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12.05.2015

Solid State Lighting

LIDIA CAPPARELLI

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Co-funded by the Intelligent Energy Europe Programme of the European Union

Reference

1. Solid State Lighting Annex: Life Cycle Assessment of Solid State Lighting – Final Report, *International Energy* Agency's (IEA) Energy Efficient End-Use Equipment (4E), www.iea-4e.org, *September 2014*

2. Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part I: Review of the Life-Cycle Energy Consumption of Incandescent, Compact Fluorescent, and LED Lamps, *Navigant Consulting (US), Inc. Steve Bland, Makarand Chipalkatti, Heather Dillon, Monica Hansen Cree, Brad Hollomon, Noah Horowitz, Michael Scholand, Leena Tahkamo Aalto University & Université Paul Sabatier (Toulouse III), Fred Welsh,* 2012,

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4. Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products Part 2: LED Manufacturing and Performance, *Pacific Northwest National Laboratory (US), Michael J. Scholand, LC Heather E. Dillon, June 2012*
5. US Department of Energy: Technology fact sheet on efficient lighting strategies. http://www.eere.energy.gov/buildings/documents/pdfs/26467.pdf
6. Life Cycle Assessment of light sources – Case studies and review of the analyse, *Department of Electronics, Lighting Unit, Aalto University, Finland, Leena Tähkämö, September 2013*
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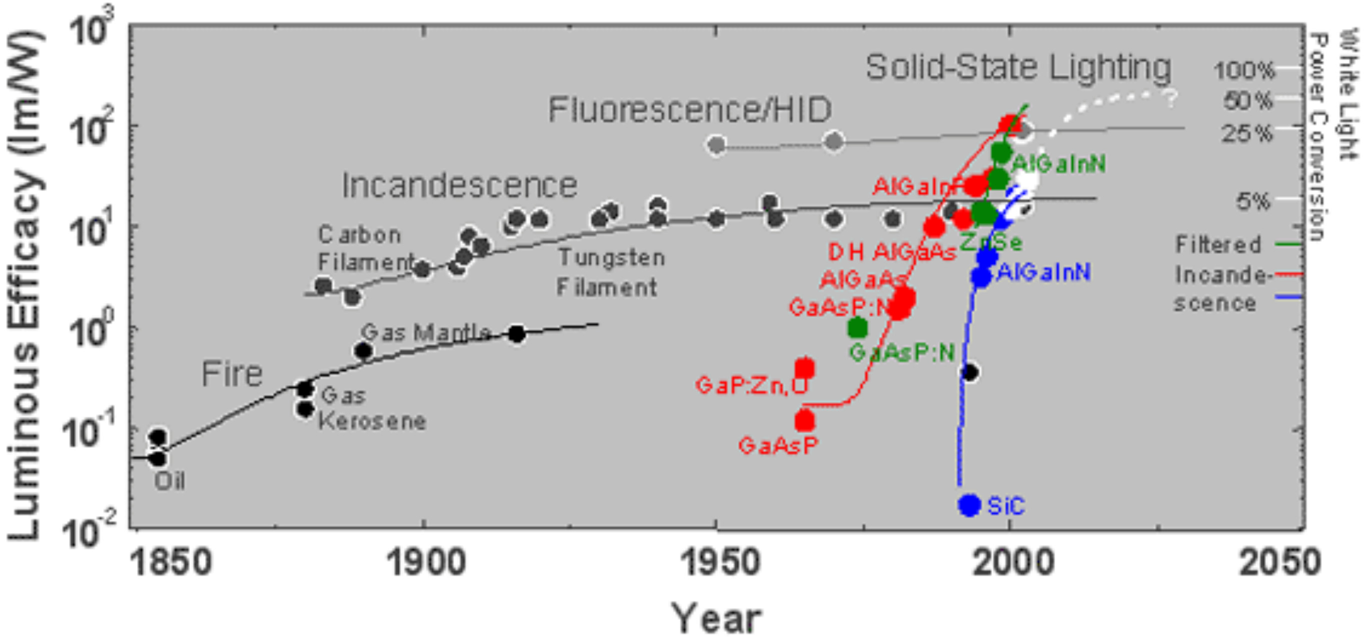
History of Lighting



***NOTE: High-intensity discharge lamps** (**HID lamps**)* are a type of electrical gas-discharge lamp. Varieties of HID lamp include:

- Mercury-vapor lamps
- Metal-halide (MH) lamps
- Ceramic MH lamps
- Sodium-vapor lamps
- Xenon short-arc lamps

Report

This report consists of three parts:
(1) introduces the LCA method
(2) reviews LCA studies of light sources (lamps, luminaires), concentrating on the studies of LED products;
(3) conclusions are drawn and future recommendations provided.

Framework of LCA

- Determine purpose, audience, intended use of results
- Define product to be analyzed, functional unit (later), basic unit processes in life cycle, impact categories, data requirements…

LCI: Data collection & calculation procedure to quantify inputs & outputs of unit processes grouped into phases

LCIA: evaluates the significance of LCI results,downstream effects e.g. global warming potential, natural resources depletion, human toxicity effects…

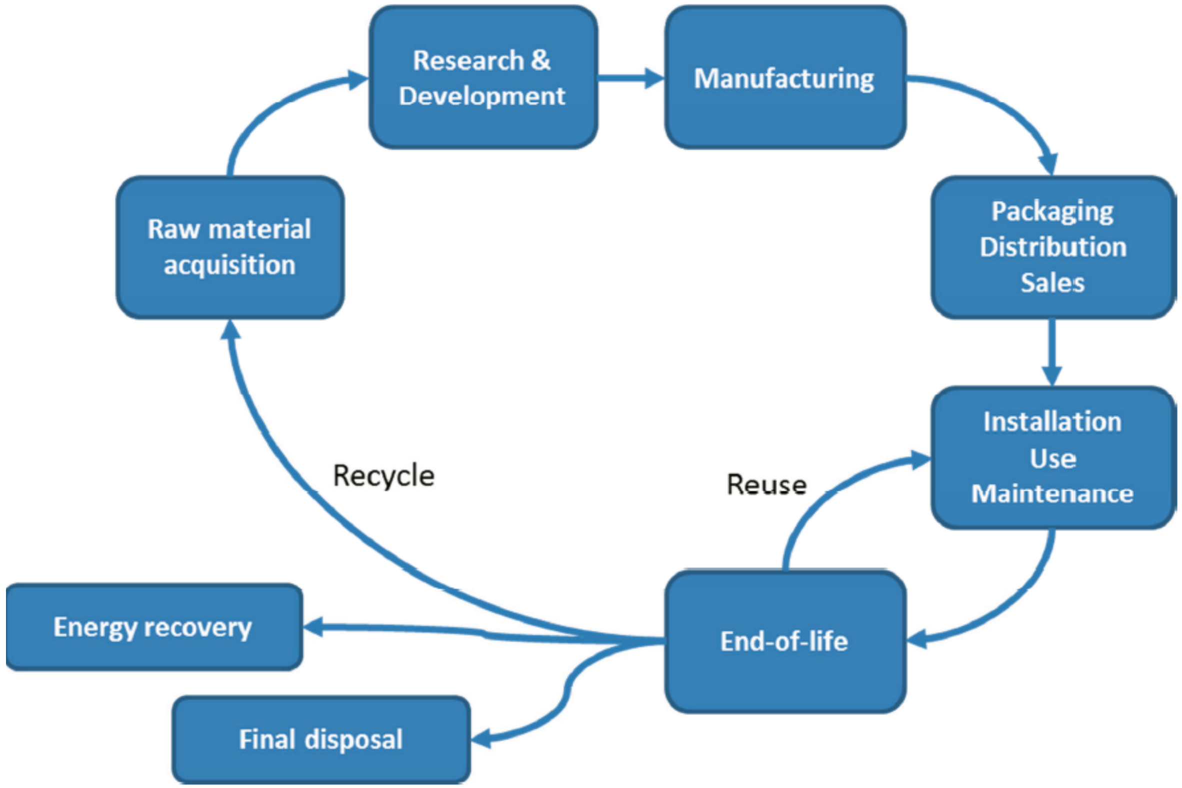
Interpretation: significant issues, consistency & reliability of data, recommendations…

The ***manufacturing phase*** encompass primary resource acquisition, raw material processing, manufacturing, and assembly. This data includes direct estimates of manufacturing phase energy consumption, carbon dioxide emissions impacts due to manufacturing energy use, and data on disassembled lamp components (combined with the utilization of a life-cycle inventory database).

The ***transportation phase*** is defined as the transporting of a packaged lamp from the manufacturing facility to the retail outlet.

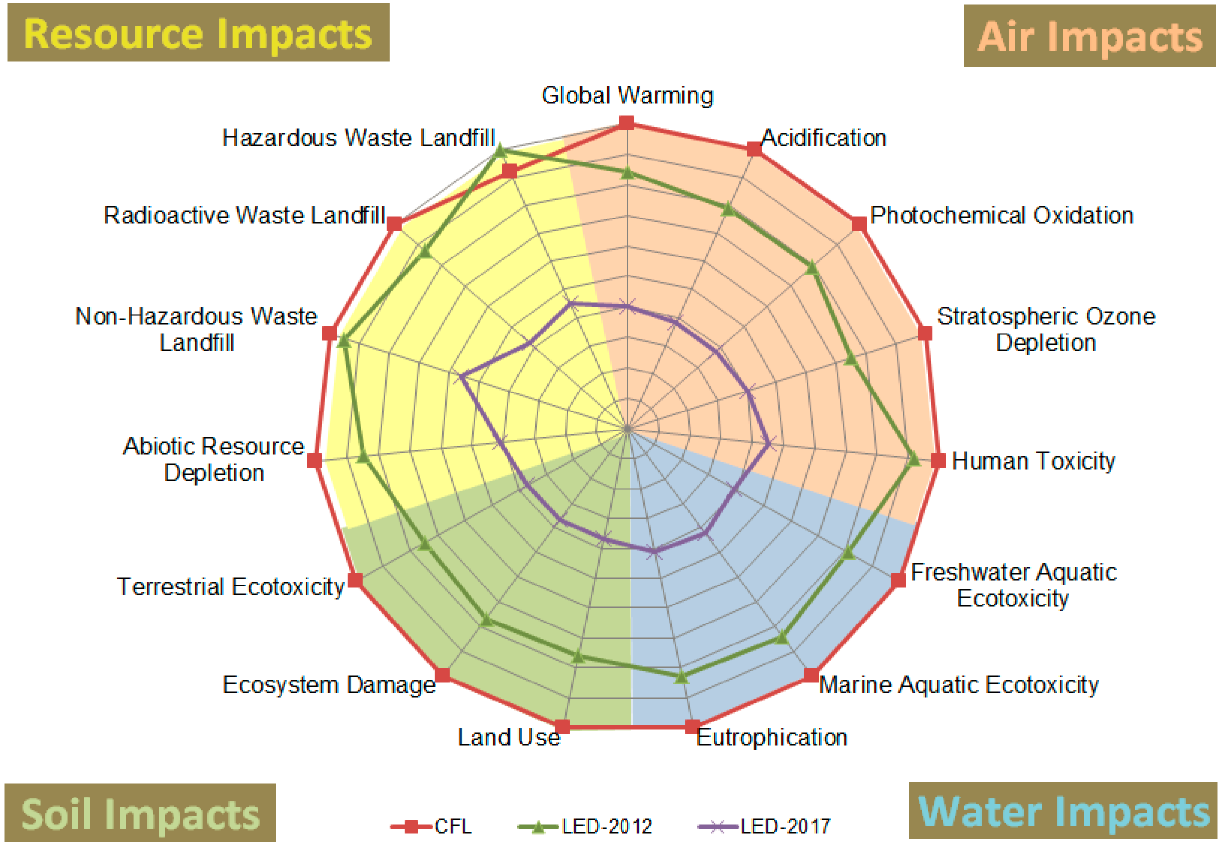
The ***use phase*** energy consumption is calculated based on the assumed wattage and lumen output characteristics of the incandescent, compact fluorescent, and LED technologies analyzed.

Life Cycle of a product



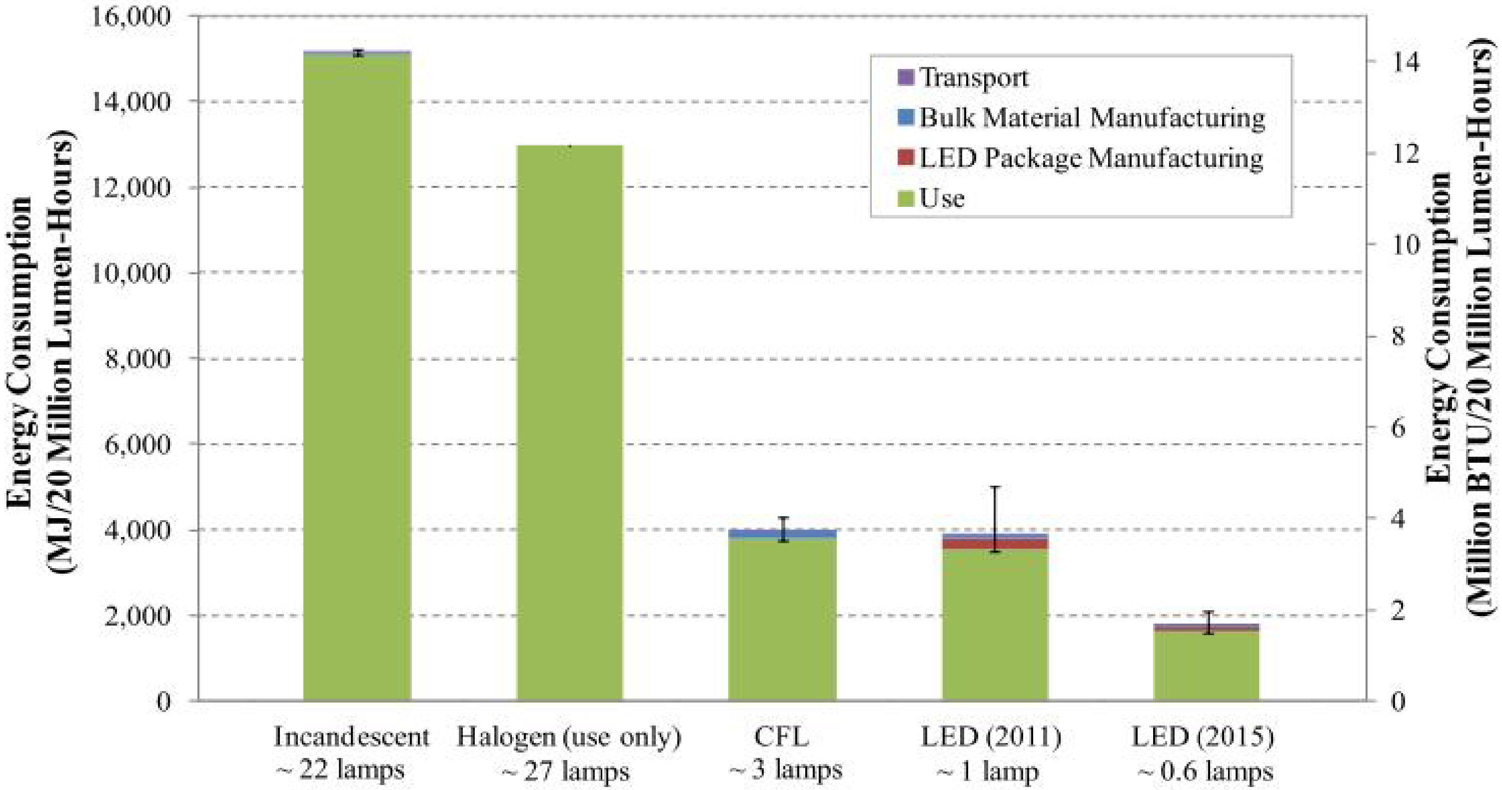
Tähkämö 2013

LCA study by US DOE

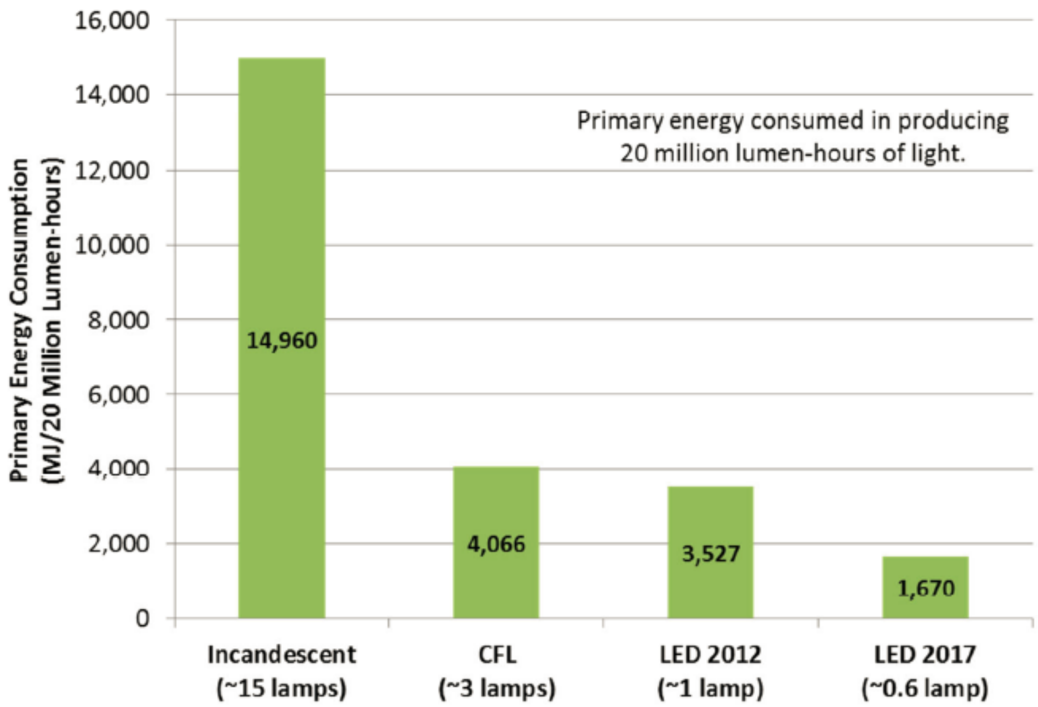


Life-cycle environmental impacts of three household lamp technologies including current (2012) and future (2017) LED lamps (US DOE 2012b).

Energy Life-Cycle of Incandescent, CFL and LED lamps



LCA study by US DOE



Primary energy consumption over the life cycle of three lamp technologies (US DOE 2012b).

It is forecasted that LED lighting will represent 46 percent of general illumination lumen-hour sales by 2030, resulting in an annual primary energy savings of 3.4 quads (Navigant Consulting, Inc., 2012a).

NOTE: quad is a unit of energy equal to 10^{15} (a short-scale quadrillion) BTU, or 1.055×10^{18} joules (1.055 exajoules or EJ) in SI units
The **British thermal unit** (**BTU** or **Btu**) is a traditional unit of energy equal to about 1055 joules

LCA study by US DOE

Key findings

•The average life-cycle energy consumption of LED lamps and CFLs was similar, and was about one-fourth the consumption of incandescent lamps.

•If LED lamps meet their performance targets by 2015, their life-cycle energy is expected to decrease by approximately one-half, whereas CFLs are not likely to improve nearly as much.

•The use phase of all three types of lamps accounted **for 90 percent of total life-cycle energy, on average**, followed by manufacturing and transport. Most of the uncertainty in the life-cycle energy consumption of an LED lamp was found to centre on the manufacturing of the LED package. Various sources estimated this at anywhere from 0.1% to 27% of life-cycle energy use.

•The energy these three lamp types consumed in the use phase constituted their dominant environmental impact.

LCA study by US DOE

Key findings

- Because of its low efficacy, the incandescent lamp was found to be the most environmentally harmful of the three types of products, across all 15 impacts examined in the study.
- The LED lamp had a significantly lower environmental impact than the incandescent, and a slight edge over the CFL.
- The CFL was found to be slightly more harmful than today's LED lamp on all impact measures except hazardous waste landfill, because of the LED lamp's large aluminium heat sink. As the efficacy of LED lamps continues to increase, aluminium heat sinks are expected to shrink in size—and recycling efforts could reduce their impact even further.
- The light source that performed the best was the LED lamp projected for 2017, whose impacts are expected to be about 50 percent lower than the 2012 LED lamp and 70 percent lower than the CFL

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LCA study by US DOE

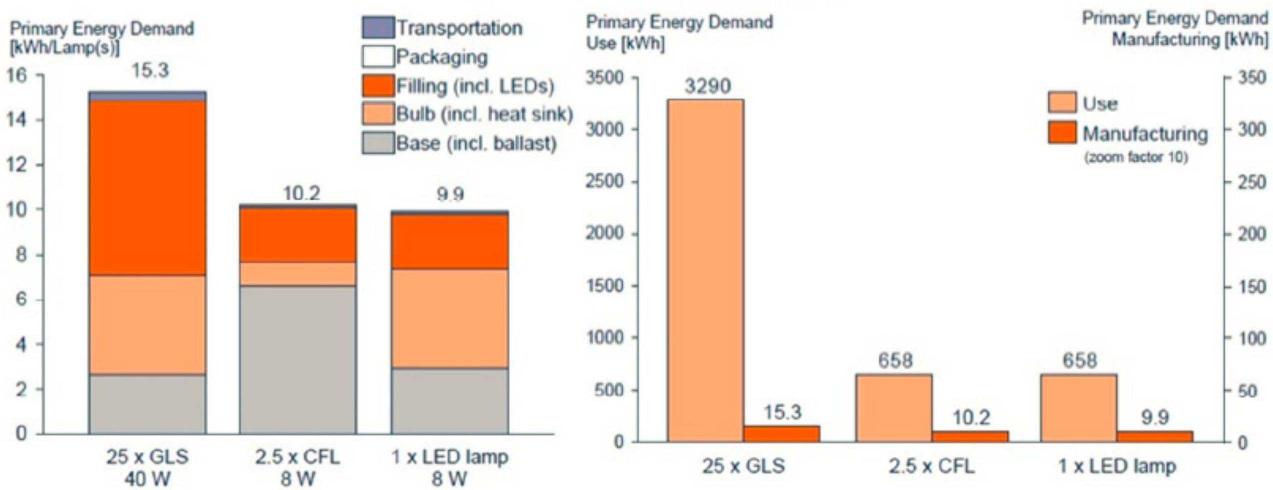
Key findings

- The selected models were generally found to be below restrictions for elements that are regulated at the national level in the US.

- Nearly all of the lamps (regardless of technology) exceeded at least one California restriction—typically for copper, zinc, antimony, or nickel.

- Examination of the components in the lamps that exceeded the California restrictions revealed that the greatest contributors were the screw bases, drivers, ballasts, and wires or filaments. Concentrations in the LED lamps were comparable to concentrations in cell phones and other types of electronic devices, and usually came from components other than the LEDs themselves.

LCA study by Osram

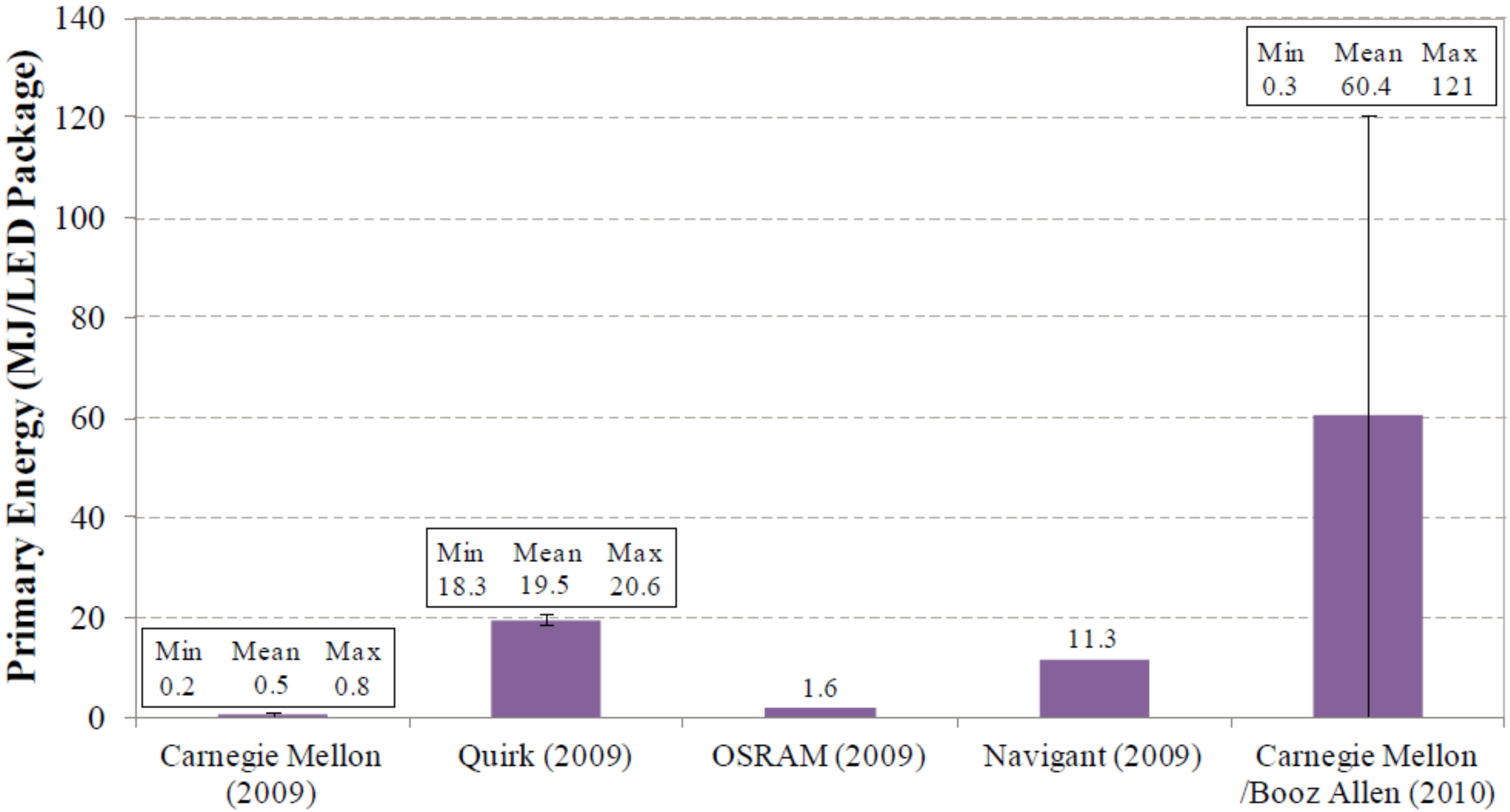


Detailed primary energy demand for manufacturing, and primary energy demand for manufacturing and use (OSRAM 2009).

LCA study by Osram

The electricity use dominated the life cycle environmental impacts. Less than 2% of the total energy demand is needed for the manufacturing of any of the lamps, including LED lamp. The manufacture of LEDs was found not to be energy-intensive: 0.4 kWh was needed for production of an LED (OSRAM Golden Dragon Plus), while 9.9 kWh was required for the manufacturing of the LED lamp including 6 LEDs. Incandescent lamps have the greatest environmental impacts, while CFL and LED lamp have similar environmental profiles.
In contrast to the primary energy consumption of incandescent lamps (3 305 kWh), CFL and LED lamps use less than 668 kWh of primary energy during the life cycle. Thus, using CFL or LED lamps can save 80% of energy.

Comparison of Manufacturing Energy per LED Package from LCA Studies



Manufacturing phase energy consumption

In order to determine the average number packages (each of one mm2 of total die area) incorporated into an 800 lumen output LED lamp, it is assumed:

•ten separate products and that each one have approximately 40 to 80 lumens of lamp light output lumens for mm2 of die accounts

•50 lumens per one mm2 of LED die (the mean of the range) is representative of a 2011 LED lamp product. Furthermore, since many of the surveyed LED lamp products utilized one mm2 of LED die per package, it is then inferred that this lumen output per LED die is transferable to the package level. Assuming 50 lumens of lighting service per package, an LED lamp would require sixteen packages to produce a light output of 800 lumens.

To calculate the aggregate LED lamp manufacturing energy, three main assumptions were made.
The manufacturing energy consumption for an LED lamp:

1. Is sum of the energy associated with manufacturing the bulk lamp materials plus the energy associated with the manufacture of a single LED package multiplied by the number of packages. Thus, assuming that the packages have incorporate equivalent die areas, an LED lamp that uses 5 packages has a lower embodied energy consumption compared to an LED lamp that uses 16 packages.

2. is not correlated to efficacy, as long as total die area remain constant.

For example, an LED package of 50 lm/W has the same embodied energy consumption as an LED package of 60 lm/W. Also, based on the first two assumptions and expected increases in lamp and package efficacies, it is projected that the average number of LED packages required to produce an 800 lumen output lamp will decrease from sixteen in 2011 to five in 2015 (DOE, 2011a).

3. remains constant if wattage does not change. However, changes in wattage may affect the thermal management for the lamp causing a change in product design and material use. The previous LCA studies that were used to calculate the embodied energy of the LED bulk lamp materials evaluated LED lamp product that have an average wattage of about 12 Watts.

Manufacturing phase energy consumption

Manufacturing Phase Primary Energy (MJ/20 million lumen-hours)

Manufacturing Process	Incandescent			CFL			2011 LED (16 LED Packages)			Future 2015 LED (5 LED Packages)		
	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Bulk Lamp Material	10.1	42.2	106	11.3	170	521	38	87.3	154	25.4	58.5	103
1 LED Package[1]	N/A	N/A	N/A	N/A	N/A	N/A	0.12	16	83.5	0.11	14.6	76.2
Total LED Packages contribution	N/A	N/A	N/A	N/A	N/A	N/A	1.9	256	1,336	0.54	73	381
Total	**10.1**	**42.2**	**106**	**11.3**	**170**	**521**	**39.9**	**343**	**1,490**	**25.9**	**132**	**484**

The average or mean manufacturing energy estimate is an average of all derived values. The energy consumption values are all normalized to the functional unit of 20 million lumen-hours, thus the different lifetimes of the 2011 LED and 2015 LED lamp products cause their energy consumption to differ.

Manufacturing phase energy consumption

The mean values for total manufacturing energy of incandescent, CFL and LED lamps are 42.2 MJ, 170 MJ, and 343 MJ per functional unit respectively. Therefore, on average CFL manufacturing is over four times and LED manufacturing is eight times more energy intensive than incandescent lamp manufacturing. Interestingly, the mean estimate for the LED lamp indicates that the LED bulk lamp materials represent about 25 percent of the total LED lamp manufacturing; with the remaining 75 percent from manufacturing the LED package. This indicates the importance of the LED package, both the energy needed to produce one and the number of LED packages needed to reach the desired luminance.

Energy used in Extraction+Processing +Manufacture

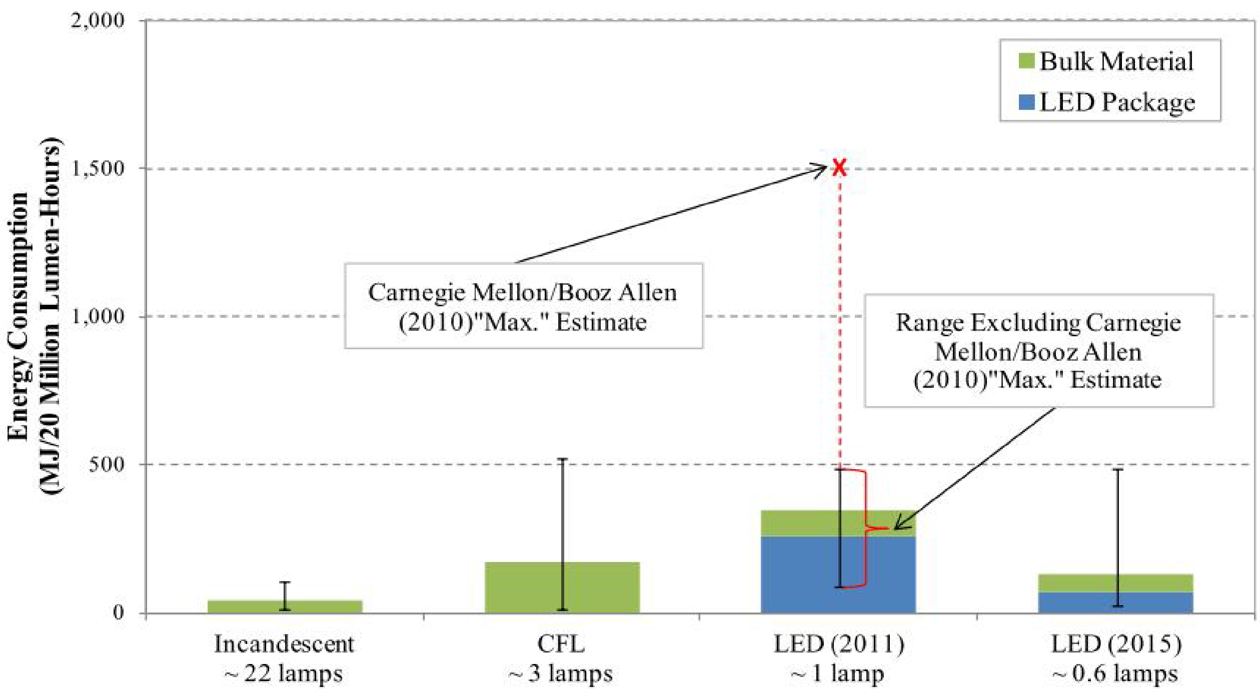


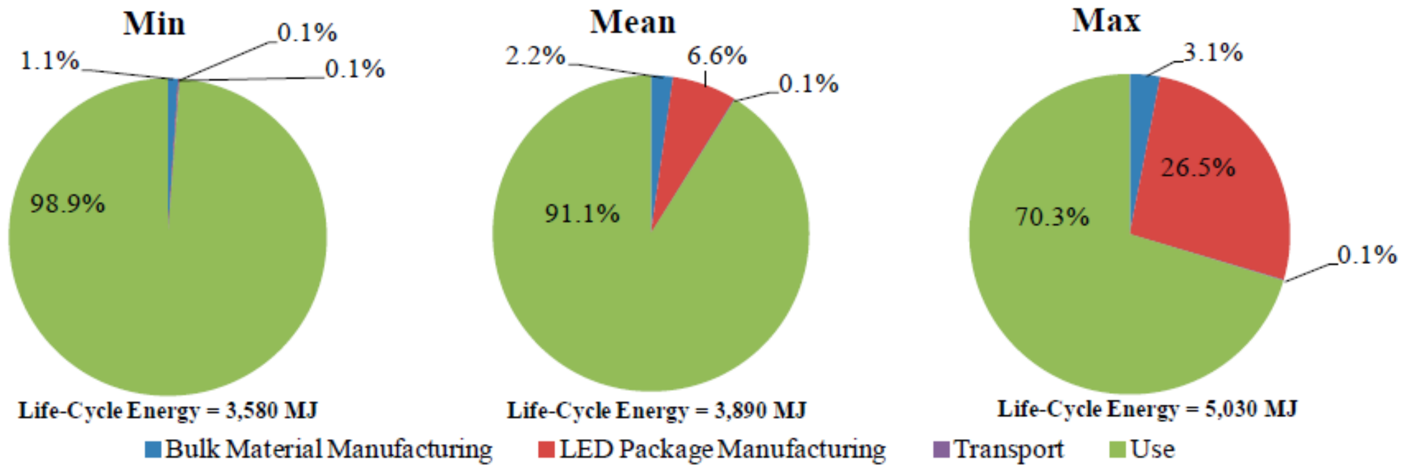
Figure 4.4 Life-Cycle Manufacturing Primary Energy (MJ/20 million lumen-hours)

The future (2015) LED lamp specifications are determined using efficacy projections provided by the 2011 study.

- LED package efficacy is expected to increase to 202 lm/W by 2015 (DOE, 2011a).
- Using this assumption, as well as predicted improvements to luminaire and thermal efficiency, the wattage of the lamp is projected to decrease to 5.8 Watts.
- lifetime of about 40,000 hours (DOE, 2011a).

As previously discussed, it is predicted that the number of LED packages required to produce 800 lumens will decrease as efficacy increases. Therefore, by 2015 the same LED lamp product is projected to only need five packages (DOE, 2011a) instead of 16 packages.

Total Life-Cycle Energy Consumption Results



Saving potential of a CFL compared to an incandescent bulb

	Incandescent Bulb	**Compact Fluorescent Lamp**
Power input	100 W	20 W
Average durability	1,000 h	10,000 h
Luminous flux	1,400 lm	1,400 lm
Relation heat to light	95 % to 5 %	75 % to 25 %
Necessary lamps in 8 years (3 h/day * 365 days = 1095 h/year)	8	1
Energy consumption in 8 years with a burning time of 3 h/day	876 kWh	175.2 kWh
Energy costs (0.14 EUR/kWh)	122.64 EUR	24.53 EUR
Costs per lamp	0.50 EUR	10.00 EUR
Total costs in 8 years	126.64 EUR	34.53 EUR
Savings	**--**	**92.11 EUR**

Outdoor use

LED LAMP SAVINGS	NORMALLIGHT	H P SODIUM	LED
Number of lights	2000	2000	2000
Electricity price per kwh	$0.20	$0.20	$0.20
Lamp hours per day	10	10	10
Maintenance per lamp (year)	$450	$220	$0.00
Life time hours per lamp	2,000	16,000	60,000
Watts consumed per lamp	250	150	100
Cost a year per 2000 lamps	$365,000	$219,000	$146,000
Total Maintenance cost (year)	$900,000	$440,000	$0.00
Total cost a year current prices	$1,265,000	$659,000	$146,000
Life time per lamp in years	0.55	4.38	16.44
Electricity / Maintenance (lifetime)	$20,794,521	$10,832,877	$2,400,000

Outdoor use

ROI	LED vs Normal Light	LED vs Sodium Light
Lamp price per unit	500	500
Investment for 2000 lamps	1,000,000	1,000,000
Total savings per year	1,119,000	513,000
Lifetime savings on lights	18,394,521	8,432,877
Payback on LED investment	0.89 (under one year)	1.95 (under two years)

Outdoor use

	Unit	HQL-125W	SPNa-70W	Metal Halide 50W	Valopaa LED 35W
Input Power	KW	0,16	0,08	0,58	0,035
Purchase price and installation	€	0	140	165	330
Energy costs / year	€	72	36	26	16
Mass replacement	€/vuosi	12	10	20	0
Repair costs	€/vuosi	10	10	15	3
Costs at purchase	€	0	140	165	330
Costs after:					
1 year	€	94	196	226	349
2 years	€	188	252	287	368
3 years	€	282	308	348	386
4 years	€	376	364	409	405
5 years	€	470	420	471	424
6 years	€	564	476	532	443
7 years	€	658	532	593	461
8 years	€	752	588	654	480
9 years	€	846	644	715	499
10 years	€		700	726	518
20 years	€		1260	1387	705
30 years	€		1820	2003	890

OSRAM HQL® or HWL- high pressure mercury vapour lamps

SPN – Sodium Vapor lamp

NOTE: In the example below, the energy price is 0,1€/KWh (energy and transmission) and the luminaires are used 4500 hours per year.

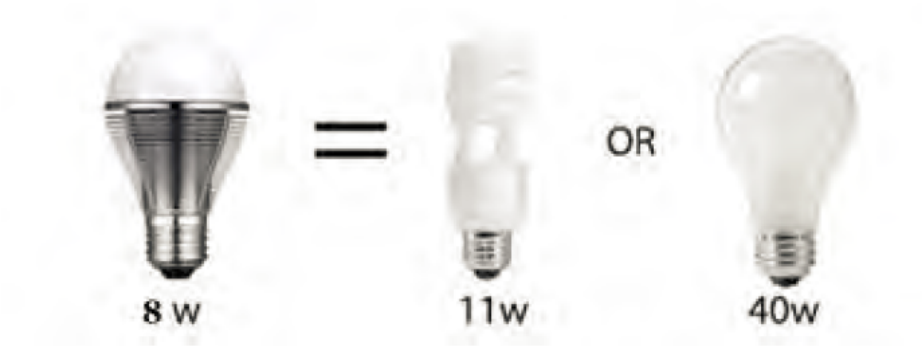
Energy and cost savings with high quality efficient lamp technology – Indoor use

Criteria	Indandescent	Halogen	CFL	LED
Lumen (lm)	660	700	740	810
Watt (W)	60	46	14	12
Efficacy (lm/W)	11	15	52	67
Lifetime (hrs)	1000	2000	10000	30000
Purchase price (€) 10 years*	10	20	9	10
Energy costs (€) 10 years*	72 €	55 €	17 €	14 €

* Assumption: operation time 1000 hrs/a

Fig. 4 Energy and cost savings

The comparison of an LED Bulb vs a CFL Bulb



Life Span of each bulb:	**50,000 hours**	**10,000 hours**	**1,200 hours**
	10$ – 20$	1,25$	

Light Bulb Cost Comparison Chart

Cost comparison of 40W incandescent equivalent	LED	CFL	Incandescent
Light bulb projected lifespan	50,000 hours	10,000 hours	1,200 hours
Watts per bulb	8	11	40
Cost per bulb	$9.97	$1.25	$0.66
kWh of electricity used over 50,000 hours	400	550	2,000
Cost of electricity (@ 0.11964 per kWh)	$48	$66	$239
Bulbs needed for 50,000 hours of use	1	5	42
Bulb expense	$9.97	$6.25	$27.57
Total cost for 50,000 hours	$58	$72	$267

Cost comparison of 75W incandescent equivalent	LED	CFL	Incandescent
Light bulb projected lifespan	50,000 hours	10,000 hours	1,200 hours
Watts per bulb	14	19	75
Cost per bulb	$25	$2.50	$0.66
kWh of electricity used over 50,000 hours	700	950	3,750
Cost of electricity (@ 0.11964 per kWh)	$84	$114	$449
Bulbs needed for 50,000 hours of use	1	5	42
Bulb expense	$6.50	$12.50	$27.57
Total cost for 50,000 hours	$90	$126	$476

Light Bulb Cost Comparison Chart

Lamp (A19) bulb technology	Price per bulb (Est.)	Lifespan (Hrs. @ 3 hrs./day; varies by Mfr.)	Watts (Varies by Mfr.)	Lumens (Varies by Mfr.)
60-Watt Incandescent	$0.41-$1.00	1,000-2,000	60	630-860
LED (60-Watt–Equiv.)	$11-$22	15,000-25,000	9-12	570-830
CFL (60-Watt–Equiv.)	$1.50-$7.00	8,000-12,000	13-15	740-840
Halogen (60-Watt Equiv.)	$1.00-$2.75	985-1,250	43	565-750

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Light Bulb Cost Comparison Chart

LED		Incandescent		CFL		Halogen	
Ge 60w	11$						
Philips 60w	16$			Philips 60w	2$	Philips 60w	1$
Ge Reveal 60w	20$	Ge Reveal 60w	1$				

Lifespan: 3hrs/day

Ge 60w LED	**15.000 hrs = 14 y**
Philips 60w LED	25.000 hrs = 23 y
Philips 60w CFL	12.000 HRS = 11 y
Philips 60w Halogen	1200 hrs = 1,1 y

Light Comparison

ENERGY EFFICIENCY & ENERGY COSTS	Light Emitting Diodes (LED)	Incandescent Light Bulbs	Compact Fluorescents (CFL)
Life Span (average)	50,000 hours	1,200 hours	8,000 hours
Watts of Electricity Used (Equivalent to 60 watt bulb)	6-8 watts	60 watts	13-15 watts
Kilowatts of Electricity used	329 KWh/y	3285 KWh/y	767 KWh/y
Annual Operating Cost	$32.85/year	$328.59/year	$76.65/year
ENVIRONMENTAL IMPACT	**Light Emitting Diodes (LED)**	**Incandescent Light Bulbs**	**Compact Fluorescents (CFL)**
Contains toxic mercury	No	No	Yes
RoHS Compliant	Yes	Yes	No
Carbon Dioxide Emissions	451 pounds/year	4500 pounds/year	1051 pounds/year
LIGHT OUTPUT	**Light Emitting Diodes (LED)**	**Incandescent Light Bulbs**	**Compact Fluorescents (CFL)**
Lumens	Watts	Watts	Watts
450	4-5	40	9-13
800	6-8	60	13-15
1,100	9-13	75	18-25
1,600	16-20	100	23-30
2,600	25-28	150	30-55
IMPORTANT FACTS	**Light Emitting Diodes (LED)**	**Incandescent Light Bulbs**	**Compact Fluorescents (CFL)**
Sensitivity to Low Temperatures	None	Some	Yes may not work below -10 degrees F or over 120 degrees F
Sensitivity to humidity	None	Some	Yes
Turns on instantly	Yes	Yes	No takes time to warm up
On/Off cycling effect	None	Some	Yes CFLs warm slowly and reach full brightness gradually; turning a CFL bulb on & off quickly can drastically reduce its life span
Fragility	Very Durable LEDs can handle jarring & bumping	Not Durable glass or filament breaks easily	Not Durable glass breaks easily
Heat Emitted	3.4 btu's/hour	85 btu's/hour	30 btu's/hour

Environmental impacts of SSL products

Studies

- ✓ end-of-life of LED lamps and luminaires has been studied by Hendrickson et al. (2010).

Conclusion:

Reduce the environmental impacts of SSL products by implementing design for end-of-life in the product development process, e.g., by facilitating the disassembly and thus enabling the recovery of components, parts and materials in order to improve the material reuse and recycling.

Environmental impacts of SSL products

Studies

- ✓ material composition of LED products

Raised study by Lim et al. (2011) included whole LED lamps and comparing their metal contents by the leaching tests.

Conclusion:

CFLs exceeded the limits of copper, lead and zinc, and LED lamps exceeded the limits of copper and lead.

LED product material composition was studied in detail by the US DOE (2013).

Conclusion:

Concentrations of the regulated elements were at the same level in LED lamps as in other types of electronic devices, such as cellular telephones (US DOE 2013). The tested lamps generally complied with the federal requirements but few CFLs and LED lamps exceeded the Californian regulations for hazardous waste (i.e., lead, copper, nickel, antimony, zinc).

Environmental impacts of SSL products

Studies

- ✓ LCAs of light sources do not adequately address the system-level, e.g., the whole building or a building electrical installation system.

Dubberley et al. (2004) analysed the environmental impacts of an intelligent lighting system for commercial buildings in the US. The lighting system consisted of a sensor, wireless network, ballast and batteries.

Conclusion:

Intelligent system causes significantly lower potential environmental impacts than a conventional lighting system. This affirmation is mainly due to the fact that use of intelligent lighting systems that produce light “on-demand” and adapts light quantity as function of the real-time needs, consumes definitively less energy than a classic system.

Uncertainties in the LCAs of SSL products

Studies

- LCA contains a large number of input parameters for which the accuracy is unknown. This creates uncertainties in the results (LCA results cannot be stated to an uncertainty less than 5 to 20 %).

- Is not possible to compare two LCA studies unless all similar impact indicators have been defined rigorously and are identical.

Uncertainties in the LCAs of SSL products

Studies

Specific source of uncertainty:

• data of the LED component. (in the LCIA databases, there is no up-to-date data on the LED component available).

The newest data was provided by US DOE (2012b), which stated that the high power LED component actually caused 94.5 % lower environmental impacts compared to the 5 mm indicator LED found in the Ecoinvent (2010) database when compared on the basis of lumen output (US DOE 2012b). This difference in impact is largely due to the increase in the luminous flux package of the LED component, from 4 lumens produced by one indicator LED in the 2010 Ecoinvent database to 100 lumens produced by one high-brightness LED.

Uncertainties in the LCAs of SSL products

Studies

- the data quality (there is no sufficiently accurate data available on every component or product).

The data even in the newest environmental databases does not cover all the unit processes involved in manufacturing and other LCA stages.

LED lamp in 2012

The contributors to environmental impact are:

•energy in use, which represents an average of 81% across the fifteen indicators. The proportion of impact varies from a high of 94.1% for abiotic resource depletion to a low of 57.1% for non-hazardous waste landfill.

•the raw materials used in manufacturing the LED lamp. These include a range of components, the LEDs and the large heat sink. On average the impact from the raw materials is 16.8%, with a high of 35.8% (for ozone depleting potential) and a low of 4.8% (for abiotic resource depletion).

•Manufacturing is the third most impactful step in the LCA, with just 2.3% and the disposal and transport impacts are extremely low, both less than 0.1%. As with the incandescent lamp and CFL, the packaged LED Lamp is assumed to be transported over 11,000 kilometers by sea and road, but the impacts are virtually negligible.

LED lamp in 2017

The profile is similar to that of the 2012 lamp, however the significance of energy is diminished due to the fact that this lamp is considerably more efficacious.

In this analysis, energy in use represents an average of 78.2% of the impact, followed by raw materials at 19.3% and manufacturing at 2.3%. The transportation and disposal of the lamp are negligible, at less than 0.2% each.

Conclusions

Use (energy consumption) rules the environmental impacts of the light sources

In any LCA of a light source (lamp, luminaire), use of the product causes the greatest environmental impacts over the life cycle due to the emissions from the energy production. The most significant environmental parameters are the luminous efficacy (lm/W) and the useful life.

Achieving environmental benefit:

•The dominance of the use stage is the clearest in incandescent lamp (90 % or greater) due to its low luminous efficacy and simple manufacturing process free of hazardous materials.

Conclusions

Use (energy consumption) rules the environmental impacts of the light sources

- The replacement of low-efficacy lamps (incandescent lamp in indoor and HPM lamp in outdoor applications).
- The manufacturing of CFL and LED lamps tends to have a higher share (up to 30 % of the total life cycle impacts from manufacturing but usually less than 10 %).
- Using low-emission electricity, such as hydropower.
- When the two changes (lamps of high luminous flux and low-emission energy production) occur simultaneously.

Conclusions

Manufacturing stage causes the second greatest environmental impacts

- The LCAs found that the manufacturing of an incandescent lamp caused approximately 1-7 %, a CFL 1-30 % and an LED lamp 2-20 % of the total life cycle impacts on the average.

- Single environmental impact categories may have higher scores, e.g., in case of CFL or LED lamp the manufacturing was found to cause approximately 50% of hazardous waste to landfill and 40% of human toxicity potential (DEFRA 2009).

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Conclusions

Manufacturing stage causes the second greatest environmental impacts

- the environmental impacts:

  - in CFL manufacturing are due mainly to the ballast (printed circuit board and components),

  - in the LED lamp manufacturing primarily due to the aluminium heat sink (However, today there are several new LED lamp designs on the market that have greatly reduced or completed eliminated aluminium heat sinks.

Other life cycle stages, such as transport, packaging and end-of-life, are negligible in the total life-cycle perspective. However, in certain environmental impact categories, they may have a notable effect.

Conclusions

Strongest contributors to the environmental impacts of SSL products

- is the energy consumption in use.

In case of a low-emission electricity production, the manufacturing may become dominant of the life cycle impacts. (develop an algorithm for calculating the impact of energy
consumption during ”use” phase by adjusting the energy mix)

- manufacturing of the LED package, the driver (electronics) and aluminium parts.

Conclusions

Light Pollution

- One of the most obvious environmental impacts of lighting is the light emitted or reflected towards the sky that contributes to the light pollution (hormone levels and circadian rhythms, predator-prey relationships, and blooming).

- Solutions:

  - An environmental impact category is needed in order to consider also the environmental impacts of the light itself in an LCA.

  - Using LED luminaires: the light may be distributed very precisely avoiding light pollution.

Features and Benefits of U-Tron LEDs

1. The right product for the application. Today's LEDs output the illumination necessary to protect our streets, our sky, and our environment.
2. The LEAST costly alternative available today. LED Street Lights deliver the best economic return compared to conventional alternatives considering the total life-cycle costs including installation, maintenance and energy.
3. Consume less energy. Generally, a LED consumes less than 1.15 watts to operate. This low power consumption means you save on your energy costs.
4. No heat output, less CO2 pollution. LEDs can convert almost all the energy used into light, creating a highly efficient light source. In contrast, conventional lighting emits heat and/or light pollution.
5. Long lifetime. An LED can last for up to 100,000 hours. High Power LEDs can last up to 50,000 hours. In comparison the lifespan of an incandescent light is about 1,000 hours and for a halogen light is about 2,000 hours.

6. Environmentally safe. LEDs are made from non-toxic materials - unlike fluorescent lights which contain mercury. Plus they can also be recycled.
7. Durable. No loose or moving parts. They can withstand extreme temperatures and have a high Impact Resistance. Shock-proof since they have no filament and glass envelope - unlike traditional lamps.
8. Easy on the eyes. No Strobe - eliminates the visual fatigue which can be caused by the strobe effect of traditional street lamps
10. No Cleaning Necessary. No burned insects accumulate on the surface, so no reduction of light intensity - unlike conventional lamps.
11. No Radiation. No ultraviolet or infer red emissions. LEDs only emit light in the visible spectrum.

Manufacturing solid state lighting (SSL) with light emitting diodes (LEDs) for easy disassembly at end-of-life will facilitate potential end-of-life uses, thereby reducing life cycle costs and environmental impacts, according to a recent study.

SSL with LEDs is designed to be more energy efficient than older types of lighting. One type of LED SSL consists of the LED 'lamp', which is like a light bulb, with a standard type of base (such as a screw type) connected to an LED 'luminaire' (or fitting), such as a table lamp or ceiling fixture.

This would reduce life cycle costs and environmental impacts by reducing the need for new materials and components for future products. At end-of-life, products or parts of products may be reused, serviced, remanufactured, or recycled.

In order to determine the performance of a 2017 lamp, the 2012 LED lamp analysis was modified as detailed in the list below:

- Efficacy improvement from 65 lm/W (Philips EnduraLED lamp) to 134 lm/W system output

- in order to hold lumen output at approximately the equivalent of a 60 watt incandescent lamp. Wattage is reduced from 12.5W to 6.1W while lumen output is adjusted from 812 to 824 lumens.

- Lamp lifetime will increase, benefitting from less heat generated in the lamp itself and improvements in the LEDs and the drive electronics. The lifetime is adjusted from 25,000 to 40,000 hours.