Lighting

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS –** Lighting accounts for approximately 19% of all electricity generated worldwide. Global sales of lamps are estimated at 2,913 million units in 2010 and are expected to increase up to 4,661 million units by 2020. Lighting energy consumption can be reduced by energy efficiency improvements to the lighting systems, which are made up of lamps, luminaires and ballasts (the latter for discharge lamps). Key efficiency improvements are associated with the choice of lamp. Major lamp types used in the domestic sector include the traditional (inefficient) incandescent tungsten filament lamps (general lighting service, **GLS**), halogens lamps (**HL**) and the more efficient compact fluorescents lamps (**CFL**). In 2010, GLS and halogen lamps accounted for approximately 72% of market share in the European Union and 84% in the United States (2009). Many countries (e.g. Australia, the European Union, the Republic of Korea) have regulations in force to phase out the use of GLS. In the Republic of Korea, where regulations have been in force for some years, GLS and halogen lamps account (2009) for only 24% of the total units, the rest (76%) being CFLs; in the European Union and in the United States, CFLs account for 28% and 16% of the market share, respectively. In 2007, the global sales of GLS lamps were estimated at 12.5 billion units per year, while the production of CFLs increased by 70% from 2005 to 2007, reaching the level of approximately 3.5 billion lamps in 2007. In the non-domestic sectors (commercial, street lighting), fluorescent tubes comprised approximately 76.5% of light output in 2005 with the remainder being made up of GLS, CFLs, light emitting diodes (**LEDs**) and high intensity discharge (**HID**) lamps, the latter used for street lighting.

■ **PERFORMANCE AND COSTS –** The domestic lighting market is undergoing a significant transformation driven by the phase out of GLS lamps that are being replaced by the 50% more efficient halogen lamps and by CFLs, which are up to 80% more efficient and durable. GLS lamps have a typical efficiency of 6 to14 lumens per watt (lm/W) of electrical power absorbed and about 1,000-hour lifetime. More efficient lamps for the domestic market include new infrared coated (**IRC**) halogen lamps with 10 to 30 lm/W efficiency and 2,000 to 8,000 h lifetime, CFLs (35 to 70 lm/W, 6,000 to 15,000 h), and LEDs (25 to 100 lm/W, 12,000 to 50,000 h). New products for non-domestic market include ceramic metal halides (**MH**) with 70 to 107 lm/W efficiency and 6,000 to 20,000 h lifetime, and **T5** fluorescent tubes (38 to 106 lm/W, 16,000 to 48,000 h). CFL lamps cost between €1.5 and €11.4 while halogen lamps cost between €2.0 and €8.0. In the non-domestic lighting market, T5 fluorescent tubes are the most efficient option, with good efficacy level, good colour rendering and appearance. Some HID lamps such as **MH** and high pressure sodium lamps (**HPS**) are mostly used in the commercial non-domestic sector. With efficiencies of 65-130 lm/W and 70-107 lm/W, respectively, they are the most efficient options for street lighting. MH lamps also offer high colour rendering for street lighting. The cost of HPS and MH lamps range from €8.0 to €25.0 and from €11.0 to €50 per unit, respectively.

■ **POTENTIAL AND BARRIERS –** The global demand for CFLs has risen significantly over the last decade and will continue to increase over time. In OECD countries, sales could increase from 1.35 billion units in 2010 to 1.6 billion units in 2027. Global demand for halogen lamps is also expected to rise, though at a slower rate. By 2014, LEDs, ceramic MH lamps and T5 fluorescent tubes are expected to emerge as the most efficient lamp types. They are also known as ultra-efficient lamps (UEL) because they can reach efficacies of over 100 lm/W, with good lighting quality and colour appearance (e.g. 2,500-4,000 K). Improvements to luminaire and ballast designs are also likely to occur. Major barriers to the take up of these technologies include the lack of information and customer awareness of efficiency and cost benefits, as well as a certain reluctance to change due to the higher initial (capital) cost. A certain health risk perception associated with the mercury content of CFLs should now disappear with the new CFL generations entering the market.

PROCESS AND TECHNOLOGY STATUS

Lighting accounts for approximately 19% [1] of all electricity generated worldwide. Global sales of lamps are estimated at 2,913 million units in 2010 and are expected to increase to 4,661 million units by 2020 [20]. In 2005, he global consumption for lighting was estimated at 2,650 TWh, or 134.7 petalumen-hours (Plmh) [1]. Today's lighting technologies offer significant potential for electricity savings and greenhouse gas emissions reduction compared to older technologies, which are currently being phased out in most OECD countries.

A lighting system consists of the following components:

- **Lamp,** a light bulb or tube, i.e. the source of light;
- **Luminaire,** a fitting for the lamp; and
- **Ballast,** a device that is required for discharge lamps, low-pressure sodium (LPS) and high intensity discharge (HID) lamps to control the voltage running through the lamp, enable lamp ignition and operation.

■ **Lamp Technologies -**. Most common lamp technologies are discussed below.

Incandescent tungsten filament lamps, also referred to as general lighting service (**GLS**) lamps, are the

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traditional lighting technology that still dominates the market in most countries. In 2010, about 52% of lamp sales in the EU were GLS lamps [2] whereas in 2007 the global GLS sales amounted to approximately 12.5 billion units [3]. These lamps are highly inefficient if compared to new, modern lighting technologies, and almost all OECD countries and many non-OECD countries are phasing out GLS lamps in favour of more efficient lamps [1, 2, 3].

Linear fluorescent tubes are available in three major diameters: T12 (38 mm), T8 (26 mm), and T5 (16 mm) [4]. T12 tubes are now considered as obsolete. All three require the ballast. In 2005, linear fluorescent tubes accounted for 66% of all lamp sales by business volume in Japan, 24% in India, 21% in Australia, 16% in Europe, 12% in China, 7% in Russia and 4% in the US [1].

Compact fluorescent lamps (CFL) operate similarly to linear fluorescent tubes. They consist of two, four or six small fluorescent tubes, either integrated or non-integrated. Integrated CFLs have a common base attached to the ballast, whereas non-integrated CFL lamps plug into a luminaire that includes the ballast. Integrated CFL are designed to replace GLS lamps. The GLS phase out policies implemented in many countries have resulted in a growing market share for CFLs. For example, CFL sales are estimated at 34% in Australia, 76% in the Republic of Korea, and 50% in the United Kingdom [2]. In other countries, the share of CFLs is expected to increase over time as phase out programmes and information campaigns become more established [1, 2].

Halogen lamps are commercially available in two variants: infrared coated (**IRC**) lamps and non-IRC lamps, both consisting of an incandescent filament housed inside a small quartz capsule filled with a halogen gas [5]. The IRC lamps use a more accurately designed filament in a halogen gas filled capsule, which is coated with spectrally selective materials. The coating allows visible light to leave the lamp, but reflect infrared light back onto the filament. This translates into a higher lamp efficacy[1] because less electricity is needed to maintain the filament at a given operating temperature [5]. Halogen lamps can run on 12 V (i.e. low-voltage halogens) and on 220 to 240 V. The IRC halogens are a new technology that is less available in the marketplace compared to non-IRC coated halogens. However, they are likely to become more prominent in the near future [6] because R&D investment and competition are pushing efficacy improvements and cost reductions. In countries with advanced phase-out programmes (e.g. Korea, Australia and the UK, the shift from GLS to halogen lamps has been greater than anticipated. The sales of all halogen lamp types has jumped from 24% in 2008 to 45% in 2009 in Australia and from 17% in 2008 to 30% in 2010 in the United Kingdom [2].

High Intensity Discharge (HID) lamps are available on the market in three main variants, i.e. mercury vapour lamps, high pressure sodium (HPS), and metal halide (MH). These lamps are mainly used for street lighting but occasionally they are also used in other non-domestic settings. In some OECD countries, discharge lamp sales are expected to fall. For example, in the UK, sales are expected to fall by a cumulative 17% in real terms between 2009 and 2014 [9] as policy has moved to promote the use of efficient 'white' lights in many new and replacement lighting programmes. These lights are increasingly substituted by LED and fluorescent lamps, which are more energy efficient and have a longer life span [9].

Light emitting diods (**LEDs**) and organic light emitting diods (**OLEDs**) are most recent, highly efficient lighting technologies The current market penetration of LEDs and OLEDs is relatively low, but they are expected to become leading technologies for indoor lighting in the future [2, 7]. The IEA 4E benchmarking programme examined the sales of LEDs in a number of OECD countries and reported few sales up to 2009 inclusive [2]. This is due to the high cost and the lack of consumer awareness about benefits [7]. OLEDs have been available on the market since 2009, but are mainly used in display applications such as mobile phones, TVs, and computers. Their performance currently trails LED performance. However, in the long-term, OLEDs are expected to achieve high efficacy and widespread use in white-light production [8].

■ **Luminaires -** The main role of the luminaire is to distribute, diffuse and direct the light emitted by one or more lamps onto a desired surface [1]. The efficiency of a luminaire is measured by its light output ratio (LOR). This is the ratio of the luminaire's light output to the light output of the lamp(s), and is normally expressed as a percentage. LOR values above 50% are usually classed as efficient, but efficiency also depends on the lighting distribution required [10]. There are many different designs of luminaires covering a range of LORs. In 2010, over 1 million energy efficient luminaires options were available in the UK market alone [9].

■ **Ballast –** Ballasts are required in all discharge lamps i.e. fluorescent tubes, CFLs, low-pressure sodium (LPS) and HID lamps, to enable discharge ignition and operation. They require different amounts of energy to function depending on the design, and may influence the efficacy of the lamp itself [1]. There are two broad categories of ballasts: electro-magnetic and electronic. In Europe, ballasts are classified according to the Energy Efficiency Index (EEI) system which includes 7 classes: A1, A2, A3, B1, B2, C and D. Electronic ballasts are rated as 'A' ballasts, with A1 being the most efficient. Electro-magnetic ballasts are rated as 'B', with 'B1' the most efficient one [11]. Ballasts rated as C and D are now discontinued. A ballast can use from a few percentage points up to 40% of the overall lighting system electricity [1]. Most OECD governments have requirements for ballast electricity use but differences in performance are still very significant [1].

[1] Efficacy or efficiency at which a lamp converts electricity into light, given as lumen per watt (lm/W).

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PERFORMANCE AND COSTS

The performance of a lamp is assessed by the following parameters:

• **Luminance efficacy** – Measured as lumens per watt (lm/W), it describes the energy efficiency at which a lamp converts electricity into light [4]. The higher the value the more efficient the lamp;

• **Colour performance** – Described by the colour rendering index (Ra), it measures how well a lamp shows colours accurately. Best performing lamps have values between 80 and 100 [4];

• **Colour appearance** – Described by the colour temperature and measured in *Kelvin* (K), it characterises colour warmth and coolness. The warmer the light, the greater the Kelvin value. For example a GLS lamp will have a warm colour temperature of 2,700 to 3,000K, compared with a cool colour temperature of 4,000 to 6,000K for a lamp which mixes well with daylight, such as a cool white fluorescent tube [4];

• **Lamp lifetime** – This is the average number of hours a lamp can work, usually intended as the time after which half of the lamps in a sample fail [4].

Lamp performance and requirements, as well as the choice of the lamp technology depend on applications, e.g. domestic lighting, commercial lighting, street lighting.

■ **Domestic Lighting -** GLS lamps have dominated the domestic market for decades. However, they are inefficient (5-17 lm/W) and have a short life span (1,000 hours) if compared with other available light technologies (see Table 1). They are being phased out in most OECD countries and replaced with CFLs and halogen lamps. Non-IRC halogen lamps can deliver 20-30% savings over GLS lamps, while new, more efficient IRC halogen lamps save up to 50% of the electricity consumed [6]. IRC halogen lamps have a luminance efficacy between 10 and 30 lm/W [4,5,12] and a lifetime of 8,000 hours [4]. CFLs have even greater efficacies saving up to 80% energy compared with GLS lamps [13], and offer lifetime of up to 15,000 hours [4]. Price estimates vary significantly, but average prices per unit are between €2.0 and €8.0 for halogen lamps and between €1.5 and €11.5 for CFLs [13,14]. Most domestic lighting products are also used in non-domestic sectors e.g. hotels, offices, retail spaces [2].

■ **Commercial (non-domestic) sector -** Linear fluorescent tubes are a dominant technology in the non-domestic sectors [1]. These efficient lamps are mainly used for commercial lighting in offices, commercial buildings and industrial applications with ceiling heights below 5 meters. The T5 lamps are the most efficient fluorescent tubes, having efficacy between 38 and 106 lm/W, good colour rendering and colour appearance, and a lifetime of up to 48,000 hours [4]. They cost same as or less than less efficient T8 tubes, e.g. up to €10 per bulb compared to about €19 for T8 bulbs [15]. T5 lamps have potential for future market growth and further increases in efficacy [12]. Some HID lamps such as MH and HPS lamps are also used in the non-domestic sector, see Table 1 for more details.

LEDs are a promising emerging light technology that can be used in different applications. The technology is currently more prominent in the non-domestic sector due to price barriers in the domestic sector. Non-domestic LED products are delivering efficacies between 50 and 100 lm/W, and further improvements are expected over time. Some estimates anticipate an average 10% increase per year [2]. In terms of efficiency and colour rendering LEDs are now comparable with CFLs [7]. The typical LED price is currently between €10 and €55.00 per unit [8,14] but is projected to decrease over time (see Table 4 for price change over time). OLED efficacy has improved by two orders of magnitude over the last decade. However, the performance of OLEDs is not yet sufficient for general illumination applications. OLED life span is currently over 10,000 hours [1] but is projected to be comparable to LED lifetime (50,000 hours) in the longer term. Prices are currently high, but projections in the long-term appear to be similar to LEDs once manufacturing of OLED panels ramps up [8].

■ **Street Lighting -** In 2005, street lighting accounted for approximately 4-5% of total lighting electricity consumption [1]. The International Energy Agency reports [1] that almost 62% of total outdoor light in OECD countries is provided by HPS and LPS lamps, 30% by mercury vapour lamps and 6% by MH lamps. The market share distributions closely match the street lighting market shares in the EU (see Table1). Average efficacy of street lighting is linked to the proportion of old, inefficient mercury vapour lamps that remain in operation [1]. Some OECD regions such as North America and the EU are phasing (or have phased) out mercury vapour lamps and HID lamps in favour of more efficient HPS lamps. Both HPS and MH lamps offer high efficacy (i.e. 66 to 130 lm/W and 70 to 107 lm/W, respectively), with unit costs between €8.0 to €25.0 and €11.0 to €50.0, respectively [15,16]. Although HPS lamps have a higher efficacy compared to MH lamps, they have lower luminaire efficiency. Thus HPS lamp overall efficiency is inferior unless used at high power ratings. MH lamps also have better colour rendering (65 to 96 Ra) compared to HPS lamps (25 Ra) [4], making them a superior option for street lighting [1,17].

POTENTIAL AND BARRIERS

The IEA report *Light's Labour's Lost* [1] outlines major barriers for the uptake of efficient lighting in OECD countries. In particular:

• **Lack of customer information/awareness** (and lack of time to make informed decisions about lighting) can lead to consumers to miss the opportunities to reduce energy costs and save money;

• **Lack of confidence** in new lighting technologies due to the market introduction of poor quality new lighting products, which occurred in the recent past years;

• **High equipment costs** of energy-efficient lamps compared with conventional lamps, particularly for LEDs;

• **Inadequate incentives through design and supply chain** where lighting decisions are often taken by who is not the final user and often has no incentive to select the most energy-efficient options; and

• **Perceived health/environmental issues** concerning the mercury content of some CFLs (actually, the mercury content of CFLs has been reduced by 90% and current levels are not thought to be dangerous to human health [9]).

New regulations and information campaigns have fostered lighting efficiency improvements in many countries. For example, Australia, the Republic of Korea and the UK have seen the efficiency of sold lamps to rise by 50% over 3 years, despite regulations are not yet fully implemented in these countries [2]. In the Republic of Korea the average efficacy of all lamp sales was 45 lm/W in 2009, which is twice as high as any other country or region that has efficient lighting regulations in place. This is approximately three times better than Canada and the United States, where regulation has made little impact on lamp sales as of 2009 [2]. Korean regulations have been in force since 2003, resulting in an efficient lighting stock. Further regulations in Korea will likely lead to additional increases in lamp efficacy to 2014 [2].

European Regulation (EC) 244/2009 came into force in 2009. It sets ecodesign requirements aiming to remove the least efficient non-directional lamps from the market. The lamps phased out thus far include all non-clear GLS lamps, candle lamps, golf-ball lamps, inefficient CFLs (class B and below) [2], clear GLS lamps rated 60W and higher, and linear halogen lamps rated 100W and higher. Most non-directional lamps must be classified Class C or higher beginning September 2012, and Class B or higher beginning September 2016.[2]

As of April 2010, European Regulation (EC) 245/2009 and its amending Regulation (EU) 347/2010 requires the phase out of several types of fluorescent lamps such as T8 halophosphate linear lamps. Ballasts for fluorescent lamps are also required to have a minimum B2 classification if non-dimmable and an A1 classification if they are dimmable. The regulation also requires that HPS lamps and the least efficient MH lamps be removed from the market in April 2012. This is the same date that energy efficiency limits for HID ballasts will come into effect. In April 2015, high pressure mercury (HPM) lamps will be phased out. Beginning in April 2017, non-integrated CFL 2-pin lamps and MH lamps rated 400W and below will be phased out if they do not meet minimum requirements. Also at this time, the minimum energy efficiency class for fluorescent lamp ballasts will be A2 (i.e. require electronic ballasts). Fluorescent luminaires must be compatible with these ballasts. New lighting regulation is currently being developed to set ecodesign requirements for directional lamps, LEDs and halogen lighting converters. Regulations in Europe and other OECD countries have encouraged research into new efficient lighting technology. Manufacturers are currently working on next generation CFLs known as "Super" CFLs [3], which are expected to gain market share as GLS lamps are fully phased out in all OECD countries. Super CFLs are designed to overcome current CFL drawbacks and are operated using digital technology. This technology delivers CFLs that have a minimum of 70 lm/W, and a 50% lower operating temperature. Super CFLs are also fully dimmable, smaller, restart at any light level setting, and maintain 80% of initial lumens at the end of life [3]. In addition they are reported to contain lower levels of mercury and have a minimum 10,000 hours lifetime [3]. Super CFLs are expected to initially carry an approximate US$ 2 price premium but that this is likely to decline to US$ 1 as the market matures [3].

The market share of IRC coated halogen lamps is also likely to increase as GLS lamps become fully phased out. LED and OLED lights are also becoming more efficient and the price decreases annually. As the price drops, the market share is likely to increase accordingly. Global demand for CFLs has risen significantly over the last decade and continues to rise. In OECD countries, sales could increase from an estimated 1.35 billion in 2010 to 1.6 billion in 2027 (see Figure 1 for more information). Global demand for halogens will continue to increase but the rate is predicted to be less than CFLs [3]. The lamp types that are likely to be the most efficient by 2014 are LEDs, ceramic MH lamps and T5 fluorescent tubes [12]. These have the highest energy efficiency improvement potential, some of which would be classified as ultra-efficient lamps (UEL) [12].

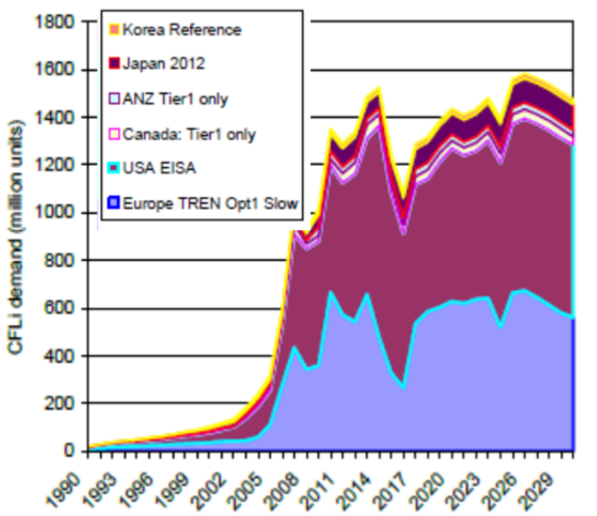

Figure 1 - CFL sales in OECD following pending and potential GLS phase-out regulations[3]. (IEA estimates)

[2] Class C lamps correspond to the efficiency achieved by high voltage halogen lamps. Class B corresponds to the efficiency achieved by IRC coated low voltage halogen lamps. Level A corresponds to the efficiency achieved by a relatively well-designed CFL [6]

[3] The IEA carried out a study in 2010 [3] looking at the effects of the global phase out of GLS under a number of different scenarios projecting potential European lighting regulations. Post study, the Ecodesign regulation that came into force is most similar to the Europe TREN Option 1 in Figure 1 above.

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[4] The market share data quoted in this report is considered indicative by the referenced authors

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Table 1 – Summary Table – Typical Key Data and Figures for Lighting Technologies

Domestic Lighting (Typical current international values and ranges)				
Technical Performance	GLS	Halogen lamps	CFLs	LEDs
Energy Input/ Output	Electricity (W)/Lumens (lm)			
Typical size, W	40-100 [18]	20-100 [13]	15 -40 [15]	1-16 [13,15]
Energy efficiency (efficacy), Lm/W	5-17 [12,13]	10-30 [5,4,12,13]	35-75[5] [12,13]	>15-1005[4]
Lifetime, hours x 1000	1.0 [4], [2]	2.0 – 8.0 [4]	6.0 – 15.0 [4]	12,0 ->50,0 [4]
Correlated Colour Temperature (K)	2,700–2,800 [4]	3,000 [4] 3,800-4,400 [13]	2,400-6,500 [13]	2,800–6,500 [13]
Colour Rendering Index (RA)	100 [4]	98-100 [4]	65-92 [4]	80 [12]
EU market share (2010), % [2][6]	52% (59%, 2009)	20% (18%, 2009)	28% (23% 2009)	0[7]
United States market share 2009, % [2]	84%[8]		16	07
Australia market share 2009, % [2]	21	45	34	07
Republic of Korea market share 2009, % [2]	14	10	76	0.3
Canada market share 2009, % [2]	65	11	24	07
Costs (€ 2011)	Typical current international values and ranges			
Product cost, euro/unit[9]	1.93 – 11.5 (av. 4.33) [13]; 0.71 [19]	2.0–8.0 [11]	1.50-11.35 (av. 8.54)[10] [13,14]	11.0-57.0 [8,14] See Tab. 4
Data Projections (by technology variant)				
Efficiency, 2010-2030	Estimated 0.1% annual efficacy improvement [2]	Estimated 0.3% annual efficacy improvement [2]	Estimated 0.6% annual efficacy improvement [2]	70 lm/W (2010) 111 lm/W (2015) 152 lm/W (2020) 175 lm/W (2025) 184 lm/W (2030) [8]

Street Lighting (Typical current international values and ranges)				
Technical Performance	Metal Halide	High Pressure Sodium	Mercury Lamps	Fluorescent lamps
Typical size (W) [16]	60-250	50-400	80-400	
Energy efficiency (Lm/W) efficacy [4]	70-107	66-130	36-58	T8: 60-100 T5: 38-106
Average luminaire efficiency (%) [1]	34-40	30	30	
Lifetime, hours x 1000 [4]	6.0-15.0	12.0 – 28.5	12.0 – 20.0	T8: 12.0 – 60.0 T5: 16.0 – 48.0
Correlated Colour Temperature (Kelvin) [4]	3,000–6,000	2,000	4,000	2,700–6,500
Colour Rendering Index (CRI) (RA) [4]	65-96	25	42-49	80–85
EU Market share (2005), % [16]	3	47 (9 for LPS)	32	8
Global total outdoor light [1]	6	62 (HPS and LPS)	30	
Costs (€ 2011)	See Table 2 below			

[5] Luminous efficacy for CF and LED lamps varies considerably, depending on wattage, components and configuration. This will also increase as the technology develops
[6] The market share data for the EU, US, Australia, Republic of Korea and Canada is considered indicative by the referenced authors.
[7] The IEA 4e benchmarking programme (2011) [2] examined the sales of LEDs in a number of OECD countries and found that very few sales were reported
[8] US reported incandescent filament and incandescent halogen together
[9] Using the conversion factors from the Coinmill website on the 1st Nov 2011 (1 USD = 0.71 Euro and 1 GBP = 1.14 Euro)
[10] Excludes one irregular figure

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Table 1 (continued) – Summary Table – Typical Key Data and Figures for Lighting Technologies

Commercial Lighting (Typical current international values and ranges)				
Technology Variants	Metal halide	High pressure sodium (SON)	Fluorescent tubes Triphosphor coated	LED
Typical applications [4]	Commercial uses with good colour rendering: high bay areas (indoor space with high ceiling), floodlighting, external lighting, retail, hotels	High bay areas, flood lighting, street lighting, etc., that need to be lit for a long periods	Offices, commercial buildings, and low bay industrial uses (below 5m)	A variety of different applications
Typical size (W)	70-400 (up to 1000W available)	30-400	T8[11]: 10–70 T5: 6–80	1-16 [11, 17]
Energy efficiency (efficacy), Lm/W [4]	70-107	65-103	T8: 60-100 T5: 38-106	>25-100 [5]
Lifetime, hours x 1000 [4]	6-20	12–28.5	T8: 12–60 T5: 16–48	12->50
Colour Temperature (K)	3,000-6,000 [4]	2,000 [4]	2,700–6,500 [4]	2,800-6,500 [11]
Colour Rendering Index (CRI) [4]	65-96	25	80 – 85	80 [12]
Market share (2005), %	All HIDs : Japan: 42%, Europe 30%, Australia 18%, US: 8% [1]		EU 16%; India 24%; Japan 66%; US 4%; Australia 21%, Russia 24% [1]	All OECD: 0% with the exception of Republic of Korea: 0.3% [2]
Costs (€2011)	Typical current international values and ranges.			
Product cost, Euro/unit [9]	11.0-50.0 (special types over 100.0) [16, 15]	8.0-25.0 [16, 15]	T8: 2.0–19.0 T5: 3.0–10.0	11.0-57.0 [7, 14] Table 4

Data Projections (by application)	Domestic	Commercial	Industrial	Outdoor (incl. street lighting)
Av. share of global 2005 production, % [1]	14	45	29	12

Table 2– Average Price of Different Street Lighting Components (Euro)[12] [16]

Lamp Type	Lamp	Electronic ballast	Magnetic gear	Luminaire (incl. magnetic gear)
High Pressure Mercury vapour lamp -80W	3.6	n.a.	12.4	157.0
High Pressure Mercury vapour lamp -125W	3.6	n.a.	21.7	157.0
High Pressure Mercury vapour lamp -250W	8.2	n.a.	20.8	239.0
High Pressure Mercury vapour lamp -400W	11.5	n.a.	29.8	321.0
High Pressure Sodium lamp, ovoid, frosted-110W	18.4	n.a.	21.7	157.0
High Pressure Sodium lamp, ovoid, frosted-220W	22.5	n.a.	20.8	239.0
High Pressure Sodium lamp, ovoid, frosted-350W	25.1	n.a.	29.8	321.0
High Pressure Sodium lamp, tubular, clear-50W	14.7	n.a.	29.6	159.0
High Pressure Sodium lamp, tubular, clear-70W	14.7	120.0	32.4	163.0
High Pressure Sodium lamp, tubular, clear-100W	17.4	123.0	33.6	177.0
High Pressure Sodium lamp, tubular, clear-150W	18.8	126.0	39.3	186.0
High Pressure Sodium lamp, tubular, clear-250W	20.2	n.a.	43.3	220.0
High Pressure Sodium lamp, tubular, clear-400W	22.0	n.a.	59.3	
High Pressure Metal Halide lamp-70W	22.3	120.0	32.4	163.0
High Pressure Metal Halide lamp-100W	27.0	123.0	33.6	177.0
High Pressure Metal Halide lamp-150W	27.0	126.0	39.3	186.0
High Pressure Metal Halide lamp-250W	54.0	n.a.	43.3	220.0
High Pressure Metal Halide lamp-60	40.1		n.a.	243.0 electron
High Pressure Metal Halide lamp-140	47.3		n.a.	266.0 electron
Low Pressure Sodium lamp 131 W	48.2	n.a.	76.8	565.0
Tubular florescent 36W	4.0		5.0	150.0

[11] The two most commonly used types of fluorescent tubes have two common diameters: 26mm (T8) and 16mm (T5) [2].
[12] Price assumptions in Tichelen et al (2007) for different lighting parts (Source: Assumptions based on a combination of own experience and retail prices displayed in manufacturer catalogues) for EU countries.

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Table 3 - LED Efficacy Improvements for Different Colour Rendering Index (CRI) [8]

Lumens per watt	2010	2015	2020	2025	2030
Low CRI (<40)	86.2	127.5	168.8	193.5	204.1
Med CRI (41-75)	77.7	118.5	157.6	180.3	189.8
High CRI (76-90)	64.3	107.1	147.3	168.5	176.3
Very High CRI (91-100)	50.2	91.6	133.5	156.8	165.8

Table 4 – LED Prices Projection for Different Colour Rendering Index (CRI) (€ per kilo-lumen)[13] [8]

	2010	2015	2020	2025	2030
Low CRI (<40)	64.9	13.9	3.3	2.1	1.9
Med CRI (41-75)	88.9	20.8	4.8	3.2	3.0
High CRI (76-90)	120.3	32.7	6.4	3.8	3.6
Very High CRI (91-100)	151.7	52.8	9.6	4.8	4.4

Table 5 OLED Efficacy Improvements for Different Colour Rendering Index (CRI) [8]

	2010	2015	2020	2025	2030
Low CRI (<40)	43.6	122.6	168.2	178.1	179.7
Med CRI (41-75)	30.8	107.7	154.9	163.7	164.8
High CRI (76-90)	21.3	91.6	140.6	148.9	149.9
Very High CRI (91-100)	11.6	70	128.4	138.9	139.9

Table 6 - OLED Prices Projection for Different Colour Rendering Index (CRI) (€ per kilo-lumen) [8]

	2010	2015	2020	2025	2030
Low CRI (<40)	97.1	19.0	4.2	2.6	2.5
Mid CRI (41-75)	140.9	33.2	6.0	3.4	3.2
High CRI (76-90)	177.6	57.7	1.8	4.3	3.9
Very High CRI (91-100)	230.3	109.6	15.3	5.3	4.7

[13] Price per kilolumen is a common metric for measuring the costs of LED with time. The prices have been converted from US dollars to Euros using conversion factor of 1US$=0.71 €

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