7. LED STRATEGY

7.1. High brightness LED market

We can divide application of High Brightness (HB) LEDs to six different areas (Figure 7.1.1):

- Backlight TV/monitor – LEDs are used for screen lighting
- Mobile – LEDs are used for display lighting
- Sign – signal devices, advertising panels
- Lighting – such as office or industrial lighting
- Automotive – all luminaires in cars
- Other applications

Figure 7.1.1:
HB LED market segments.

Lighting share in consumption of HB LEDs was 15% in the year 2011 (Figure 7.1.2). Figure 7.1.3 shows progress in adoption of LED technology from 2009 to 2011.

Figure 7.1.2:
HB LED market by application in the year 2011.

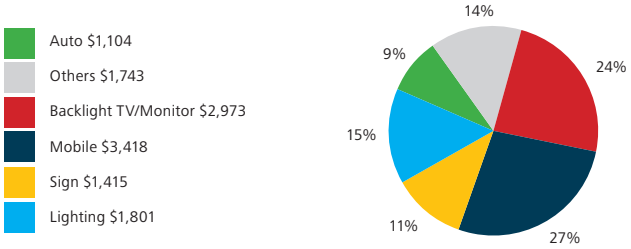
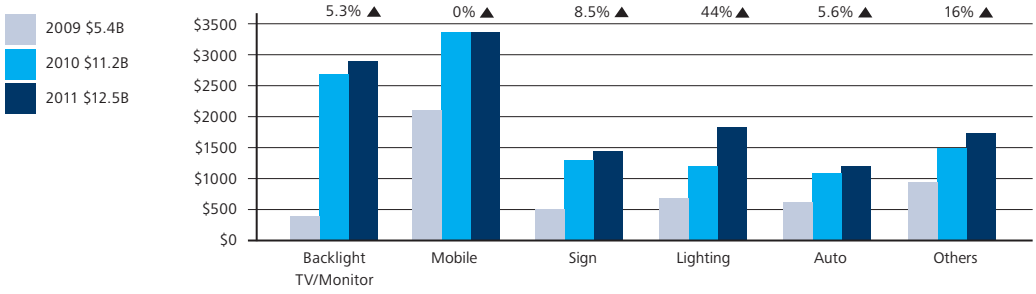


Figure 7.1.3:
HB LED market growth from 2009 to 2011.



International experts expect the biggest growth of HB LEDs market share in lighting application (Figure 7.1.4). Particularly, the most significant growth is expected in commercial, industrial, and architectural lighting (see Figure 7.1.5). Regarding technology, we can expect increasing market in general lighting for LED-based luminaires opposed to decreasing trend for traditional light sources (Figure 7.1.6).

Figure 7.1.4:
Projection of HB LED market share growth in lighting application. (CAGR -0.2%)

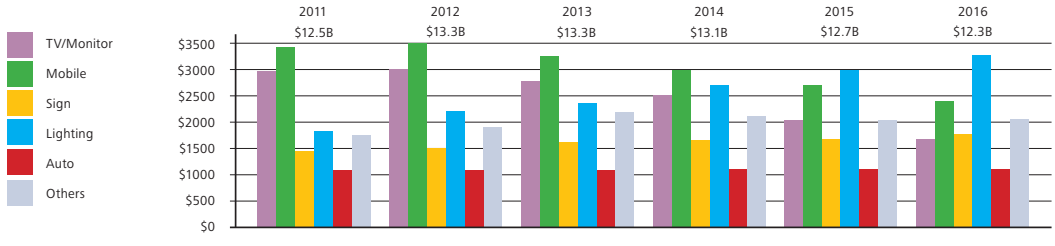


Figure 7.1.5:
Solid state lighting market 2009 – 2016.

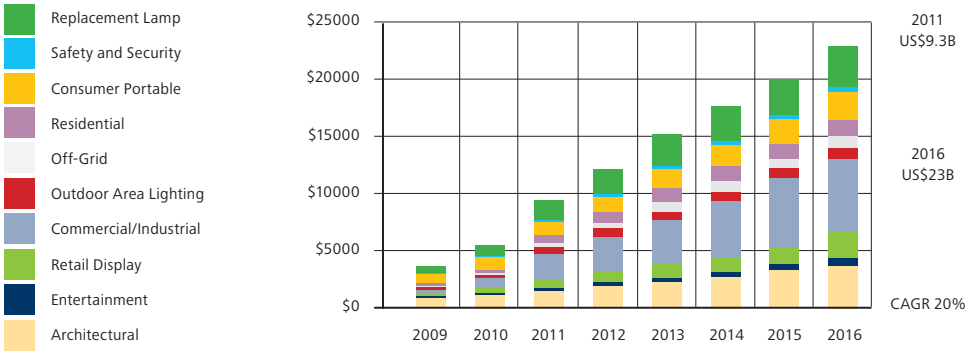
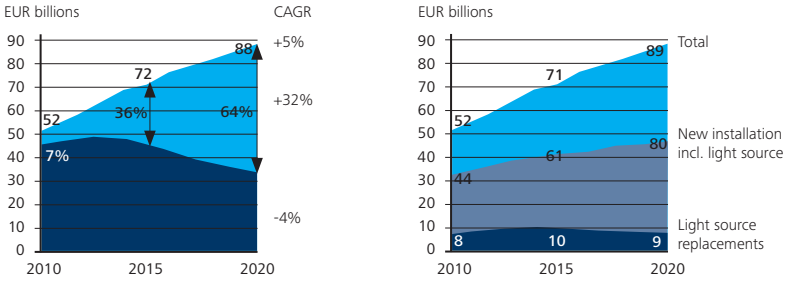


Figure 7.1.6:
General lighting market by technology.

Figure 7.1.7:
New installation and replacement market trends in general lighting.

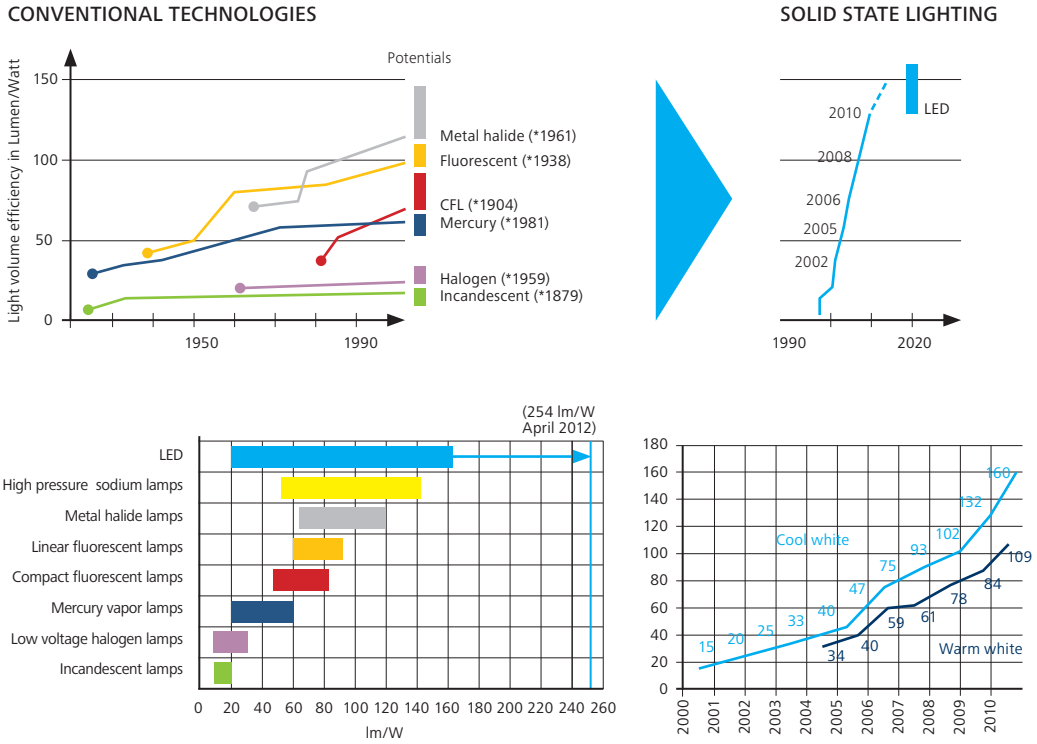


When projecting number of newly installed lighting fixtures compared with light source replacements (Figure 7.1.7) we can expect nearly linear growth for new installations and steady trend for replacements.

7.2. Lighting efficiency comparison

If we compare efficacy of the light sources over the time (Figure 7.2.1), we can confirm that LED technology is the fastest growing technology in lighting.
Producers of LEDs often announce new records in efficacy of LED light sources. For example Cree, Inc. achieved laboratory record in April 2012 – LED efficacy of 254 lm/W. This is untouchable efficacy compared with conventional technologies such as fluorescents or incandescent.

Figure 7.2.1:
Efficacy of conventional light sources versus LEDs.



7.3. HB LED

According to the history of LED cost track, we can expect price decreasing for LED chips and modules. Experts estimate the price would decrease from 13 $/klm (price from 2010) to 0.95 $/klm in the next 3 years which is more than ten time less in just five years (Figure 7.3.1).

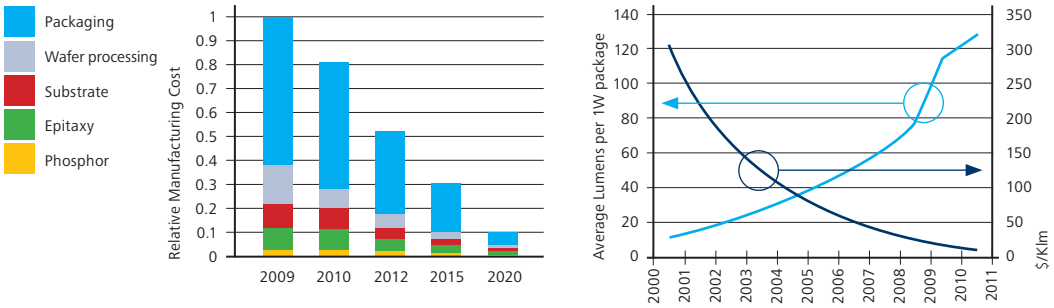
Figure 7.3.1:
Estimated future prices for 1000 lumens package.

	2010	2011	2012	2013	2014	2015	2016	2017	2018
$/Klm	**13.00**	7.70	4.57	2.71	1.60	**0.95**	0.56	0.33	0.20

Three main reasons for such a rapid price decrease are: (1) LED packaging, (2) LED dies manufacturing technology, and (3) increasing efficacy of LED dies (Figure 7.3.2). Regarding the manufacturing technology, major savings are on:

- Substrate materials - silicon instead of GaN or SiC,
- Wafer sizes – 300 and 400 mm wafers instead of 4 and 6 inches-sized wafers,
- Epitaxial growth – improved thin GaN technology on silicon substrates.

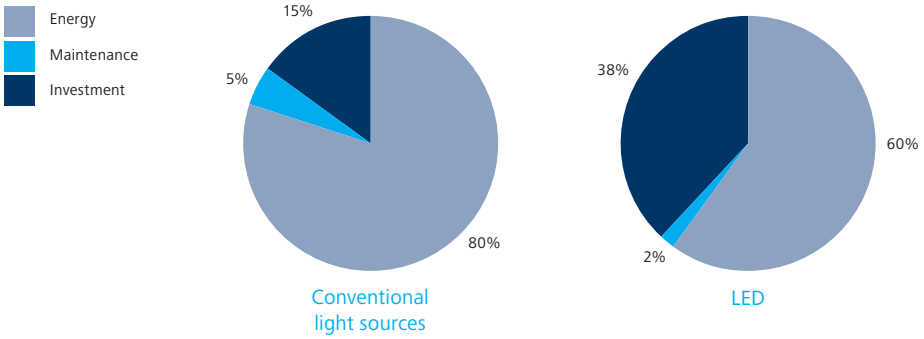
Figure 7.3.2:
HB LED package cost and efficacy tracks.



7.4. LED luminaire cost track

LED lighting fixtures have higher acquisition prices compared to conventional ones. But we should look at the price differently. However initial cost is higher (but continuously decreasing), putting together energy-savings and very low maintenance cost over the luminaire lifetime, it makes the LED luminaire commercially attractive.

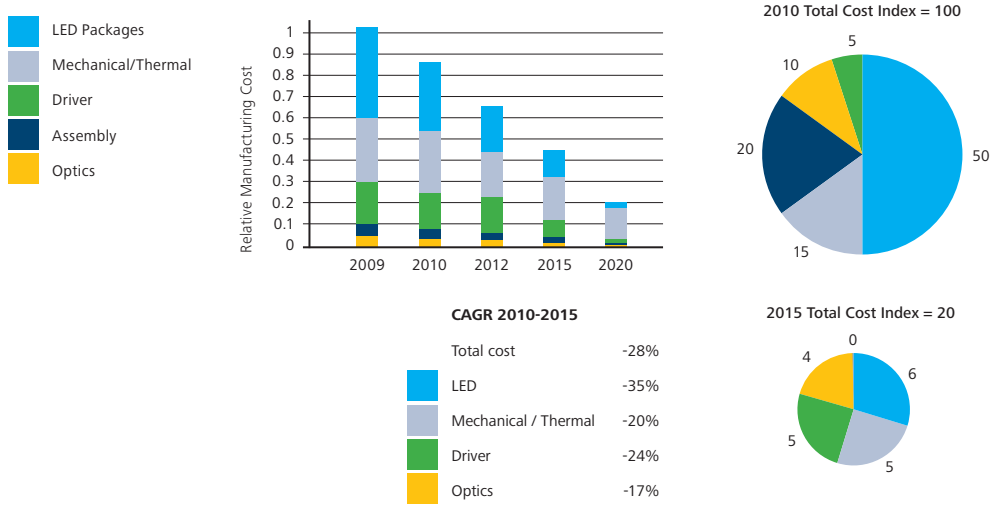
Figure 7.4.1:
Total cost of ownership for conventional and LED light sources



Simplified price of LED-based luminaire consist of LED light source, optical part, cooling system, and electronic gear. Cost-track experts expect following trends (Figure 7.4.2):

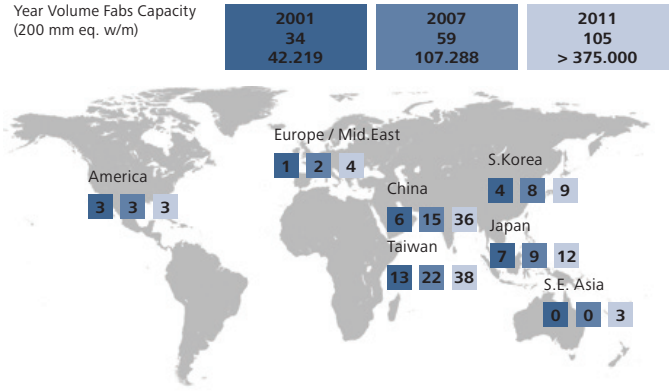
- Minor changes in costs of optics, and assembly (reflectors and labor costs)
- Significant cost reductions in semiconductor area (electronic gears and HB LED packages)

Figure 7.4.2:
LED luminaire cost tracks. (Based on DOE SSL Manufacturing Roadmap)



Increasing efficacy of HB LEDs also allows for smaller (cheaper) cooling systems. Huge investments to OMCVD (Organo-Metallic Chemical Vapor-phase Deposition) technologies confirm aforementioned expectation (Figure 7.4.3).

Figure 7.4.3:
OMCVD FAB development worldwide.



7.5. LED retrofits versus LED luminaires

LED retrofits are the first step of LED technology entering market but not the ideal step. LED luminaire adequate for general lighting has to fulfill many requirements such as:

- Optimal light distribution
- High system efficacy
- High CRI
- Various Stabilized CCTs
- Low Glaring Rates
- Dimming Possibilities
- Long Lifetime
- Durability

Different technologies ask for different approach to construction, optics, thermal management, and electronic solution. Therefore replacement of standard light sources by LED retrofits using original lighting fixture does not deliver expected solution, only interim one.
LED retrofits are comparable to the first car (Figure 7.5.1). You can drive it but with a lot of compromises. Better cars (adequate LED luminaires) are arriving right after - no compromises, just satisfaction.

Figure 7.5.1:
Retrofit LED light bulbs are like horseless carriages. Retrofit is first stage in LED-based luminaire evolution.

We can reach highest light quality standard with LED technology only via interconnected and well-done optical, thermal, and electronic design during luminaire development (Figure 7.5.2).

Figure 7.5.2:
Well-done optical, thermal, and electronic design of LED luminaire provides starting point on a way to the highest light quality standard.