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Status of LED-Lighting world market in 2017

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Abstract

Lighting is responsible for about 15% of global electricity consumption. LEDs are a new technologies introduced in the market over the last 10 years. LED offers a very high efficiency compared to traditional lamps and higher lighting quality compared to fluorescent lighting in the non-residential sector. Through technology development and energy efficiency policies the LED lighting is fast penetrating the lighting market, offering energy and cost savings and higher lighting quality. This report offers a snapshot of the latest developments in term of market and technologies for solid state lighting and in particular for LED in the different markets. It follows a previous study by the JRC carried out in 2011.

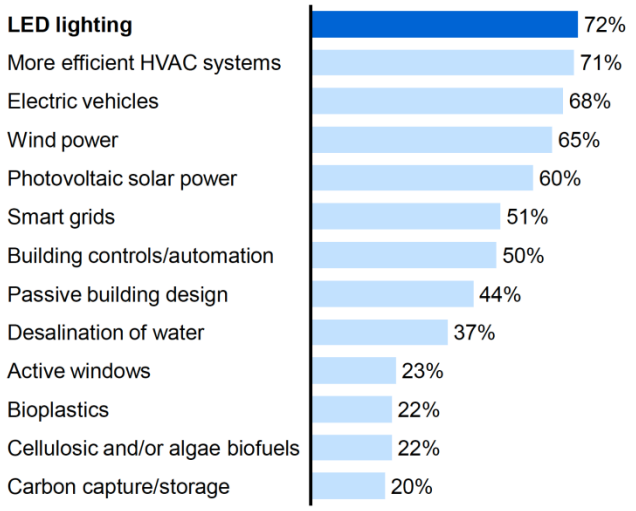
1 Introduction

Lighting is undergoing a rapid transformation as Light Emitting Diodes (LED) become the number one source of light. The LED market evolution is continuing with a steep decline in cost per unit and a high energy-efficiency improvement.

The global LED lighting market is growing with maturing light culture. The market is experiencing now a shift from conventional lighting to LED lighting with easy availability of LEDs in light bulb format, thereby posing a tremendous growth potential for the market. Year 2014 brought LED lighting mainstream as awareness at all levels is very high, and LED products are available widely and at different price levels. The major trends featuring the market includes shifting distribution channel, advancement in LED technology, demand for interior automobile lighting, and increasing green construction.

Customers of any type and from any country need to understand the offer and have the confidence in the performance of new technologies. They also need to understand the benefits of purchasing or specifying products referring to green technologies. As Lauren Williamson underlines, "many businesses and residents are taking sustainability seriously. Brands are realigning their brand values to compliment sustainable activities that can be implemented into their business model. Sustainable motives are more conscious among consumers, however businesses that are able to compliment these with pricing and cost motivators will be in a strong position to ride the commercial growth of sustainable products" [WIL-16]. A 2011 survey conducted by McKinsey on clean technologies answering the question "Which of the following technologies do you expect will be commercially viable by 2020?" indicated that 72% of the 4025-people considered LED lighting as the most probable one (Figure I.1) [MCK-11].

Figure I.1 – Clean Technology survey, answer to the question "Which of the following technologies do you expect will be commercially viable by 2020?" [MCK-11]



In parallel, Global Warming has created a huge need for conserving energy, especially for lighting which represents roughly 19% of world's electricity annual consumption. The Paris Agreement, which was signed by more than 190 countries to commit to limit the temperature increase to below 2° in order to combat global warming, constitutes a frame for development of policies supporting energy efficient technologies.

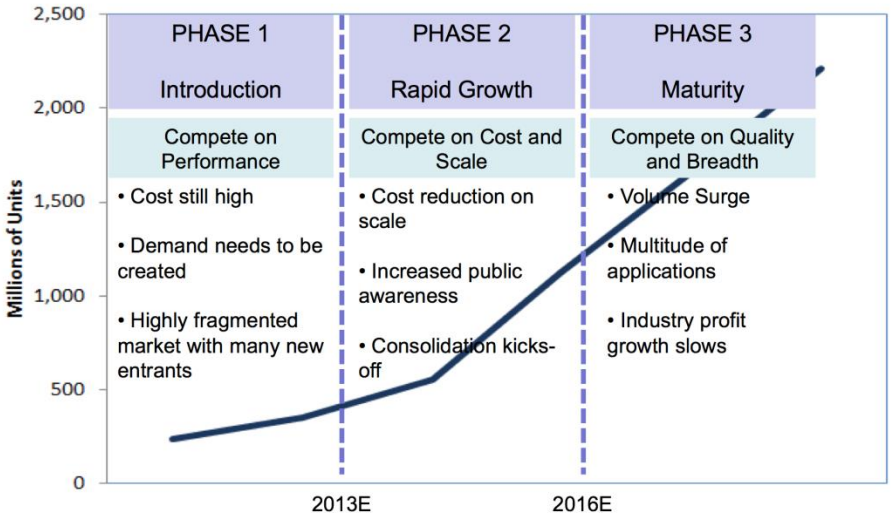
The key factors driving the growth of the LED lighting market includes the rise in global LED penetration, falling prices of LED lighting, phasing out of conventional lighting, rising industrial demand for power efficient lighting and favourable government policies. More

especially, governments around the world are encouraging the use of LEDs in public and private spaces. Thus today, the main drivers for LED lighting came largely on the back of government decisions, such as bans of inefficient lighting by the European Union, the United States, and Canada, and the Chinese government's decision to adopt LED ahead of its planned ban. Government initiatives, however, will play a decreasing role during the next years. Then it expected that the growth will be supported by private initiatives such as the rebates offered by utilities in the United States.

As more and more countries are getting close to phasing out conventional bulbs, LEDs are continuing their march to the top of the market. In fact, LED technology is transforming the lighting industry underpinning rapid market penetration. Declining costs and efficiency increases are leading to increased adoption of LEDs for general illumination applications previously dominated by traditional lighting technologies. Market size estimates vary but all point to significant growth in LED share.

LED lights are already at the forefront of the trend and it has created a billion-dollar industry that will continue to be driven by social and market forces. Only LED lighting can be used as a comprehensive replacement for legacy lighting: it is available in both cold and warm colour, temperature varieties, is colour-tuneable and can be dimmed. Additionally, solid-state lighting can be applied in any field of lighting. By contrast, other lighting technologies like HID, CFL and even OLED, have more restrictive applications. Thus, the LED replacement lamp is the winner in the medium term, as it progressively replaces traditional technologies around the world. To this end, LED replacement lamps are already at a price point that successfully challenge traditional technologies and will take over that market completely by 2020. As shown in Figure I.2, world market analysts consider that LED lighting entered to the maturity era since 2015-16.

Figure I.2 – LED lighting entered Phase 3 (maturity) since 2016 [ONS-13]



However, in 2015, LED penetration rate is still low. According to the IHS Lighting Intelligence Service, the LED lamp penetration rate was below 10% [HIS-16] and Philip Smallwood (Strategies Unlimited) said "Of the 44 billion sockets used in the world, penetration of LED products in 2015, just for lamps, is about 5%, so very low" [WRI-16b]. As LED lamp price reaches parity with CFL, LED penetration expected to increase quickly, but price erosion is everywhere, it is no longer easy for LED manufacturers to make money nowadays; however, since the market is still growing, the companies that survive will eventually have a chance to raise profitability.

In an attempt to differentiate their products and increase margins, a number of "premium" LED products have been developed, offering more than just illumination. They

include smart lighting controlled through connected devices, data transmission though LED frequency modulation, and human-centric lighting (HCL)[1].

The shift from luminous efficacy to light quality is a mandatory trend in the LED industry; in the future competitive lighting products will no doubt shift from low standard level of luminous efficacy demands to developing high quality lighting products that are beneficial to health. Luminous efficacy (lm/W) is only a numerical measurement of lumen output, but light quality emphasizes the quality of the light and the impact of lighting on human health [LED-16].

Standardisation is a key issue that will need to be solved soon. The success of Zhaga products might help with compatibility of products from different manufacturers. New legal requirements and stronger enforcement of laws and standards already in place are also expected in key regions. Lighting Europe, the industry association, periodically calls for more control on noncompliant LED imports from Asia [F&S-15].

[1] See JRC Scientific and Policy Reports "*Accelerating the Deployment of Solid State Lighting (SSL) in Europe*", 2012, A. de Almeida, G. Zissis, M. Quicheron, P. Bertoldi

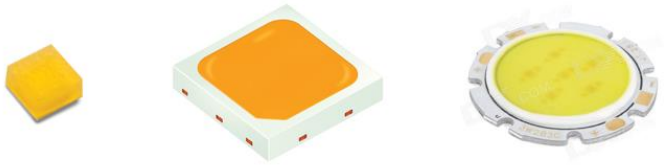
2 Technology Evolutions

In 2017, Cree has announced the XLamp XP-G3 Royal Blue LED that the company claims to be the highest performing royal blue LED on the market. Cree said that the new LED delivers **wall plug efficiency** as high as 81% although the conditions for that performance level were not specified [WRI-17].

Concerning **luminous efficacy evolution** for phosphor-converted white LEDs (pc-LED), the main limit is phosphor conversion efficacy. Today, for a 3000K-CCT, 80-CRI phosphor the theoretical limit for a broadband phosphor is around 265 lm/W, and the theoretical limit for a mix of narrower 30-nm-wide phosphor in red and 70-nm-wide phosphor in green is 310 lm/W. Narrowband phosphor offers a potential 20% performance improvement and has led to a focus in that area for LED manufacturers. It is expected that for mid-power LEDs, efficacy will peak at 240 lm/W in 2017, and that high-power efficacy will peak at 180 lm/W in 2017 - for 4000K-CCT LEDs in both cases. Under-driving either type of LED could deliver a substantial gain with, say, a high-power LED achieving the 230 lm/W level. The US Department of Energy's LED performance roadmap is largely in agreement with these numbers [WRI-15].

A recent innovation in the domain of LED-component (upstream domain) is the **Chip Scale Package** (CSP) LED. As the trend towards smaller, lighter and thinner luminaires continues to gain momentum, LED manufacturers have responded by shrinking the size of their LED packaging. One result of this trend is the growing popularity of CSP technology. CSP is done at the wafer-level, eliminating the separate step of having manufactured LEDs go through a packaging line (packaging can sometimes be 60% of the total cost). CSP technology eliminates the traditional sub-mount to directly attach the LED die to the PCB, allowing for overall system cost reductions. As fully functional LED packages that are equal to or slightly larger than the size of a die, CSPs are increasingly being implemented in lighting designs. Figure II.1, shows a CSP LED compared to a classic packaged-LED and a COB-LED.

Figure II.1 – (a) CSP LED (b) packaged LED and (c) COB-LED

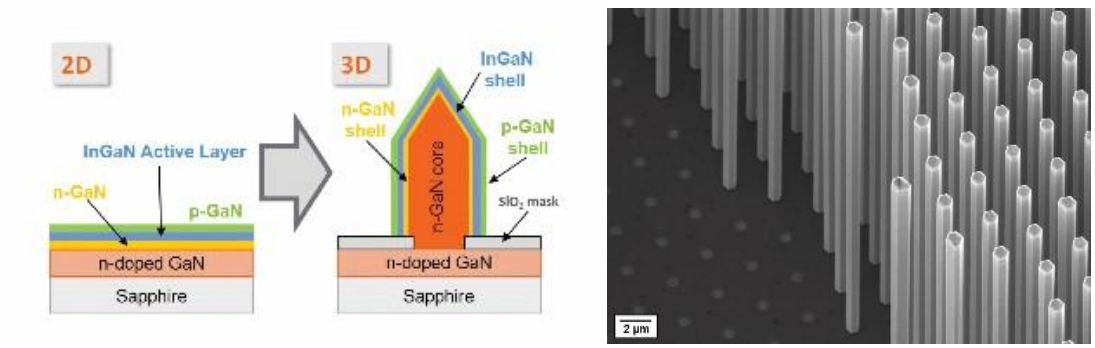


(a) (b) (c)

The CSP LEDs have a wider beam angle, more design flexibility, and it can be overdriven. However, CSP LEDs are not as efficient as high-power LEDs and low yields result in much higher prices, currently [SMA-16].

Another regain of interest concerns **Nanowire LEDs.** Nanowire LEDs were first reported by Harvard University in 2000 and the first patent filled in 2002 by Postech Foundation for an axial PN junction architecture. Since then, companies have shown growing interest in nanowire-based LED for improved light extraction and thermal conduction. Nanowires for LEDs are made up usually of an inner core of gallium nitride (GaN) and a layer of indium-gallium-nitride (InGaN). Nanowires are very small - about 2 µm high and 10-500 nm in diameter. Figure II.2, shows the LED-nanowire structure

Figure II.2 - LED-nanowire structure



Today, nanowire LEDs are still in their infancy, so it is not yet clear whether they can displace the traditional planar LED through superior performance, lower cost, or a combination of the two. Evaluating the potential for superior performance forms part of the activities of European projects involving one of the world's leading chipmakers, Osram, while French start-up Aledia is pursuing the opportunity for driving down device costs.

From 2003 to 2014, 246 patent families were published on nanowires as active layers for LED applications. Publications increase almost constantly over the past ten years. Nanowire LEDs regain interest recently as an alternative approach to conventional phosphor based LEDs, a full-colour LED array consisting of red, green and blue (RGB) InGaN based nanowire LEDs monolithically integrated on a micro-scale level has been proposed and fabricated [LPR-16].

In the downstream domain, we should mention the spectacular success of **LED filament lamps**. Featuring a classic heritage design, classic filament LED Lamps (Figure II.3) combine the familiar shapes of classic incandescent bulbs with the benefits of the long-lasting LED technology. They deliver beautiful, decorative warm-white light while saving around 90% on energy costs compared with traditional light bulbs. The designs used several LED filament light producers arranged in the same or similar pattern to that found in the wires of a standard incandescent bulb.

Figure II.3 – LED Filament lamps

Historically, the first LED filament-type design light bulb was produced by Ushio Lighting (Japan) in 2008 intended to mimic the appearance of a standard light bulb [HAK-09]. By the mid-2010s, LED filaments were being introduced into the market by several

manufacturers. Since 2013, LED lighting manufacturers are actively promoting filament LED lamps, and the revenue and sales of

this particular product has markedly risen. In 2015, LED filament lamps entered a fast growth phase [LAED-16a].

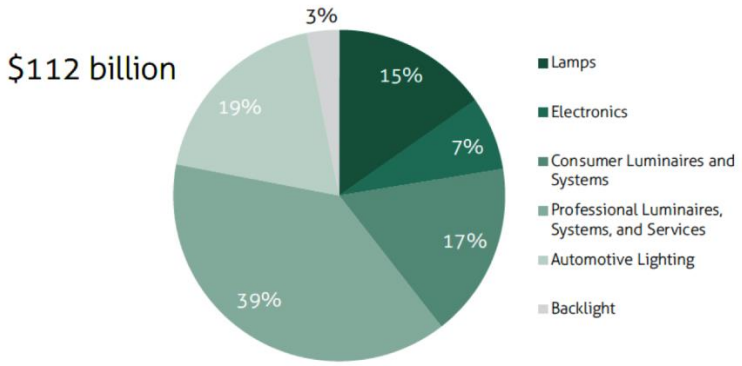
The LED "Filament" typically consists of many (sometimes hundreds) of tiny unpackaged LED chips mounted on a transparent substrate instead of metal substrate. This is commonly referred to as Chip-On-Glass (COG). These transparent substrates are made of glass or sapphire materials. This transparency allows the emitted light to disperse evenly and uniformly without any interference. This enhances the flux geometry of the lamp. In the absence of a heat sink, LED filament bulbs may use a high thermal conductivity gas inside the bulb to aid heat dissipation. The LED filament is then encapsulated in a resin made up of a silicone and phosphor mixture that performs the usual transformation of the LED chips' blue light into white light. This innovative design allows the use both of both blue LEDs as well as red LEDs to modulate the correlated colour temperature (CCT). Most manufacturers rely solely on the phosphor to set the CCT. This added degree of control allows the lamp maker to provide a more accurate level of CCT, and flexibility during the manufacturing process. The downside is that the CRI performance will not be as consistent when using the combination of both blue LED and red LED chips [LIN-15]. The large number of LEDs (typically 28 per filament) simplifies the power supply compared to traditional LEDs. Two filaments with a mix of red and blue is thus close to 110 V, or four close to 220 V to 240 V. Furthermore, modern LED filaments have a great potential as they are more efficient than many conventional LED lamps, and the new lamps provide better flux geometry. Degradation of silicone binder, and leakage of blue light are design issues in LED filament lights and lifespan of LED emitters is reduced by high operating temperatures.

The LED filament bulb became popular in the lighting market mainly because major buyers and consumers in decorative lighting, art lamps, chandeliers and classical luminaires were gradually replacing conventional light sources, including filament bulbs and halogen light sources with LED lights. Previously, traditional LED bulbs failed to meet the aesthetic demands of traditional luminaire manufacturers, which paved the way to LED filaments emergence on the market [LED-16a].

3 Evolution of the World Lighting Market and LED penetration

Lighting is large and growing addressable market. Traditionally, the global lighting market can be broken down into the following segments: general lighting, automotive lighting and backlighting. General lighting splits into service, systems (that includes electronics), luminaires and lamps. Figure III.1 shows a snapshot of the estimated global lighting market in 2014 that is used as basis for forecasting the future]. At 2014, the total revenue of the Global Lighting market is estimated in the order of US$ 122 million [PET-16].

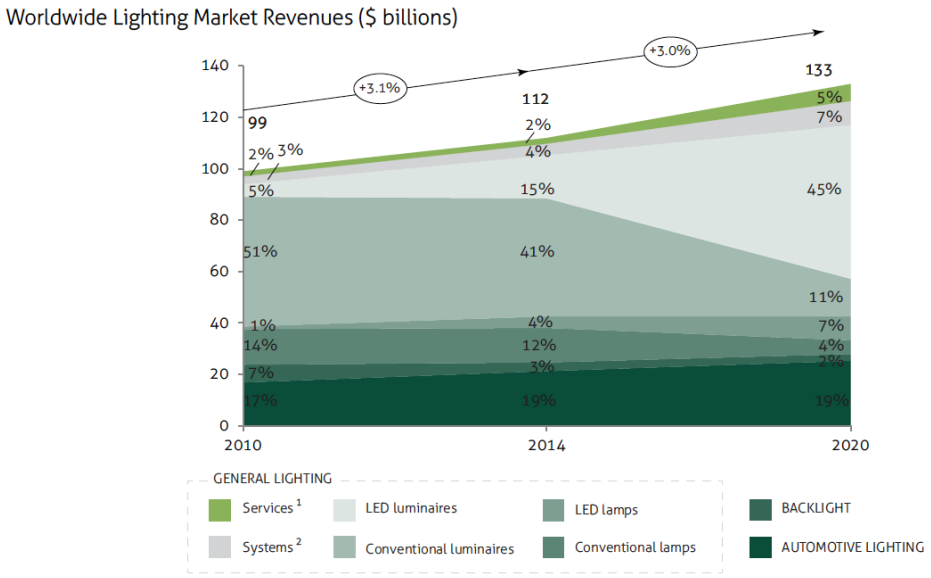
Figure III.1 – Addressable Global Lighting market snapshot at 2014 [PET-16]



In the backlighting segment, which is out of the scope of this report, revenue growth is expected to stagnate due to the increased use of organic light emitting diode (OLED) technologies [STA-17]. The market share of OLEDs in smartphone and television displays is set to experience accelerated growth at the expense of LED and liquid crystal displays. In fact, LED backlight market demands fell short of expectations, which caused sliding ASP of LED chips and LED package. This trend has been markedly observed during second half of 2015, when LED chip and package prices sharply plunged to the point that some LED chip and package spec prices are now close to material costs [LED-15b].

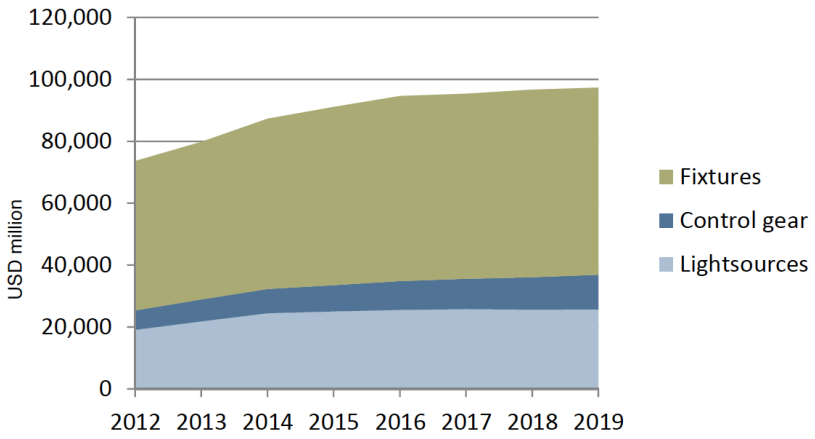
Based on the McKinsey's "2020 Lighting Market Model" [MCK-12], Figure III.2, shows the projected evolution of the global lighting market for the above-mentioned sectors. Conventional luminaires and lamps shares are rapidly decreasing thus LED-based technologies become dominant.

Figure III.2 - Projection of worldwide lighting marker revenues per sector based on McKinsey's 2020 Lighting Market Model [PET-16]



Traditionally, the lighting usually industry includes 3 branches: lamps, luminaires and lighting controls. Figure III.3 shows historical and Forecast market sizes by branch.

Figure III.3 - Historical and forecast market size by traditional industrial branch [F&S-15]

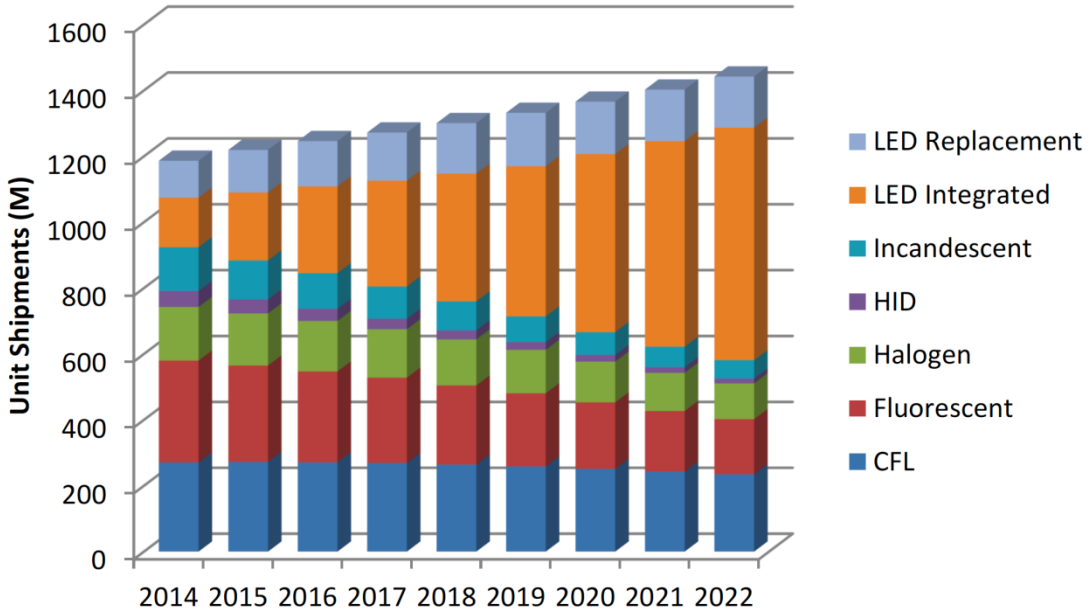


Fixtures (luminaires)[2] are always dominant. Projection shows that lamp's segment would saturate from 2017-18. This can be explained primarily by the fact that LED technology has longer lifespan that legacy technologies, this implies that re-lamping frequency is expected to reduce significantly in the next years. Figure III.4 shows, following Strategies Unlimited 2016 analysis, the luminaire branch units' shipments evolution for different technologies including LED-based products [SMA-16]. If fact, LED luminaire

2 In this report, the terms "luminaire" and "fixture" are considered as equivalent

market is forecasted to grow with ac CAGR 12% to US$ 21,3 billion in 2018 [SMA-14]. In parallel, average selling prices (ASP) are continuing to drop through this time period: High-bay luminaires are expected to drop in price about 12% from US$ 400 to US$ 350. Troffers will decrease about 33% from $120 to $80 [WRI-16b].

Figure III.4 – Evolution of luminaires units shipped by technology [SMA-16]

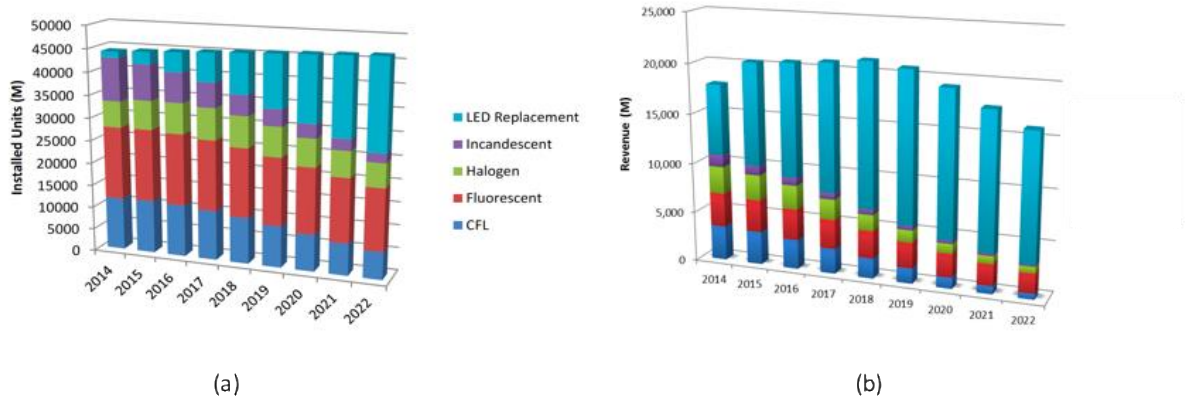


Control gear (ballast) is the fastest growing branch. The control possibilities that LED offers will give rise to increasingly complex control gear giving comfort, security and flexibility to lighting that has thus far only been seen in niche markets. In fact, the flexibility of LED lighting will provide demand for controls, both in the form of LED drivers and lighting management systems, offering the full spectrum of personalisation. For sure, control gear will play a pivotal role with the rise of LED due to the long-term increase on functionality [F&S-15].

Strategies Unlimited predicts that the overall market for lamps peaking around 2018 to 2019 at around US$ 21 billion, growing from about US$ 16,8 billion in 2014 [WRI-16b]. Smallwood predicts that for lamps the market will decrease beginning around 2018. But the decrease will impact legacy lamps more so than LED-based products. Subsequent to the peak, legacy lamps will have a -13% CAGR through 2022. But LED lamps will be growing at 8% over that same period. So there still will be opportunity in the LED lamps space [WRI-16b].

Concerning LED-based light sources, Philip Smallwood from Strategies Unlimited tried to give some estimation on the evulsion of the LED-Lighting downstream market. Figure III.5a shows that the number of the worldwide installed lamps would not significantly change for the next few years. However, the LED-based lamps penetration will increase very rapidly in replacement of legacy technologies [SMA-16]. However, the lamp branch revenue is expected to shrink as shown in Figure III.5b [SMA-16]

Figure III.5 – LED-lamps versus legacy technologies market size (a) in number of pieces and (b) in revenue [SMA-16]

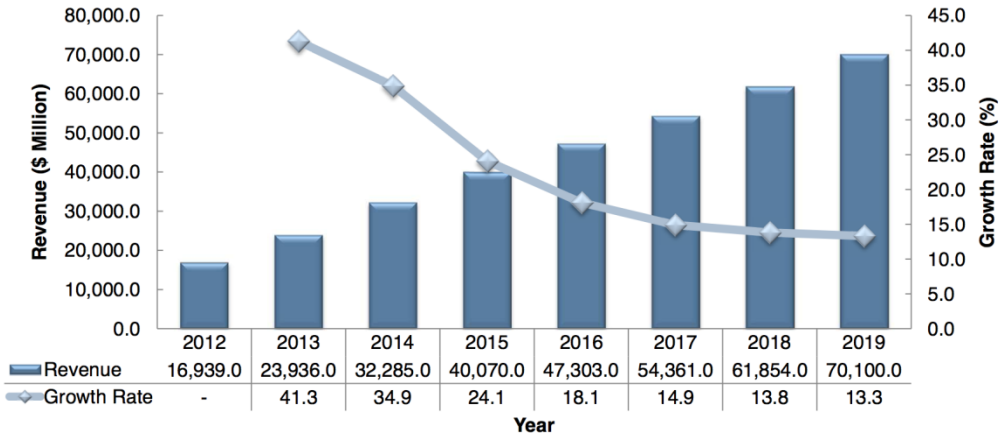


(a) (b)

Both IHS and Strategies Unlimited estimate that by the end of 2015, LED lamps comprised 6% of the global installed lamp base [SMA-16] [IHS-15]. IHS forecasts that penetration of the global installed base will remain below 40% through 2022 [IHS-15]. LEDs made up less than 4% light of total lumen-hours light in 2014. By 2023 LED share is expected to reach 84% [GMI-17] and by 2030 will goes up to 88%, accounting for the majority of lighting installations [BGL-16].

As explained above, LED technology share for General Lighting is experiencing important growth across several application sectors and will continue to grow throughout the next decade but year-over-year (YoY) growth rate is expected to shrink. Frost & Sullivan valuated the 2014 LED market revenue at US$ 32,3 billion [F&S-15]. Figure III.6, shows both historical and forecasted LED for lighting revenue and YoY growth rate [F&S-15]. Even if revenue is increasing, YoY growth rate is decreasing and tend to stabilization at around 13% by 2020.

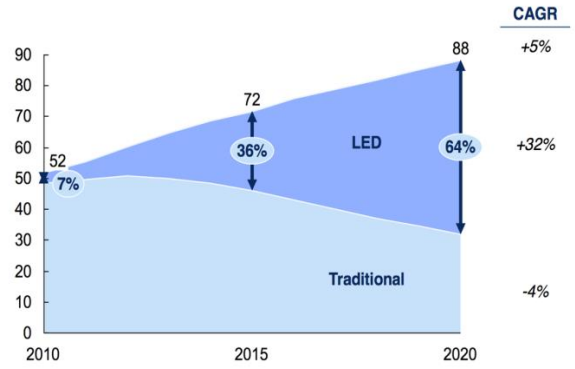
Figure III.6 - historical and forecasted LED for lighting revenue and year-by-year growth rate evolution [F&S-15]



Years 2013 and 2014 have been the breakthrough years for LED in the professional market, in Europe, North America and China. More especially, 2014 has seen significant inroads for LED in the large residential market, which will help LED to increase the penetration of total lighting sales. In November 2014, LED Inside [LED-14] has projected

that LED lighting market penetration will reach 31% of the global lighting market in 2015, when Frost & Sullivan, evaluated one year later that LED lighting represents roughly 40% of the market in value for the same year [F&S-15]; reality is beyond predictions. Figure III.7 and associated table show the evolution of market sizes for legacy and LED technologies [JAU-12] [F&S-15].

Figure III.7 - Evolution of market sizes for legacy and LED technologies [JAU-12]; (b) historic and forecasted LED market penetration [STA-17]



Year	Traditional (USD m)	LED (USD m)
2014	54,972	27,261
2019	27,261	70,100
CAGR (2014-19)	-13.1%	16.8%

Even if for the next couple of years, the bulk of the projections made by different analysts seems to be coherent, it should be underlined that the mid- and long-term forecasts may be diverging. Table III. T1 show an example [PET-16]: the projected penetration rate for 2022 varies from 67% to 80%. Nonetheless, according to Frost & Sullivan's 2017 update the LED lighting market could expand to an US$ 80 billion market by 2020 and the penetration rate will attain 97% by 2025 with India, Asia-Pacific, Latin America, and Africa set to record the highest growth rates [F&S-17].

Table III.T1 - Global Market Share of LED Lighting Measured as a Percent of Total Lighting Revenue [PET-16]

	Scope	2014	2016	2018	2020	2022
IHS Global Insight	Lamps	31%	42%	52%	61%	67%
Strategies Unlimited	Lamps	41%	56%	68%	76%	80%
Strategies Unlimited	Luminaires	33%	44%	53%	61%	69%
LED Inside	Lamps & Luminaires	26%	34%	54%		

Following Evergreen, the global LED lighting market is expected to be valued at US$ 92,40 billion by 2022 and is expected to witness a shipment of 14,01 billion units at the same year at a CAGR of 13,66% and 21,23%, respectively, between 2016 and 2022 [EVE-17].

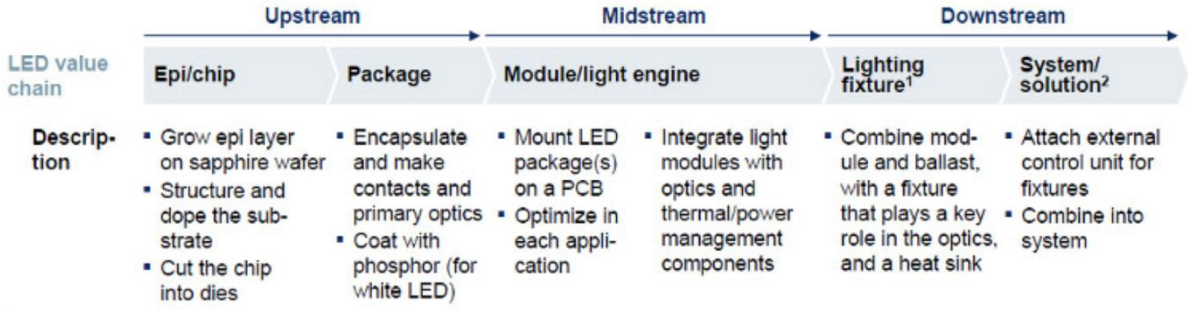
Navigant Research estimates that unit shipments of LED lamps worldwide will grow from 68 million pieces in 2013 to 1,28 billion by 2021 [NAV-17]. Although shipments of LED products will expand at a compound annual growth rate (CAGR) of 44.3% through 2021, they will not be sufficient to compensate for the overall decline in commercial lighting

revenue as the industry moves toward much more long-lasting lamps, says the report. Lamp and luminaire revenue will both grow for the next few years, before beginning an inexorable decline in 201. More precisely, global lamp revenue is expected to decline from US$ 23,0 billion in 2017 to US$ 21.5 billion in 2026 [NAV-17]. Furthermore, there are certain factors hindering the growth of the market like high initial set up cost, complicated distributed channel, and slow reaction by bulk market consumers [KOA-16].

4 LED Chain value evolution

The LED Lighting value chain is traditionally divided in Upstream, Midstream and Downstream as shown in Figure IV.1.

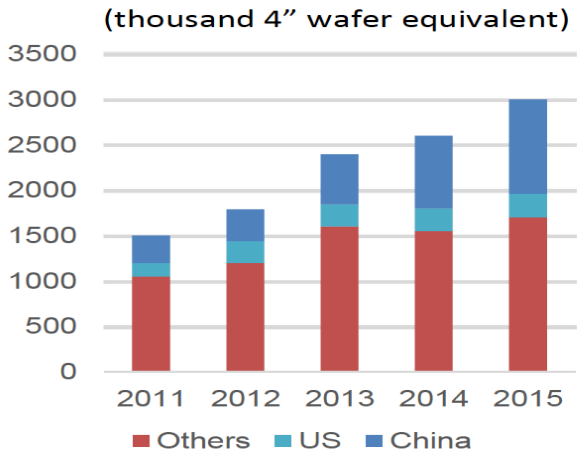
Figure IV.1 – LED lighting value chain



4.1 Upstream

Figure IV.2 shows the world's LED chip production capacity. China is the world leader for **LED components** production.

Figure IV.2 - Worldwide LED chip production capacity in 4" wafer equivalent (data: LEDInside and Semi) [LOU-16]



In 2011, many Chinese manufacturers began to produce LEDs, and the LED TV industry failed to meet expectations. Figure IV.3, shows the Chinese packaged-LED market relative value forecast split among end-use domains.

Figure IV.3 - Chinese packaged-LED market relative value forecast split among end-use domains [ENE-14a]

(data HIS)

Concerning LED-components, due to the oversupply situation in the LED industry (estimated to 16-19% [LOU-16]), LEDs ASP prices plunged. Thus, LED component costs are forecasted to decline with technological advances in manufacturing, as much as 70% by 2020 according to a US DOE estimate [BGL-16]. LEDinside estimated the global HB-LED market value in 2015 will increase at an incremental rate of 2% to US$ 14,52 billion. Even though lighting demands spurred LED usage volume growth, ironically the increasingly energy efficient LEDs are reducing usage volume. Additionally, LEDs still are under immense pressure to further lower prices. Based on these observations, LEDinside projects in the next five years the LED industry Compound Annual Growth Rate (CAGR) is unlikely to reach more than 10% in the future.

Philip Smallwood (Strategies Unlimited) arrive at the same conclusions for **packaged LED** industry: The revenue will grow from US$ 15 565 million (2014) with a CAGR of 7% to US$ 21,6 billion in 2017 and US$ 22,1 billion a year later (2018) [SMA-16] [WRI-15b]. Figure IV.4 shows the evolution of the market size. It is clear that "historical domains" (Displays, Mobile applications and Signage) are stagnating. Growth today relies mainly on General Lighting: the revenue will pass from UD$ 5 263 billion in 2014 to US$ 9 109 in 2019 (12% CAGR in the reference period) [SMA-16]. Figure IV.5 shows the historical and forecasted packaged LED revenue split among the various general lighting domains (replacement lamps are considered as separate domain). In the reference period replacement lamps is the winner [SMA-16].

Figure IV.4 - Global Revenues for Packaged LEDs 2014 – 2019 according Strategies Unlimited [SMA-16]

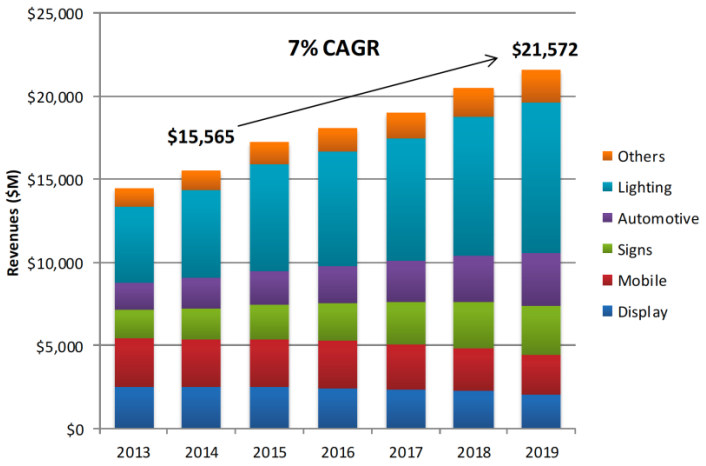
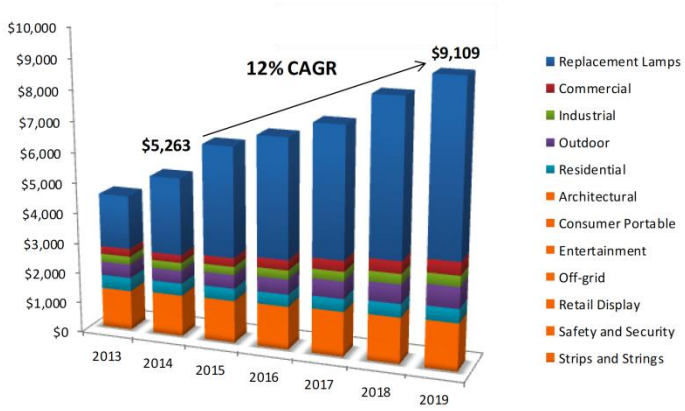
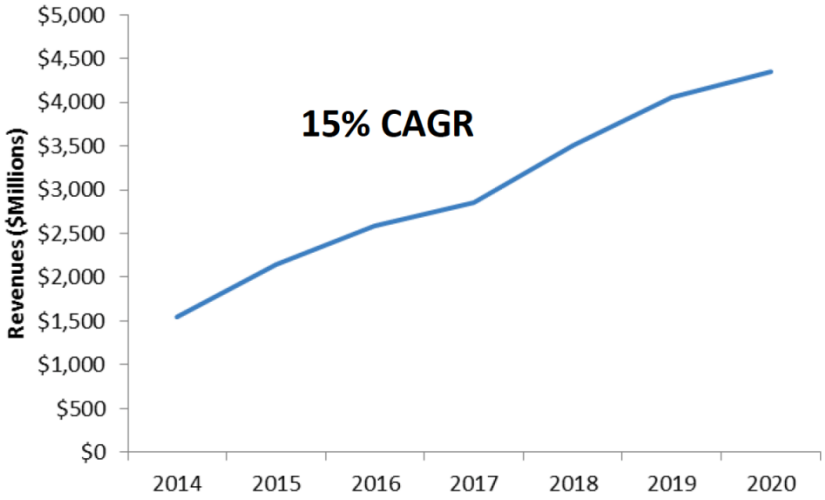


Figure IV.5 – General Lighting Revenues for Packaged LEDs by application domain [SMA-16]



Following Smallwood, COB-LEDs sector is still growing and a CAGR of 15% is expected within the 2014-20 period (Figure IV.6) [SMA-16].

Figure IV.6 – Evolution of Revenues for COB LEDs in the period 2014 to 2020 [SMA-16]



Since 2015, backlighting market stagnation implied that many manufacturers have incurred losses. Even though manufacturers in the LED industry are being pressured to lower prices in the short term, in the long run there will be limited room for further LED price cuts. This can be explained by the growing number of manufacturers withdrawing from the market in the near future, as LED prices is close to manufacturing costs and reduce companies' profitability [LED-15b].

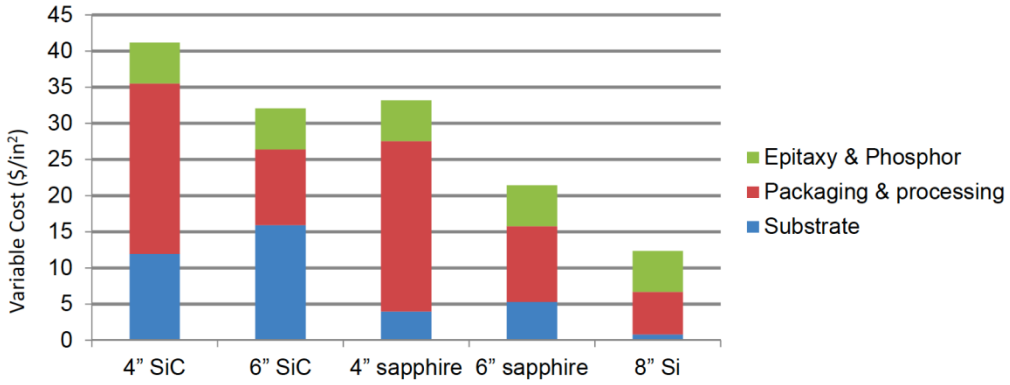
Since few years, China has become the world's largest LED lighting manufacturing. However, over the last decade, the Chinese government largely supported the local LED industry through massive financial subsidies, incentives, and resources to improve domestic LED companies manufacturing capacity. That way, national and regional governments in China have invested heavily in promoting companies at each level of the industry, from epitaxy to luminaire assembly. However, local manufacturers are still very dependent on international manufacturers for certain upstream MOCVD equipment and materials. Hence, future Chinese policies will encourage innovation, and focus on upstream raw materials, for example wide bandgap semiconductor development, or smart lighting applications following the emergence of the Internet of Things (IoT) [LED-15b]. Furthermore, due to currency fluctuations in 2015, end market demands in different countries have been much lower than expected. Many SMEs in the LED industry are facing financial loss pressures, with plenty sinking into negative cash flow cycles. These developments have ousted smaller manufacturers, due to their broken finances. [LED-15b].

As a first answer, Chinese LED companies listed on the stock exchange have been acquiring international manufacturers through issuing shares on the market. That way, some Chinese manufacturers are targeting major international LED players' patents and lighting brands, in hopes of strengthening their patent portfolio and overseas distribution channels. Additionally, more Chinese LED manufacturers are also transforming their business models. Some LED manufacturers aiming to leave behind hotly contended red sea markets are entering other market sectors through mergers and acquisitions [LED-15b].

In any LED product, the raw material costs around 37% of the total product cost with value addition accounting to 23,2%. While the cost of raw material in each stage see a marginal rise, the acquisition cost of the component by a value chain element from its upstream element almost doubles [F&S-16].

Concerning substrates, Philips, Osram Opto, and Samsung are all actively exploring GaN on silicon (GaN-on-Si) technology and Soraa stil works on GaN on GaN substrate [WGR-14]. GaN-on-Si offers a baseline wafer cost advantage of about UD$ 0,002/mm^2 However, the performance of GaN-on-Si has, over the last four to five years, stayed 10% behind GaN-on-sapphire [WRI-15]. Thus, bulk production of LED dies continues to be on 6" sapphire substrates. Epistar is working on 200mm sapphire wafer technology. Producing LEDs on silicon is no longer considered as attractive as it was a few years ago, and modest profit margins, falling LED prices and other factors mean that larger players from semiconductor-related industries are now less likely to enter the market. While no big player is expected to enter the market in 2016, there is a small, but unlikely, chance that a new company with, a genuinely game-changing technology could enter the market [HIS-16]. Nano-wire (either GaN or ZnO) LED technology may be attractive but the technology used by Aledia (France) and GLO AB (Sweden) is still in very early stage. Figure IV.7, illustrates the 2015 estimate variable cost of LED chip manufacturing for some of the above sited substrate technologies.

Figure IV.7 - illustrates the 2015 estimate variable cost of LED chip manufacturing (6" SiC is not yet available and 8" Si is in R&D level) [LOU-16]

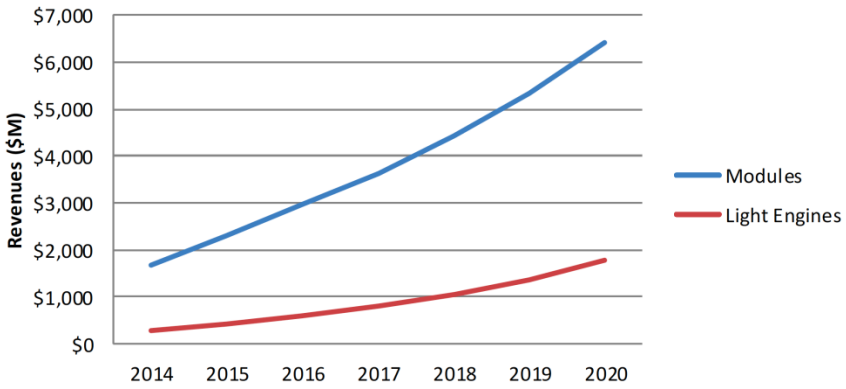


The segmentation of the packaged LED market also remains largely consistent with prior years. The 0,5 W dividing line between the mid- and high-power segments remains. But that line may create ambiguity in some of the data where applications are dissected relative to the types of LEDs used. Many LEDs that look like traditional mid-power devices in plastic packages with no secondary optics can be driven at levels of 1 W and higher today.

4.2 Midstream

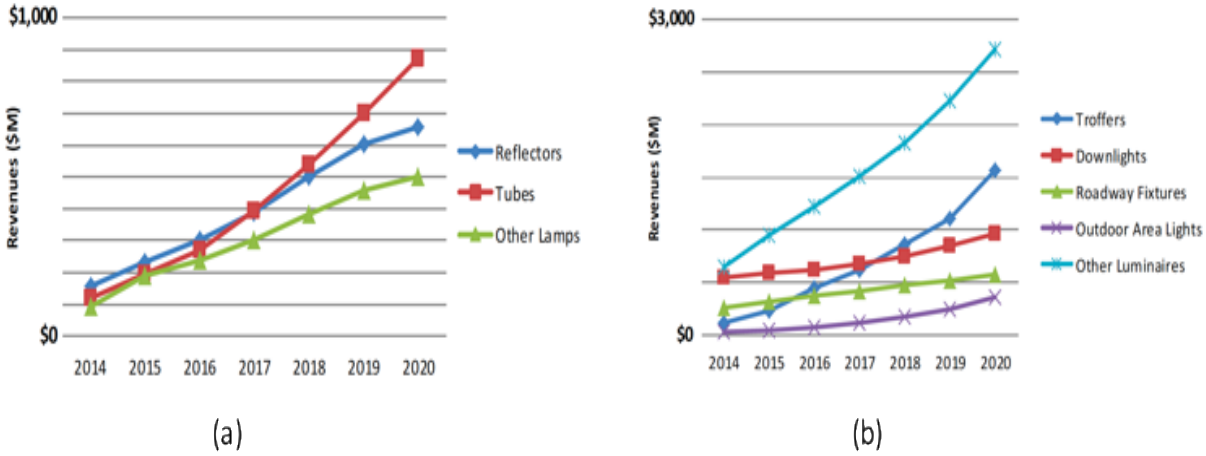
In 2016, Ph. Smallwood estimated the evolution of the two market segments as shown in Figure IV.8 [SMA-16].

Figure IV.8 – Evolution of market segments for LED-modules and LED-engines [SMA-16]



Following 2016's Strategies Unlimited analysis, the Figure IV.9a and b show the market size evolution for LED-modules and LED-engines for use in LED-lamps and in LED-Luminaires [SMA-16]. It is clear that the luminaire segment is dominant.

Figure IV.9 – Evolution of market segments for LED-modules and LED-engines for (a) lamps and (b) luminaires [SMA-16]



Yole's analysts in collaboration with PISEO estimated that the open **LED lighting module** market including flexible LED strips will grow from approximately US$ 3 billion in 2015 and to more than US $10 billion by 2020. Yole's market metrics take into account mid- and high-power modules, COB and flexible strips sold on the open market [YOL-15]

Pars Mukish said 'The main benefits to lighting integrators of using LED modules cover faster product development cycles, less complexity for integration as well as the

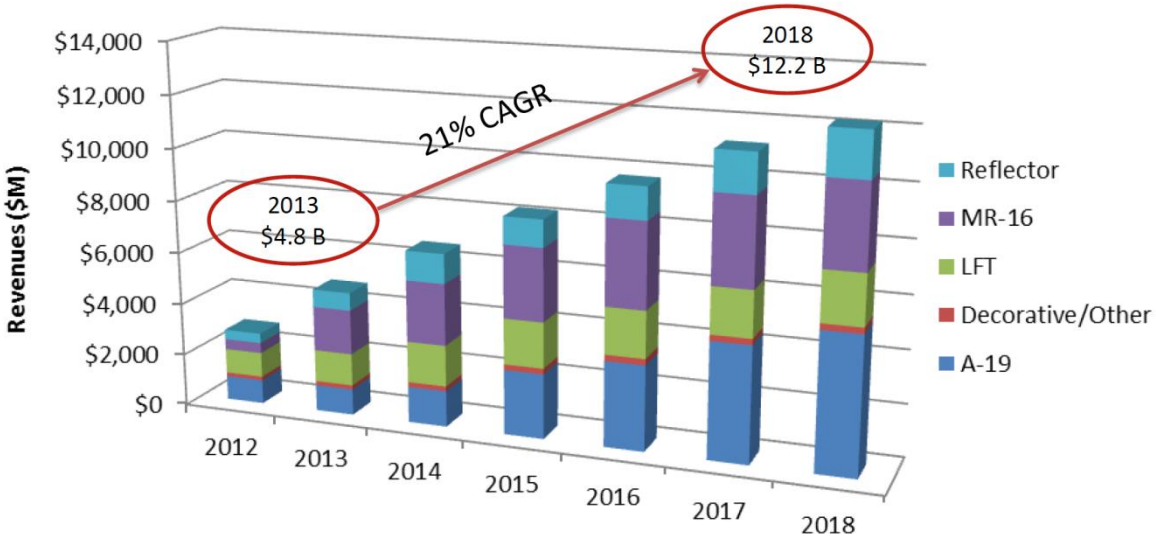
management of high level parameters, which is directly handled by the LED module supplier" [YOL-15]. Furthermore, LED modules need additional components to give the light effect desired, such as clamp holders and optics. Complete standardization of LED sub-systems is still difficult as integration of LED modules must follow specific rules in areas such as design and electrical insulation. In this context, the Zhaga consortium[3] has been created to develop guidelines for interchangeability of LED light sources made by different manufacturers. Standardization will further reduce development and maintenance but will also limit the possibility of differentiation between suppliers.

Most LED lighting module suppliers are packaged LED manufacturers that have used vertical integration to capture more value within the supply chain. These players have a strong competitive advantage in terms of mastering the LED binning strategy. However, some other types of players are also involved in this business. They mainly want to diversify their activities and/or define new strategies to support the development of their primary business. They are: LED luminaire, LED driver, optic, connector, heatsink, etc. manufacturers.

4.3 Downstream

As has been underlined in the previous chapter, according Strategies Unlimited the full marker size (in number of shipments) for lamps and luminaires will either stagnate or will grow very slowly from 2017-18. However, The **LED-lamp** revenue will increase from US$ 4,8 billion (2013) to 12,2 billion in 2018 corresponding to 21% CAGR [SMA-14]. Figure IV.10 shows the LED-lamp market evolution in revenue.

Figure IV.10 – LED Lamp Market size evolution by lamp type [SMA-14]



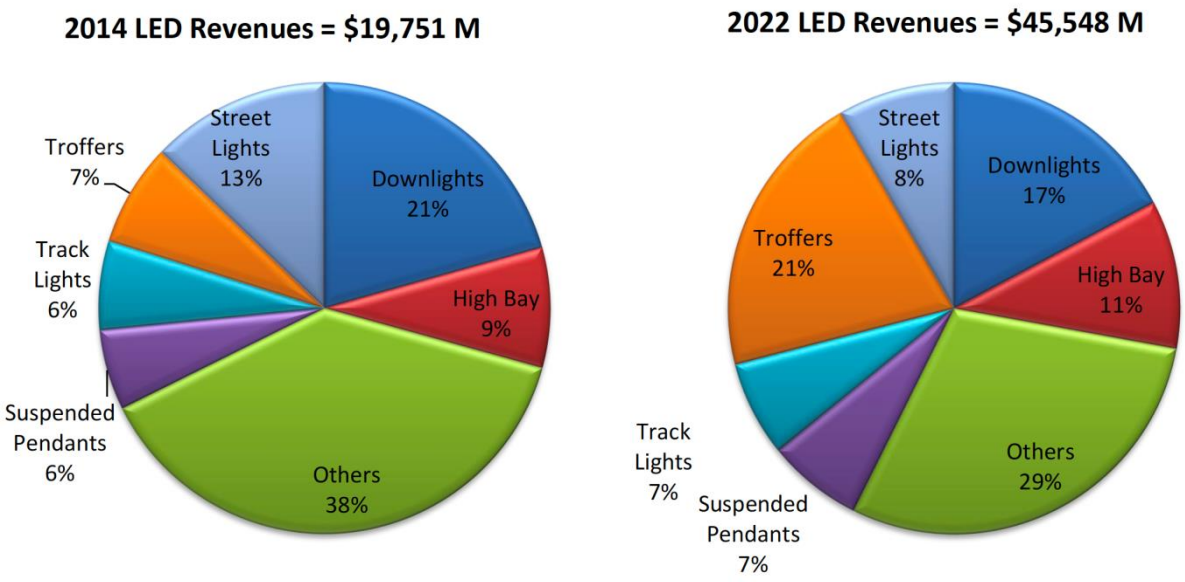
LED filament lamps are expected to grow rapidly. Since 2013, LED lighting manufacturers are actively promoting filament LED lamps, and the revenue and sales of this particular product has markedly risen. In 2015, LED filament lamps entered a fast

[3] http://www.zhagastandard.org

growth phase, which is expected to boost global shipment volume to over 50 million LED lamps in 2015. LED filament bulbs resemblance to traditional incandescent bulbs has made it a very popular product; moreover since it can be directly installed it has made little impact on European and American consumers' user habits. These features of LED filament lamps have spurred demands, and brought filament LED market value to an estimated US$ 40 million in 2015 [LED-16a].

Furthermore, The **LED-based luminaire** revenue will increase as shown in Figure IV.11 from US$ 19,8 billion (2014) to UDS 45,5 billion in 2022 [SMA-16].

Figure IV.11 – Evolution of LED-based luminaire revenue by luminaire type [SMA-16]



5 LED End-use Domains

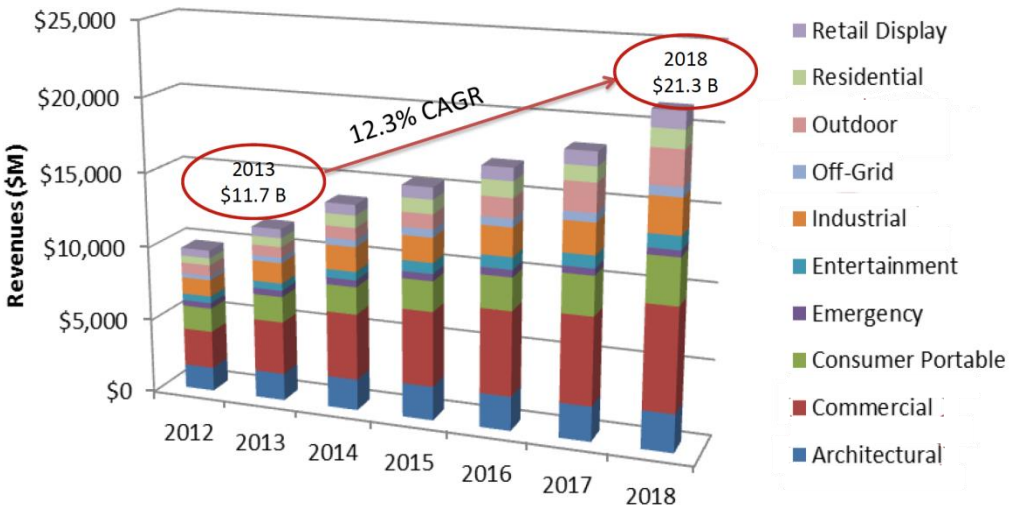
Growth of the LED industry initially came from small display applications and was driven forward by larger LCDs. Since 2012, most companies have been participating in the ultimate application for the LED business, general lighting. The acceptance of LED lighting is escalating in almost all major end uses such as industrial buildings, residential and commercial buildings, as well as outdoor application areas.

Following Frost & Sullivan, in 2014, the largest applications for LED were residential, outdoor, architectural, and retail lighting. Except for architectural, which pioneered LED lighting, the applications have been the winners of the 2013–14 boom. The fastest-growing applications, in the 2014–19 period, are expected to be industrial, office, and hospitality. Industrial in particular will grow from a low base, while adoption in the large office space will increase outside of the headquarters/representative buildings that were more of the architectural adopters [F&S-15].

According to LEDinside, the residential LED lighting market was expected grow at a 30% clip from 2014-2016. However, after 2017, the LED residential lighting industry will plateau as demand slows and growth rates cool. The industry will become more integrated with a more focused use of resources. Prices will also become more reasonable. Price is a decisive factor in the **residential lightin**g market. Indeed, consumer price sensitivity in this market is extremely high. Consumers still hesitate to purchase products with the highest absolute price. In 2014, in the global light bulb market, there have been large-scale price cuts owing to government subsidies for energy-efficient lighting and manufacturers discounting products. The residential lighting market itself is mature. The distribution model for LED lighting products is similar to other fast-moving consumer goods (FMCG). The key to success in the FMCG industry is having excellent retail channels. The residential LED lighting market uses the same retail channels as traditional lighting: supermarkets, convenience stores and hardware stores. Only with a mastery of the retail channels can a sales team negotiate favourable prices with retail operators. [LED-14b]. Forecasts for LED uptake in the residential segment remain high and are expected to reach over 70 % in 2020 [IMA-17].

In 2013, **non-domestic** was the foremost application segment accounted for over 80% of industry share [GMI-17]. More especially, following Strategies Unlimited analysis, commercial, industrial, outdoor and architectural Lighting domains represent more than 60% of the market size [SMA-14]. Figure V.1 gives the LED luminaire market evolution by end-use.

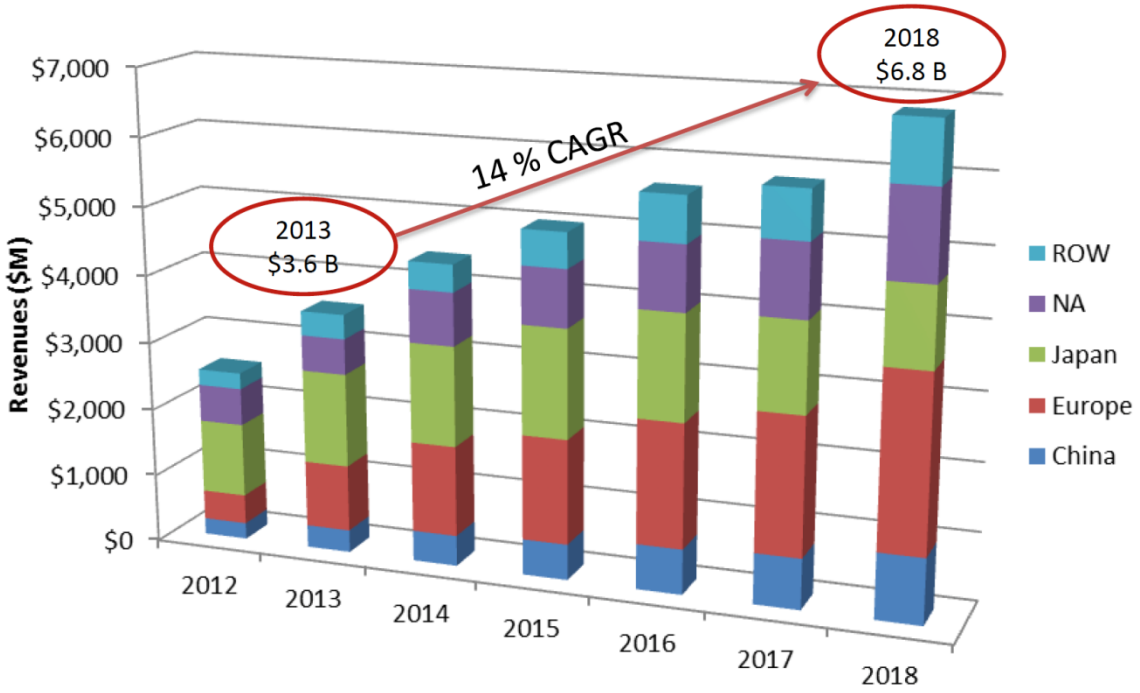
Figure V.1 – Luminaire market evolution by end-use [SMA-14]



More precisely, the **global industrial and commercial** LED lighting market was valued at US$ 12 928 million in 2012 and was expected to grow at a CAGR 30,8% during the forecast period from 2013 to 2019 [TRA-13].

Among all end-uses, **commercial domain** was the largest and accounted for 52,5% of the market in 2012. Following Smallwood, the luminaire revenue will increase from US$ 3,6 billion in 2013 to 6,8 billion in 2018 (14% CAGR) [SMA-14]. It is expected to maintain leading position throughout the forecast period owing to increased use of LED lights in emerging regions namely Asia Pacific and Middle East [TRA-14]. Figure V.2 shows the evolution forecast for the commercial lighting luminaires by world region till 2018; Europe has the largest share [SMA-14].

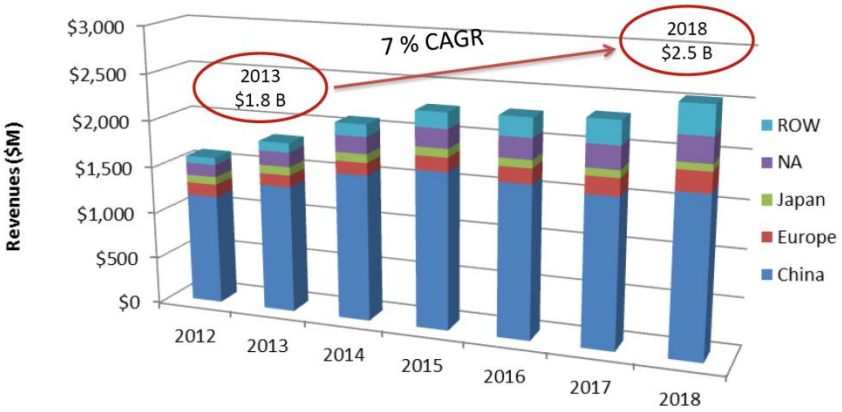
Figure V.2 – Commercial Lighting Luminaire domain market evolution by world region [SMA-14]



The ongoing improvement of efficacy, competence of SDCM control and colour rendering index in LEDs accelerate high-end **commercial lighting** market's development that demands higher light quality. High-end commercial lighting market mainly includes museum, galleries and other exhibition lighting applications that primarily use downlights, projectors and reflectors. LEDinside reports that the market scale of two frequently used luminaires for high-end commercial lighting, namely Downlight and Projectors and Reflectors separately reaches US$ 1,88 billion and US $1,54 billion in 2016. It's projected that the market scale of Downlight is to reach US$ 2,01 billion and Projector and Reflectors at US $1.59 billion in 2017. Based on LEDinside's data, both COB and DOB LEDs are introduced to high-end commercial lighting market, among most frequently used downlights and track lights, 40% and 75% of these luminaires use COB LEDs as its light source. Based on the sets of luminaires, mainly COB that are under 30W. Meanwhile, the percentage of COB used in downlight has 11% of CAGR while track spotlights reach 6% of CAGR. The majority of the track lighting product makers are European manufacturers, with product features including optical design and product ID design, also with DALI dimming system. [LED-16e]

Architectural segment is the second largest end user segment and is expected to witness strong growth during the forecast period. Increased use of decorative and functional architectural lightings in landscapes, signage, statues, columns and other decorative features have been driving the market. Japan and Europe are the fastest growing regions fir architectural lighting. [TRA-14]. Strategies Unlimited predicted a 7% CAGR for the LED luminaire market in this domain going from US$ 1,8 billion in 2013 up to US$ 2,5 billion in 2018. Figure V.3 shows that the market size tends to a plateau from 2016, but 2018 seems to be decisive [SMA-14]. LED penetration is forecasted to reach 90% by 2020 [IMA-17]

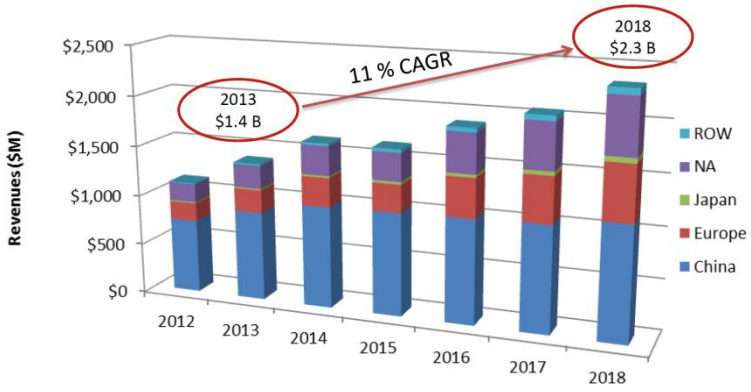
Figure V.3 – Architectural Lighting luminaire domain market evolution by world region [SMA-14]



According to LEDinside analysis, the global LED **stage lighting** market scale sufficiently increased by 14% to US$ 745 million in 2017 from US$ 655 million in 2016. The light source revenue for stage lighting has reached a size of USD 382 million (which is 51% of the full domain revenue), among which a share of approximately USD 150 million is contributed by LED light sources, with the LED penetration rate at 39%. The market size of traditional stage light source has been shrinking in recent years, while LED light sources surges relatively fast. As the technology of LED lighting gradually takes hold, the price of LED stage lights keeps dropping. The growth of its market scale in the following years will slow down while currently it is continuously growing. By 2020, the estimated market size is likely to surpass US$ 1 billion. In 2016, global LED-filament lamp market demand was 150 million pieces. In 2017, the market demand is predicted to hit 300 million pcs, up 100% YoY. As for branding development LEDVANCE and Philips Lighting are the top two LED-filament lamp branding vendors. Moreover, filament OEM supply majorly comes from Chinese manufacturers. [LED-17].

According to LEDinside, the LED **industrial lighting** market has enjoyed accelerated growth in recent years owing to the rising demand worldwide and government subsidies. Figure V.4 gives an idea of the evolution of the LED luminaire market till 2018 [SMA-14]. The market of LED industrial lighting is forecast to grow from US$ 2,93 billion in 2016 to US$ 5,20 billion in 2020, representing a CAGR of over 15% during the five-year period. [LED-16f]. More especially, Taiwan's optoelectronics association forecasted that LED explosion-proof lighting value to reach US$ 248 million in 2020 when the size was US$ 151 million in 2013 [ENE-16].

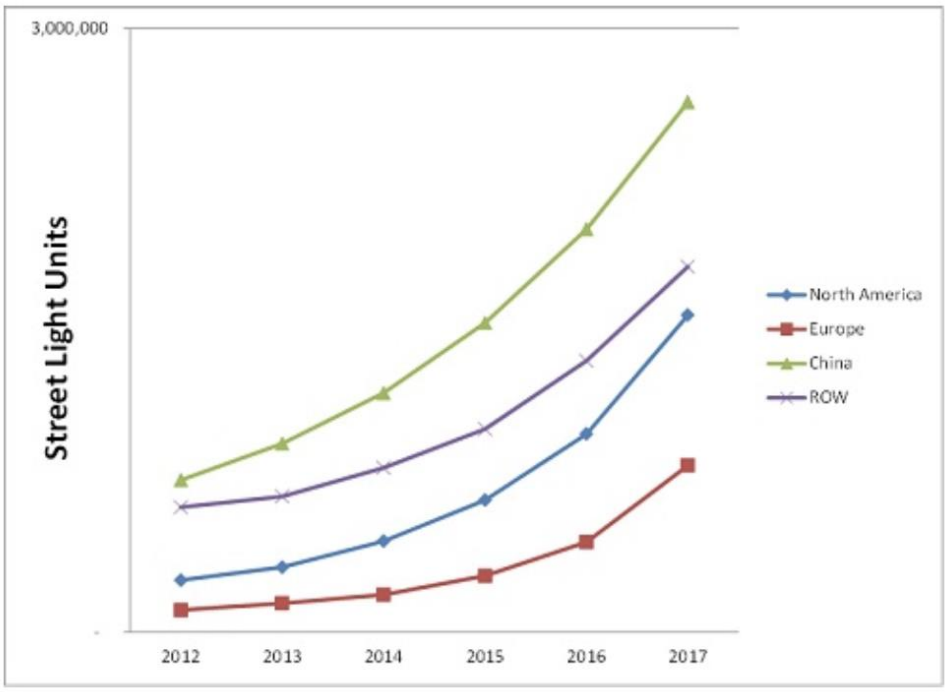
Figure V.4 – Industrial Lighting luminaire domain market evolution by world region [SMA-14]



LED technology is no longer exclusive to the lighting industry. The added value of LED solutions and the benefits they offer at the system level are now well-known. LEDs are gradually expanding into new speciality market segments: transportation with a special focus on the automotive sector, medicine, agriculture and more.

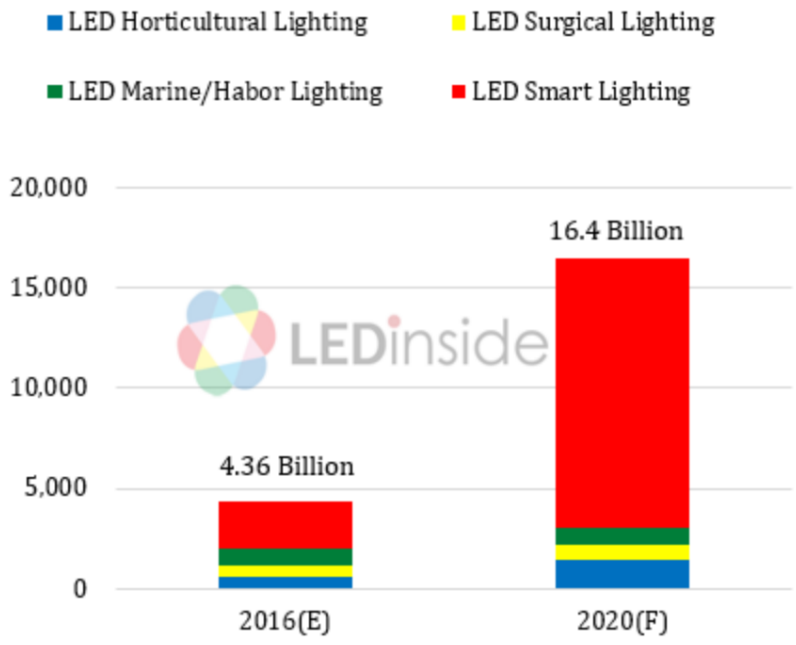
The market share of LEDs **in street lighting** worldwide will grow from 53,3% in 2014 to 93,8% in 2023, as falling prices for LED street lights are spurring a global transition from older lamp technologies to newer, more efficient, and more controllable LEDs. Governments and regulatory agencies worldwide encouraged the implementation of LED lighting in various ways, including: ARRA funding in the US, the 12th 5-year plan in China, and the European 20/20/20 initiative. Developed countries as well as emerging economies installed LED street lights on a large scale. Following Strategies Unlimited, unit shipments of LED street lights are forecasted to have a CAGR of 31% while revenues are forecasted to only grow 16% from 2012-2017 as downward pressure on prices continue due to competition [STU-14]. Furthermore, as LED prices continue to erode (in North America and Europe alone prices are predicted to decrease on average -20% and -15% respectively) and the long lifespan of LED lamps results in fewer replacements, overall revenue from street lighting will begin to fall. Navigant forecasts that global street lighting revenue will decline from US$ 2,5 billion in 2014 to US$ 2,3 billion in 2023 [NAV-14]. The Figure V.5 shows the forecasted regional growth for LED street lights. China has the largest shares in this domain. The demand for more efficient and longer lasting lighting will only grow as the demand for and price of electricity continue to rise [STU-14].

Figure V.5 - Forecasted regional growth for LED street lights [STU-14]



According LEDinside, four LED **specialty lighting** applications that are attracting growing interests include **horticultural lighting, surgical lighting, marine/harbour lighting and smart lighting**. Figure V.6, shows the market evolution of those 4 application domains. The combined market scale of these four applications is estimated to grow from US$ 4,36 billion in 2016 to US$ 16,4 billion in 2020, with the CAGR during this forecast period reaching 30% [LED-16c]

Figure V.6 - Market value for 4 speciality lighting applications, revolution from 2016 (established values) to 2020 (forecast) [LED-16c]



Demand for LED products in the **surgical lighting** application is picking up as LED light sources continue to improve in terms of luminous efficacy and colour rendering. According to LEDinside, the scale of the global LED surgical lighting market will expand from US$ 612 million to US$ 787 million during the 2016-20 period. Major regional markets for LED surgical lighting include Japan, Europe and North America. LED-16c].

In the **marine/harbour lighting** market, products are governed by stricter regulatory standards and thus their average sales prices are also higher compared with general lighting products. For the LED lighting industry, LED marine/harbour lighting is a specialty application that provides high margins and a stable source of revenue. The total value of the global LED marine/harbour lighting market will come to US$ 820 million this year, based on LEDinside's projection [LED-16c].

Another niche application market that is worthy of interest is **horticultural** lighting. The outlook is also very bright for the LED horticultural lighting market. LEDinside forecasts that the scale of the LED horticultural lighting market worldwide will grow rapidly from about US$ 576 million in 2016 to around US$ 1,42 billion in 2020 [LED-16c] and is expected to reach US$ 5,11 billion by 2022. Note that in 2016 LED revenue represented 23% of the global growth lighting size estimated at US$ 2,5 billion [MAM-17]. Furthermore, plant lighting market benefits from legal medical cannabis cultivation and recreational marijuana in Colorado and Washington. Entrepreneurs and lighting manufacturers aiming at the Gold Rush are waiting for action [LED-16b]. The grow lights market comprises key manufacturers such as Philips (Netherlands), General Electric Company (US), Osram Licht AG (Germany), Gavita Holland B.V. (Netherlands), LumiGrow, Inc. (US), Heliospectra AB (Sweden), Transcend Lighting Inc. (US), and Sunlight Supply Inc. (US); and raw material suppliers such as Beacon Lighting India (India); end users such as Walters Garden, Inc. (US), Green Sense Farms (US), and Borst Bloembollen B.V. (Netherlands); and suppliers such as Shenzhen Juson Technology Co., Ltd. (China).

The automotive exterior lighting market is also forecast to grow in the coming year. Because there has been less competition in this area, price erosion has not been as severe as it has been in the lighting sector. Japan, North America and Europe are the most established regions for automotive production and have made up most of LED sales to the automotive sector; however, growing markets in South Korea and China are now becoming increasingly important [HIS-16].

According PISEO, the LED automotive lighting market reached US$ 22,4 billion in 2015 [PIS-16] and it is expected to grow at US$ 27,7 billion in 2021 [YOL-16]. The use of LEDs has evolved from being a basic, functional feature to a distinctive feature with high-value potential. LED technology has given manufacturers the opportunity to stand out through lighting design and additional functionalities. LED automotive lighting developments have gradually shifted from high class car models to mid to high class car models. In addition, adaptive driving beam are an emerging trend. Adaptive driving beam headlights control semiconductor that are incorporated in the LED headlight, shutting off particular lighting beam area, which prevents glaring issue from oncoming vehicles. Adaptive driving beam headlights allow both high brightness and security at the same time, and have become one of the main highlighted developments for each manufacturer [LED-15b].

6 Regional LED market updates

The developed markets of North America and Europe account for approximately 45 % of the global lighting market [IMA-17]. Following LEDInside, LED lighting is to account for 23% of total lightings in Europe by 2016, which is the highest across the world. The second and third highest regions are to be found in North America and China. However, Asia- Pacific region is to witness fastest growth rate in LED lighting [LED-16b]. North American & European market is expected to show significant growth in outdoor and residential application segments. LED lighting market has huge growth opportunity in the emerging markets of Asia Pacific due to tremendous demand from residential application segment. The Middle East and Africa is expected to show remarkable growth in coming years [R&M-17]. Emerging markets, including Asia Pacific, the Middle East, and Latin America, comprise 28% of the global LED lighting market. Looking ahead to 2015, growth prospects in these markets are especially promising because of rapid population growth, favourable government policies and an abundance of private-sector LED lighting projects [LED-14]. Figure VI.1 shows the 2014 world region market shares and Table VI.T1 lists the main regional growth drivers.

Figure VI.1 – Base-line: LED Lighting market by region in 2014-15 [LED-14]

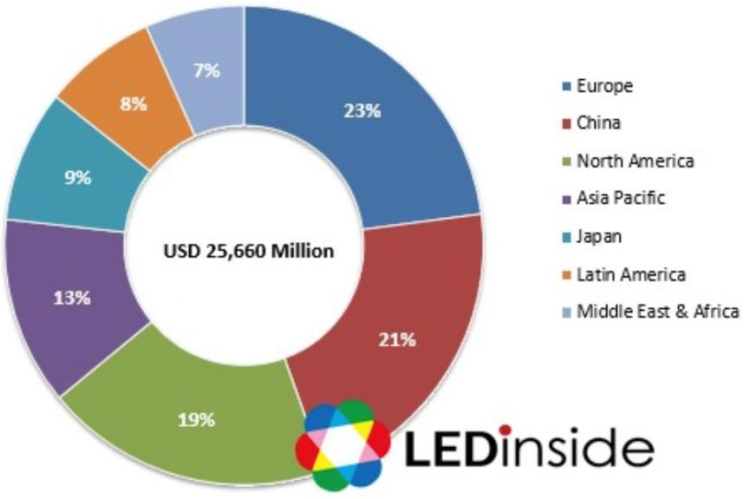


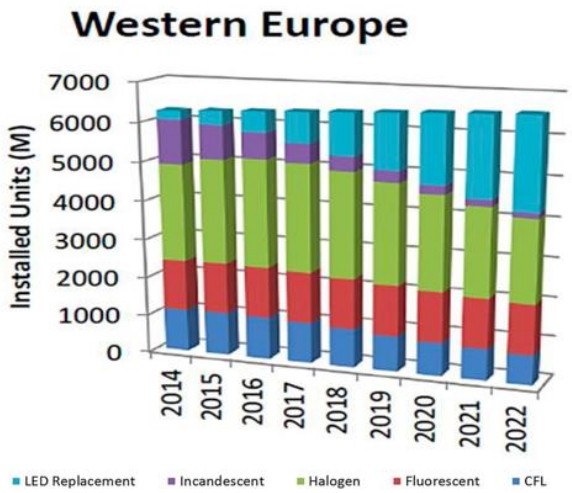
Table VI.T1 - Regional LED market drivers [LED-16b]

Region	Country/ city	Market Driver	Note
Latin America	Brazil	Policy ، Standard	Phase out of incandescent bulb; government's certification and regulations
		Commercial Lighting	Supermarkets; shopping malls
	Mexico	Policy	Government's approval of energy saving policies
	Jamaica	Policy	Waived import tariffs for solar power and LED lighting products
Middle East & Africa	Dubai	Mega Deal	Agreement between Philips and the Dubai government to provide LED lightings for 262 newly constructed buildings.
		Construction	The construction of infrastructure accelerates LED lighting developments
	Africa	Mega Potential	About 15% of the global population or 500 million people live in areas without access to electricity
		Mega Deal	In 2015, Philips invested EUR 1.2 million in LED lighting center in Africa; Osram and GE have invested in strategies and development; SFT Optoelectronic participates in Lighting Africa Project, a United Nations Environment Program (UNEP), providing 100,000 LED streetlights to African countries
	India	Policy	India is to convert approximately 1 billion unit of streetlights into LED bulbs within three years; LED streetlight bids
Southeast Asia	Malaysia	Policy	Phase out of incandescent bulbs; Economic Transformation Program (ETP) ; EPPs; Tax preference policy
		Mega Deal	The conversion of 1,700 7-Eleven shops with GE LED lighting in Malaysia is estimated to annually save USD 2.4 million
	Indonesia	Policy	Free LED bulbs giveaway; incentives for local manufacturer; preferential tax policy
	Singapore	Policy	Green public housing and installation of LED luminaires
	Thailand	Policy	Thai government's LED streetlights replacement and preferential tax policy
		Emerging Industry	Development of tourism industry accelerates commercial LED luminaires application
		Standard	TIS certification
Oceania	Australia	Policy	Phase out of incandescent bulbs; energy rebate policies
		Import Reliance	Half of the country's lighting products rely on Chinese imports

6.1 Europe

Geographically **Europe** was the largest segment and accounted for 33,1% in 2012 owing to increase in investment by government in efficient lighting technologies. In addition, countries such as Russia, Germany, Denmark and the UK are focusing on deployment of efficient lighting to improve lighting quality and to lower overall operational cost, which will further increase the demand for LED lighting products and solutions [R&M-17]. In 2014 Europe is still the largest LED lighting market. However, market shrinkage started, it comprises 23% of the global LED lighting market despite of large-scale subsidies for LED lighting users [LED-14]. The Global Lighting Association (GLA) predicts that LED luminaires will account for more than 95% of the luminaire market in Europe in 2020 [IMA-17]. Figure VI.2 forecasts for LED lighting penetration against legacy technologies.

Figure VI.2 - LED-lamps versus legacy technologies market size in number of pieces [PRU-15]



In October 2015, VITO, an independent research organization, prepared a comprehensive study of the energy saving potential of SSL in the European Union. VITO estimated that 82 million LED lamps were sold in 2013, representing 5% of all lamp sales, and that this brought the total LED installations to 144 million units and 1n3% of the installed base. VITO forecasted that LED lamp sales would increase to 375 million units (22% of all lamps sales) and the penetration of the installed base would rise to around 800 million units (7%). VITO presented various scenarios for later years, with the LED penetration rate of the installed base in 2020 ranging from 42 to 46%. [VIT-15].

The recovery of **Eurozone** boosts the consumer confidence of European consumers as well as the demands in the lighting market. Due to the depreciation of the euro and logistics costs, European lighting companies have begun to keep manufacturing in their countries or outsource it to their eastern neighbours, such as Poland. This "Made in Europe" trend has also helped the local vendors to expand overseas by spurring their export sales. On the other hand, the euro's fall has been squeezing the profits of Asian OEMs as their European clients demand greater price reduction. Some Asian lighting manufacturers have started to promote their own brand products in order to offset the effects of the price cuts and reduce their reliance on overseas orders [LED-15a]. Furthermore, general consumers LED lighting distribution channels are clearly identified. As example, IKEA announced from 2012 that customers will only be able to buy LED lamps by 2016, and they intend to install large numbers of LED lamps in their stores and warehouses[4]. IKEA plans to sell 500 million LED-lamps by 2020 [BEN-17].

LED replacement lamp retail prices are decreasing rapidly. For instance, in January 2015, **Danish** consumers were able to buy LED lamps providing 400 lm of light for only €2,90, and Philips brand LED lamps with 470 lm for €6,50 and with 806 lm for €13.20 (note: one year ago, the price for these same lamps was double or more). This development, coupled with market moves by companies like IKEA, are indicative of the fact that the LED market is becoming an affordable mass market for European consumers, with benefits for households, energy security and the environment [CLA-15]. Similar price reduction as shown above for Denmark can be found around in **EU**, with such low prices, the payback for these three LED lamps at current prices is less than 1 year in sockets operated 3 hours per day, and approximately 2,5 years for sockets operated 1 hour per day [CLA-15].

In **France,** RATP, the Paris transportation authority begun in 2013 the generalization of the equipment of LED lamps (LED tubes), of all its network metropolitan and suburban networks. By 2017, 369 stations will be re-lamped representing 300 km of corridors and platforms. This operation represents an investment cost of €11 million and should reduce its energy consumption by 50% [MON-13]. Furthermore, thanks to the energy transition law, French government decided in 2016 to buy a large number of LED replacement lamps from Edison and distribute them to households. Following the family's revenues, up to 10 lamps can be received for free or at a minimum cost. The operation is handled by different intermediates who can recover funds from Energy Savings Certificates national scheme [EXP-16].

Swedish government decided to fully support transition to LED technology. In that frame, a new R&D grant programme for lighting has been established for the period 2017-2021. The program has as objective connecting academia and business. Globally SEK 60 million will be invested.

United Kingdom use 18% of its annual electricity consumption for lighting (58 TWh). Approximatively, 1700 companies are working in the lighting supply chain [LIA-14]. In 2014, UK LED lighting market size was anticipated to be valued over £400 million at manufacturers' selling prices (MSP); this includes all finished products, non-domestic and domestic used within building and construction sectors [GMI-17]. The UK LED market is forecast to match LED growth, achieving 15,4% CAGR between 2015 and 2020 passing

[4] http://www.ledsmagazine.com/articles/iif/2012/10/ikea-stores-will-only-sell-led-lighting-by-2016.html

from £651 million to a total size of approximately £1,3 billion [AMA-16]. In 2013, the fixture marked size high as £72 million [LIA-14]. In December 2011, the Secretary of State announced the creation of the Advanced Manufacturing Supply Chain Initiative (AMSCI). Up to £125 million was made available through the first two rounds of the initiative to create more competitive supply chains that anchor high value work in the UK, and generate new employment opportunities. Additional funding of £120 million for two further AMSCI rounds was announced in the 2012 Autumn Statement to support research and development, skills training and capital investment to help UK supply chains achieve world-class standards, and to encourage major new suppliers to locate in Britain [LIA-14].

6.1.1 Russia

Russia represents a potentially large-scale domestic market. In Russia, the Law No. 261-FZ "On Energy Saving and Greater Energy Efficiency and on Amendments to Certain Legislative Acts of the Russian Federation" dated November 23, 2009 pushes state-supported energy conservation initiatives in the public housing and utility sector. This includes LED lighting. However, in 2016, energy efficiency was not a prime issue in Russia anymore. This is mainly due to the fact that the cost of 1 kWh has remained at the same level – that is, about 5 RUB and as long as 1 kWh in Russia does not cost 10 RUB or more, it is hard to expect any real interest of investors in energy saving. [L&B-16].

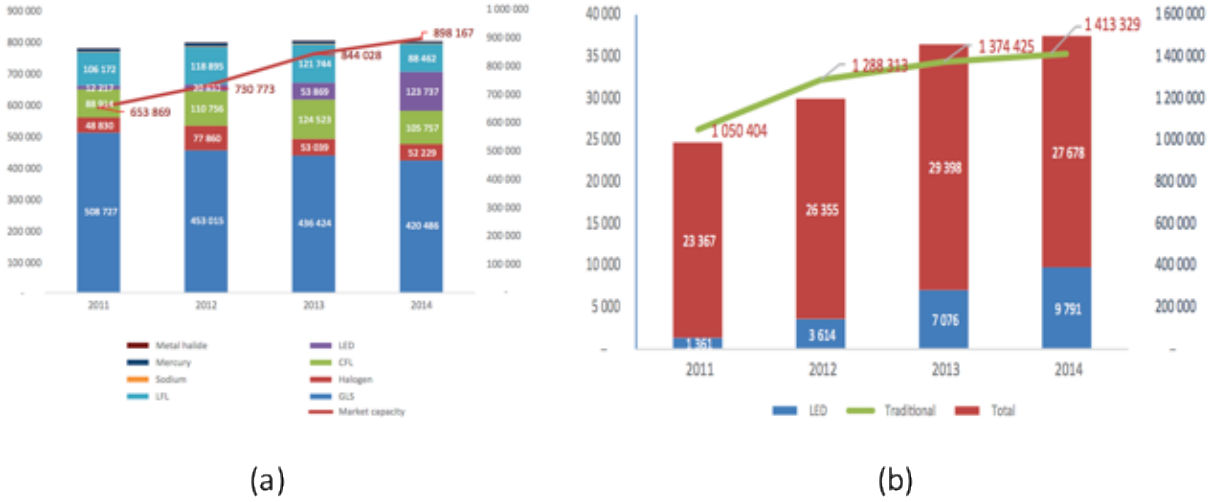
Domestic semi-conductor industry could play an important role in the upstream market for the lighting products. However, Russian semi-conductor industry represents less than 1% of the world market. [F&S-11]. In 2015 semiconductors for energy efficient producers including lighting represented 28% of the domestic semiconductor industry revenue.

The Russian lighting market has traditionally been divided into two parts: professional (technical) lighting and decorative interior lighting. These two segments have shown different dynamics in Russia. Whereas the project segment features many Russian manufacturers, the decorative one has been dominated by European brands: about 30% are from Italy followed by Spain (20%), Germany (10%), and Austria (10%). Poland, Greece, Belgium, France, and England hold another 20% in about equal shares.

Following Sergey Borovkov (Lighting Business Consulting), the Russian lighting fixtures market capacity grew by 62% in quantitative terms (from 24,7 million pieces in 2011 to 37,5 million pieces in 2014) and by 37% in terms of value (from US$ 1,288 billion in 2011 to US$ 1,413 billion in 2014). Figure VI.3 shows the Russian market size for lamps and fixtures. It can be seen, that the overall market growth was mainly due to growth of LED technology shares. In 2011-2013 legacy lighting fixtures market grew, but in 2014 it began to shrink. In 2011-2014, the LED lighting fixtures market capacity grew by 619,4% in quantitative terms and by 69,6% in terms of value. Traditional lighting fixtures market capacity grew by 18,4% in quantitative terms and by 18,0% in terms of value. In 2011-2014, the share of LED lighting fixtures grew from 6% to 26% (in quantitative terms) and from 32% to 41% (in terms of value) [L&B-16].

In any case, the share of domestic manufacturers is small, and, often involving just the assembly of lamps using foreign-made parts. In both parts, as the domestic lighting industry ecosystem is fragmented and there is not any domestic major player, it can be considered that domestic that is very attractive for export opportunities from other countries. But, taking into account domestic currency depreciation in front of Euro or US dollar, in 2016, the European equipment became twice as expensive in Russia, while the clients grew twice as poor as said Andrey Golovin, KNX Russia association Executive Director [L&B-16].

Figure VI.3 – Russian lighting market capacity both in quantitative terms (left hand axis, in thousand pieces) and in terms of value (right hand axis, in thousand US$) in 2011-2014 (a) Lamps market capacity (b) fixtures market [L&B-16]



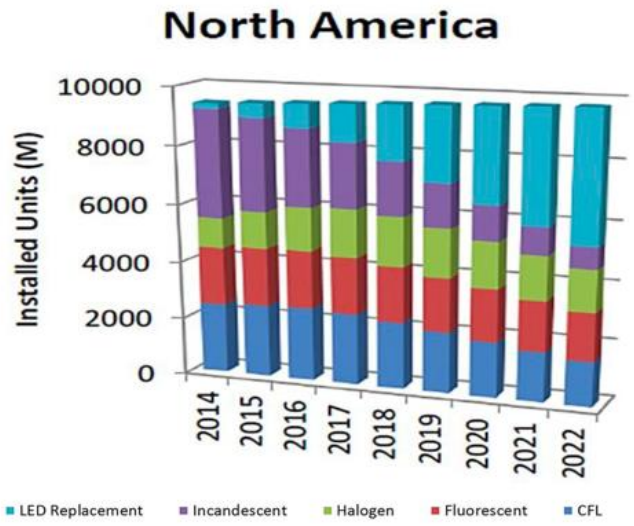
(a) (b)

(data: Lighting Business Consulting)

6.2 North America

The **North America** LED market is expected to reach US$ 11,7 billion by 2022 growing at a CAGR of 9,7% during the forecast period. The General lighting market dominated the North America LED market in 2015 and would continue till 2022 thereby achieving a market value of US$ 4,56 billion by 2022 growing at a CAGR of 9,5% during the forecast period. The Automotive market is expected to reach a market size of US$ 1,66 billion by 2022. Figure VI.4 shows forecasts for LED lighting penetration against legacy technologies.

Figure VI.4 - LED-lamps versus legacy technologies market size in number of pieces [PRU-15]



The **US market** dominated the North America LED market in 2015 and would continue till 2022 thereby achieving a market value of US$ 8,68 billion by 2022 growing at a CAGR of 8,8% during the forecast period. The **Canada** application market is expected to reach a market size of US$ 1,76 billion by 2022. The **Mexico** market would witness the growth rate of 14,2% during 2016-2022 [R&M-16].

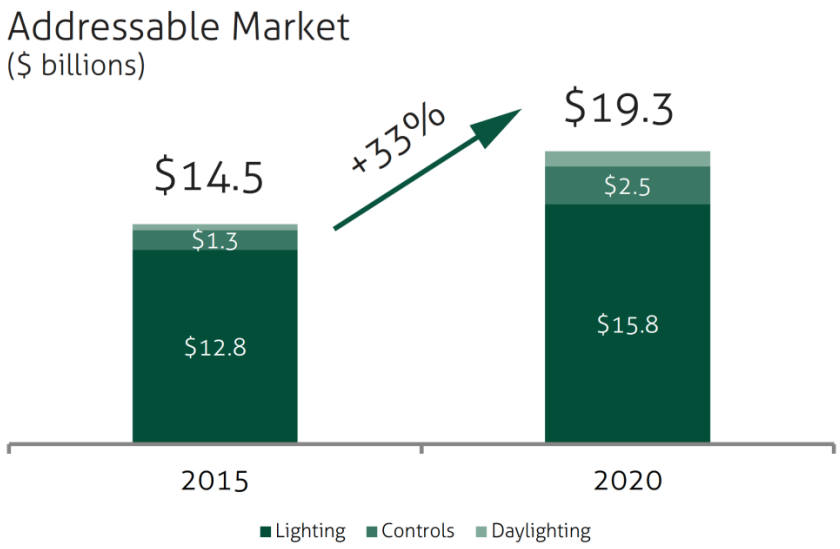
In 2014, the **United States** holds 19% of the overall LED lighting market. Currently, there is a push in the industry to obtain certification from the US Environmental Protection Agency Energy Star and the DesignLights Consortium (DLC), a US-based non-profit organization. Firms which receive certification from these organizations are eligible for subsidies from local utilities providers.

Strong Dollar Policy makes the United States become the growth driver of global LED lighting demand market and the world's products become relatively cheaper. This trend is expected to still affect the American market in 2016. Meanwhile, in order to maintain industrial development, the United States is promoting LED lighting local assembly, which will meet the local market demand better and expand market. In addition, American major manufacturers are actively developing LED lighting business, with the rising LED lighting penetration rate. LED commercial and industrial lighting demand is strong in the US market, among which demand for Troffer, panel lights, tunnel lights and high bay lights grows fastest and they begin to develop towards intelligence and optical communications and other new application areas [LED-16b].

Major American lighting companies are currently engaged in an aggressive expansion of the LED lighting market. They are continuously raising the penetration rate of LED lighting by launching many new products. The direction of the application development is moving towards smart lighting, light communication, and other emerging fields.

Figure VI.5 shows the evolution of US LED lighting market from 2015 to 2020. The addressable market includes non-portable luminaires (as defined by the National Electrical Manufacturers Association), poles for outdoor lighting, emergency lighting fixtures, daylighting, and lighting controls. It excludes portable and vehicular lighting fixtures and certain related lighting components, such as lighting ballasts and most lamps.

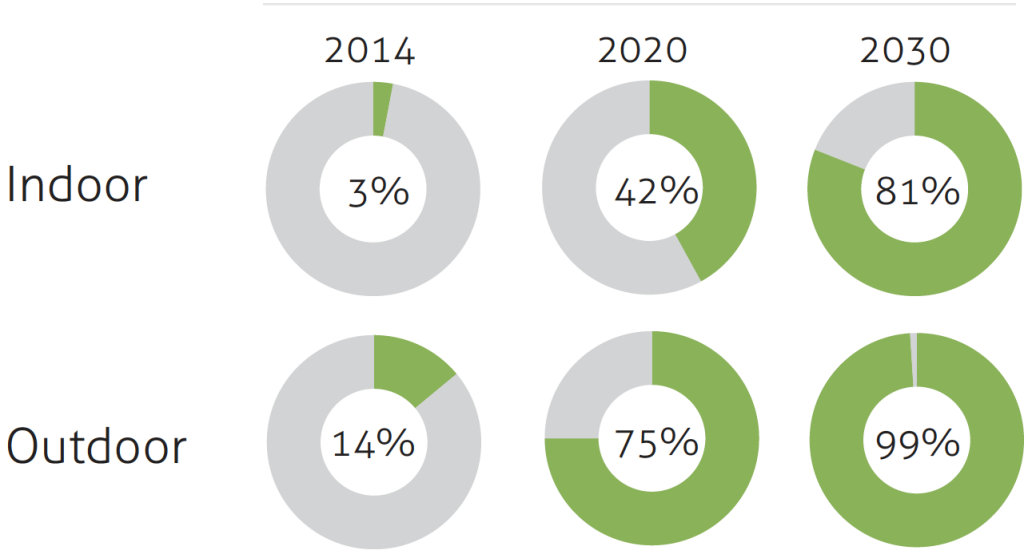
Figure VI.5 – US LED Lighting market growth forecast (data from Acuity Brands) [BGL-16]



Nowadays, the 5 largest LED Lighting exporters to US are China, Germany, USA, Italy and Mexico. Malaysia and Indonesia are the largest ASEAN exporters, ranked 22nd and 28th respectively [REC-16]

US DOE projections estimate that LED lighting will make up nearly half of all U.S. lighting shipments by 2020, and 84% by 2030. Figure VI.6 forecasts US LED Market Share of Lighting Shipments [BGL-16].

Figure VI.6 – US LED Lighting market growth forecast (data DOE) [BGL-16]



According NEMA's data LED A-Line lamp shipments in US decreased 8,1% in the first quarter of 2017 compared to 4th quarter 2016. However, LED A-line lamps continued a YoY climb increasing 4,7% compared to first quarter 2016. Incandescent and halogen shipments posted a quarter-to-quarter decrease in first quarter 2017 compared to 4th quarter 2016, 14,9%, and 24,8% respectively. CFL lamps posted a quarter-to-quarter increase of 18,5% percent. Incandescent, halogen, and CFL lamp shipments all decreased in a YoY comparison of first quarter 2017 to first quarter 2016 decreasing 5,7%, 12,4%, and 39,9% percent respectively [NEM-17]. Figure VI.7 shows the relative penetration of US market by the different technologies till 2017.

Figure VI.7 - relative penetration of US market by the different technologies till 2017 [NEM-17]

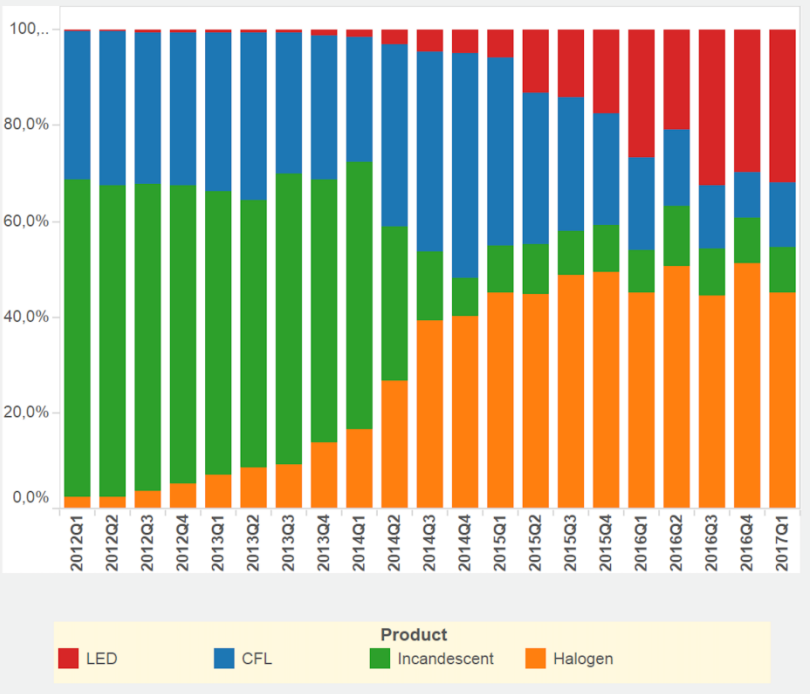
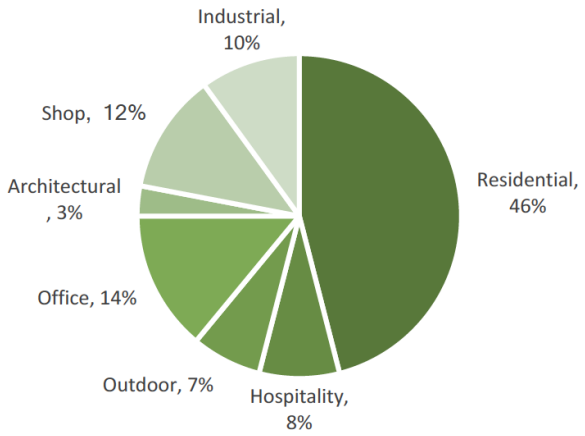


Figure VI.8 exhibits the 2016's US LED Light Market Distribution among end-use domains. Residential domain with 46% shares is the largest one followed by office lighting (14%).

Figure VI.8 - 2016's US LED Light Market Distribution among end-use domains [REC-16]



In 2014, the fastest-growing segment is light tubes [LED-14]. LEDinside forecasted that the percentage share of light tube and troffer/panel light products will be around 14,3% [LED-15a].

In the domain of street lighting several cities announced full switching to LED lighting in the next years. Los Angeles city council is a leading actor in this transformation. Such

way, in addition to more than US$3 million in annual reduced maintenance costs, Los Angeles has saved 63% energy and US$ 8,8 million in annual savings from the energy reductions [TEC-17].

North America (which is predominately the US) show aggressive growth of 44% in LED street light units in year 2012 through 2017 [STU-14]. In the US, price wars on LED street lights attracted a lot of attention in 2013. One headliner was Cree's UD$ 99 LED street lamp [CRE-13].

The same year, CREE announced 60W and 40W equivalent dimmable quality LED lamps for retail prices around US $10,00 for residential lighting. Current prices for this type of lamps are now US$ 7,00-10,00, and can be found even lower when combined with an electric utility rebate schemes (e.g. US$ 2,97 in Connecticut) [CLA-15].

Though prices have been coming down, product quality has not been compromised as the DOE has on-going efforts to implement stringent product quality requirements. The US has a market that can sustain declining prices along with technological advancements in SSL outdoor lighting [STU-14]. In reality, LED lighting product quality is improving, helping commercial LED lighting in the US grow.

6.3 Indian subcontinent

India is showing tremendous growth in the area of LED lighting, it will be one of the LED growth-driving top regions by 2018-19. The drivers to this rapid growth are many including energy savings by LED lights, their long life, consumer thinking and mainly government encouragement. However, Indian consumer awareness for energy efficient lighting and especially LEDs is still low.

The government has promulgated a series of policies from all perspectives to support the industry's development, among which the most important are Street Light National Programme (SLNP) and Domestic Efficient Lighting Program (DELP). The objective is to reduce the share of national energy consumption for lighting from 18% to 13% in 2020 [ELC-14]. For promoting LED manufacturing facilities in India, the government has reduced import duties and state governments have reduced value added tax (VAT). In addition, to help multiple investments enter India, the government implements free tariff (basic tariff) of LED component imports, facilitating LED products into assembly in India as semi-finished products and developing the local market [LED-16b]. That way, the cost of procurement of LED bulbs has come down drastically over the past two years [WIL-14]. Table VI.T2 summarises some key milestones for the development of LED and Energy Efficient Lighting in India.

Table VI.T2 - Key milestones for the development of LED and Energy Efficient Lighting in India [ELC-15]

Area	Topic	Measure	Current value	Target (year to achieve target)
Consumer demand	• Energy consumption	• Lighting power consumption, as proportion of total power consumption	• 18%	• 15% (2017) • 13% (2020)
	• LED market in India	• Size of LED market (# LEDs or value of LEDs sold)	• Rs. 2000Cr	• Rs. 10K Cr (2016) • Rs. 21k Cr (2020)
LED testing	• LED Testing	• Capacity for LED testing	• 3 labs	• 15 labs (2017) • 20 labs (2020)
LED Luminaires and Electronics Manufacturing	• Manufacture of LED Luminaires	• Proportion of India's LED Luminaire consumption manufactured in India	• <40%	• 60% (2017) • 80% (2020)
	• Export of LED Luminaires	• Proportion/ Value of total domestic Luminaire production exported	• <5%	• 25% (2020)
	• Manufacture of electrical components for LEDs	• Proportion of Electronic components (by value) for LEDs mfg in India, manufactured locally	• ~20%	• 40% (2020)
R&D/ Training	• Education in Lighting engineering	• # Annual students seats available in Lighting Engineering (undergrad + post grad)	• 0	• 50 (2015) • 250 (2017) • 500 (2020)
	• R&D centres for lighting technology	• # R&D centres and level of investment required	• 0	• 3 centres (Rs 150 Cr for set-up) (2020)

The focus of the new government program was on three applications: (1) Self-ballasted replacement lamps. Primarily focused in the residential market, which is still dominated by incandescent lamps. The goal is to replace more than 700 million lamps in the next 3 years; (2) Downlights. Aimed at showrooms, shop windows, and offices where the poor colour quality of CFLs has led to these applications being dominated by inefficient halogen lamps. The goal is to introduce 50 million LED lamps in these applications; (3) Roadway and street lights. Targeted to replace most of the 35 million existing street lights in the next few years [SUJ-15].

That way, more than 100 million LED lamps were acquired in a series of tenders, with the procurement price declining from Rs 310 in January 2014 to Rs 54 in March 2016 [INT-16].

There are also some examples of concrete actions engaged: Under SLNP program, the Indian government has taken action by planning to purchase 200 million LED light bulbs by the end of 2016 and has already issued tenders for businesses to retrofit streetlights across the country [R&M-17]. As of October 2016, Energy efficiency services limited[5] (EESL) has distributed 174,5 million 9W LED bulbs and 1,32 million LED streetlights across the country [F&S-16]. In Andhra Pradesh state, EESL procured two million LEDs under memorandum of understanding with the state, to provide them to 3,7 million households at a subsidized cost of Rs 10. In Puducherry state, EESL undertook several projects to install LED street lights and 750 000 LED bulb replacements for households [JIT-15].

Electric Lamp and Component Manufacturers' Association of India (ELCOMA) set the following objectives for 2020: generate consumer demand for energy efficient lighting products to enable the reduction of lighting power consumption from 18% to 13%; develop strong domestic manufacturing capability to reduce reliance on imports (increase

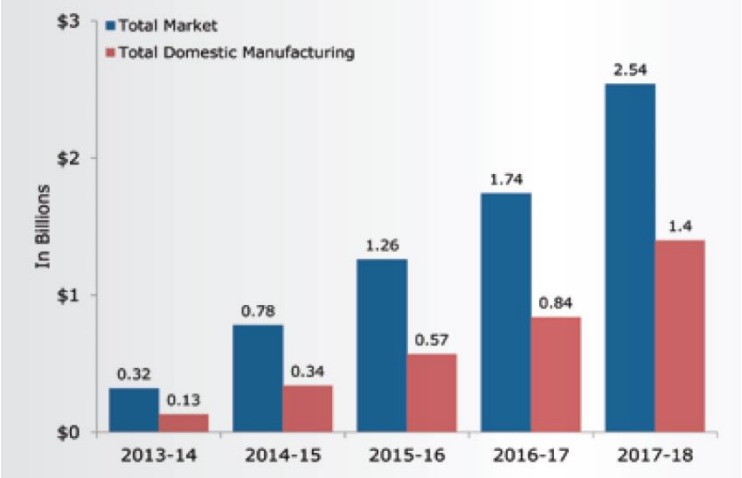
[5] Energy Efficiency Services Limited (EESL) is a joint venture of NTPC Limited, Power Finance Corporation, Rural Electrification Corporation and POWERGRID, Energy Efficiency Services Limited (EESL) was set up under Ministry of Power (India) to facilitate implementation of energy efficiency projects.

the proportion of LEDs in use that are manufactured in India from <40% to 80%) and enable exports (increase the proportion of manufactured products for export from <5% to 25%); and promote R&D and education in lighting to build skilled manpower (by establishing educational programs in lighting engineering for 500 students and three research centres by 2020) [ELC-14].

In parallel, there are many ESCO companies now operating in India. The Bureau of Energy Efficiency[6] (BEE) empanelled through an accreditation process more than 30 ESCOs in the domain of Lighting [JIT-15].

The Indian lighting industry has seen a strong growth of 59%, growing from Rs 8 500 Cr[7] (US$ 1,4 billion) in 2010 to Rs 13 500 Cr (US$ 2,16 billion) in 2013 and will reach RS 37 600 Cr (US$ 6 billion) in 2020. In 2014, less than 40% of this market has been covered by domestic production. Figure VI.9 illustrates the forecasted evolution of the Indian global lighting market indicating the share of domestic OEMs.

Figure VI.9 - Forecasted evolution of the Indian global lighting market indicating the share of domestic OEMs [ELC-14]



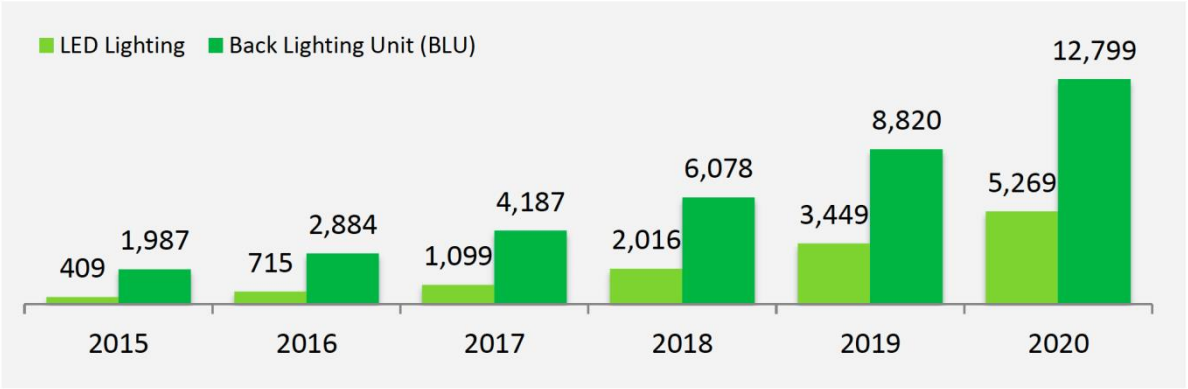
The LED lighting market will grow to Rs 21600 Cr (US$ 3,45 billion) by 2020 from Rs 1 925 Cr (US$ 300 million) in 2013. The market CAGR is 41% for the period 2013-18 [ELC-14], or, 66% following Frost & Sullivan for the period 2015-20 [F&S-16]; the LED's market penetration is accelerating. Figure VI.10, illustrates the LED Lighting and Backlighting Units (BLU) market revenues.

Absence of a local supply ecosystem has only forced the burgeoning LED demand to be met through imports. Cheaper imports and lack of component ecosystem forcing manufacturers to resort to low value-add activities such as module making or assembly of fixtures. Around 65% of the domestic demand is still fulfilled through imports, which was the prime reason for the Government taking a dim view of imports in the past couple of years. Furthermore, large volumes of low quality imports in recent years have affected consumer confidence in new technologies, thus increasing the need for quality-control on supply in the market [F&S-16].

[6] The Bureau of Energy Efficiency (BEE) set on 1st March 2002 under the provisions of the Energy Conservation Act, 2001

[7] A crore (abbreviated Cr) denotes ten million Indian Rs

Figure VI.10 - LED Lighting and Backlighting Unit (BLU) market revenue (in US$ million) [F&S-16]



Indian LED industry has obtained its government's full support. Among the plethora of measures adopted to boost local manufacturing ecosystem is the "Preferential Market Access" (PMA) policy whose importance to the industry cannot be understated. The PMA adapted to LED lighting, introduced in 2014, is a beacon of farsightedness when it comes to exploiting the long-term potential of the LED industry. Such way, all Central Government ministries, departments (except defence), and the agencies under their control have to procure 50% of their requirements of LED products from domestic manufacturers [F&S-16].

Indian consumers prefer luminaires over basic lighting fixtures Additionally, during the last years, customers have been using increasing amount of smart controls in lighting and smart control software becoming popular (for occupancy, dimming, security and monitoring, etc.) to save power.

6.4 Asia Pacific

LED lighting market developed relatively earlier and accounted for over 40% of the overall share in 2014. China LED lighting market is expected to grow at a CAGR of over 35% from 2016 to 2023 [GMI-17]. However, Asia-Pacific is expected to register the highest growth rates in LED lighting market in the coming years. UNEP in the frame of enlighten program estimates that in the absence of new policies, 57% of the lighting energy demand in 2030 would come from Asia [UNP-14]. Therefore, developments in Asia will be critical for LED Lighting market growth.

LED lighting in Southeast Asia has strongly developed in recent years and gradually strengthened to replace traditional lighting. Although under the influences of the overall economic environment in 2015, growth slows down, it is expected that along with policy incentives and increase of replacement demand, LED lighting penetration rate and import scale of Southeast Asia will continue to increase in the next few years. Southeast Asia is becoming a major hub for Chinese manufacturers exporting LED lighting products [LED-16b].

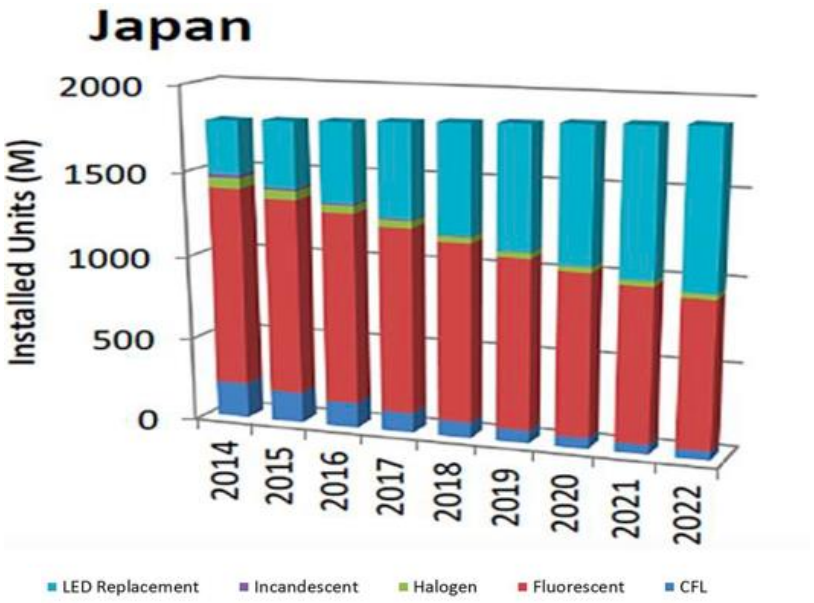
6.4.1 Japan

In Japan, since Fukushima disaster in 2011, the consumer preference is towards high-efficiency products, and the Japanese lighting companies are launching products with low-power drivers, hoping they will tap into the energy-saving demand. The drawback of these products is the high prices since they use more LED packages to meet their luminous flux standards [LED-15a].

In Japan, a LED mass market appeared in 2012, where LED sales constituted 40% of sales of lighting sources [JSC-13]. In 2013, LED luminaire sales in Japan were approximately 60% of national luminaire sales [JSC-14]. Since the start of 2012, the

Japan has installed 73 million LED lamps [BLO-15] nationwide, which represents 30% of all bulbs sold in Japan over that period. Figure VI.11 shows forecasts for LED lighting penetration against legacy technologies.

Figure VI.11 - LED-lamps versus legacy technologies market size in number of pieces [PRU-15]



According to the Institute of Energy Economics in Japan, switching all of Japan's lighting to LEDs would save about 92,2 TWh of electricity, 9% of Japan's total annual consumption. However, Japan had just 9% of the global LED lighting market in 2014. Indeed, the Japanese LED lighting market is relatively mature. LED commercial lighting is already common in Japan's schools, hospitals and retail chain stores. Still, the outdoor and industrial LED lighting segments have considerable potential to expand [LED-14].

While LED sources light more than 70% of new luminaires, LED replacement lamps are not very popular [JLM-16]. In 2015, only 28 million, 8% of replacement lamps sold, were LED [JLM-16a]. Fluorescent lighting is currently a dominant competitor; however, the government has proposed to ban the production and importation of fluorescent lamps, beginning in 2020 [LED-15].

Statistics show that in 2014 the size of the Japanese market demand for Chinese LED lighting products accounted an important YoY downsizing of 3,8 percentage points. This effect is expected to continue in the future [ENE-14c].

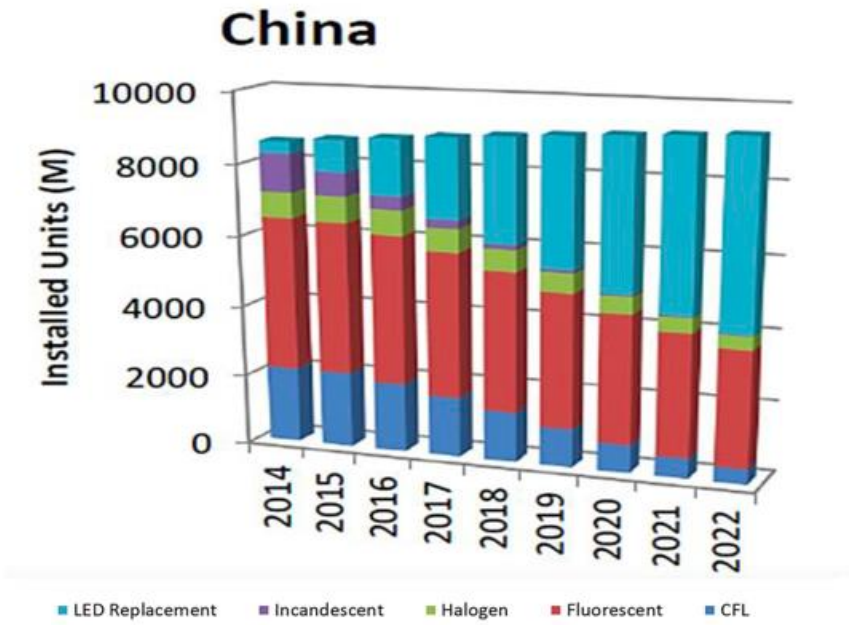
LEDs' rising luminous efficacy can help lighting products cut energy consumption, which is very important in Japan where power prices are high. Meanwhile, first tier lighting manufacturers are optimistic about energy savings achieved by integrating smart lights with human centric lighting [LED-16].

6.4.2 China

In 2014, China comprises 21% of the overall LED lighting market. As the manufacturing base of most LED lighting producers, China boasts a complete LED supply chain and many cost advantages. Traditional lighting manufacturers, lighting OEMs, emerging LED lighting manufacturers, and LED packaging manufacturers all are expanding their LED lighting businesses. In 2014, developing viable channel distribution is a top priority for vendors in China.

In 2013, the market size of the domestic LED industry was over 260 billion RMB [ENE-14a]. The latest statistics show that in 2014 the Chinese lighting industry sales of US$ 520 billion, an increase of 10,6%. Which exports US$ 41,55 billion, an increase of 15,4%. Figure VI.12 shows forecasts for LED lighting penetration against legacy technologies.

Figure VI.12 - LED-lamps versus legacy technologies market size in number of pieces [PRU-15]



The LED lighting product sales value was US$ 950 billion, up 43,9%, of which exports US$ 9 billion, an increase of 50%. Figure VI.13 gives the share of different product classes for this year [ENE-14b].

Figure VI.13 – Chinese LED products value split among different product classes for 2014 [ENE-14a]

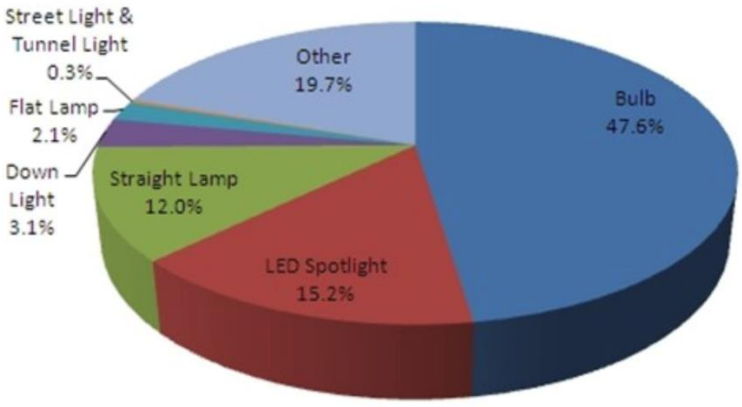


Table VI.T3 shows the Chinese Solid State Alliance's (CSA) 2014 estimates for 2015 domestic sales of LED lighting products and the penetration of the installed lighting base [CHI-15].

Table VI.T3 - Domestic Sales Forecast of LED Lamps and Luminaires in China and Penetration of the Installed Base [CHI-15]

LED Product Type	2015 Sales (Million units)	2015 Socket Penetration (%)
Omnidirectional lamps	860	20
Spotlights	400	40
Downlights	180	25
Tube replacements	800	30
Planar lights	120	30
Street lights	8.9	33
Total	**2,369**	-

After a disastrous response to the multiple product failures plaguing the initial installation of LED street lights in 2009, **China** has mandated product quality requirements on all manufacturers bidding for LED street light installations. This, coupled with the government's strong push for decreased energy usage, should help the country attain its goal of reducing energy consumption and carbon intensity by 16% and 17% respectively [STU-14].

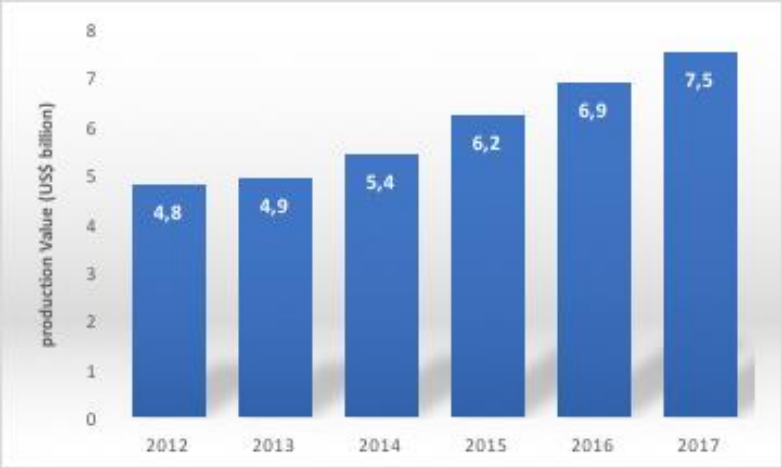
In 2015, the lighting market in China continues to grow on the back of stable demand for lighting. However, since the market is highly competitive and there is little variation in product quality among different manufacturers, vendors are competing mainly on price. At the same time, without proper distribution channels, manufacturers were forced to exit the market [LED-14]. In fact, China is a manufacturing hub for the world's leading lighting products, including wafers, PCB, power drivers, thermal dissipation modules and a variety of accessories. For global lighting brands, China has become the one-stop shop for LED OEM. Nevertheless, lighting products made in China are of varying quality, with a large disparity between product prices. That makes sourcing a challenge for manufacturers. Consequently, it is imperative to have an in-depth understanding of each of the main components as well as the technology used in their manufacturing in order to keep costs low while maintaining quality [LED-14b].

Till now, the majority of LED lighting manufacturers in the country are focused on raising luminous efficacy and lowering costs, while ignoring more advanced lighting applications such as offering comfortable smart LED lights or developing lights beneficial to human wellbeing. Only some high-class hotels, retailers, exclusive shops, clubhouses, mansions, and high end lighting projects place emphasis on lighting environments in China. Other lighting application environments tend to have rudimentary requirements [LED-16].

6.4.3 Taiwan

The top three segments of Taiwan's photonics industry in terms of production values are Flat Panel Displays, Photovoltaic & Solar Cells, and LED & Solid State Lighting. LED & Solid State Lighting segment is number one among the top three products with the highest growth rate in production value; in 2014, the growth rate of this segment was 30% [ROB-15]. Figure VI.14 shows the value of domestically manufactured LED and SSL products based on data from Photonics Industry and Development Association (PIDA).

Figure VI.14 - Value of domestically manufactured LED and SSL products [ROB-15]



(data: PIDA, 2016-17 are forecasts)

Taiwan has to deal with the challenge of competition from other countries (especially from mainland China) and has to transfer the traditional OEM business model to become a service-oriented model for customers. Innovative applications and advanced photonics technologies will stimulate the next growth in Taiwan. PIDA expects that, among others, UV/IR LED and AMOLED displays would be the winning ones.

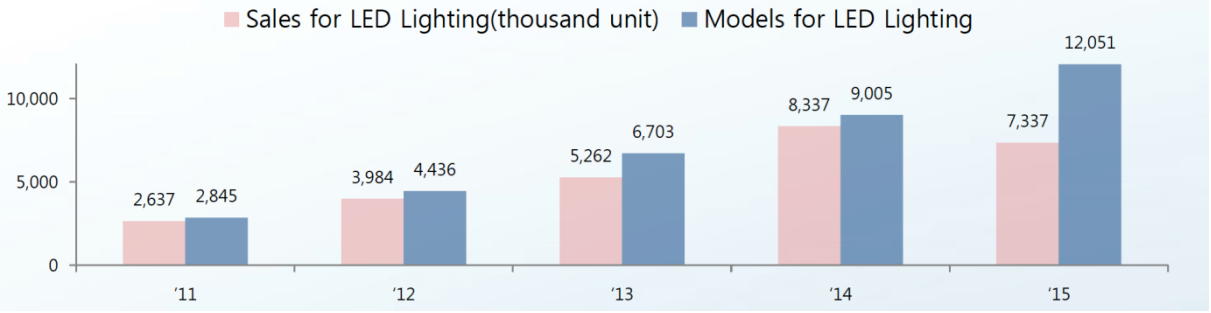
6.4.4 Korea

Lighting market in South Korea has emerged as one of the fastest growing sectors of the lighting market in South Korea due to its increasing demand in the country. The market has registered a remarkable CAGR of 68,3% during 2008-2013 but it is revised down to 22,99% over the period 2014-2019 [R&M-15]. There have been constant innovations and technological advancements in the field of LED lighting technology in order to provide the customers energy saving, environment friendly and advanced LED lighting solutions. The increasing awareness among people about the use of LED as a source of lighting, increasing government regulations and initiatives to promote LED lighting products has LED companies to produce advanced LED lighting produced at affordable prices. Korea Rail Network Authority decided to replace the conventional lighting with LED systems. In Seoul area lighting will be replaced in 79 metropolitan subway stations. The expected will attain cost of about € 187 000 per year in maintenance and € 165 000 per year in electricity bill [JEO-17].

Shift in demand from superior to low-end LED products is one of the key trends upcoming in this market. The declining ASP of LED lamps stems from the presence of a good mix of high-, medium-, and low-end products in the market. The high-end products are generally sold to commercial and industrial customers, which account for 30% of the overall LED demand [L&M-15]. During the last years, Korean lighting market experienced a Sharp increase in sales volume for LED Lighting products (Figure IV.15) [JEO-16].

Figure VI.15 - Volume for LED Lighting sold in Korea domestic market [JEO-16]

	'11	'12	'13	'14	'15	Note
Sales for LED Lighting (thousand unit)	2,637	3,984	5,262	8,337	7,337	2.8 times ↑
Companies for LED Lighting	555	825	1,257	1,510	1,892	3.4 times ↑
Models for LED Lighting	2,845	4,436	6,703	9,005	12,051	4.2 times ↑



The Korean Government program 20/60 aims to increase the share of LED lights to 60% in private sector and 100% in public sector [JEO-16].

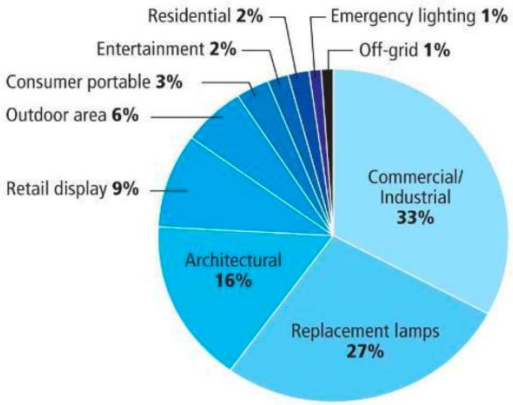
However, in Korea, LED for Backlighting Units still drive LED growth. By 2015, Korean LED manufacturers started to apply flip chip LEDs on a large scale in TV backlight. Korean TV manufacturers also started to increase the usage of flip chip LEDs in their products. LEDinside has observed a growing number of Taiwanese and Chinese LED manufacturers promoting flip chip LED technology and even smaller CSP LEDs in the TV backlight market, which spurred the rapid ascension of flip chip LEDs market penetration in the LED TV market in the last few years [LED-15b].

6.4.5 Australia

Australia possesses about 7-8 million families and each family has 75 lamp holders on average. Due to an early start to phase out incandescent lights, the current products are mainly dominated by MR16 lamps and traditional ceiling lights. Under the requirements of pursuing lighting energy conservation, LED lighting will have more opportunities. In recent years, filament lighting is much applied in commercial lighting space, spur the filament lighting orders demand in China [LED-16b]. The rising cost of energy and increased focus on strong cost management has supported the strong take-up of energy-saving products, as LED lighting, in Australia.

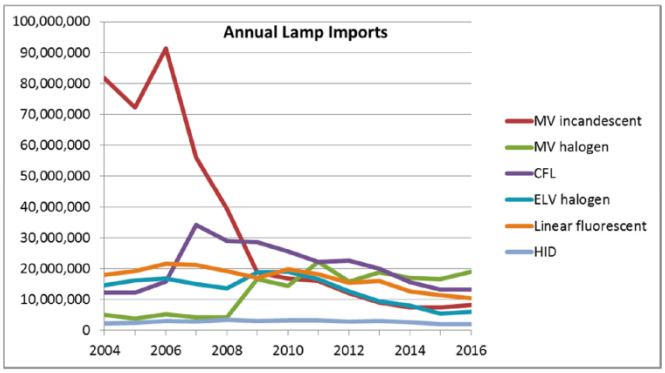
Australia has traditionally taken its technology lead from the US and Europe, but the rise of China as an economic superpower has changed the way the country does business, especially when it comes to lighting. Two-way trade between China and Australia is worth more than $130 billion and has been growing rapidly over the past decade. During this period, there has been a flood of new LED products into Australia, which is helping the country move away from traditional sources. But the handy proximity to China hasn't been the only factor in the growth of an Australian lighting market that's now worth $AU 2,5 billion, according to Lighting Council Australia (LCA) [LUX-14]. Figure VI.16 illustrates the domestic Australian lighting market by end-use domain.

Figure VI.16 - Domestic Australian lighting market by end-use domain [BOI-17].



The Australian government offers subsidies at State levels (such as Victoria's VEET and New South Wales ESS initiatives) in order to encourage LED lighting growth in the national market. Australian LED specialists LEDified are also penetrating their local market with their eco-friendly and cost reduction based sales model in order to grow their market share. The core of their success is due to the value model that they can demonstrate to potential customers, as highlighted below. Their product range of LED light tubes and commercial LED downlights have been at the heart of LEDified's penetration of the LED lights market in Australia [WIL-16].

Figure VI.17 - Australian lamp imports evolution since 2004 [COY-17]



The domestic market LED shares increases rapidly. In January 2017 1,7 million LED lamps and 2,5 million LED luminaires were declared [COY-17]. Figure VI.17 illustrates the Australian lamp imports evolution since 2004. Inefficient lighting (lamps) has decreased but may not decrease further.

6.5 Rest of the World

Following Future Market Insights study the 10-year (2015-2025) forecast for the **Middle East** SSL (LED and OLED) lighting products the market is expected to register a CAGR of 14,3% by value over the forecast period [FMI-16]. The LED light fixture market in the Middle East is booming: LED luminaires make up 20% of the market in 2016, by 2022 it is forecasted that they will comprise approximately 49% of the total market. Strategies Unlimited says that LED luminaire technologies will have a CAGR of 13% from 2015 through 2022 in the **Middle East and Africa** (MEA) in terms of revenues. The MEA luminaire market was worth approximately US$ 2,35 billion in 2015, not including lamps [LUX-16].

The LED lighting market in the **Gulf Cooperation Council** (GCC) is a high-growth market, which is driven primarily by increased functionality, energy efficiency targets, and increasing awareness among customers. GCC area is estimated to represent roughly 38% of the regional lighting market. Currently, LED lighting accounts for only 37,6% of the total lighting market in the GCC region; however, it is expected to be a high-demand lighting technology across the region by 2020, accounting for approximately 56,8% of the total lighting market. The GCC market, worth US$ 910 million in 2015, will witness a compound annual growth rate (CAGR) of 16,8% between 2015 and 2020 to reach revenues of US$ 1,98 billion [F&S-17a]. Events such as the Expo in Dubai in 2020 and the World Cup in Qatar in 2022 will deliver solid impetus to growth in the GCC region, especially in the hospitality market. The latter is increasingly using the latest lighting and controls as a differentiator [LUX-16].

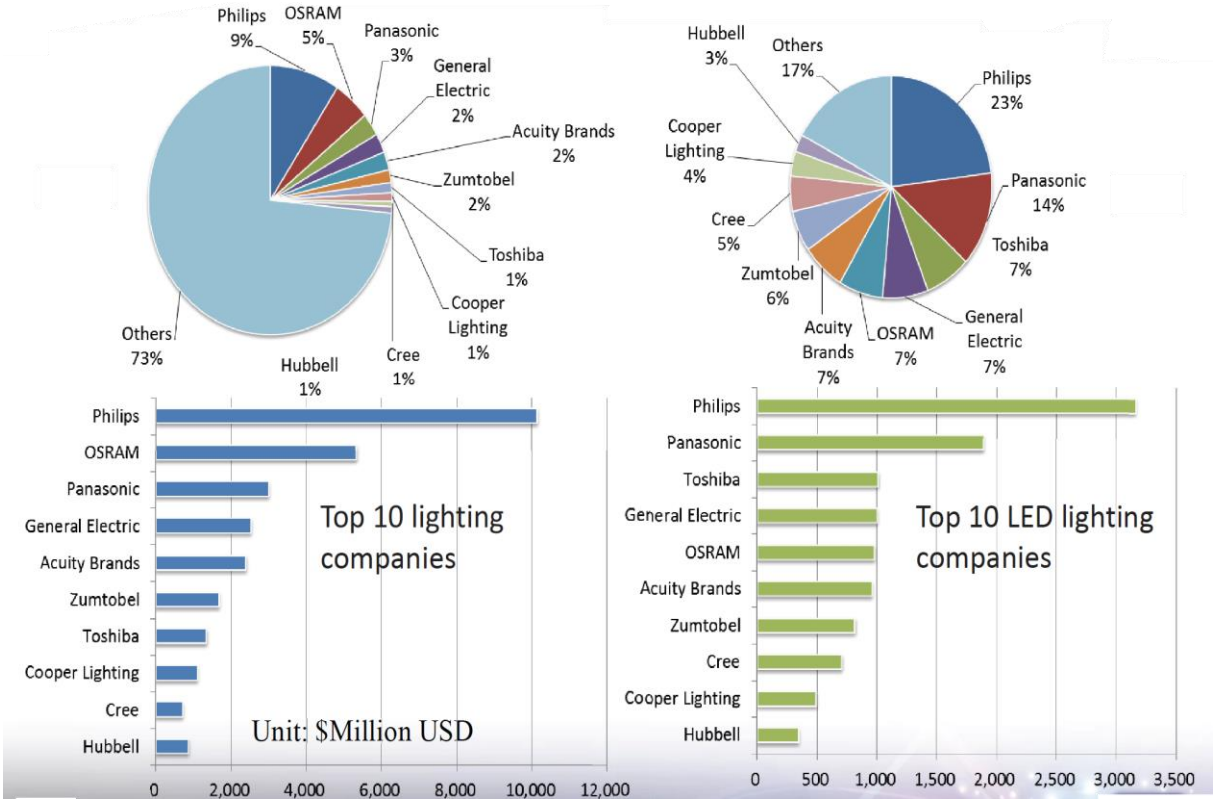
Africa LED lighting market is still very small but it is a rising star in the world market, there is big potential in basic lighting sector and municipal lighting sector. Because Africa stands in front of low-end lighting applications, which means it does not request for high quality LED lights but more likely to accept low price, long lifespan, durable with basic lighting functions, maintenance free for 3 years, easy for operations LED lights in the market. Furthermore, African market is particularly fond by autonomous solar lighting solutions for illuminating remote areas without grid access. LED lighting **African** market but will see high growth rate of 53% at least till 2022 [SUM-13]. **South Africa** is an important one among Africa markets. Public policies, environmental and energy saving concerns are driving the local take-up of energy-efficient lighting. China export value to South Africa of LED lights is US$ 47,5 million in 1st quarter of 2015 corresponding to a YoY rate of 6,3% [HTI-15].

At the global COP21 climate talks, **Brazil** devoted to raise energy efficiency by 10% by 2030 – an achievement LED lighting could accelerate. Brazil has a big potential LED lighting market. Following, Raghu Raj Singh, a lead analyst from Technavio, the LED lighting market in Brazil is expected to grow at a CAGR of more than 14% in 2017-21 period. The residential and retail segments are the largest contributors to the market. In fact, increasing urbanization in Brazil is leading to growing demand for LED lighting products to cater to the growing number of households. As the residential sector is the major revenue contributor in the LED general lighting market in Brazil, the growth of the residential sector will positively impact the market. The commercial sector in Brazil is also growing rapidly, which has led to rapid urbanization in many areas of Brazil such as Rio de Janeiro and São Paulo. [TEC-17]. Street lighting is also an important target for LED growth in Brazil. The Brazilian government is investing in large-scale urban infrastructure projects, in order to meet the needs of the growing population. For instance, in 2016, the Brazilian government announced a concession of 34 infrastructure projects that will be awarded to the private sector. All these projects will require lighting sources, which will lead to an increase in the use of LED lighting, as it is more efficient than traditional lighting sources TEC-17]. In Brazil, public lighting covers for over 4% of the nation's whole electricity consumption, LED to contribute making important energy savings. In addition, to saving maintenance and energy costs, LEDs provide city leaders opportunities to improve lighting services and offer wider socio-economic benefits for communities by reducing accidents, modernizing city infrastructure, as well crime [WEL-17]. China is a major exporter of LED lighting products to Brazil. To maintain high lighting product quality in the domestic market, Brazil introduced in 2015, mandatory certification requirements for LED bulb and LED lamp two kinds of lighting products, although the LED lamps and LED driver has not been specified, but the development trend, the future may there will be some new regulations. According to the Brazilian legislation, LED lighting products must have Inmetro certification requirements for certification bodies must be accredited local institutions Brazil LED bulb and lamp standard is actually the International Electrotechnical Commission (IEC) and the US Energy Star standard assembly, that is to say to meet the safety requirements of European standard, the subject of energy efficiency to meet US requirements [ENE-14].

7 Industrial landscape update

No industrial sector remains the same; the "ecosystem" is in perpetual change to best take advantage of the opportunities within this sector. This is the case of Lighting Industry. Following Frost & Sullivan, in 2014, it was 5 000 active market competitors in the LED lighting domain [F&S-15], but the global industrial and commercial LED Lighting market is still dominated by few brands, more especially, in 2014, 16,7% of market share held by top 2 companies. However, nowadays the situation is rapidly changing. Figure VII.1 shows the situation in the reference year (2014).

Figure VII.1 – Lighting and LED-lighting industry majors landscape in 2014 [ROB-15]



(data: PIDA)

Today, the organized market players include Philips Lighting, Osram Opto, Ledvance, Cree Incorporation, Zumtobel AG and GE Lighting. However, the world's leading legacy light bulb-makers - GE Lighting, Osram/Ledvance and Philips Lighting– are facing tough competition from consumer-electronics firms, particularly Asia's Samsung, LG and Sharp, as well as from specialized LED manufacturers such as Cree and Veeco. Hence, Philips Lighting, Osram/Ledvance, and GE Lighting are all determined to make the most of their LED know-how, and look at different ways to compensate the disappearance of their replacement bulbs market component. R&D and new product development have been limited to LED for years but this is now changing [F&S-15].

The following companies can be considered today as the important players in the global lighting market: Acuity Brands, Digital Lumens Inc, Hella, Koito, Cooper Industries Plc, Magneti Marelli, Nichia, Stanley Electric. Other Prominent Vendors In the market are: Bridgelux, Citizen Electronics, Dialight, Eaton, Everlight Electronics, Epistar, Hubbell, Intematix Corporation, Gyled, Lite-On Technology, LG Innotek, Mitsubishi, Kyocera Corporation, Panasonic Corporation, Samsung Electronics, Seoul Semiconductor, Sharp,

Toshiba Corporation, Toyoda Gosei, Lighting Science Group, Solid State Lighting Systems, Samsung, Avances Lumínicos Plus S.A. de, Black Dog LED, Litecontrol, Lowcled, Endo Lighting, Iris Ohyama [LED-15A] [ZIO-17] [GMI-17].

At the same time, new small, local entrants everywhere in the globe are focussing on LED solutions and close to their target customer base will provide a new form of competition to the large, global participants.

Table VII.T1 summarizes main actors in the LED Supply Chain: Upstram, Midstream, and Downstream [DOE-16].

Table VII.T1 - Main industrial actors in the LED Supply Chain [DOE-16]

Supply Chain	North America	Europe	Asia
Die Manufacturing	• Cree • Lumileds • Bridgelux • Soraa • SemiLEDs • Luminus Devices	• OSRAM Opto Semiconductors • Optogan • Plessey Semiconductors	• Nichia • Toyoda Gosei • Toshiba • Sharp • Epistar • SemiLEDs Optoelectronics • MLS Lighting • OptoTech • FOREPI • Everlight • Lumens • Kingbright • Samsung • LG Innotek • Seoul Semiconductor • Elec-Tech Opto • Epilight • HC SemiTek • Sanan Optoelectronics
LED Package Manufacturing	As above	As above	As above and: • Lite-On • Unity Opto • Lextar • Nationstar • Shenzhen Jufei • Honlitronic • Refond
Luminaire Manufacturing	• GE Lighting • Eaton/Cooper Lighting • Hubbell Lighting •Soraa •MSi •Kim Lighting • Acuity Brands • Cree • Lighting Science Group •Feit	• Philips • Osram Sylvania • Zumtobel	• Panasonic • Toshiba • Sharp • LG • Samsung • Forest Lighting • Kingsun • Zhejiang Yankon • Shenzhen Changfang • Opple Lighting • PAK Corp • Nationstar • NVC Lighting Tech Corp • FSL

LED manufacturers had an especially tough year in 2015. Despite rising LED lighting market demands, and large scale replacements of traditional luminaires, the oversupply situation in the market has caused average sales price (ASP) of LEDs to plunge 30% to 40%. Growing number of manufacturers have incurred heavy losses and are exiting the market [LED15b]. Today, many large LED chip and packagers are investing in CSP technology including Samsung, Lumileds, LG Innotek, Seoul Semiconductor, Epistar and Lextar [SMA-16].

As pricing is key to further adoption, especially in applications less prone to total cost of ownership (TCO) calculations [F&S-15], most of the LED light manufacturers are focusing on development of cost effective products with improved performance to get competitive advantage.

The emergence of cost-competitive LEDs has caused a "paradigm shift" in the lighting industry that has changed everything. The LED lighting industry rapid technological change has been brought by enormous changes in the regulations affecting lighting. Short product lifecycles are a result of new manufacturing and materials science that are the result of companies trying to improve the economies of scale to make price points more attractive to customers.

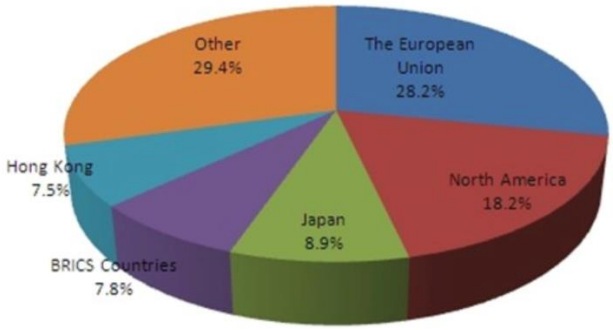
Till 2015, lighting companies have focused on professional lighting solutions in developed markets such as the US, Europe and Japan. They seek to capture certain market segments via product diversification and differentiation. In the emerging markets, rapid economic growth, favourable government policies, and mega urban projects are constantly generating new opportunities. LEDInside analyst J. Wu noted that the main growth centres in the global lighting market from 2016 year will be the US and India [LED-15a].

Lighting companies are now trying to capture different market segments through product diversification and technological advancements. In 2014, the average product development time was estimated by Frost & Sullivan at 9–12 months [F&S-15]. This is contrasting with legacy lighting technologies where the product development period was between 3 and 5 years. However, penetration in large applications will require tailor-made solutions and new products that enter the market rapidly. This requests a significant R&D effort. The level of research and development (R&D) required is very high. In 2014, average R&D spend per company was estimated by Frost & Sullivan at 7,6% of their Market Revenue. This effort is higher than the 5,0% has been dedicate to product marketing. This R&D effort is not easy to afford by small companies; thus, it is expected that many lighting companies, especially in the fixture market, will not be able to fund this LED drive and will leave the market [F&S-15]. Under these conditions the market for luminaires will be particularly challenged, as LED integration requires new knowledge and expensive R&D. Concentration in this very fragmented market is expected during the few next years. The LED adoption will sweep away hundreds of fixture companies that cannot cope with the new competencies and R&D needed. There is a chance for large LED light source manufacturers to save good, medium-size fixture companies by providing the LED know-how in return for their help in reaching local customers and winning project-based business together [F&S-15].

Since several years now China has been established as the world's largest lighting products, consumer and exporter. However, due to several reasons, including excessive government incentives, the LED market moved into an oversupply situation and the competitive market has been tough ever since. In fact, every level of the supply chain is experiencing oversupply, and severe price competition has caused 20% of domestic companies in the industry to withdraw or merge with others [CHI-15a]. However, this consolidation has taken longer than expected. So far only smaller players, primarily in China, have left the market [IHS-16]. The national government is concerned about the excess production and is ending subsidy programs, but competition between regional governments to establish new factories is still strong. For example, Jiangxi province is promoting the manufacturing of LEDs on silicon substrates and has established the "Nanchang Optical Valley" with a revenue goal of approximately US$ 7 billion by 2020 [CHI-16].

In 2014, the main clients of Chinese exported LED lighting products was primarily Europe (28,2%) followed by US (18,2%) [ENE-14c]. Chinese exports to the Middle East (6%), South Korea, and Southeast Asia (9%) are growing, while the fractions going to Japan (5%) and Russia are falling [CHI-15b] [CHI-15c]. Figure VII.2, shows the Chinese export shares for each world region.

Figure VII.2 – Chinese export shares by world region for 2014 [ENE-14c]



It should be noticed that while China exports about half of the SSL products that they produce, following China Association of Lighting Industry (CALI), these only represent about 25% of total lighting exports from China. The remaining 75% of China's exports are comprised of legacy technology light sources [CAL-16]. LED lighting products manufactured in China are using chips made by the leading international chip makers.

Exports that incorporate chips made by Chinese companies are mainly sent to regions where intellectual property (IP) protection is not rigorously applied [DOE-16].

The lighting industry in Europe is undergoing a major realignment. Although Osram and Philips have dominated the global production of traditional lamps, both are planning to divest their lamp businesses to focus upon the provision of lighting services.

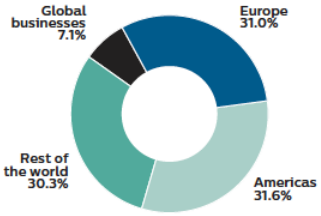
Philips Lighting is the market leader; the following extract for the 2016 Annual report summarizes the company performances [PHI-16].

Financial performance

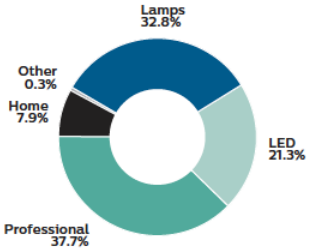
Philips Lighting

Comparable sales growth	LED-based sales	Adjusted EBITA margin	Net income	Free cash flow
2016 (2.4%)	**2016** 55%	**2016** 9.1%	**2016** EUR 185 million	**2016** EUR 418 million
2015 (3.5%)	**2015** 43%	**2015** 7.3%	**2015** EUR 240 million	**2015** EUR 632 million

Sales by geography



Sales by Business Group



Business Groups

Lamps	LED	Professional	Home
Sales EUR 2,333 million	**Sales** EUR 1,518 million	**Sales** EUR 2,683 million	**Sales** EUR 559 million
Nominal sales growth (18.1%)	**Nominal sales growth** 13.8%	**Nominal sales growth** (2.7%)	**Nominal sales growth** 8.7%
Comparable sales growth (15.8%)	**Comparable sales growth** 16.1%	**Comparable sales growth** (0.5%)	**Comparable sales growth** 11.0%
EBITA margin 18.6%	**EBITA margin** 9.2%	**EBITA margin** 3.5%	**EBITA margin** (8.2%)
Adjusted EBITA margin 20.2%	**Adjusted EBITA margin** 9.4%	**Adjusted EBITA margin** 5.4%	**Adjusted EBITA margin** (3.6%)

It has been the first casualty as the profit margin on the individual LEDs is eroded because of overproduction in China. The achievement in price declines because of

economies of scale, and general competitive pressure have drastically impacted the market [WGR-14]. Philips is a leading provider of conventional and LED lighting products, systems, and services and holds dominant market positions, including the largest patent portfolio in the lighting industry, according to a company statement. The company's lighting portfolio includes legacy technologies (incandescent and halogen lamps, fluorescent lamps, CFLs, HID lamps) and LED lamps; electronic components (electronic ballasts and drivers); luminaires for consumers and professional users; and integrated lighting systems and services.

Lighting sales by Business Group includes Lamps (38% of 2015 sales); Professional (37%); LED (18%); Home (7%); and Other (0,1%). Philips' LED Business Group reported sales of US$ 1,3 billion in 2015, US$ 958 million in 2014, and US$ 772 million in 2013 [BGL-16].

Since a couple of years, Philips is set to spin-off its lighting business. The Dutch electronics group Philips has attracted bids from several private equity groups for the majority of its lighting components business, up for sale as it focuses on higher-margin activities [WGR-14].

In May 2016, Koninklijke Philips N.V. announced plans to sell at least a 25% stake in its Lighting Division in an initial public offering (IPO) [NYT-16]. The spinoff is part of the company's plan to focus on healthcare. Industry analysts value the business at around € 5 billion. Philips Lighting reported sales of € 7 465 billion and adjusted EBITDA of € 739 million in 2015 [BGL-16]. As a matter of fact, Philips lighting division announced an IPO float that would raise over US$ 700 million for the company to expand its global presence in the global lighting market and drive the transition to LED lighting systems and services [WIL-16]. **Lumileds**, the Philips LED manufacturing operation, which is separate from Philips Lighting, is also planned to be spun off from Philips [BLO-16].

Osram is one of the world's leading lighting manufacturers and has a history dating back more than 100 years. Osram is defined by itself as a focused lighting technology provider in the areas of automotive and specialty lighting, opto-semiconductors, luminaires, lighting systems, and solutions. Company's product portfolio ranges from high-tech applications using semiconductor-based technologies, such as infrared and lasers, to networked, intelligent lighting solutions for buildings and urban areas [OSR-16a]. OSRAM itself was a carve-out. It spun off of Siemens in July 2013 and has been traded on the Frankfurt Stock Exchange ever since. In spring 2015, a decision is taken to reorganize Osram as a holding company with clear decentralized management structures [BER-16].

Fiscal Year (FY)[8] 2015 has been very successful for Osram: the revenue increased by 8,4% (YoY rate) to €5.6 billion and the adjusted EBITA reached €576 million [BER-16].

[8] Osram's FY starts October 1st.

Figure VII.3 - Osram's 2015 LED revenue share including (w/lamps) or excluding lamps (w/o lamps) [BER-16]

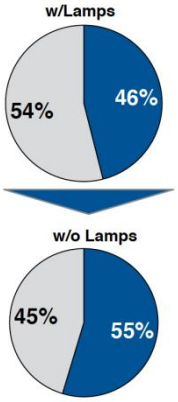


Figure VII.3, exhibits Osram's 2015 LED revenue share. The same year the group invested further in LED source manufacturing, expanding its operations in Regensburg (Germany) and Malaysia [OSR-15].

On July 1, 2016, Osram separated its former Lamps Business Unit, which primarily consisted of the general lighting lamps business, under the name **LEDvance GmbH**, as planned as part of the strategic realignment of Osram business model [OSR-16] and decided in April 2015 [BER-16]. Around 9 000 employees at 17 global production locations and 50 country agencies ensure worldwide availability, direct contact with customers and premium products. This "General Lighting" business division achieved a turnover of approximately €2 billion in the 2014/15 fiscal year [LED-16g].

Since the separation of LEDvance, Osram's operating activities covered are organized into four Business Units: Specialty Lighting, Opto-semiconductors, Digital Systems, and Lighting Solutions [OSR-16a].

The carve-out of LEDvance, created a lot of confusion about **Osram Sylvania** status (the US operation of Osram). In fact, Osram and Sylvania are not separate companies. The US operation of Osram is still Osram Sylvania, as it has been for more than 20 years. However, that is the legal entity. In media, marketing and other materials the company goes simply by Osram. LEDvance is also a separate company from Osram Sylvania. Osram has licensed the Osram trademark and the Sylvania trademark for general lighting products exclusively to LEDvance. This is strictly for general lighting, and does not include SYLVANIA. Automotive lighting products, allowing LEDvance to sell Sylvania and Osram branded general lighting products in the US and Canada. Osram continues to sell Sylvania branded automotive products, and its lighting services business remains Sylvania Lighting Solutions. Osram also sells many products under the Osram brand – just not light bulbs. Osram's focus is now only lighting technology, in a variety of forms, under many brands. Sylvania did not become LEDvance. The general lighting business portion of Osram became LEDvance and is exclusively licensed to sell Sylvania branded general lighting products [EDI-17].

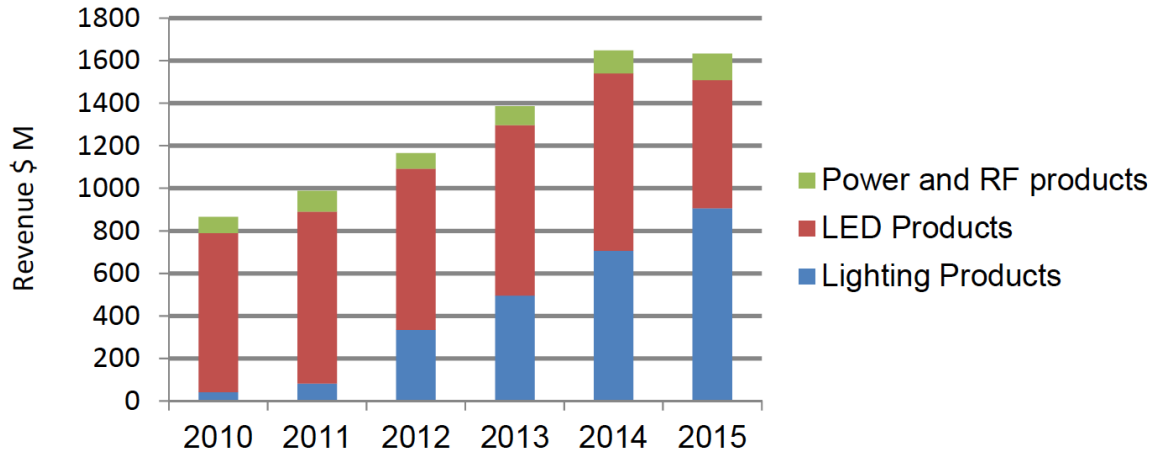
LEDvance offers the largest LED retrofit portfolio of all time with the Osram brand for the 16/17 lighting season, with well over 200 new LED lamps ranging from simple to smart and functional to highly attractive. In terms of light, LEDVANCE also remains a full-range provider. It remains one of the few producers to offer products with legacy lighting technologies. LEDvance can therefore always offer the optimum solution for any requirement, meaning all from a single source for both resellers and consumers [LED-16g]. However, less than one month after LEDvance creation, Osram has announced in June 27th, 2016 the € 400 million sale of LEDvance. IDG Capital Partners is the leader of the trio buying LEDvance that also includes the Chinese LED manufacturer and lighting company **MLS Co, Ltd**. (parent of US-based Forest Lighting), and financial investor Yiwu

State-Owned Assets Operation Centre. The deal protects the structure and employees of LEDvance. The CEO and the management team are expected to remain in place after the close of the transaction that is expected in Osram's fiscal 2017 that begins in October. MLS will likely continue to use the **Forest Lighting** brand, LEDvance will continue to use the **Sylvania** brand in North America, and the Osram brand elsewhere around the globe for its lighting products [WRI-16]. MLS announced on the same date it signed a new partnership agreement with Zhuhai Harmony Zhuoyue Investment (**Harmony Zhuoyue**), and under the new agreement its investment in the company would scale up from RMB 178,57 million to RMB 1,25 billion, while its total subscribed capital contributions would remain unchanged. MLS also stated it is a limited partner (LP) of Harmony Zhuoyue, and will not participate in daily operations and management including investment policies. In other words, the main buyer of Ledvance is Harmony Zhuoyue and not MLS, who is just a collaborating partner [LED-16h].

GE Lighting has been among the leaders working on LED-based retrofit lamps in the past few years, so the focus shift to LED lamps isn't exactly surprising. Still, the move completely away from CFLs is bold given that LED-based lamps still cost more. GE Lighting is a part of GE's home appliances segment, which generated US$ 7,4 billion of the company's US$ 147 billion revenues in 2012 [FOR-13]. In 2015, the home appliances and lighting generated a US$ 8,8 billion revenue with a net profit of US$ 700 million (56% YoY growth rate) [GEC-15]. GE Lighiting's decision to leave the Asian lighting market has sent another shock wave within the global lighting industry. LEDinside, pointed out that less than 10% of GE Lighting's total lighting revenue comes from China. Other markets in Asia also make up a very small percentage. At the same time, pricing and brand competition in the region has intensified. By withdrawing from this region and reinforcing its presence in North America, GE Lighting has also shown that the industry's thinking has shifted from expanding channel network and market share to maintaining profitability and one's survival [LED-16i]. The company recently said it would no longer sell compact fluorescent lamps (CFLs) and of course, in 2015, separated its luminaires business into "**Current, Powered by GE**" [WRI-16a] [GEC-15]. GE Lighting produce a large number of LED filament lamp in Hungary. General Electric and Current sell their LED bulbs through Wal-Mart, which has a huge network of 11 000 stores spread across 27 countries [FOR-15].

Cree Inc. was formed in 1987 by researchers from the North Carolina State University and has its HQ in Durham North-Carolina. The company is a market-leading innovator of lighting products, LED components, and semiconductor products for power and radio-frequency applications. In 2015 Cree had over 3 000 employees, a flat revenue of US$ 1,6 billion. However, 2015 was not so successful for CREE: the company's margin decreased to 29%, compared with 38% 2014 and the final financial result was a net loss of US$ 64 million when in 2014 the balance was positive. In fact, Cree's 2011 to 2014 revenue CAGR was in the order of 20% [LOU-16]. Figure VII.4, exhibits the company's segmented revenue evolution till 2015. In 2015, lighting became the largest segment but revenue on other LED products shirked significantly.

Figure VII.4 – Cree's segmented revenue evolution till 2015 [LOU-16].



According to Forbes, the key competitors of Cree are Osram, Philips and General Electric. In terms of revenue, these players are considerably larger than Cree. These companies have the capacity to create vast economies of scale on LED production. Cree bulbs, however, are still the cheapest available in the market. Cree's retail partner Home Depot has around 2 300 stores. [FOR-15]. Cree put a stake by investing SiC substrates instead of sapphire. This is of course an important differentiating facto form concurrence. However, SiC based products may be not so competitive as shows table VII.T2.

Table VII.T2 – Retail price comparison between SiC (Cree) and sapphire (Philips) 100-W equivalent lamps

100W replacement LED

	Cree	Philips
Price ($)	20.00	9.00
Power(W)	18	14.5
Substrate	SiC	Sapphire
Flux (lm)	1600	1500

(data: Amazon 2015) [LOU-16]

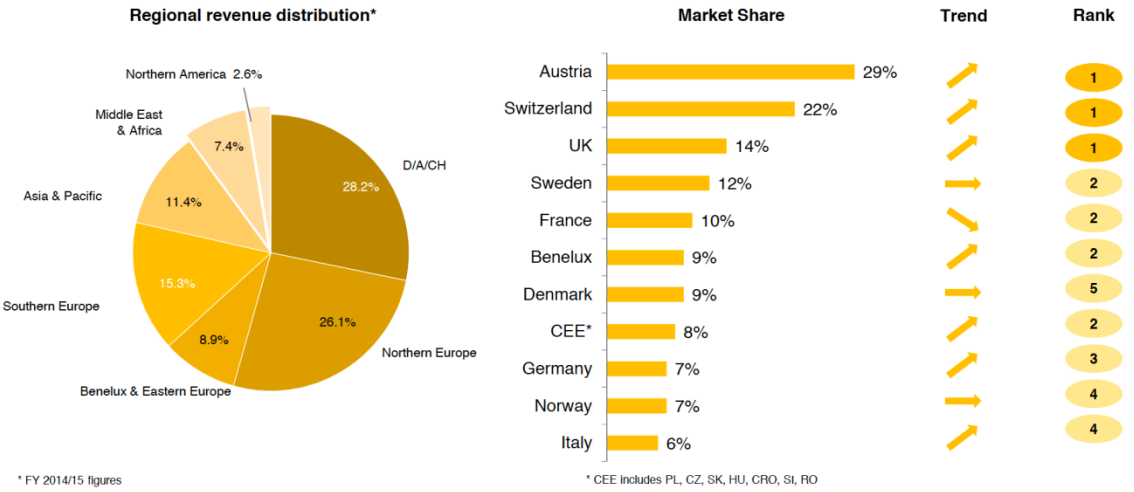
Soraa, Inc. funded by Suiji Nakamura, also known as SJS Technology, Inc., manufactures LED products made from gallium nitride substrates. The company offers LED lamps, snap systems, and optical light engines. It offers its LED products for outdoor, residential, retail, museum/gallery, restaurant, and hospitality applications. The company sells its products through distributors and sales agents in the United States, Canada, and internationally. It also serves customers through online retailers. In 2016, Nakamura creatde SoraaLaser, an independent spin-off from Soraa Inc. SoraaLaser's visible laser light sources are based on its proprietary and patented semi-polar GaN laser diodes, combined with advanced phosphor technology. These laser light sources provide novel properties compared with other light sources by combining the benefits of solid-state illumination such as minimal power consumption and long lifetime, with the highly directional output that has been possible only with legacy technology. [LUX-16a]

The largest European luminaire manufacturer, **Zumtobel**, does not manufacture LED chips or packages, but seems to have adapted well to the production of LED luminaires, which now account for the majority of its sales [ZUM-16]. In fact, the Zumtobel Group covers a major part of the value chain as illustrated in Figure VII.5.

Figure VII.5 - Zumtobel Group covers a major part of the LED-lighting value chain [SOU-16]

The 2015's revenue of the group was valued at €550 million. It should be noticed that 80% of the group's lighting revenue is coming from European market [SOU-16]. Figure VII.6, shows the Zumtobel's market shares.

Figure VII.6 - Zumtobel's market shares across the world [SOU-16]



Among the Zumtobel Group, **Thorn**, has a comprehensive portfolio of indoor and outdoor lighting (applications include offices, retail, industry, schools, roads, tunnels, sports facilities). It targets electricians and electrical consultants, wholesalers and contractors, businesses and municipalities. The brand has strong market in UK, Ireland, Scandinavia, France, Australia, New Zealand and Hong Kong. The 2015 revenue of Thorn was €400 million [SOU-16]. **Tridonic** is the group-wide specialist in innovative lighting components and systems. It proposes complete solutions for lighting operation and control. The brand has product portfolio that includes LED modules, LED drivers, electronic control gear, sensors, lighting control & management, software solutions. Its targets are OEM supplier to luminaire manufacturers worldwide, wholesalers. Tidonic's 2015 revenues were around €400 million thereof approximately 80% with customers outside the Zumtobel Group [SOU-16].

Zeta Specialist Lighting is a leading UK developer and manufacturer of LED lighting systems. In 2013, Zeta was awarded an Advanced Manufacturing Supply Chain Initiative (AMSCI) grant of £723,000 for a project whose aim is to restore manufacturing of LED lighting back from China to Bicester in Oxfordshire. A new factory facility has already been built to double production capacity and enhance the company's LED product range. At present, Zeta's supply chain is complicated and long, based on several different manufacturers in Asia. This project will allow it to condense the supply chain and use locally sourced components, which in turn will deliver shorter lead times and higher quality, boosting customer confidence in UK manufactured products [LIA-14].

Lucibel (France) is one of very few pure-play LED providers that successfully generate above market level hyper-growth in a universe that is forecasted to grow around 30% annually until 2020. This sustainable transition is driven by the emergence of disruptive LED technologies, macro-economic factors, rising energy costs and environmental pressure. Other than many incumbents that have to manage the financial challenges of a costly switch to LED technologies, Lucibel is ahead of the curve, innovating and proactively building its position in the most lucrative market segments. Lucibel was founded in 2008 and owns fully a LED manufacturing facility in Shenzhen, China. Lucibel's premium offering consists mostly of specification-grade products which according to management estimates represent about 65% of the demand, with the remainder being non-configurable mass products. Lucibel achieved a consolidated turnover of € 21,5 million in 2013 against € 6,3 million in 2012. The Group has a total workforce of 220 FTEs, divided between the parent company and its subsidiaries, including seven international affiliates. The 2016 company's revenue is estimated to attain €85,4 million with a net benefit of €3 million (till 2014 the company's balance was negative) [CSI-14]. Lucibel sells its products in 28 countries through 7 international sales subsidiaries. However, in 2013, only 24% of company's revenue was outside of French market [LUC-14].

Founded in 2011, **Aledia SA** (France) develops and manufactures innovative light-emitting diodes (LEDs) based on a unique 3D architecture using gallium-nitride (GaN)-on-silicon microwires. The technology uses standard silicon wafers with diameters of 8 inches (200 mm) and existing CMOS wafer-fabrication processes and tools, enabling production of LED chips at 25 percent of the cost of traditional planar LED chips. In 2015, Aledia completed its Series B financing round and the execution of development and supply contracts with major LED buyers. The round, totalling up to €28,4 million, includes new investments from Valeo, one of the world's largest automobile-equipment manufacturers and the world's second-largest supplier of car lighting systems; IKEA GreenTech AB, the venture capital arm of IKEA; and the Ecotechnologies fund of Bpifrance, the French national industrial bank. Aledia's existing international investors – Sofinnova Partners, Braemar Energy Ventures, Demeter Partners and CEAi/ATi – also participated in the round [ALE-15].

Regarded as a downstream consolidator of lighting technologies, **Acuity Brands** (US) has leveraged strategic acquisitions to further its integrated tiered solutions strategy, positioning the company as a differentiated, value-added solutions provider. Recent acquisitions of Distech Controls (building automation and energy management technology/3.98x revenue multiple) in September 2015 and ByteLight (indoor location software for LED lighting) in April 2015 advance its capabilities in integrated controls. The company reported record results in the 2nd quarter of 2016 fiscal year, highlighting the highest quarterly sales in the company's history. Net sales increased 26% in the quarter and operating profit increased 36% compared with the year ago period. LED product sales climbed 40 percent in the quarter and now account for 55 percent of total net sales—up from only 13 percent in 2013 [BGL-16]. Acuity Brands acquired Juno Lighting Group from Schneider Electric SA for cash consideration of US$ 385 million. Juno manufactures down lighting and track lighting fixtures for both residential and commercial applications, serving electrical distributors, lighting showrooms, home centres, contractors, architects, engineers, lighting designers, and commercial facilities

throughout North America. The company's complementary product line is expected to boost growth in the residential, retail, and hospitality markets.

Eaton's Cooper Lighting Division represents over US$ 2,0 billion in sales (~10% of total company sales) with approximately 80% generated within North America. LED lighting accounts for over 55% of Eaton's lighting fixtures sales, growing at a double-digit pace from only 13% in 2011. The company derives ~48% of its lighting sales from commercial construction, with the remainder roughly evenly split between industrial, residential, and outdoor. Industry analysts rank Eaton Lighting as the number two player in North America, the number three player globally, and among the top two players in driving innovation around value/energy efficiency and connected solutions. Eaton has completed 11 tuck-in acquisitions since 2005, mainly in the niche LED and lighting control space. With the most recent acquisition of Ephesus, Eaton gained an entry to the LED sports lighting space [BGL-16].

In **Taiwan**, in 2014, LED Packaging and LED Epitaxy/Wafer sectors accounted for a value of US$ 3,148 billion (9% growth) and US$ 1,574 billion (12% growth). The sum of these two sectors correspond to 88% of the total LED and SSL OEM production value (US$ 5,4 billion): Taiwan clearly focus on the upstream LED sector. The main domestic LED manufacturers include Epistar, Lite-On and Everlight. Since a few years, the mainland Chinese LED components industry has emerged as a competitor for the Taiwanese LED industry. Furthermore, Taiwan faces an increasingly unfavourable trend in the long-term development of LED packaging and module industries. The Taiwanese LED industry is looking for high-profit markets. For this purpose, Taiwan needs to focus on several high-potential niche products to strengthen the differentiation of the products such as UV and IR LED applications [ROB-15]. Following Credit Suisse analysis, **Everlight** claimed it has more than 50% market share in the Taiwanese LED light bulb retail market via its own brand, and intends to enter the global market with dual brands strategy (Everlight for greater China, Zenano for Europe and the US). We think Everlight's strategy to capture the general lighting market via own brand could lead to lower returns given (1) intense competition from global Tier-one brands and regional lighting players, (2) higher marketing expense is required to build brand image, and (3) total available market for retrofit is much smaller than new fixture on a long-term basis. **Epistar's** capacity has been fully utilised since 2012 and it continues. It has also taken full control of Huga (51% holding) that help Huga to improve the production yield and fill the capacity by leasing Huga's equipment [CRE-12].

In Korea, there are three big LED players: **Seoul Semiconductor**, **LG Innotek** and **Samsung**. In recent years, Korean companies ceded their position as the lowest cost players in general lighting LEDs to Chinese companies, which put great pressure on their businesses. Among those three companies, **Seoul Semiconductor** has the longest history, the most intellectual property (IP), and, as an LED specialist, the company doesn't have the luxury of exiting the market. **LG** and **Samsung**, on the other hand, are both diverse conglomerates that are more than capable of exiting a market, or reducing the size of their business units if needed, to improve overall company profitability. **Samsung** has seen declines in its LED market share and ranking in recent years and **LG Innotek** has come up again a tough competitive environment leading to variable quarterly results [HIS-16]. **Seoul** Semiconductor have filed several patents to bolster their market share in the filament LED light bulb market, which has an estimated value of US$ 1,3 billion. The luminaire is predicted to emit high-quality light that is close to natural light, which is achieved through COB technology [LDF-16].

Although product manufacturing has often been relocated to countries such as China in the past, there are signs of the flow reversing. **NVC Lighting** Technology makes a wide range of light fittings, lamps and control gear and with an annual turnover of £600 million is the largest lighting manufacturer in China with a bigger share of the Chinese lighting market than any other company. It has grown rapidly since it was founded in 1998 and was listed on the Hong Kong stock exchange in 2010. NVC Lighting invested £20 million in its UK subsidiary based in the West Midlands.

Opple lighting, is a US $500 million Chinese lighting company, is present in 50 countries and employs 7 000 people. Opple is one of China's largest LED vendors, known for aggressive international expansion with a low-price strategy. It entered Europe in March 2014, setting up headquarters in southern Holland. It became in 2014 the first large Chinese company to be established in India [LUX-14a]. It is investing US$ 9 to 10 million in India for branding, distribution and R&D. Opple's Indian plans include about 30 branded retail shops and about 300 'shop-in-shops' [LUX-14a]. In 2014, Opple announced also the possibility to establish a LED-Lighting product plant in eastern France [ECH-14].

"Price war" and 2015 industry crisis affected also major companies: **Cree** experienced a decline in its component LED business in 2014 and 2015. **Samsung** exited the LED lamp market, thus removing a captive market for its component business. **Toshiba** announced it was leaving the LED market, and it was also reported that **Sharp** was considering closing one of its LED factories [HIS-16].

8 Future developments and perspectives

Following Mike Hornung, IAHS analyst, for the lighting industry, 2015 was as a year filled with research and development. The one technology, at **LED-die level**, for both lighting and displays identified as one to watch was quantum dots (QDs). The advantage of QDs lies in the unique property that, when illuminated, they emit a very specific colour. The colour depends on the size of the crystal, and quantum dots can be manufactured to emit any colour in the visible spectrum. When used in combination, they can accurately produce any colour in the visible spectrum. In the lighting industry, QDs are only now beginning to be deployed in commercial products, and in the latter half of 2015, the first commercial lighting-related QD product was released. This product essentially replaced the phosphor on a blue LED with a red and green QD covering, to produce a high CRI white luminaire. QD technology for general lighting applications is currently limited. With the transition from traditional technologies to LED well under way, much of the residential market focus (which accounts for half of the lighting market) is on driving the costs of LED lamps down as far as possible, in order to further spur adoption. Although light quality is also a major concern for consumers, they are not likely to pay extra for a QD luminaire, when they are already paying a premium for a standard LED lamp [IHS-16].

In the domain of **General Lighting**, following Frost & Sullivan analysis, the next challenge is to offer personalized lighting products that make the most of digital LED light advantages. LED drivers and lighting management services will be key. But, it is expected that the average price of control gear will rise notably in Europe and North America by 2019 and this is justified by the increase of offered functionalities. New markets for services and solution designs open up, but require good contacts and customer knowledge, which might favour local companies above global participants. Lighting as a Service (LaaS) on cloud-based networks for efficient and personalised management of applications will pave the way for connected lighting and living, and better energy and facility management. Financing, leasing, and maintenance are other service models that will evolve around LaaS [F&S-15]. Globally, IoT will shift focus from energy efficiency, product reliability, and OEM costs to include controllability, connectivity, and technology integration in smart buildings and smart cities [F&S-17].

In **Automotive Lighting**, laser lights are expected to fill the void left by LED lights in the high-class car model sectors, but since automotive laser supplies are only available in small volumes it will be applied in specific car brands and car models. It is hoped the proliferation of laser car lights will spread to more car models, following the entry of more suppliers in the market [LED-15b].

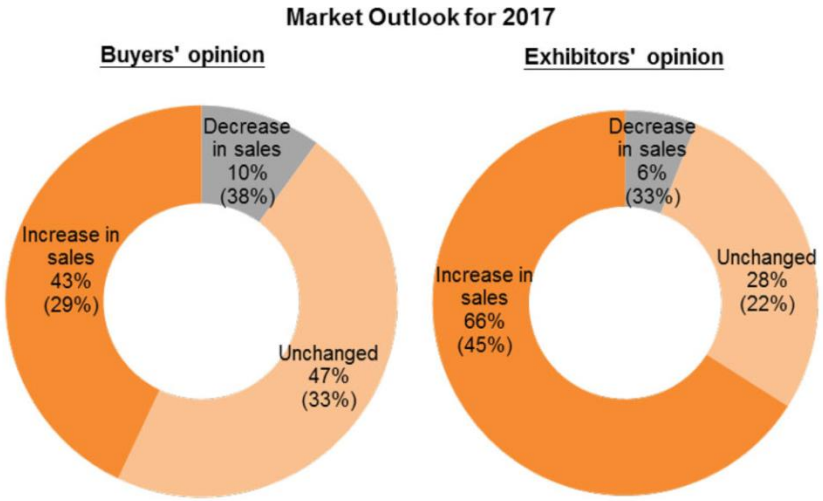
Following LEDInside analysts, due to intense LED pricing competition in the white LED market, manufacturers are searching for innovative or **special lighting** applications to boost profitability. For instance, LED manufacturers are turning their focus to LED applications in the non-visible light spectrum, such as UV or IR LEDs. LEDs in the non-visible LED sector has a small market size that cannot be compared to LED lighting or backlight applications. However, it has a very high technology barrier due to technology challenges that need to be overcome, customization demands, and need to work closely with system manufacturers. Therefore, non-visible LED products gross margins are evidently better than white LEDs. The largest market for UV LEDs for example is UV-exposure and curing applications, but manufacturers are also starting to value disinfection and sterilization applications. At the moment, UV-C has an exceptionally high technology barrier, and there are only a handful of manufacturers in this sector. Hence, LED manufacturers have started to develop UV-C wavelength LEDs. In the IR LED sector, the largest market application for the technology is still remote controllers or security applications. IR LED market applications can be applied on a broad scale in image sensors, motion sensors, photo interrupter detectors, proximity sensor, position sensor, biometrics, pulse oximeter sensor and others applications. IR LED applications in mobile devices are expected to added value features including information security, health

management and others. The sector is projected to be highly profitable, and will spur IR LED market development [LED-15b].

The inventor of the blue LED, Dr Shuji Nakamura, says **laser diodes** are the future of lighting – and have compelling advantages over LED. Laser diodes are droop-free, and can be combined with phosphors to safely produce highly directional output with superior delivered lumens per watt compared to other light sources. Laser lighting is already used for automobile headlamps at BMW and Audi, because the laser diode's efficiency is ten times higher than that of the LED headlamp. The radiation distance of a laser diode headlamp is almost 700 metres, whereas LED headlamp is only 300 metres, and current automobile headlamps are only 100 metres. To fit general lighting needs it is necessary to work very hard to make the laser diodes highly efficient [LUX-16a].

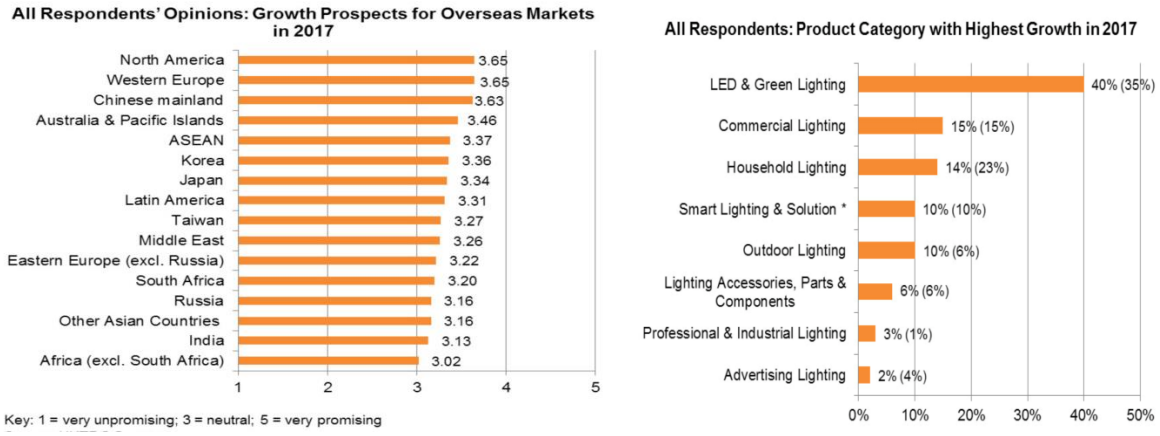
All-in-all, the lighting industry appears to be optimistic about their trade prospects for 2017, despite uninspiring sales performances over the past year. The markets it regards as having the greatest potential for next year are the traditional strongholds of North America and Western Europe, followed by the Chinese mainland. The product category regarded as offering the highest growth potential over the year to come is LED. Smart lighting systems, meanwhile, continue to be viewed as the focus of the industry's future development. These opinions were expressed by attendees of the Hong Kong International Lighting Fair, held in October 2016. HKTDC Research polled 393 buyers and 261 exhibitors at the Fair, in an attempt to collate insider views on the market prospects and business trends for the lighting industry. In terms of the prospects of individual markets, the traditional markets of North America and Western Europe were seen as those with the highest potential for growth in 2017. Figure VIII.1 and VIII.2 show this optimism and prospects.

Figure VIII.1 – Market outlook for 2017 following a poll executed in Hong Kong International Lighting Fair



(data HKTDC Research) [HTD-16]

Figure VIII.2 – Growth prospects for regional LED lighting markets (left) and product category with the highest growth potential (right) following a poll executed in Hong Kong International Lighting Fair



(data HKTDC Research) [HTD-16]

9 Conclusions

Lighting is responsible for about 15% of global electricity consumption. LEDs are a new technologies introduced in the market over the last 10 years. LED offers a very high efficiency compared to traditional lamps and higher lighting quality compared to fluorescent lighting in the non-residential sector. Through technology development and energy efficiency policies the LED lighting is fast penetrating the lighting market, offering energy and cost savings and higher lighting quality. This report offers a snapshot of the latest developments in term of market and technologies for solid state lighting and in particular for LED in the different markets. It follows a previous study by the JRC carried out in 2011.

Lighting is undergoing a rapid transformation as Light Emitting Diodes (LED) is becoming the number one source of light in buildings. The LED market evolution is continuing with a steep decline in cost per unit, high energy-efficiency ratings.

The global LED lighting market is growing with maturing light culture. The market is experiencing now a shift from conventional lighting to LED lighting with easy availability of LEDs in light bulb format, thereby posing a tremendous growth potential for the market. Year 2014 brought LED lighting mainstream as awareness at all levels is very high, and LED products are available widely and at different price levels. The major trends featuring the market includes shifting distribution channel, advancement in LED technology, demand for interior automobile lighting, and increasing green construction.

Customers of any type and from any country need to understand the offer and have the confidence in the performance of new technologies. They also need to understand the benefits of purchasing or specifying products referring to green/clean technologies.

The recent elimination (placing on the market) on 1 September 2018 of most of the halogen lamps will give a new boost to the penetration and developments of LED lamps in particular of the residential market. LED offer energy and cost savings to residential consumers.

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List of abbreviations and definitions

AC: Alternative Current (50 or 60 Hz)

AMSCI: Advanced Manufacturing Supply Chain Initiative (UK)

AMOLED: Active Matrix OLED display

ASEAN: Association of Southeast Asian Nations

ASP: Average Sales Price

BEE: Bureau of Energy Efficiency (India)

BLU: Backlighting Unit

BRICs: Brazil, Russia, India and China

CAGR: Compound Annual Growth Rate

CALI: Chinese Association of Lighting Industries (China)

CCT: Correlated Colour Temperature

CFL: Compact Fluorescent Lamp

GCC: Gulf Cooperation Council

COB: Chip-on-Board

COG: Chip-On-Glass

CRI: Colour Rendering Index

CSA: Chinese Solid State Alliance's (China)

CSP LED: Chip Scale Package

DALI: Digital Addressable Lighting Interface

DC: Direct Current

DELP: Domestic Efficient Lighting Programmed (India)

DLC: DesignLights Consortium

DOB: Driver-On-Board

DOE: Department of Energy (USA)

EBITDA: Earnings before interest, taxes, depreciation, and amortization

EESL: Energy efficiency services limited (India)

ELCOMA: Electric Lamp and Component Manufacturers' Association of India (India)

ESCO: Energy service company

EU: European Union

FTE: Full Time Equivalent

FMCG: Fast-Moving Consumer Goods

FY: Fiscal Year

GE: General Electric

GLA: Global Lighting Association

GLS: General Service Lamp

IP: Intellectual Property

HB-LED: High Brightness LED

HCL: Human-Centric Lighting

HID: High Intensity Discharge lamp
IEA: International Energy Agency
IEC: International Eletrotechnical Committee
IoT: Internet of Things
IPO: Investment Public Offering
IR: Infrared
JRC: Join Research Centre (European Commission)
LaaS: Lighting as a service
LCA: Lighting Council Australia
LED: Light Emitting Diode
LFL: Linear Fluorescent Tube
LFT: Linear Fluorescent Tube-like (LED)
MEA: Middle East and Africa
MSP: Manufacturers' Selling Prices
MOCVD: Metal-Organic Chemical Vapour Deposition
NA: North America
NEMA: National Electrical Manufacturers Association (US)
OEM: Original Equipment Manufacturer
OLED: Organic Light Emitting Diode
pc-LED: Phosphor Converted white LEDS
PCB: Printed Circuit Board
PIDA: Photonics Industry and Development Association (Taiwan)
PMA: Preferential Market Access policy (India)
QD: Quantum Dots
R&D: Research & Development
RATP: Régie Autonome des Transports Pariens
ROW: Rest of the World
SDCM: Standard Deviation Colour Matching
SLNP: Street Light National Programme (India)
SSL: Solid State Lighting
TCO: Total Cost of Ownership
UK: United Kingdom
UNEP: United Nations Environment Programme
US: United States of America
UV: Ultraviolet
VAT: Value Added Tax
YoY: Year-over-Year

Currency conversion rates (as in August 2017)

1 US$ = 0,849 €

1 $AU = 0,668 €

1 SEK = 0,105 €

1 RMB = 0,126 €

1 Rs = 0,013 €

1 RUB = 0,014 €

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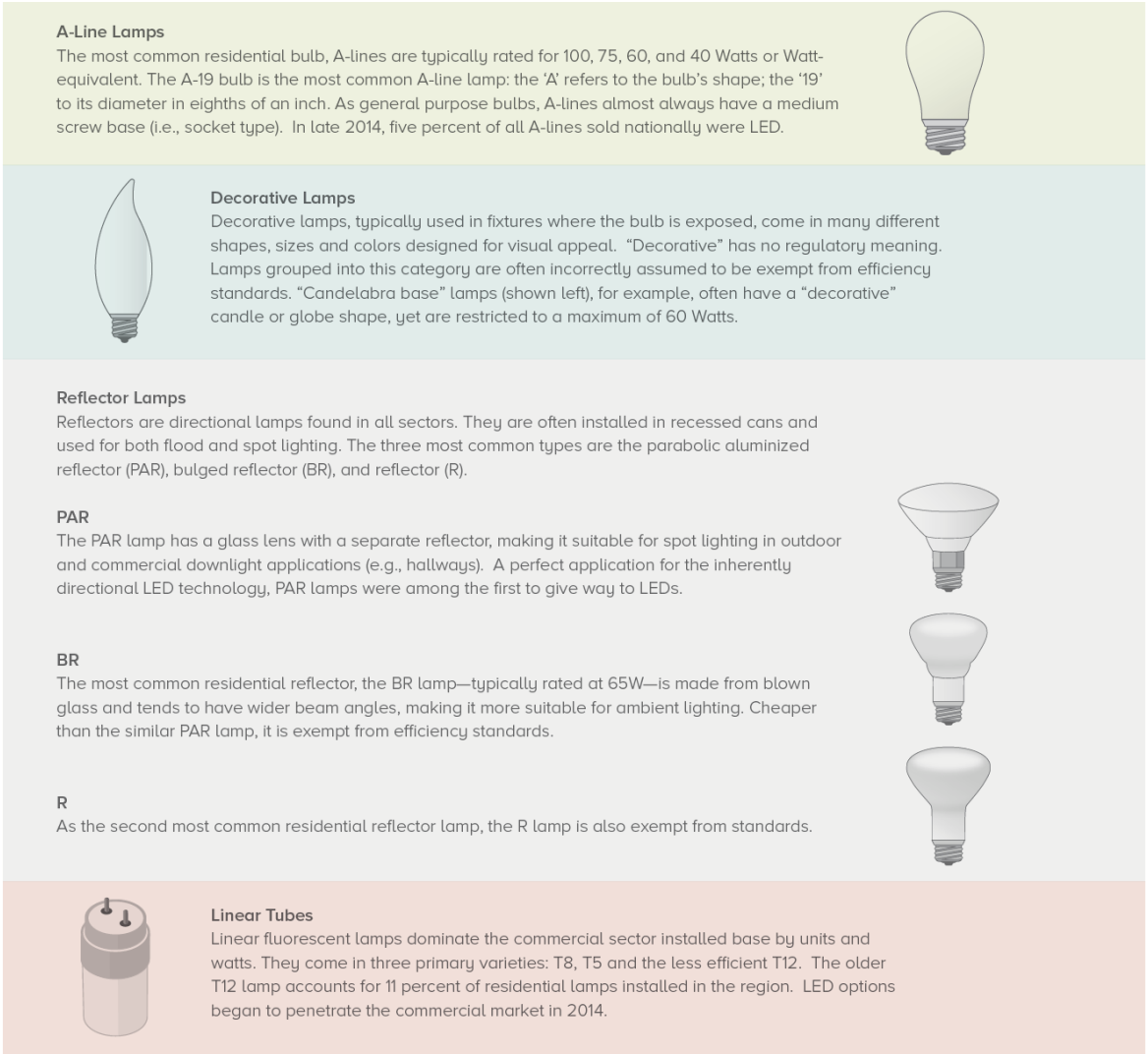
Annex – Definitions

LED-Module: A number of packaged LEDs mounted onto a printed circuit board (PCB) that has NO driver electronics. The module can have any level of integration including optics, thermal management, housing enclosures, etc., as long as it does not have the driver electronics on board.

LED-Engine: An LED module with the added driver electronics, whether on board, integrated, or separate, as long as it's sold as a complete unit. AC light engines will also be included under this definition. An AC light engine connects directly to the AC mains while delivering photometric and electrical performance similar to that of DC-driven designs.

General Service Lamp (GLS): *New definition* - General service lamp General service lamp means a lamp that has an ANSI base; is able to operate at a voltage of 12 volts or 24 volts, at or between 100 to 130 volts, at or between 220 to 240 volts, or of 277 volts for integrated lamps, or is able to operate at any voltage for non-integrated lamps; has an initial lumen output of greater than or equal to 310 lumens (or 232 lumens for modified spectrum general service incandescent lamps) and less than or equal to 3,300 lumens; is not a light fixture; is not an LED downlight retrofit kit; and is used in general lighting applications. General service lamps include, but are not limited to, general service incandescent lamps, compact fluorescent lamps, general service light-emitting diode lamps, and general service organic light-emitting diode lamps.

Lamp types



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