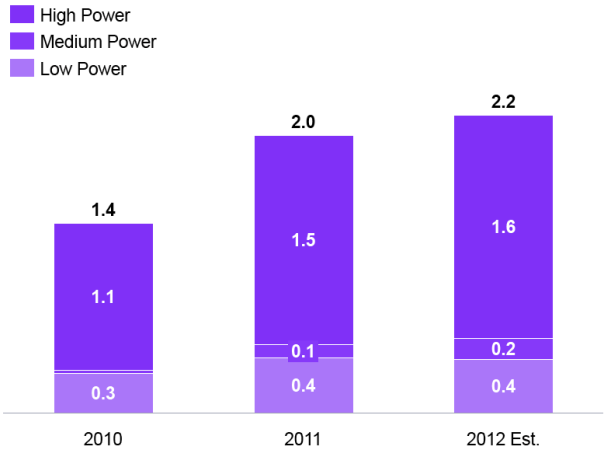


Figure 8: Share in Lighting of Packaged LEDs split among High, medium and low power chipsets (in Billion US$) [SHU-12]

Following PY. Lesaicherre [LES-12] presentation based on Strategies in Light Study 67% of packaged LED are HB-LEDs and 33% are medium power chips (Figure 9), and it is underlined that the packaged LED domain shows 15% CAGR in the period 2010-15.

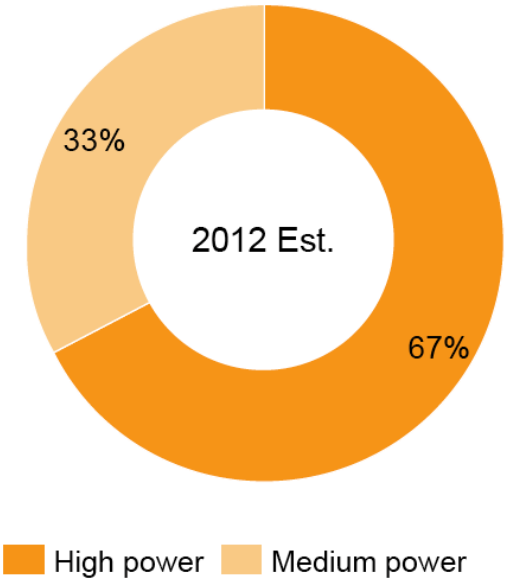
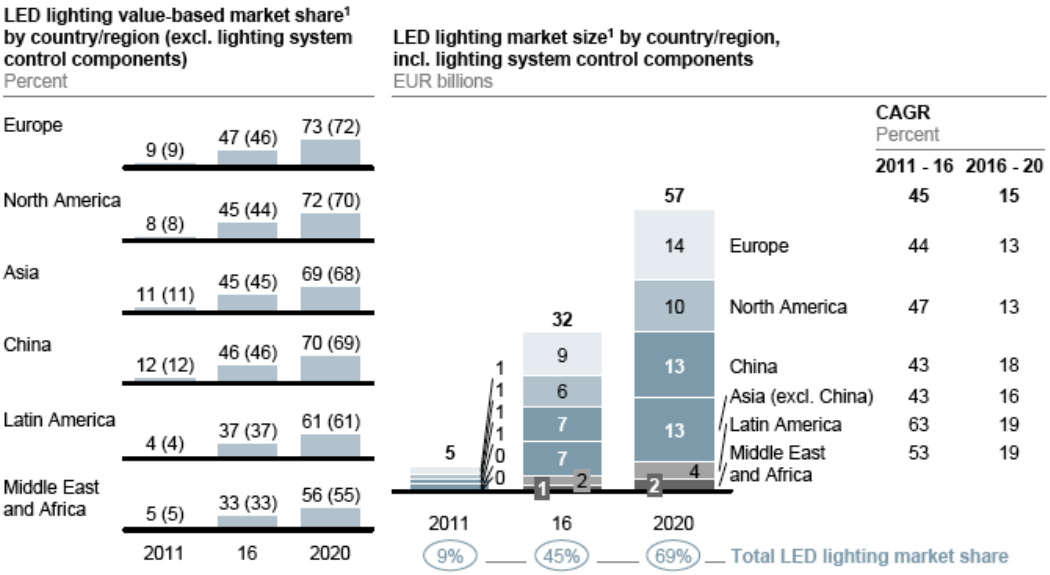


Figure 9: Parts of medium power and HB-LEDs in packaged LED market [LES-12]

Following McKinsey [MCK-12] Asia is an early adopter of LED, and leads the global LED general lighting market (Figure 10) but Europe is rapidly growing.



1 Total general lighting market: new fixture installations incl. full value chain, incl. lighting system control components and light source replacements
NOTE: Numbers may not add up due to rounding

Figure 10: Parts of medium power and HB-LEDs in packaged LED market [LES-12]

LED industry landscape updates

The worldwide LED-chip production capacity has attained in 2010 2,33 million pieces of 4" processed wafers [SEM-11]. The following pie-chart in figure 11, from T.Morrow's talk shows the production capacity by world region [MOR-12].

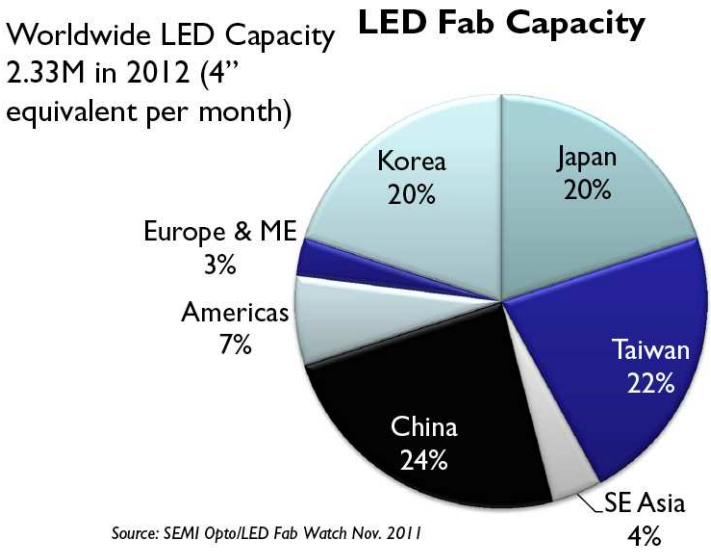


Figure 11: LED-chip production capacity breakdown among world regions (ME: middle-east, SE: south-east) [MOR-12]

However, it should be noticed that LED industry landscape is very rapidly moving. Figure 12, for SEMI, shows the evolution of the ecosystem of LED dedicated fabrics across the world [SEM-11]. It is clear that the barycentre is moving toward far-east region.

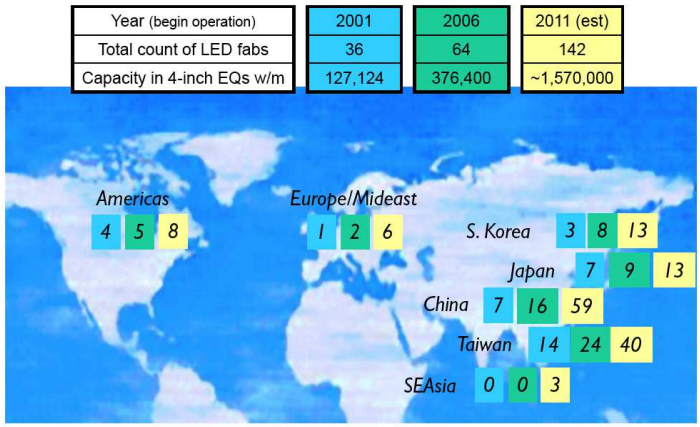


Figure 12: Landscape evolution of LED dedicated fabrics across the world [SEM-11]

Table T4a: 2012 ranking of LED suppliers with growth/decline rates [SHU-12]

Rank	Manufacturer	Country	2012 Growth/Decline
1	Nichia	Japan	5%
2	Samsung	South Korea	22%
3	Osram Opto	Germany	5%
4	LG Innotek	South Korea	-1%
5 tie	Seoul Semi	South Korea	14%
5 tie	Philips Lumileds	Netherlands/USA	21%
7	Cree	USA	18%
8	Toyoda Gosei	Japan	37%
9	Sharp	Japan	14%

10 tie	Everlight	Taiwan	-1%
10 tie	Lumens	South Korea	32%

Table T4b: 2014 ranking of LED suppliers by revenue [IHS-14]

Rank	Company Name	Company Headquarters
1	Nichia	Japan
2	Osram Opto	Germany
3	Samsung Electronics	South Korea
4	Seoul Semiconductor	South Korea
5	Lumileds	United States
6	Cree	United States
7	LG Innotek	South Korea
8	Everlight	Taiwan
9	Toyoda Gosei	Japan
10	MLS	China

LED chip manufacturing is by far the most capital intensive. Cree, for example plans to spend 30% of sales on capital expenditure in 2010. E. Shum (Strategies Unlimited) presented in SIL-12 a ranking of LED suppliers with growth/decline rates in 2012 that are summarized in Table T4a and table T4b shows the ranking by revenue published in two years later (2014). The companies cited there represent 72% of the packaged LED market.

Nichia (Japan) led the industry in 2011 with US$ 2 billion in LED revenues. Nichia grew its LEDs for lighting sales from 35% to 50% in 2011. Samsung LED, LG Innotek and Seoul Semiconductor of Korea were the number two, number four and number five suppliers, demonstrating strength in TV and monitor backlights, LEDs that were also used in lighting [BHA-12]. Samsung was a major mover as it increased its production of LEDs for use in Samsung consumer products such as TVs, and Korean company Lumens Co Ltd also enjoyed growth due to a close tie with Samsung according to Shum. Toyoda Gosei's growth came thanks to Apple mobile products. While Nichia and Toyoda Gosei were the major beneficiaries of the boom in the tablet market, CREE and Philips Lumileds were the most prominent beneficiaries of the ramp in general lighting [SHU-12]. CREE targets incrementally higher revenue and net income. For third quarter of fiscal 2013 ending March 31 The revenue target has been increased to a range of US$ 335 million to US$ 350 million. The GAAP net income target has been increased to a range of US$ 18 million to US$ 24 million and Non-GAAP net income target has been increased to a range of US$ 36 million to US$ 42 million. Operating expenses are targeted to be approximately US$ 2 million higher than previously announced, due to higher R&D and marketing costs to support the new product launch [CRE-13b].

Following New Street Research the historic lighting industry stakeholders have developed different strategies: [NSR-10]

Philips pushing into applications: According to PY. Lesaicherre (CEO Lumileds) 79% of the LEDs illumination market is shared between few players, Philips-Lumileds, is the 3rd largest stakeholder and covers by itself 14% of the market (when the 1st and 2nd players cover 29% and 25% respectively) [LES-12]. Having acquired numerous companies in the application/fixtures field, Philips has more flexibility on the upstream supply of light sources given a) the on-going fragmentation of this market and b) the attractive multiples of the peer group. Philips continually states the need to retain access to both

technology and supply of LEDs. Philips' lighting division achieved total sales of €8 442 million in 2012, with LEDs accounting for 34% of overall lighting sales in the final 2013 quarter [LIG-14a] However, sales for the full year in 2013 were slightly down in the Lighting division, to €8,413 million in 2013. More precisely, for the overall company, sales in all divisions grew in the Netherlands, China and marginally in Germany and the UK. They fell in the US, Japan and France [STE-14]. Releasing its Q4-2013 results, the Dutch manufacturing giant revealed that sales of LEDs for Q4 2013 were up 48% [LIG-14a]. With 28% of sales and around 35% of (normalised) EBIT from lighting, Philips has a lot more to lose or gain than Siemens for which lighting represents ~5% of sales and 6% of EBIT. In light of the high multiples now being paid by the market for pure play LED component businesses, we believe a sale/IPO of Lumileds and the focus on LED applications – where it holds a strong IPR portfolio - would enable Philips to benefit from the growth in LEDs without being exposed to increased pricing pressure on the capital intensive chip side. Proceeds could be invested in building a complementary wiring device/low voltage business. In fact, Royal Philips NV said Monday June 30th 2014 it plans to spin off its fast-growing LED parts business into a separate company, to win new customers and to capitalize as manufacturers integrate LED lights into an ever-widening array of products [STE-14]. The announcement told that it has started the process to combine Lumileds components and automotive lighting businesses (Philips' LED parts business, which is a major supplier to carmakers, had sales of $1,91 billion in 2013) into a separate company [LIG-14b].

Siemens sitting on the fence: Having decided not to integrate Osram into Building Technologies, the company is trying to find the sweet spot in the new lighting market before committing to large strategic moves, such as the sale of the business or the entry into the luminaire market. Siemens is in the process of trying to gauge where the lighting market is heading. Initial proposals to sell the business were rejected and synergies between lighting and Building Technologies were deemed insufficient to justify a merger of the two. At the same time, management is unwilling to follow Philips' move into LED applications (e.g. by acquiring Zumtobel). New Street Research believe that Siemens can do without lighting and should be using the current 'growth and higher margin phase' to sell the business (valued at €5 billion). Siemens is further advanced in reducing its legacy business exposure, especially in mature markets, and offers potential future owners a growth story in LEDs.

General Electric now committed to lighting: Having failed to find a buyer for its lighting business, probably because the restructuring and potential environmental costs linked to the incandescent business could not be offset by growth opportunities. GE is now looking to catch up in the LED business and remains on the lookout for partners.

Patents/intellectual property rights

Patents and Intellectual property are widely used by the LED lighting industry in order to secure market shares. The following part based on New Street Research [NSR-10] tries to extract the large picture of the LED lighting industry landscape. The patent situation for LED chips, components and applications is very complex and there are a growing number of cross-licensing agreements.

- Siemens/Osram holds important IPRs together with Nichia, licensed it to others, e.g. Cree. Nichia has the license for blue light for GaN LEDs whereas Siemens/Osram holds the license for the coatings to transform blue into white light.
- Osram claims to have the best IPR portfolio for high energy white LEDs.
- Cree holds 516 US patents with expiration dates extending to 2027.

- In 2008, Osram acquired special rights from Philips (Color Kinetics and TIR Systems) in return for granting some patents to Philips.
- Philips claim to hold 70% of all patents on LED applications (>225 patent families, >450 issued patents, 770 patents pending). Philips is licensing basic technology (LED control, Cosmopolis lamp, AlInGaP LED technology) in order to grow the market, but is retaining the differentiating technologies in house. Philips is charging royalties of 3% for single colour luminaires, 4% for tuneable white luminaires and 5% for colour luminaires based on net revenues. Royalties on LED retrofit bulbs amount to 5% with a minimum of €0.25 per unit. No royalties are due if all LED light engine modules, all LED drivers and all components for lighting control are sourced from a qualified supplier (Philips, Zumtobel and Osram).
- As highlighted by Zumtobel, it is almost impossible to develop systems in the LED application field without infringing on Philips patents.

LED-Lighting market update

This section of the report is devoted to the compilation of economical data concerning the LED-lighting market since 2011. In 2000 LED-Lighting represented just 0,6% of sector revenues. In April 2010, J.Anderson (Philips Color Kinetics) predicted that LED-lighting systems income will represent more than 75% of the sector revenue, Figure 13 shows Andreson's forecast [AND-10].

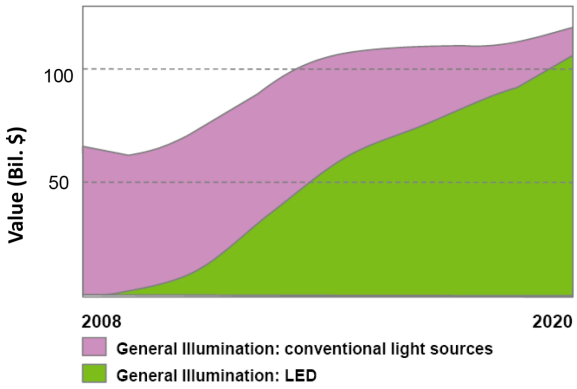


Figure 13: Revenues of Lighting Industry forecast split between LED and Classic Lighting technologies [AND-10]

Solid State lighting market almost doubled from 2010 (US $5,5 billion) to 2011 (US $9,4 billion) [BRO-12]. Furthermore, according to E.Shum, director of the LED practice at Strategies Unlimited, global solid-state lighting (SSL) revenue grew from US $9,4 billion in 2011 to US$ 11,8 billion in 2012, including replacement lamps and luminaires [SHU-12].

However, the quick adoption rate of LEDs in certain applications, in conjunction with their long life, will have a profound effect on the global lamp market in the medium term. As more and more sockets are filled with LEDs the market for replacement lamps will decrease (see discussion in paragraph on Lighting Market). This, in conjunction with the year-on-year decrease in prices for LED lamps, will lead to market growth slowing in 2015 and decreasing in 2016. By 2020, it is forecasted that LED lamps will make up 66% of the market, and the market will be shrinking [TAO-12]. The same conclusion is drawn in 2014 by M. Rosina (Yole), as shown in Figure 14 [ROS-14].

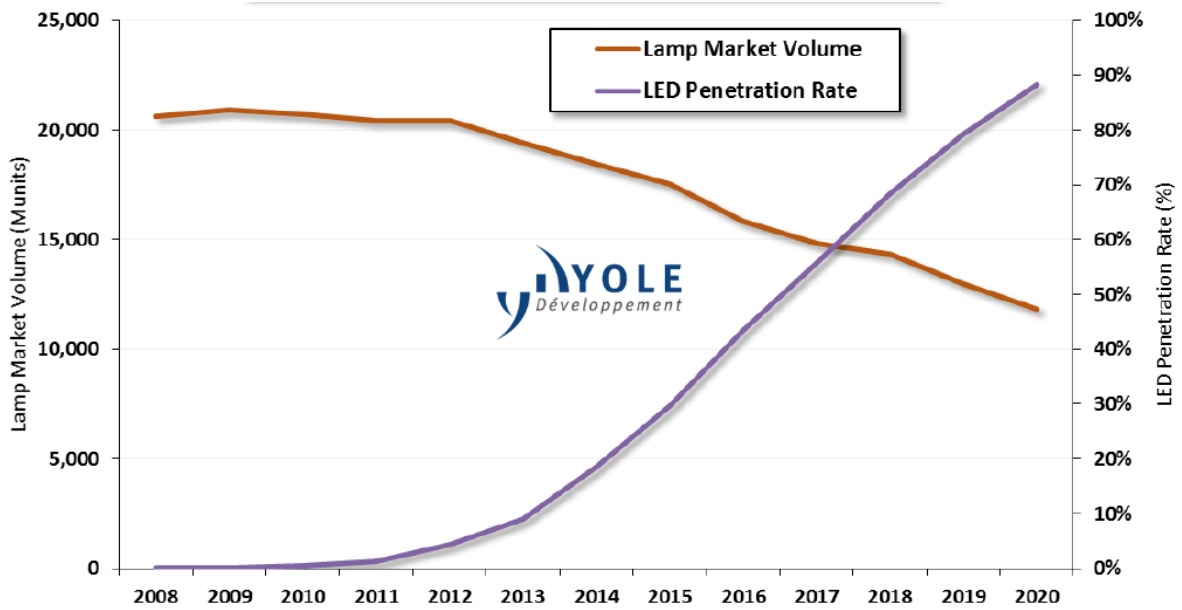


Figure 14: Volume of Lamp market and LED penetration rate [ROS-14]

Figure 15, extracted J.Brodrick's (DoE) talk at DLC Stakeholder Meeting 2012, shows the split of 2011-LED-Lighting revenue among usual application segments [BRO-12].

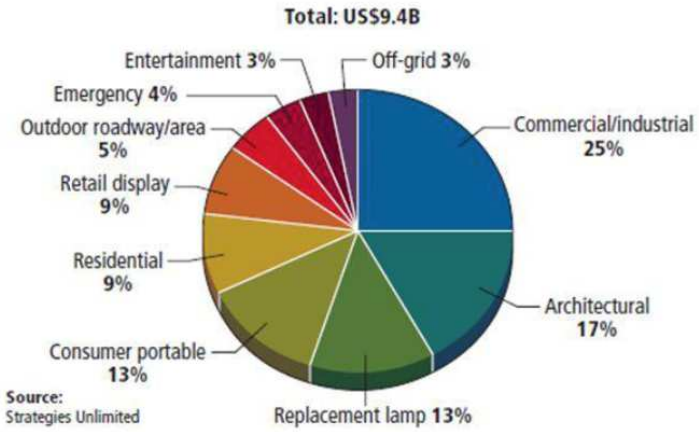


Figure 15: LED-Lighting industry revenue (2011 values) split among usual application segments [BRO-12]

It can be seen that Commercial and Industrial lighting sector accounted 25% of the total SSL market in 2011. In this segment, the revenues are forecast to grow to US$ 1,2 billion in 2016, following a CAGR of 13% [BHA-12].
Retrofit lamps are only 13% of SSL revenue in 2011, but units sold are way up due to drastic price declines [BHA-12]. M. Wright, Editor of LEDs Magazine, relates [WRI-13], following V. Bhandarkar's talk in SIL-12, that in the SSL market, replacement lamp revenue grew from US$ 2,1 billion in 2011 to US$ 2,58 billion in 2012. The largest jump came in Japan where energy concerns caused by the earthquake and tsunami that occurred in 2011 knocking out major energy-generation facilities.
Outdoor area lighting includes all street and area lighting as well as parking lot lights. While this sector is growing quickly, manufacturers are able to reduce the total LED count required per street lamp with each new generation, which dampens overall growth of revenues for LED components [BHA-12].

While outdoor area, retail display and commercial/industrial LED lighting will experience good growth; segments such as consumer portable and emergency lighting have reached market saturation (Figure 16). Continued moderate growth is anticipated in the residential, architectural lighting and entertainment lighting segments. Replacement lamps will need to reach acceptable price points for the consumer and dimming compatibility issues must be resolved.

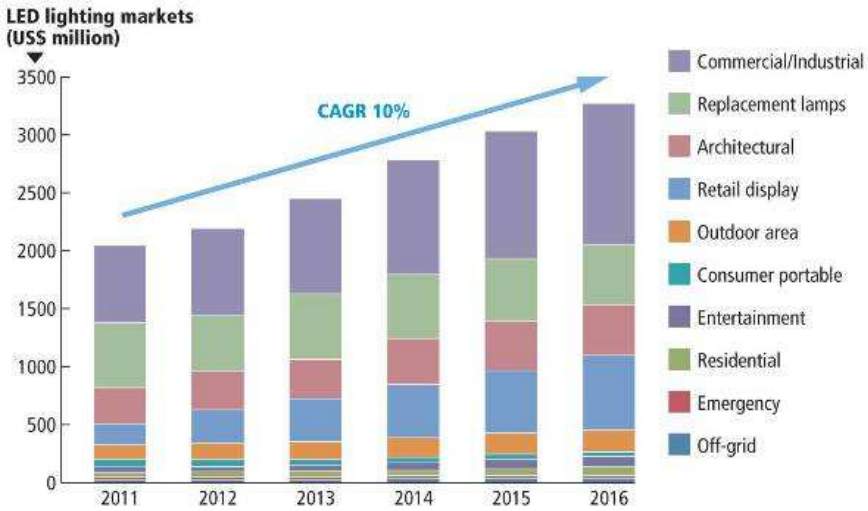


Figure 16: Forecast for LED-Lighting market segments evolution till 2016 [BHA-12]

As by 2030 it s expected that still 1,3 billion people will live in non-electrified areas, off-grid lighting segment is also important for SSLs. In this segment, as reported by Bardsley (based on IFC Lighting Africa study), over the next 20 years, Africa needs will surpass all other world-regions [BAR-13].

Milan Rosina from YOLE reported in 2013 [ROS-14] that LED lamps represented 9% of the lamp market volume and forecasted that in 2020 this share will reach 88%. Figure 17 shows the lamp market split among the different technologies in 2013 and 2020.

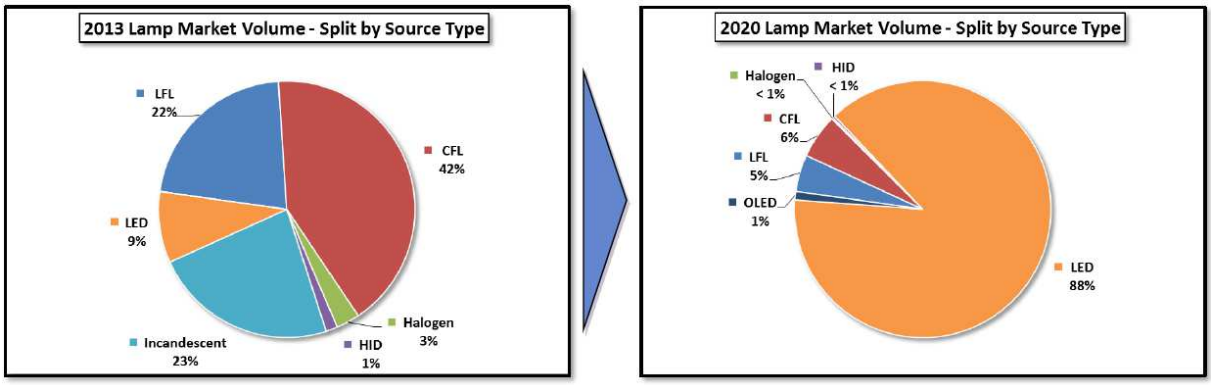


Figure 17: Lamp market volume split by technology (current – 2013 and forecast – 2020) [ROS-14]

In the luminaire sector, revenue grew from US$ 7,2 billion in 2011 to US$ 9,2 billion in 2012. The commercial market segment, representing 23% of the global lighting market, is leading the adoption of SSL. Growth in luminaires is fairly consistent across the globe. For the first time, Bhandarkar also reported on other lighting market segments that include products such as flexible strings, furniture lighting, airplane lighting, toys and others that totalled US$ 2,75 billon bring the overall market total to US$ 14,5 billion.

Bhandarkar also addressed some specific types of products. She said "LED downlights became a commodity market in 2012 - more than 50% of products sold in Japan were LEDs." Looking forward, she said, "Troffers will be the next major wave of SSL deployment starting this year." She expects the troffer market to be strong in 2014 and going into 2015. Overall, the SSL market will enjoy a CAGR of 12% through 2017. Bhandarkar projected that SSL luminaire revenue will exceed US$ 20 billion at the same year [BHA-12]. Mc Kinsey observes that fragmentation of the fixtures industry differs by region/country; the LED fixtures market is more concentrated in most geographies (Figure 18) [MCK-12].

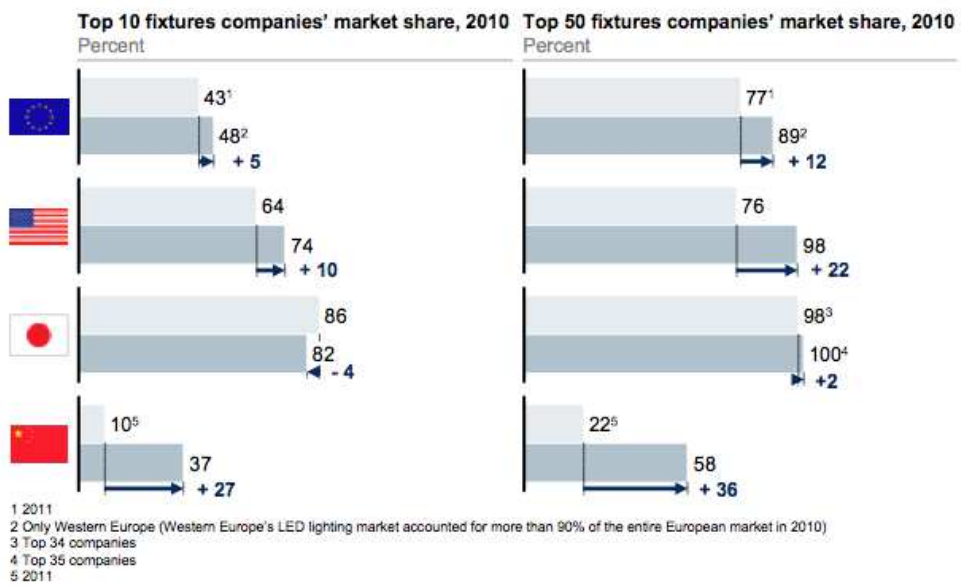


Figure 18: Fixtures industry fragmentation (dark grey: LED fixtures, light grey: all technologies)

Country-by-country situation and associated national strategies

However, following R. Chu, for each word-region, the LED market is pushed forward by different drivers (figure 19) [CHU-12]. European countries favour residential and commercial lighting fields. Japan favours replacement market, like lamp, tube light, and ceiling light fields. Asian countries (China, India, Taiwan, etc.) favour LED streetlight, traffic signal, and commercial lighting fields.

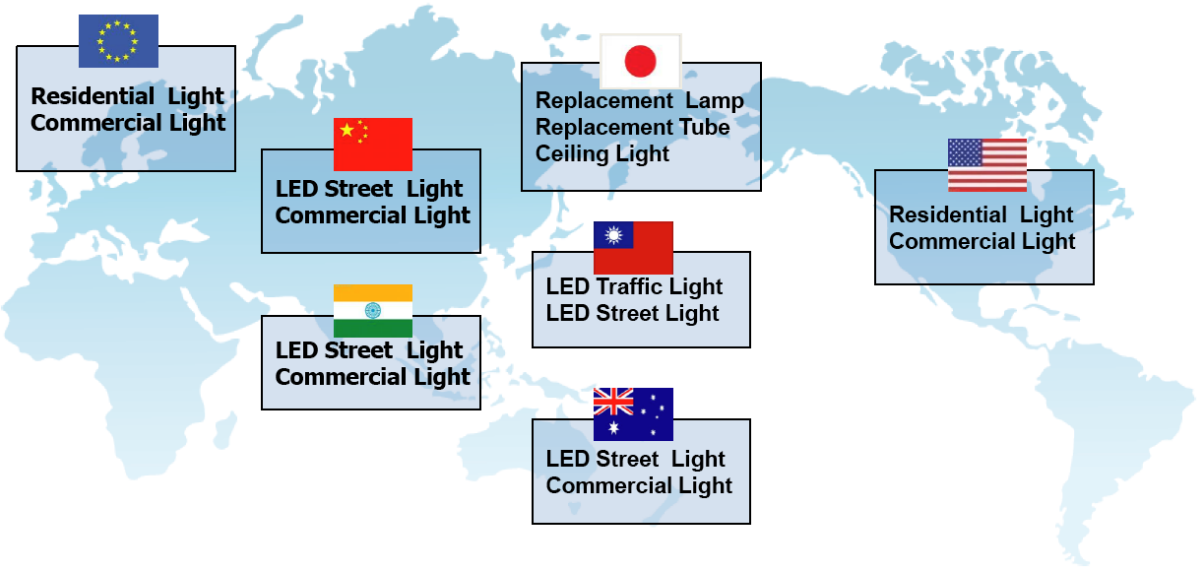


Figure 19: LED-lighting market drivers by world-region [CHU-12]

Situation in Europe:

The LED value-based market share in Europe is estimated at around 9% (2012). This figure was slightly downward adjusted when compared to McKinsey's 2011 forecast, which was 10%, based on a review of actual 2011 results of selective industry players. The share is anticipated to rise to over 45% by 2016 and more than 70% by 2020. These projections represent a slight increase over the forecast in last year's report. In addition to the effect of faster LED price erosion and accelerated LED uptake, multiple factors have changed in Europe since 2011, especially the nuclear phaseout plan in Germany and the European Commission's upcoming regulation on banning low-voltage halogen lamps all of which are expected to drive higher LED penetration. Beyond the fact that Europe is the region most affected by the last financial crisis, the McKinsey market model calculates that the upward adjustment of LED penetration combined with the premium for LED lighting (that will inevitably remain, even though it will shrink) is likely to compensate for the impact of slower economic growth in the longer term. These factors taken together will result in less of a gap versus last year's forecast than in other regions [MCK-12].

W.Gregor (ELC vice-chairman) based on a Mc Kinsey study estimated that the annual turnover of LED lamps in Europe will grow from € 0,9 billion in 2012 up to € 1,9 billion in 2015 (figure 20) [GRE-12].

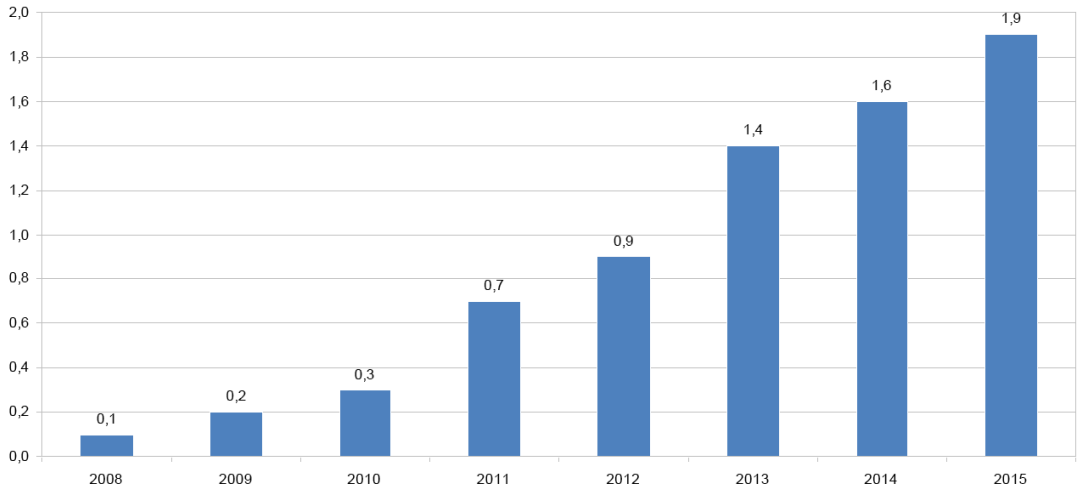
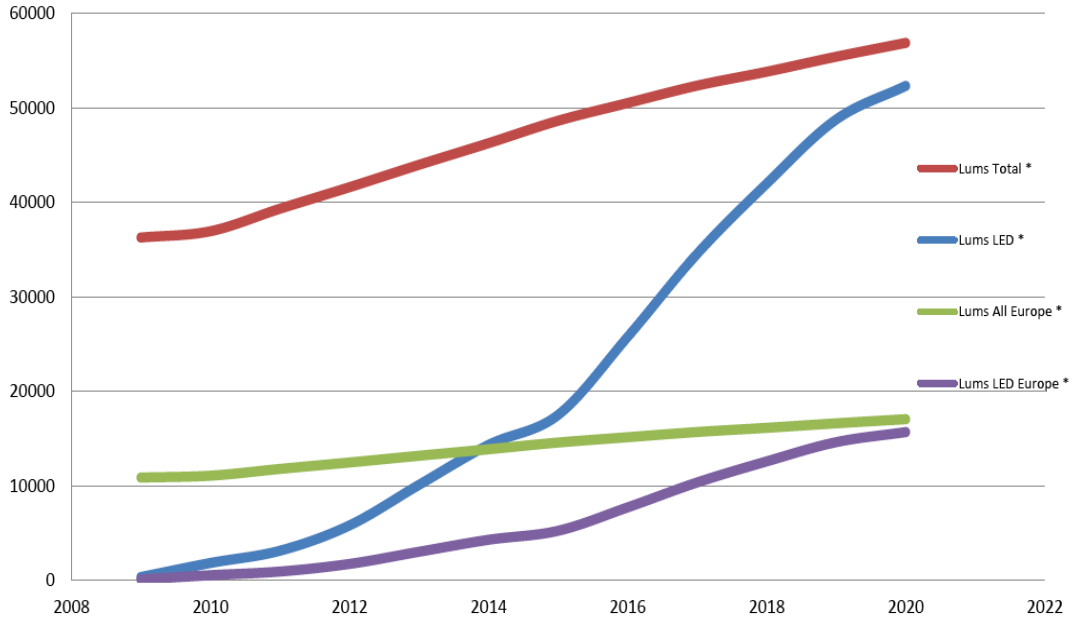
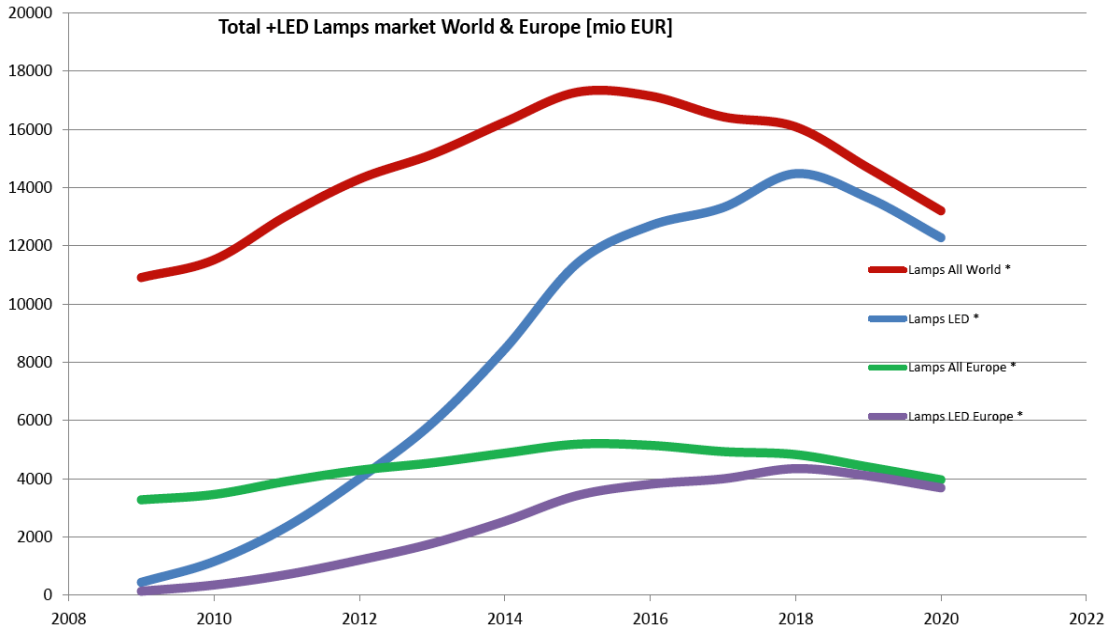


Figure 20: Projected Turnover in Europe of LED lamps in € billion [GRE-12]

A slower uptake of LED luminaires in Europe than in other world regions has been identified when, in general, similar trends for LED lamp market development are there (Figures 21a and 21b). Furthermore, we can consider that in 2012 the European LED market is a mature, though not saturated.



(a)



(b)

Figure 21 European Market turnover forecast compared to World Market in € million (a) Luminaires (b) Lamps [GRE-12]

In 2013 CLASP based on a BAU market projection estimated that by 2025 LEDs sales for tertiary lighting in European Union measured in Teralumen-hours (Tlm.h) will represent almost 50% of the total shipments [CLA-13]. Figure 22 shows that projection.

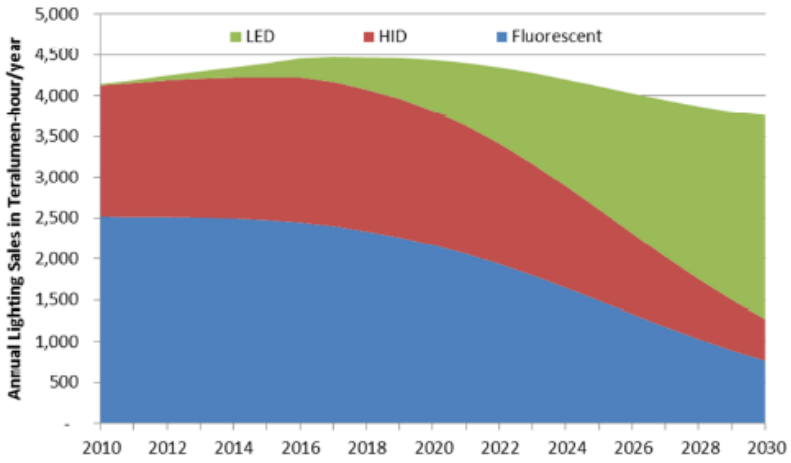


Figure 22: Annual EU Tertiary Lighting Sales in Teralumen-hours/year marker projection [CLA-13]

Concerning domestic lighting sector the following figure from PremiumLight project survey [KOF-13] shows the average number of lamps per household split among the different technologies observed in 2013 and based on national data from 12 EU countries in the period from 2010 trough 2012 (Figure 23). Globally, the number of LED non-directional lamps ranges from 0,2 to 3,2 lamps/household with the highest usage in Portugal and Sweden. Furthermore, the number of LED spots ranges from 0,6 to 2,9 spots/household with the highest usage in Austria, Denmark, Germany and Sweden.

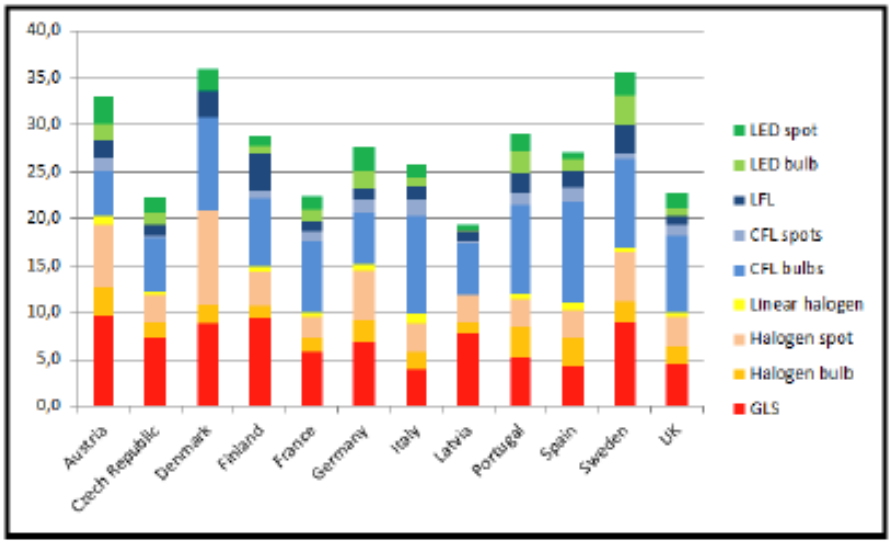


Figure 23: Average number of Lamps per home split among various technologies [KOF-13]

In UK, lighting accounts for approximately 20 per cent of the electricity used in domestic homes in the UK [DEC-11] a consumer in-home study in 2007 conducted by the Lighting Association showed an average use of 25 lamps/home including 15,6 GLS estimated to be in use 450 hours/year, 5,8 halogen lamps estimated to be in use 780 hours/year, 1 LFL estimated to be in use 925 hours/year and 2,3 CFLs estimated to be in use 750 hours/year. In fact lighting in the UK residential sector required around 17 TWh of electricity and resulted in the emission of 9 million tonnes of greenhouse gas. When in 2009 Curtis [CUR-09] in his paper affirmed that "the great majority of solid-state lighting is used in niche fixtures – it is still a niche industry – and so may be considered a supplement", PremiumLight project survey in 2013 identified 1,8 million LED lamps in UK household sector [KOF-13].

In Portugal, in 2010, a domestic lighting survey done by Directorate General for Energy and Geology, Statistics Portugal (INE) and co-financed EUROSTAT shown that 0,7 million LED lamps are installed in household (this is 1% of the total number of lamps in the domestic sector) and this corresponds to an average 0,2 LED lamp per household (for a total of 18,5 lamps/household).

In Spain, data from the national energy agency IDEA survey show that in 2011 0,18 million LED lamps have been installed in Spanish households, this is roughly 0,9% of the total number of installed lamps in the domestic sector.

In Sweden the PremiumLight project survey (2013) identified a market volume of 1 million LED lamps (E27 replacement) for the domestic lighting sector [KOF-13].

In Germany LED lamps sales in 2012 were very small (2%) [KOF-13].

Following AT.Kearney's study for LightingEurope and ZVEI [KEA-13], human centric lighting is expected to become an important market in Europe, across various applications and lifestyles. Human centric lighting is intended to promote a person's well-being, mood and health. It can improve concentration, safety and efficiency in workplace or educational environments. It can support healing processes and prevention of chronic diseases among persons with irregular daily routines or in elderly care.

The underlying market model is based on the floor space that becomes available annually for being equipped with human centric lighting solutions through new buildings and renovations of the building stock. The market volume is derived from segment- and region-specific estimates of relevant floor space, penetration rates and

prices. In order to determining the business potential of human centric lighting, the model analyses three different scenarios. The conservative scenario is regarded as the most probable, assuming selective government support, joint industry initiatives and considerable marketing investments. The more optimistic scenario is regarded as less probable in light of the current economic developments, as it assumes the resolution of the currently persisting economic crisis and extensive government support for human centric lighting. The pessimistic scenario is also considered as being less probable, assuming a fundamental worsening of the economic crisis, poor private investments and little government support. Figure 24 shows the projected European human centric lighting market volume for the next years following the 3 scenarios described above.

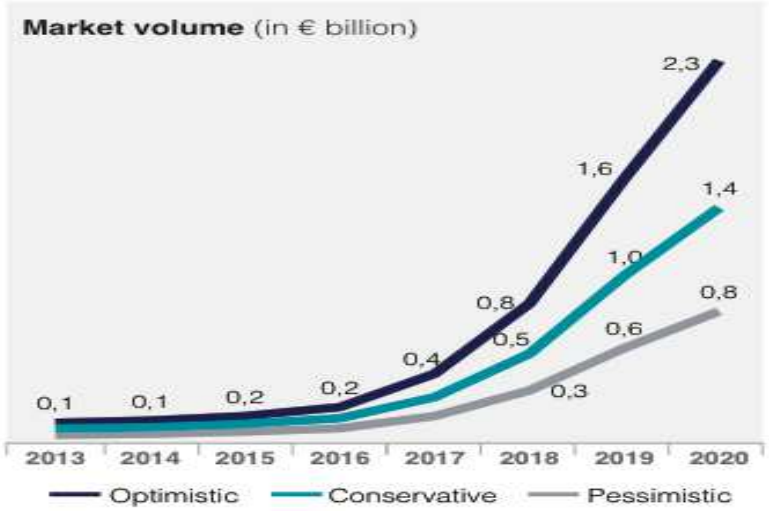


Figure 24: European human centric lighting market volume [KEA-13]

Situation in USA:

In December 2010, the US market for commercial and industrial LED lighting was forecasted to see US$ 330 million of revenue, with potential to grow next year at over 30%, and surpassing US$ 1 billion in annual revenues by 2014 [ENV-10]. More recently, Groom Energy estimated size the 2012 North American Enterprise LED Lighting market at US$ 630 million in annual revenues and that the market is growing at a rate of 40% a year through 2016 [GUE-12].

US department of Energy reported that in 2012, about 49 million LED lamps and luminaires were installed in the most common lighting applications. LED A-type lamps are about 41% of these installations, but currently only having a penetration rate in this application of less than 1%. LED MR16 lamps have the highest penetration rate at about 10% of all MR16 lamps [DOE-13].

The study [ENV-10] identified that rapid market growth is due mainly to three emerging trends:

1. Recent LED chip performance advancements which allow more cost effective designs for replacing existing lighting systems;
2. Newly introduced utility energy efficiency financial incentives for converting to these LED-based systems;
3. Increased interest from building owners in applying sustainably oriented lighting retrofits that save money for their operations.

Situation in Japan:

This is the fastest blooming market for LED replacement light bulb business, reason is mainly due to geographic and historical reason, Japan is intricately lack of any energy resources, and they have to struggle for energy harvest.

Japan's Ministry of Economy, Trade and Industry is responsible for the making and implementation of industrial polices. In the strategic energy plan of Japan made by the ministry, specific measures to achieve targets were listed, and inside the realizing a low carbon energy demand structure, it was clearly stated that one measure is replacing 100% of lights with highly-efficient lights on a flow basis by 2020 and on a stock basis by 2030.

From January to July 2012, Japan has shipped about 15,3 million (+20,6% YoY) LED lamps. The market penetration is about 23,4% [CHU-12]. The demand in 2012 is lower than expected, mainly because energy-saving awareness has increased after the earthquake occurred in 2011, causing demand to pick up earlier. Since an LED lamp has an average lifetime of 40 000 hours, it's unlikely to replace a new lamp in 10 years when a family uses 50 h/week. Therefore, LEDinside estimates that the LED lamp shipment in 2012 merely increases to 29,5 million (+2.6% YoY). Figures 25a & b shows LedInside's projections for the Japanese market.

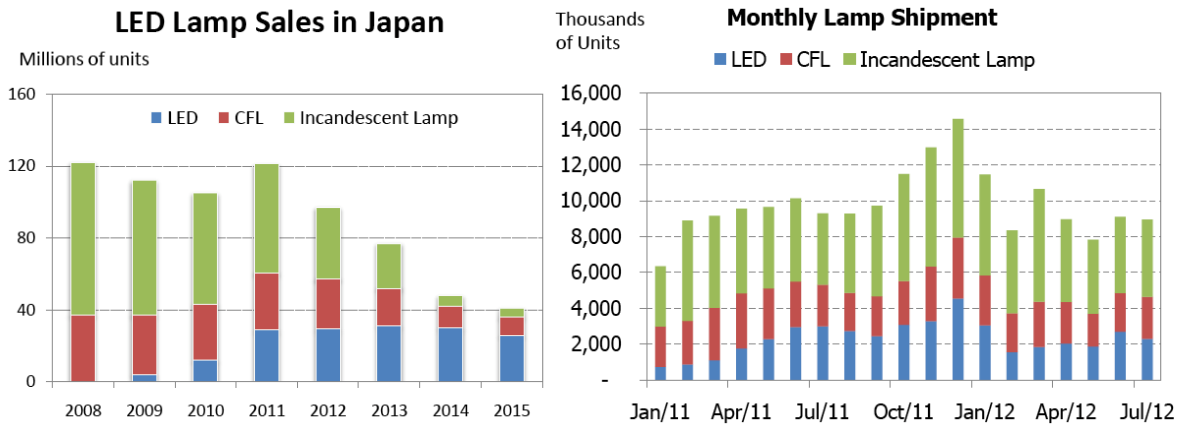


Figure 25: Japanese LED-Lighting market evolution (a) LED lamp sales (data from JELMA, October 2012) (b) Monthly lamp shipments [CHU-12]

It should be noticed here that in Japan CLF price is comparable to LEDs. In Akihabara beginning of the year able to see various supply of LED replacement Light bulb in the market, Panasonic, Toshiba Litetech, Sharp and Citizen made LED, light bulb, the price was 4 000 JPY in January 2010, dropped in 2011 to about 2 500 JPY for the same type same model. That is a significant price drop, about 37% in a year!

Situation in South Korea [ISA-13]

The Korean government announced the "Low Carbon, Green growth" strategy in 2009 and SSL forms a major part of the plan. Korea plans to invest 540,1 billion KRW in the next five years, to accelerate eco-friendly segments such as SSL. The government also allocated 4,5 Billion KRW for retrofitting existing lamps to LED lamps (second half of 2009). Korean government is proposing policies to distribute LED lighting of various aspects such as lighting power savings for expanded distribution of LED lighting products, achieving 30% LED replacement in public facilities for LED industry

development, and replacement support of traditional market lighting and small-business advertising signs. Korea LED Lighting Distribution Expansion Policy includes:

1. Spread LED lighting distribution to large market such as Industry Park, school, etc.
2. Set annual goals for distribution from 2013 on public buildings
3. Mandatory installation on new public buildings
4. Nationwide promotion on LED lighting saving effect
5. Supplement appropriate to item-specific, sector-specific situation on LED Lighting 2060 Plan

In order to drive the "LED Light 15/30 Distribution Project" forward, an estimated 350 billion KRW is to be funded by the government with effects of 4,6 times the investment. Expected energy savings are estimated to be 1,6 trillion KRW.

Situation in China and Taiwan

In China, there are numerous enterprises in LED lighting industry, including traditional lighting manufactures, manufactures in LED extension chips and packaging, and other new LED lighting manufactures. CALI estimates that there are more than 60 manufacturers dealing with LED wafer and chips production; more than 200 working on LED packaging and more than 5 000 dealing with LED lighting products. To this issue strategy is simple: "The future will be the survival of the fittest" [YAN-12].
In 2009, National Development and Reform Committee, Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Housing and Urban- Rural Development and General Administration of Quality Supervision, Inspection and Quarantine jointly issued the "Solid State Lighting Energy Conservation Industry Development Advice", SSL was identified as another revolution of lighting source after Incandescent and fluorescent, the document illustrated the current situation and trends of SSL energy conservation industry, identified the major problems and proposed guiding ideas, basic principles, development targets and focal areas [IAS-13]. The document also specified the Policy measures, including:

1. Overall planning, promote healthy development of the SSL industry;
2. Continue to increase the support of SSL technologies innovation;
3. Steadily improve the development level of SSL industry development;
4. Actively promote the SSL standard development, products testing and energy conservation certification;
5. Actively implement the incentive policies for SSL industry development;
6. Broadly conduct SSL energy conservation introduction, education and training;
7. Enhance regional and international communication and cooperation.

Following these strategic targets, Chinese government subsidises massively LED lighting industry. Subsidy support has gone towards application market, but the need for government to stimulate upstream demand still exists in the upstream market. In 2012, the annual "SSL Products fiscal subsidies" has been announced. The government would invest 1,6 billion RMB in the LED lighting sector, and the subsidies account for 30%-50% of the product prices [CHU-12]. Street lighting sector is a major target for the country: in 2009 it was 222 000 LED street lamps installed and this figure attained 1 120 000 2011. Even if, this number is very small for Chinese cities but we can see there is a tremendous growth of 500%.
In Taiwan, the energy policy is mainly based upon its development and sustainable growth, reaching a balance among the three aspects: energy (stable energy supply), environment (low-carbon emission for the reduction of greenhouse gas) and economy (maintenance of affordable energy prices). And the LED industry plays a key role to realize that balance. The Dawning Green Energy Industry Program: Reducing CO_2

emissions to the 2000 level in 2025. (Including LED Traffic Light subsidy Policy) [ISA-13].
The Taiwanese Ministry of Economic Affairs has planned to invest 2,43 billion TWD and replace 326000 mercury-vapour street lamps with LED lamps, which would save approximate 0,14 TWh of electricity and 87500 tons of CO_2. The Ministry expects to create 4,5 billion TWD of annual production value. Furthermore, the ministry has announced to provide subsidies for at least millions of lamps, deducting about half the price (200 TWD) from a single lamp. The program would cost to Taiwanese government 1 billion TWD and is expected to propose in a month's time, benefiting mainly the LED lamp sector [CHU-12].

Situation in India

The SSL policy is still yet to be fully formed in India as well as the LED industry itself. But the government has already realized the importance of policy support on SSL development and there were a number of measures and actions. India's Ministry of Power released the Economic Case for Multi-State DSM Programme to Stimulate LED Lighting in India in 2010, which is India's first specific policy framework on SSL. [ISA-13]
With the recent Central government effort to promote manufacturing of LED lighting products in India, the industry expects a significant growth in the LED market in the next five years, due to Central government thrust. The most recent product category to be brought under the Preferential Market Access policy is LED. "Due to this Central government effort and other state government efforts to boost LED manufacturing in the country, we expect the India LED market to grow from the current US$ 143 million to US$ 1279 million by 2018," VG Ramakrishnan, managing director, South Asia, Frost & Sullivan, told Electronics Bazaar. The global penetration of Indian LED products will also grow from the current 4 % to 35 % in the next five years" [RAM-13].
The Ministry for Renewable Energy and the Bureau of Energy Efficiency have also been driving initiatives such as distribution of solar LED lanterns in villages to promote energy-efficient lighting.
The India Government has been subsidizing the establishment of LED test facilities at existing Test Lab. It is expected at least 3 more Test Labs supported by Government will be established and a total of 12 Test Labs by 2013.

Situations in Russian Federation [LED-11]

The Russian lighting industry has been in decline since the early 1990s. Despite some growth in 2003 to 2006, it has never fully recovered from the recession and economic restructuring. Although in recent years the Russian LED market has been characterized by a lack of standardization, a lack of a transparent pricing policy, and low product quality, this situation is changing rapidly. The LED lighting industry in Russia is becoming more mature as the country seeks to develop a vertically integrated manufacturing infrastructure. There would be enormous opportunity for investor for LED.
There is nationwide interest in Russia in the transition to LED. Currently, the Russian business model is to address lighting systems market rather than to produce LED devices. Optogan is the lagship in LED with high investment in lighting systems. Sapphire production technology has been invented and patented by Russian companies, and a vital materials market in various regions of the world is currently developing for LEDs manufacturing.

State funding and investment from private companies is helping to build a domestic LED infrastructure and, all over Russia, companies dedicated to LED lighting technologies are emerging. A recently formed manufacturers association, established by competitive suppliers Optogan and Svetlana Optoelectronics, is likely to play an important role in the evolution of the Russian LED lighting market.
Svetlana Optoelectronics has developed a variety of LED products. The company was founded in 1996 and is based in St. Petersburg. Its initial activities were focused on fire detection equipment, but most of its current business is for LED lighting. Svetlana Optoelectronics LED products include strips and modules for indoor lighting as well as exit signs, lit paving stones and underwater lights [SCH-10].
Optogan is a leader in LED technologies with innovative, cost efficient, high quality lighting modules. Since 2005 Optogan has been developing and producing LED light crystals in Germany based on the patented Nobel Prize technology epimaxxTM. The company focuses on energy efficient and environment friendly general lighting. The international team of LED professionals and experts clearly differentiate themselves through their strong customer orientation. The Optogan Group, with its 300 employees, has plants in Landshut (Germany), Dortmund (Germany), Helsinki (Finland) and St. Petersburg (Russia). Philips has signed a joint venture agreement with Russian LED product manufacturer Optogan that sees the two companies taking a strong foothold in the fast growing LED road lighting market in Russia. The new company will be 51% owned by Philips and 49% by Optogan [MON-12].
Road lighting in Russia is an is anticipated to become one of the leading growth segments for LED, with the market expected to double over the next four years to € 100 million by 2015. Government energy efficiency programs for modernization of road lighting mainly drive this growth. It is expected that due to this also the share of LED will reach 50% as early as 2015.

Rest of world [MCK-12]

The rest of the world – Latin America, the Middle East, and Africa – makes up a much smaller share than the other regions in terms of the size of both their overall general lighting and their LED general lighting markets. The value-based LED market share in 2011 is estimated at 4% for Latin America and 5% for the Middle East and Africa combined. Projections from 2011 values were slightly over- estimated compared to the experience of industry players in local markets. Those regions are also seeing slower LED lighting growth, with a penetration of less than 40% forecast for 2016. Government industry policy may have a significant impact on LED penetration in Latin America. Import duties on lighting fixtures are high in Latin American countries [ALA-12]. Unless production facilities are locally available, LED fixtures could therefore become even more expensive. The size of the overall general lighting market has been downward adjusted in response to the lower LED penetration, faster LED price erosion, and slower economic growth. We forecast a total general lighting market for the rest of the world in 2020 of around € 10 billion – € 1 billion below 2011 forecast.

LED-Lighting price evolution

LEDs are already economically attractive in many settings, such as outdoor environments where energy or maintenance costs are high. But they face a particular economic disadvantage in their high up-front costs. At a time of serious financial constraints, this can limit LED sales even in settings where the long-term economic and social benefits clearly outweigh the costs. Continuing falls in LED pricing of 15% to 20%

per year are expected to drive widespread adoption in general lighting over the next few years [LCR-12].
The prices of lighting sources are typically compared on a price per kilolumen basis. The prices for LED-based replacement lamps have dropped considerably over the past few years but remain significantly higher than conventional lighting sources. In general, LEDs are expected to fall in price by more than 80%6 and reach a global penetration of around 60% across all lighting applications over the next eight years [LCR-12].
From J.Brodrick's (DoE) talk at DLC Stakeholder Meeting 2012: Price of downlights, retrofit lamps, and streetlights dropped 15–20% in 2011. LED cool white package dropped from US$ 13 per kilolumen in 2010 to US$ 6 per kilolumen in 2011 [BRO-12].
In fact, LED lamp and luminaire prices vary widely depending upon the application. To validate the progress on price reductions for LED-based lighting, a comparison of replacement lamps is both practical and appropriate. The most aggressive pricing has been associated with the most popular residential lamps, and consequently DoE focused on the A19 60W-equivalent (800 lm) replacement lamp for their projections. Figure 26 shows how the retail price (neglecting subsidies) has dropped over the past five years and how it compares to a typical conventional 13W CFL. Typical retail prices have dropped to a low of around US$ 15, corresponding to a normalized price of US$ 19/klm, slightly ahead of the MYPP projection. Early in 2013 DOE already observed the retail price into the $16/klm range. [MPP-13].

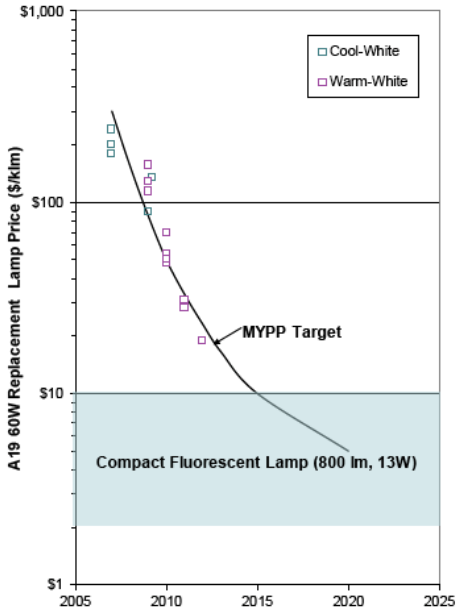


Figure 26: 60 W lamp equivalent (800 lm) retail price projections in US [DOE-13]

To achieve cost reduction it is necessary to reduce product up-front fees. For example, looking into up-front cost breakdown of a downlight luminaire shows that the LED with 45% contribution is only one contributor but represents the single largest opportunity for cost reduction (Figure 27).

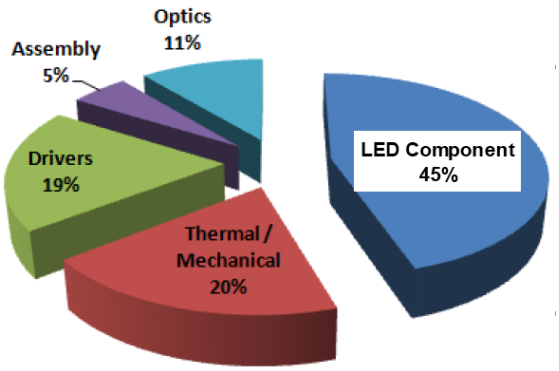


Figure 27: Up-front cost breakdown for a downlight luminaire [RND-11]

Looking closer in the LED component costs, it is found that package represents 34% of the global (Figure 28).

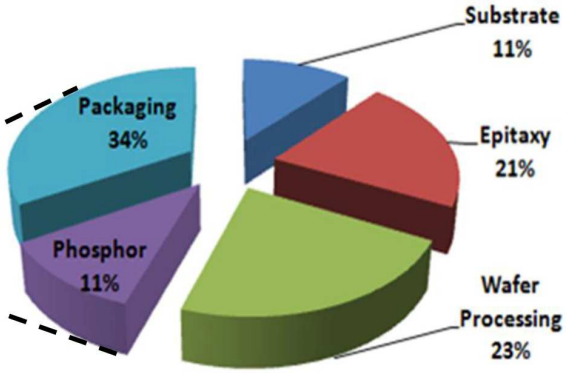


Figure 28: Cost breakdown for a single LED component [RND-11]

As shown in the following graphics (Figure 29) proposed by J.Perkins, LED component industry should focus on the cost reduction of packaging [PER-12].

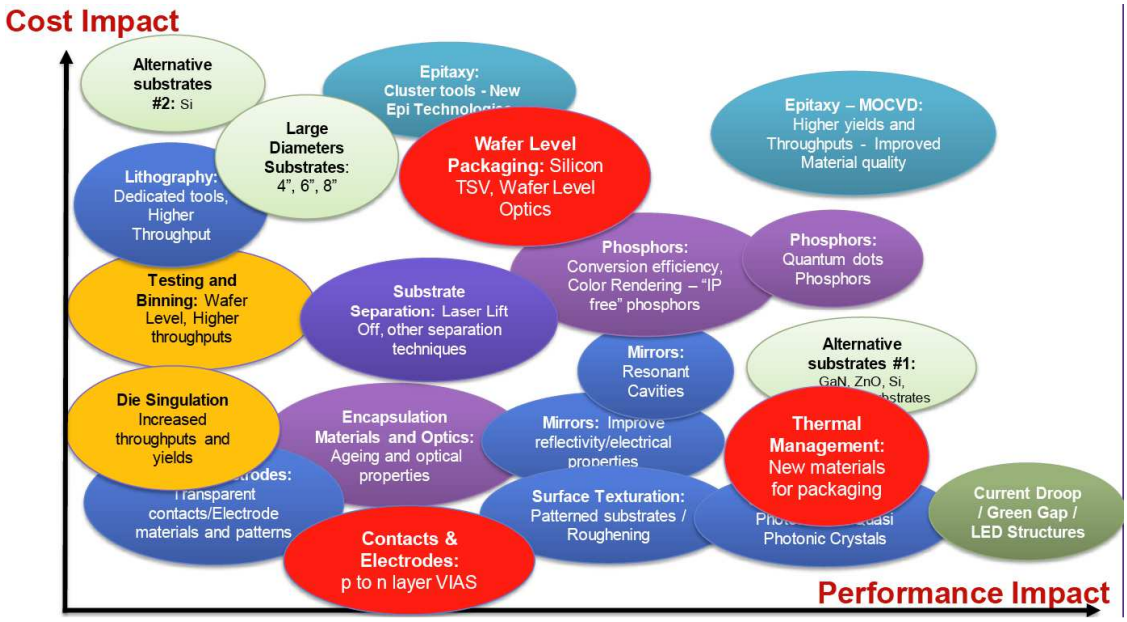


Figure 29: Cost versus performance impact of various technological solutions entering the LED component fabrication [PER-12]

Figure 30 from the SSL R&D Manufacturing Roadmap shows a projection of cost breakdown reduction for packaged LEDs [ROA-12].

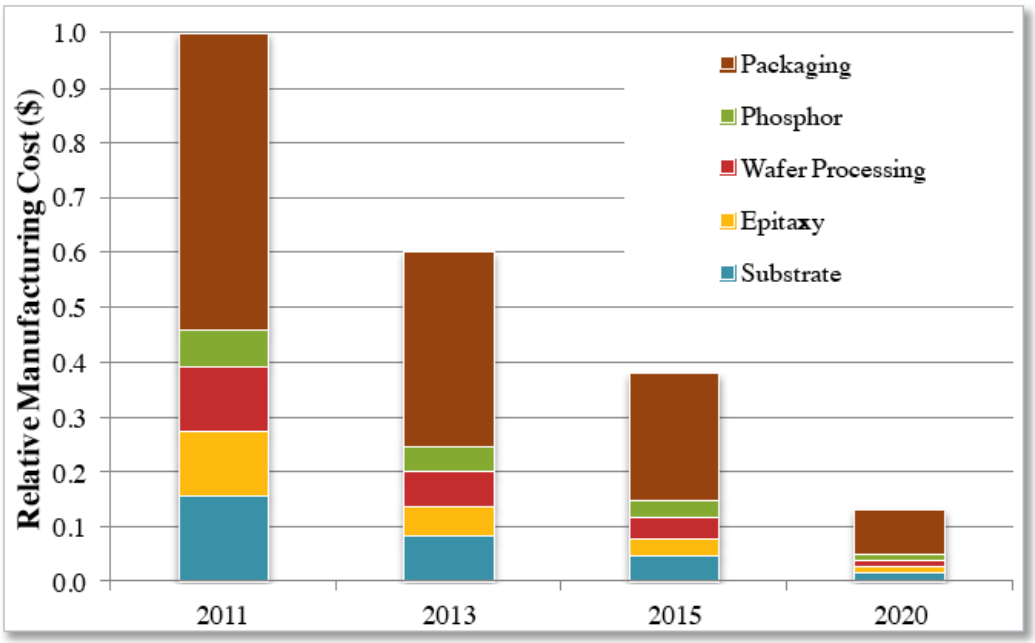


Figure 30: Projection of cost reduction of packaged LEDs till 2020 [ROA-12]

J.Perkins (YOLE Development) shown that, in 2012, taking into account upfront, energy and maintenance costs a US$ 40 LED-lamp is still non-competitive compared to a CFL. The following graphics (Figure 31) illustrates this affirmation [PER-12]. It is thus necessary to propose less expensive LED-lamps.

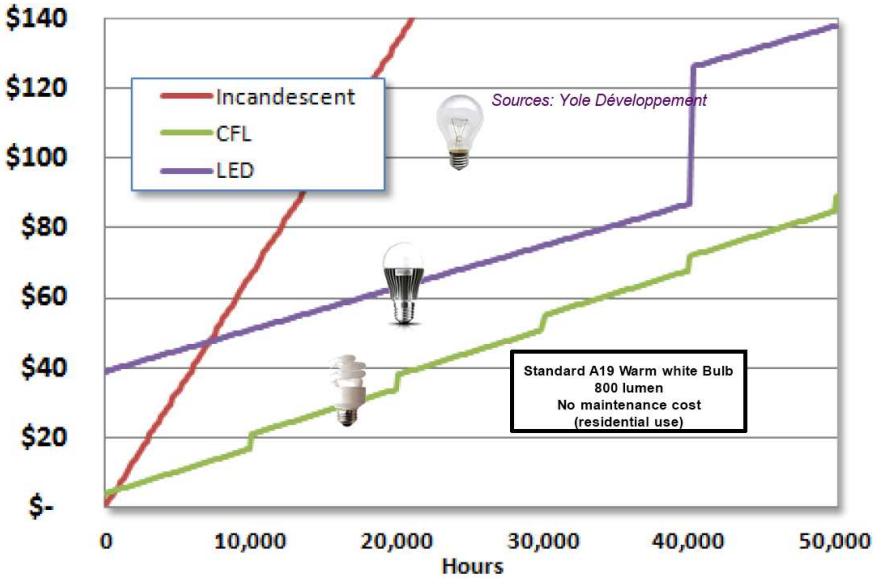


Figure 31: Global ownership costs for equivalent lamp technologies for residential applications (upfront costs: GLS < US$ 1; CFL US$ 3-5; LED US$ 40) [PER-12]

In the case of 40W equivalent LED lamp price is expected to decline steadily, with quarterly 6-8% price erosion projected. More price erosion is expected to happen on 60W equivalent lamp since it's a major lamp market battleground. R. Chu predicted that due to more

aggressive price strategies and plans are formulating the product, which expected to reach US$ 10 in 2013 [CHU-12].
In March 2013, CREE introduced a game-changing series of LED bulbs at a retail price point that gives consumers a reason to switch to LED lighting. This lamp breaks the US$ 10 price barrier: With a retail price of US$ 9,97 for the warm white 40-watt replacement, US$ 12,97 for the 60-watt warm white (2700 K) replacement and US$ 13,97 for the 60-watt day light (5000 K). The announcement sated that "the new bulbs shine as brightly as comparable incandescent lamps while saving 84% of the energy compared to traditional bulbs. The Cree LED bulbs are backed by a 10-year limited warranty". The lamp is given for a 25 000 h lifetime and 10 years warrantee [CRE-13b].

Energy Use and Energy Savings linked to LED-Lighting

Following the key findings from the Climate Group [LCR-12], LEDs achieve the expected 50 to 70% energy savings in the lighting domain, and reach up to 80% savings when coupled with smart controls. In this section some recent estimations of expected energy savings are presented.

Europe:

Following Bertoldi, JRC Ispra, Lighting uses 407 TWh/year, i.e. 15% of the total EU electricity consumption [BER-14]. This 407 TWh/year split by apllication sector as follows: 40,2% tertiary, 24,5% industry, 20,6% residential and 14,7% outdoor. However, there is still a large cost-effective saving potential of at least 12,8 TWh per year in the EU-27. With more aggressive policies the saving potential could reach 24,1 TWh [BER-08].
The European policy concept of phasing out inefficient lighting products has proven to be successful. In 2011 the European lighting industry sold for the first time more energy efficient products than less efficient products – this is a clear success of European legislation in the field of Ecodesign and a role model for other sectors that a shift towards more energy efficient products is possible. Following [LIE-13], the European lighting industry is convinced that predominately Green Public Procurement as well as adequate financial incentives for building renovation has a key role in concretely implementing energy efficiency in Europe. The European Commission has already embarked on a number of initiatives to achieve this goal and it has to be secured that initiatives such as Renovate Europe are leading the way towards concrete policy and legislative measures. It is evident in this context that the European Commission is called upon to ensure the proper implementation of the Energy Efficiency directive and the Energy Performance in Buildings Directive in all EU Member States.
CLASP estimated that tertiary lighting products, household lighting products continue to offer the greatest potential for savings (respectively 12,1-18,3 TWh; 16,0-18,6 TWh per annum by 2030 depending on level of ambition). [CLA-13]

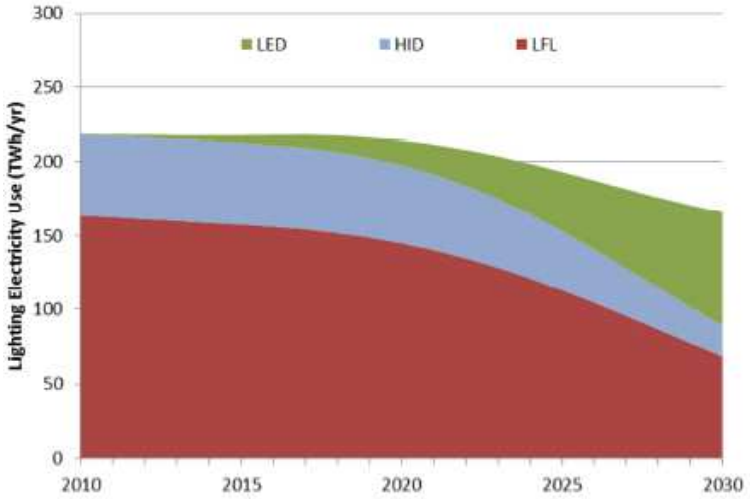


Figure 32: Estimated EU Tertiary Lighting Electricity Use, Terawatt-hours/year

In tertiary building sector CLASP elaborated a Business as Usual (BAU) scenario that wattages and operating hours of the LEDs and conventional lamp technologies are applied to the installed stock of lamps; the LED overall luminous efficacy is taken from DOE-2012 roadmap [CLA-13]. The Figure 32 presents the annual electricity consumption in TWh for tertiary lighting in Europe under the BAU scenario.
In addition CLASP proposed a second BAU scenario that exclude LEDs. This scenario, although unrealistic, shows clearly the contribution of LEDs in the energy savings. The table T5 summarises the findings.

Table T5: Electricity Consumption for Tertiary Lighting under two BAU scenarios (from [CLA-13])

	Year	2010	2015	2020	2025	2030
Stock annual energy consumption (TWh)	BAU-1 with LEDs	219	218	214	193	166
	BAU-1 without LEDs	220	221	234	252	274
	Difference (TWh/y)	**1**	**3**	**20**	**59**	**108**

Concerning Non-Directional Household Lamps CLASP developed BAU Scenario shows a rapid decline in the remaining special-purpose incandescent lamp shipments, reaching zero by 2021. This scenario, which takes into account LED long lifespan, shows that in 2030 at around 200 million unit LED non-directional lamp will be sold sales per annum in European Union households. Table T6 shows the CASP projections till 2030 in million units and annual energy consumption in TWh [CLA-13]. Roughly, 32 TWh per annum reduction of energy consumption is expected in 2030 with respect of 2010 baseline[6].
These savings can be amplified if Europe adopts more strict regulations concerning energy efficacy.

[6] This calculation is based on Average LED System Efficacy given from US DoE in 2012

Table T6: Projected Sales, Stock and BAU Energy Consumption to 2030, Non-Directional Household Lamps from [CLA-13]

EU-27 projection	2010	2015	2020	2025	2030
Sales (million units)	1,485.0	1,036.7	883.0	522.3	380.7
Stock (million units)	4,377.0	4,580.2	4,927.7	5,201.7	5,556.2
Stock annual energy consumption BAU, (TWh)	111.92	106.82	89.07	81.49	79.56

W.Gregor (ELC vice-chairman) noticed that in Europe highest savings potential is in domestic lighting, however this is the consumer group the most difficult to reach (figure 33).

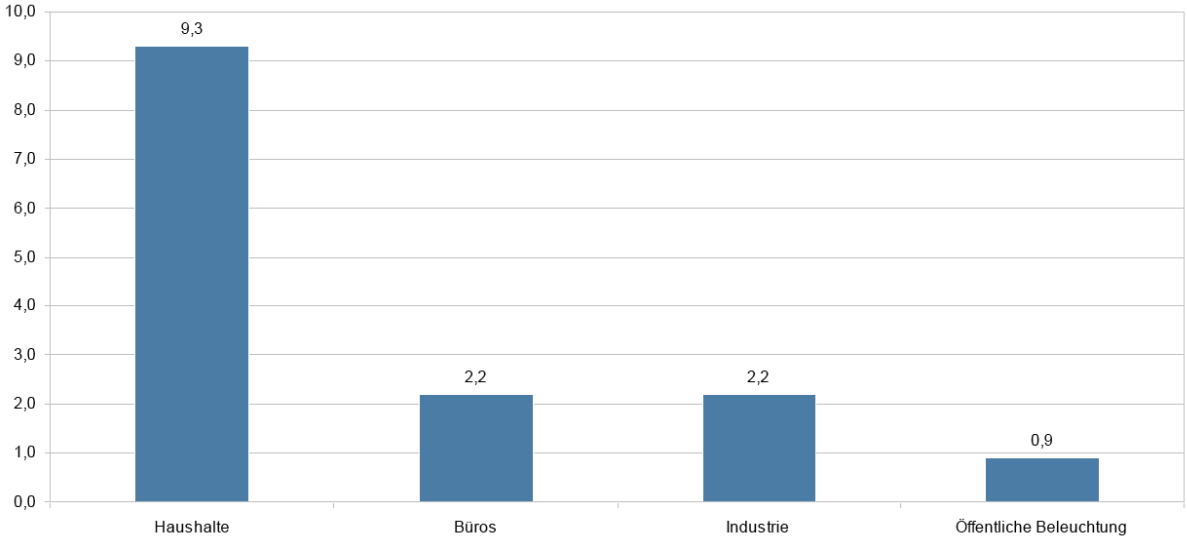


Figure 33: Savings potential in billion Euros when switching to LED lighting [GRE-12]

USA:

In the United States, lighting consumed about 18% of the total site electricity use in 2010, according to a recent U.S. Department of Energy (DOE) report [NAV-12]. The bulk of this amount being consumed by inefficient light sources such as the ubiquitous incandescent bulb, followed by linear fluorescent lamps. Figure 34 illustrates the distribution of lighting electricity consumption across the primary sectors and technology types, as estimated by Canaccord Genuity [DOR-13].

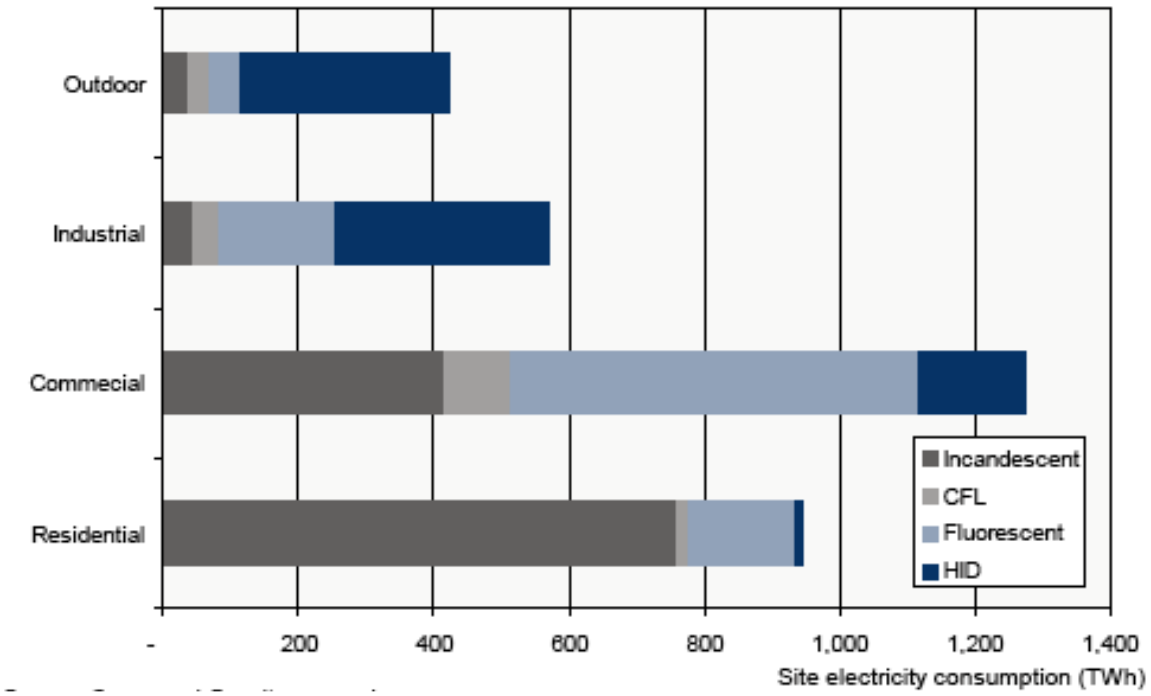


Figure 34: Global lighting 2012 energy consumption in US by sector and technology [DOR-13]

Table T7 below provides a summary from the most recent data concerning LED observed penetration in US market.

Table T7: Observed US lighting market shares of LED technologies in % of lighting fixtures

Application	Estimated LED Penetration of Installed Stock (%)[1]	
	2010	2012
A-Type	–	<1
Directional	<1	5
MR16	3	16
Decorative	–	<1
Downlight	<1	<1
Troffer	–	–
High-Bay	–	<1
Parking[2]	<1	1
Streetlight[2]	1	2

Notes:
1. Values less than 0.1% are considered negligible.
2. These estimates have been updated using data from the 2010 U.S. Lighting Market Characterization report.

The following graphics (figure 35) from [DOE-12] shows that LED lighting technology has the potential to reduce U.S. lighting energy usage by nearly one half. By 2030, the projected annual savings due to increased use of LEDs relative to conventional technology is about 300 TWh or about US$ 30 billion in energy savings at 2012's energy prices. This 300 TWh savings is equivalent to the annual electrical output of about fifty 1000 MW power plants, enough electricity to power 24 million U.S. homes. When the entire 2010–2030 time period is considered, the cumulative energy savings are about 2700 TWh or US$ 250 billion at 2012's energy prices.

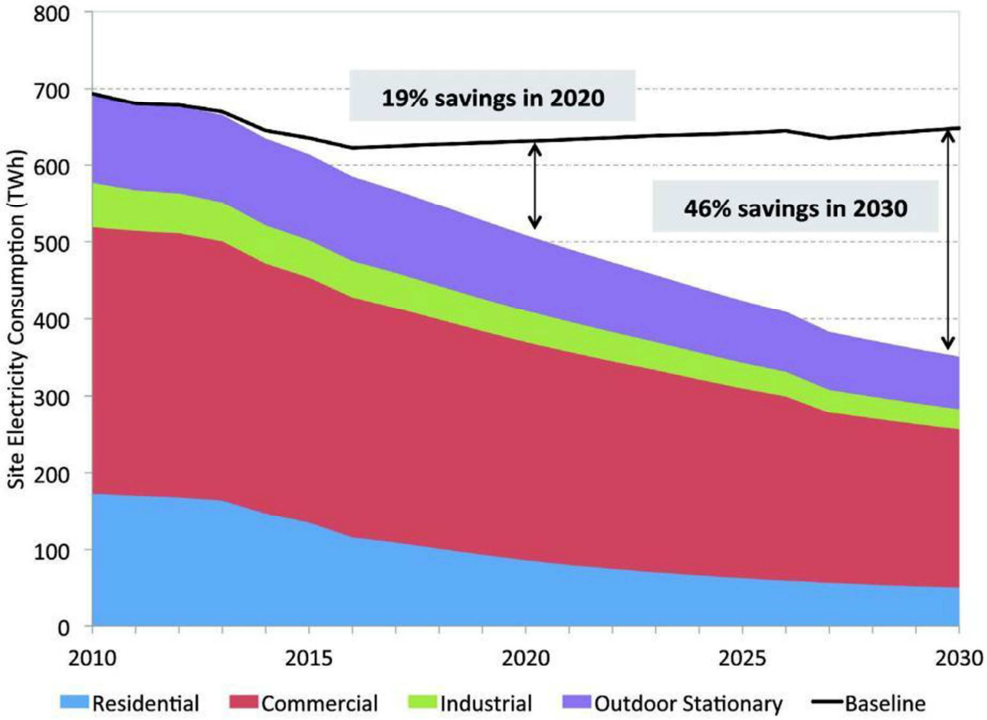


Figure 35: Potential to reduce US lighting electricity use by nearly one half - Equivalent to the electricity needed to power 24 million households [DOE-12]

DoE reports that annual source energy savings from LEDs in 2012 from the nine applications (figure 36) analysed was about 22,3 TWh, which is equivalent to an annual energy cost savings of about US$ 675 million [DOE-13].

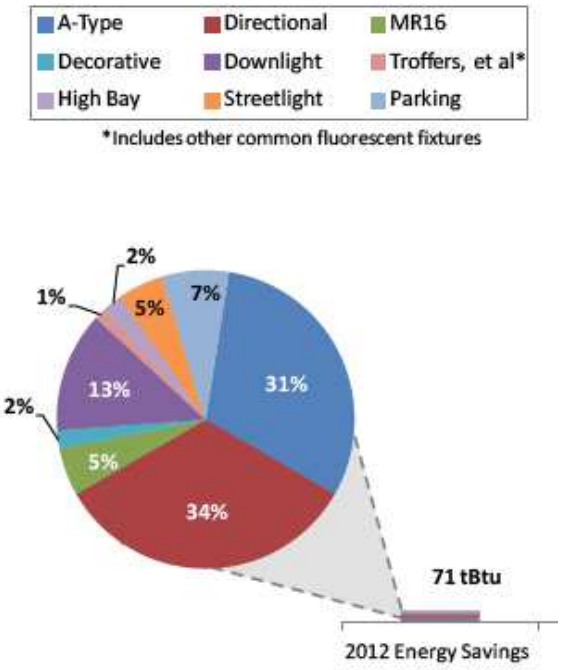


Figure 36: Energy savings achieved in 2012 in US tanks to LEDs within 9 common lighting applications [DOE-13]

The Department of Energy estimates that replacing regular light bulbs with LEDs could lead to energy savings of 190 TWh annually, or the amount of energy consumed by more than 95 million homes.

To realize the full energy savings potential envisioned by the DOE SSL program, the supply of SSL products would need to expand by orders of magnitude. In terms of light output, they need to grow from providing a very small percentage in 2012 to 1500 Tlm.h by 2025, just for the residential sector. By that time, almost half the electric light in the US should be coming from SSL sources; globally it may be more. That suggests that fundamentally new manufacturing methods and processes will be needed very soon to get the ball rolling [RND-13].

Acronyms

AC: Alternative Current (50 or 60 Hz)
ASP: Average Sales Price
BAU: Business as Usual
CAGR: Compound Annual Growth Rate
CALI: Chinese Association of Lighting Industries
CCT: Correlated Colour Temperature
CENEC: European Committee for Electrotechnical Standardisation
CEO: Central Executive Officer
CFL: Compact Fluorescent Lamp
CFLi: Integral Compact Fluorescent Lamp
CFL-ni: Non-integral Compact Fluorescent Lamp
cm-LED: Colour mixing white LEDs
CRI: Colour Rendering Index
DC: Direct Current
DIN: Deutsche Institut für Normung
DoE: Department of Energy
EBIT: Earnings Before Interest and Taxes
EEDAL: Energy Efficiency in Domestic Appliances and Lighting
EPA: Environmental Protection Agency
EU: European Union
GAAP: Generally Accepted Accounting Principles
GLS: General Lighting System (incandescent A-shape lamp)
HB-LED: High Brightness LED
HID: High Intensity Discharge lamp
IEC: International Eletrotechnics Committee
IES: Illuminating Engineering Society
IESNA: Illuminating Engineering Society of North America
IPO: Initial Public Offering
IPR: Intellectual Property Rights
ISA: International SSL Alliance
JRC: Join Research Centre
LED: Light Emitting Diode
LER: Luminous Efficacy of Radiation
LFL: Linear Fluorescent lamps
MYPP: Multi-year Program Plan
NIST: National Institute of Standards and Technology
OLED: Organic Light Emitting Diode
pc-LED: Phosphor conversion white LEDs
SIL: Strategies In Light annual conference
SSL: Solid State Lighting
US: United States of America
YoY: Year-over-Year
ZVEI: German Electrical and Electronic Manufacturers' Association

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1 KRW = 0,001 €
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