

Chapter11:Technicalpotentialforenergyefficien tlightingand savings

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11 Technical potential for energy efficient lighting and savings

11.1 Light consumption in 2005

The estimated global electric light consumption is calculated as quantity of light Q , which is the luminous flux integrated over duration of time. The unit of quantity of light is lumen-hour, lmh. The luminous flux is produced by different lamp types. Since light cannot be stored, the light consumption and production are always equal; the light produced by lamps is immediately consumed by the users.

The average share of electric light consumption per person can be expressed as the ratio between light consumption and total population in a particular year.

$$Q_p = \frac{Q}{P} \quad (11-1)$$

where

Q_p Light consumption per person, Mlmh/person, a
 Q Light consumption, Plmh/a
 P Population of the world, billion

The electric energy consumption for lighting can be expressed as the ratio between the average consumption of light per person and luminous efficacy of a particular lamp.

$$E_p = \frac{Q_p}{\eta} \quad (11-2)$$

where

E_p Electric energy consumption per person, MWh/person, a
 Q_p Light consumption per person, Mlmh/person, a
 η Lamp luminous efficacy, lm/W

The electric energy consumption per person can also be expressed in kWh/person, a (in that case the resultant amount must be multiplied by 1000). Table 11-1 shows electric energy consumption for residential lighting calculated for different lamp types. The calculation is based on estimated light consumptions. The population of the world was 6.7 billion in 2005. (IEA 2006)

Table 11-1. Estimated electric light consumption for different lamp types for residential lighting and calculated light and energy consumptions per person. (IEA 2006)

Lamp type	Luminous efficacy η [lm/W]	Light consumption Q [Plmh]	Light consumption per person Q_p [Mlmh/person, a]	Energy consumption per person E_p [kWh/person, a]
Incandescent	12	8.5	1.3	105.7
Tungsten halogen	20	1.3	0.2	9.7
CFL	45	1.9	0.3	6.3
LFL	66	8.2	1.2	18.5
Total		19.9	3.0	140.3

In the residential sector, the amount of light produced by incandescent lamps is approximately equal to that by fluorescent lamps. However, the annual electric energy consumption per person of incandescent lamps is approximately six times more than that of fluorescent lamps. In 2005, the shares of halogen and CFL lamps in both the light consumption and energy consumption were relatively low. The total annual light consumption in residential sector was approximately 3.0

Mlmh/person, and the electric energy consumption was 140 kWh/person, a.

High intensity discharge lamps are dominant in the outdoor lighting sector. The total light consumption in outdoor lighting in 2005 was estimated to be 2.3 Mlmh/person, a and the electric energy consumption was correspondingly 46.6 kWh/person, a (Table 11-2).

Table 11-2. Estimated electric energy consumption for outdoor lighting. (IEA 2006)

Lamp type	Luminous efficacy η [lm/W]	Light consumption Q [Plmh]	Light consumption per person Q_p [Mlmh/person, a]	Energy consumption per person E_p [kWh/person, a]
HID	50	15.6	2.3	46.6
Total		15.6	2.3	46.6

In the industrial sector, fluorescent lamps and HID lamps were dominant and resulted in total estimated light consumption of 5.7 Mlmh/person, a and in electric energy consumption of 96.9 kWh/person, a (Table 11-3).

Table 11-3. Estimated electric energy consumption for industrial lighting. (IEA 2006)

Lamp type	Luminous efficacy η [lm/W]	Light consumption Q [Plmh]	Light consumption per person Q_p [Mlmh/person, a]	Energy consumption per person E_p [kWh/person, a]
LFL	66	23.7	3.5	53.6
HID	50	14.5	2.2	43.3
Total		38.2	5.7	96.9

In the commercial sector, fluorescent lamps represent the largest share of electric light consumption, and also electric energy consumption. However, although incandescent lamps represent a small share of light consumption, their electric energy consumption was almost 50% of that of the fluorescent lamps.

Table 11-4. Estimated electric energy consumption for commercial lighting. (IEA 2006)

Lamp type	Luminous efficacy η [lm/W]	Light consumption Q [Plmh]	Light consumption per person Q_p [Mlmh/person, a]	Energy consumption per person E_p [kWh/person, a]
Incandescent	12	3.9	0.6	48.5
Tungsten halogen	20	1.3	0.2	9.7
CFL	45	3.9	0.6	12.9
LFL	66	44.1	6.6	99.7
HID	50	6.2	0.9	18.5
Total		59.4	8.9	189.4

Compared to the other sectors, the commercial sector accounted for the highest share of both light consumption and electric energy consumption, Table 11-5.

Table 11-5. Estimated total electric energy consumption. (IEA 2006)

Lighting sector	Light consumption Q [P/mh]	Light consumption per person Q_p [M/mh/person, a]	Energy consumption per person E_p [kWh/person, a]
Residential	19.9	3.0	140.3
Outdoor	15.6	2.3	46.6
Industrial	38.2	5.7	96.9
Commercial	59.4	8.9	189.4
Total	133.1	19.9	473.1

In Figure 11-1, with reference to the tables presented above, the share of light consumption in each sector for the different lamp types is represented.

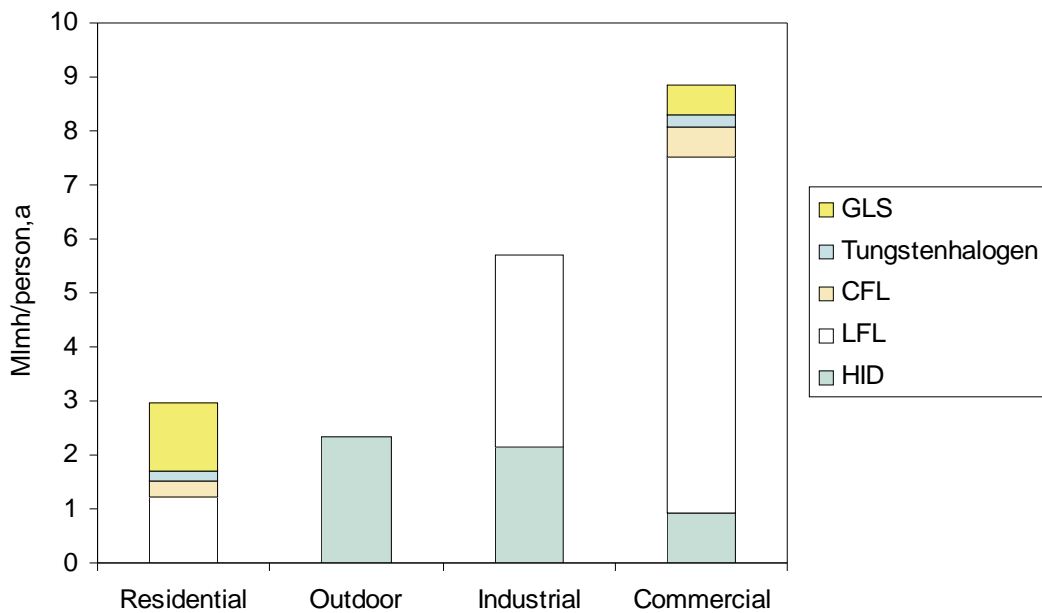


Figure 11-1. Total worldwide light consumption in different sectors by lamp type in 2005. (IEA 2006)

In Figure 11-2, with reference to the tables presented before, the proportion of electric energy consumption of the different lamp types for each sector is represented. The high share of energy consumption of the incandescent lamps, due to their low luminous efficacy, is very distinctive.

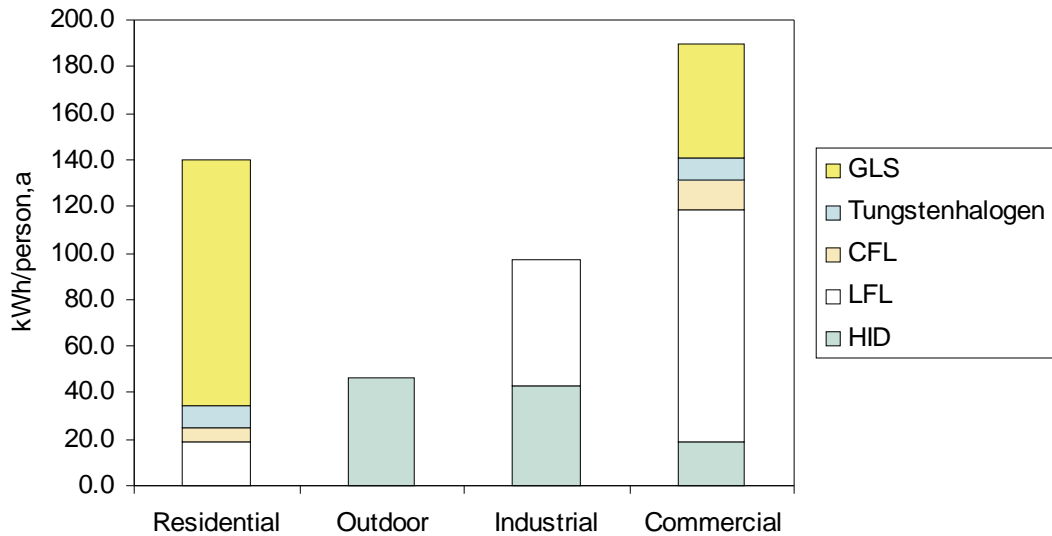


Figure 11-2. Estimated electric energy consumption in different sectors by lamp type in 2005. (IEA 2006)

In Figure 11-3, the share of electric light consumption in 2005 through different lamp types, irrespective of sector, is summarized and presented.

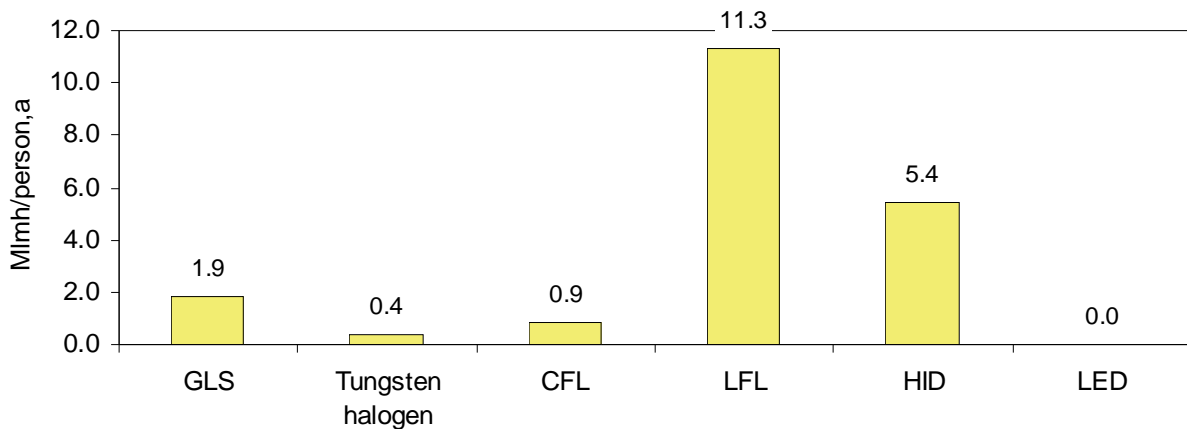


Figure 11-3. Electric light consumption through different lamp types in 2005. (IEA 2006)

The largest share of light consumption, 11.3 Mlmh/person,a, is produced by linear fluorescent lamps (LFL) followed by HID lamps with 5.4 Mlmh/person,a. Incandescent lamps have a comparably lower share of the light consumption.

11.2 Estimated electric light consumption in 2015/2030

The prognosis in the following is based on the work of the IEA ECBCS Annex 45. Figure 11-4 represents an estimation of the development of the global electric light consumption in 2015 and in comparison to 2005, an increase in the light consumption of approximately 25% is to be expected by 2015. It is estimated, however, that due to improved facility utilization factor (light output ratio multiplied by room utilization, LOR x U) of 20% and decreased mean operating time (factor of 0.8, due to improved daylight utilization and control systems), this will be compensated, Table 11-6. The increase in utilization factor will decrease the need for light production since light is wasted less in the luminaire and light is also

directed more efficiently to the task area. Despite 2015 compared to 2005), the total light produced by efficiency of luminaires and room and lighting design, and also due to increased use of daylight and lighting control systems.

the increased light demand (increased by 25% in lamps is reduced. This is due to increased gn, and also due to increased use of daylight and

Table 11-6. Comparison of different factors in 2015 and 2030, compared to 2005.

	2015	2030
Increase in total light consumption	25%	55%
Facility utilization improvement	20%	25%
Operating time factor	0.80	0.70
Resulting total light consumption	0.80	0.81

The total light consumption, for instance in 2015, 2005. At the same time, it is expected that there will be a clear reduction in the use of incandescent lamps due to legislation (step by step abolition of CFLs and LED lamps, and replacement of T12 and T8 lamps by T5 lamps. It is estimated that by 2030, incandescent lamps will account only for a very small share of the lamps in use. LEDs will represent a large share of the market and their share will increase substantially, as shown also in Figure 11-4.

is 100% x 1.25 x 0.8 x 0.8 = 80% compared to incandescent lamps), an increase in the use of lamps by T5 lamps. It is estimated that by 2030, incandescent lamps will account only for a very small share of the lamps in use. LEDs will represent a large share of the market and their share will increase substantially, as shown also in Figure 11-4.

Compared to 2005, it is estimated that there will be an additional light demand (light consumption by end user) of 55% in 2030. Due to improved facility utilization factor of 25% and decreased mean light consumption will therefore be approximately the same as in 2015. Part of the electric light consumption is replaced by daylight.

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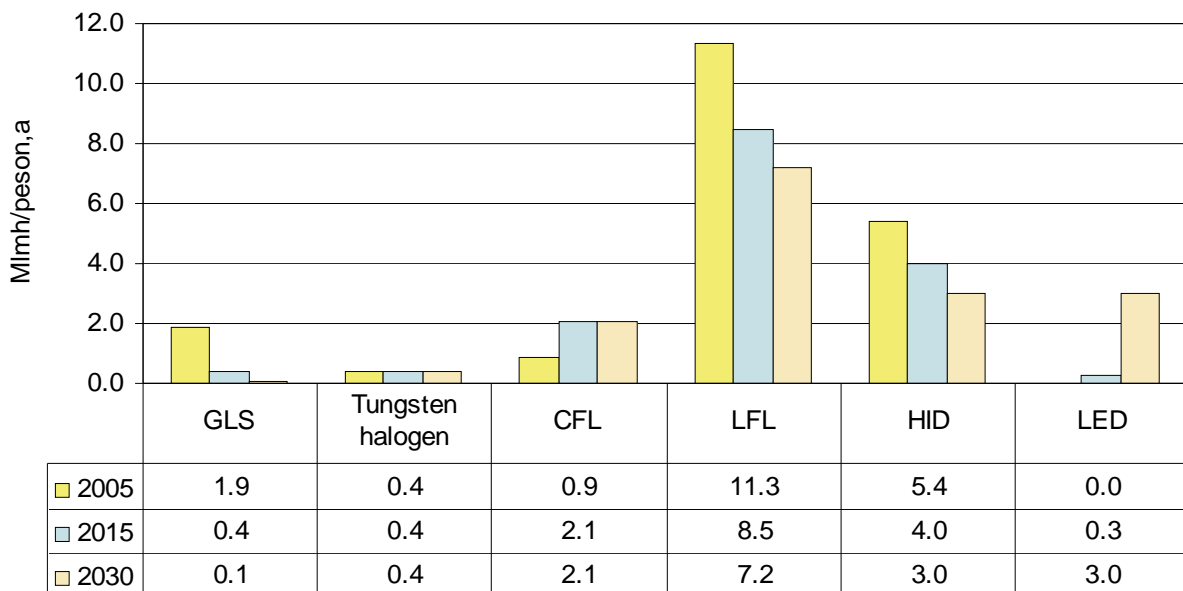


Figure 11-4. Estimated electric light consumption through different lamp types in 2005, 2015 and 2030.

Figure 11-5 shows a summarized representation of the electric light consumption through different lamp types in 2005 together with the expected development for 2015 and 2030. Part of the increase in light consumption is covered by the increases of daylight and lighting control systems. Other part of the increase in light consumption is covered by the improved facility utilization factor. Due

electric light consumption through different lamp types in 2005 together with the expected development for 2015 and 2030. Part of the increase in light consumption is covered by the increases of daylight and lighting control systems. Other part of the increase in light consumption is covered by the improved facility utilization factor. Due

to this the light production of the lamps can be decreased and at the same time the end-user will get the same amount of light on the task area.

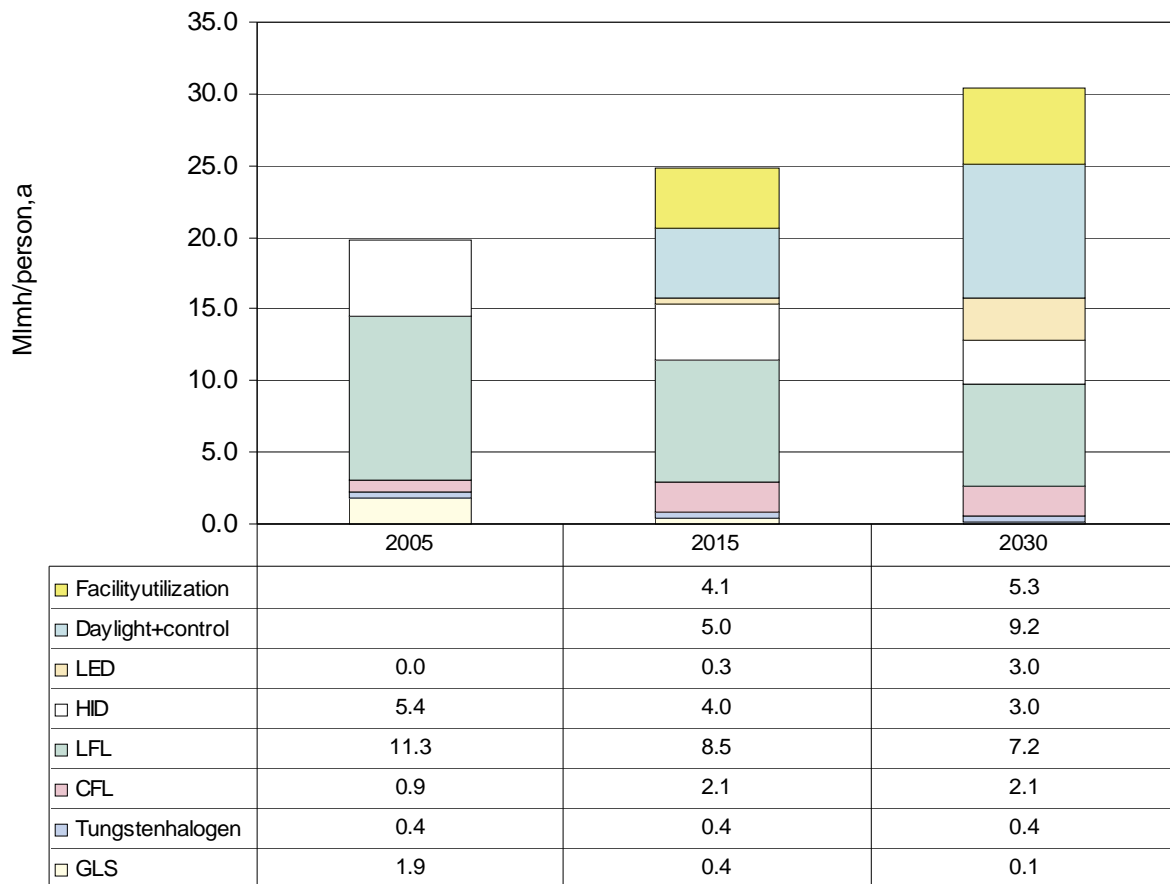


Figure 11-5 . Development of electric light consumption through different lamp types [Mlmh/person,a] from 2005 to 2030. The facility utilization and daylight+control indicate the shares of light consumption covered by improved facility utilization and through the use of daylight and control systems.

11.3 Estimated electric energy consumption for lighting in 2005/2015/2030

If we use the following plausible assumptions (Table 11-7) of the lamp luminous efficacies (lm/W), we can calculate the electric energy consumption (kWh/person,a) from the electric light consumption (Mlmh/person,a). The luminous efficacies are average values of all the lamps on the market. The case LED2 forecasts fast development of the luminous efficacy of LEDs and also their quick breakthrough on the market. Since the average luminous efficacy of LED2 is 160 lm/W, the maximum should be much higher. According to Navigant (2009) the white LED package luminous efficacy targets in 2015 are 200 lm/W in laboratory, and 188 lm/W commercially. The practical achievable maximum package luminous efficacies are about 220 lm/W depending on the CCT. (Navigant 2009)

Table 11-7. Expected lamp luminous efficacies in year 2005, 2015 and 2030. LED2 estimates a fast development of the luminous efficacy of LEDs and quick breakthrough on the market.

Luminous efficacy [lm/W]	Incandescent	Tungsten halogen	CFL	LFL	HID	LED	LED2
2005	12	20	45	66	50	60	60
2015	12	25	50	86	65	80	100
2030	12	30	55	90	80	120	160

In Figure 11-6, with reference to Figure 11-4 and Table 11-7, the proportion of electric energy consumption of the different lamp types in 2005, 2015 and 2030, irrespective of sector, is summarized.

A significant reduction in electric energy consumption by incandescent lamps in 2015 is to be expected due to legislative actions. Also, the energy consumption of fluorescent lamps reduces, as the luminous efficacy of lamps in use will increase due to replacement of obsolete technology. As the share of halogen lamps remains relatively unchanged, but their luminous efficacy slightly increases, their energy consumption will slightly decrease. This is similar with the HID lamps. The share of CFLs in light consumption will increase and at the same time their luminous efficacy will increase, resulting in overall lower total energy consumption.

Furthermore, in 2030, there will be a further reduction in the use of incandescent lamps due to the almost complete replacement by halogen lamps and CFLs. The use of fluorescent lamps and HID lamps will reduce due to replacement of obsolete technology. LEDs will penetrate further into the market and will have a corresponding share of them.

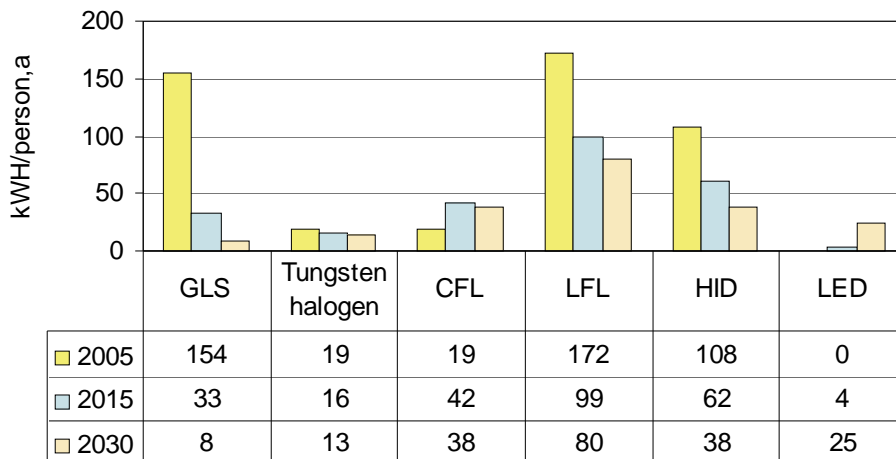


Figure 11-6. Status of electric energy consumption of lighting through different lamp types in 2005/2015/2030.

Figure 11-7 shows the reduction of electric energy consumption in 2015 and 2030 compared to 2005. The reduction is based on the replacement of inefficient lamps and also on the increased luminous efficacy of all lamp types (Table 11-7). The total annual light consumption is taken from Figure 11-5.

The scenarios for 2015B and 2030B are based on the assumption of LEDs taking over the lamp

market faster than in scenarios 2015 and 2030. Compared to the assumptions: incandescent lamps 25%, CFLs 50% of scenario 2015. The light consumption remains the same and the gap is filled by LEDs. The luminous efficacy of LEDs in scenario 2015B is 100

lm/W. In scenario 2015, scenario 2015B is based on the assumptions: incandescent lamps 25%, CFLs 50% and LFLs 75% of the light consumption same and the gap is filled by LEDs. The

In scenario 2030B incandescent and halogen lamps produce only one quarter and LFL and HID lamps half of scenario 2015. Instead, a major part of the light consumption is produced by LEDs. Tungsten halogen lamps and certain CFLs (screw cap short time, but LFL and HID lamps are used in dedicated old installations) is only 3 to 5%. Compared to scenario 2030B, but the electric energy consumption of the LEDs in use in 2030 would be 160 lm

W (Table 11-7). In scenario 2030, the light consumption remains the same and the gap is filled by LEDs. The luminous efficacy of LEDs in scenario 2030B is 160 lm/W (Table 11-7).

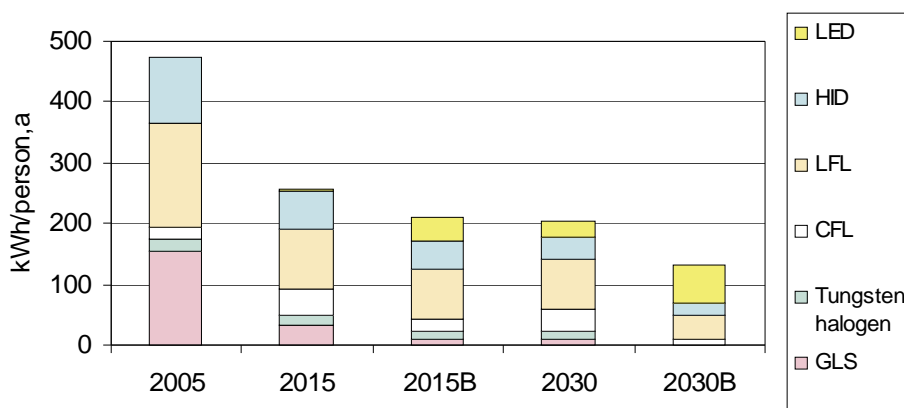


Figure 11-7. Scenarios of electric energy consumption for lighting in 2005, 2015 and 2030 by different lamp types. The scenarios 2015B and 2030B are based on increased use of LEDs.

11.4 Conclusions

The forecast of the electric energy consumption for lighting is based on the assumptions

- increasing light consumption of 25% (2015) and 55% (2030) by end user
- increasing efficiencies of the installations of 20% (2015), and 25% (2030) (light output ratio of luminaires and room utilisation)
- reduced operating time factors of 0,80 (2015), and 0,70 (2030) by daylight utilisation and controls
- phasing out incandescent (mostly until 2015), T12 (2015) and T8 (2030) lamps, replaced by CFL, LFL T5 and LED lamps.
- in scenarios 2015B and 2030B LEDs will take over the lamp market quickly and their luminous efficacy is developing fast.

Based on these assumptions we can expect a decrease in electrical energy consumption for lighting down to less than a half or even to one third of the consumption in 2005 (see Figure 11-7). These assumptions and also the forecast of lamp efficacies (Table 11-7) are rather conservative for the industrialised countries (scenarios 2015 and 2030). The remaining unknown is the development in China, India and Africa, that will define if the predicted energy savings become reality.

References

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- Navigant Consulting, Radcliffe Advisors and SSLS, Inc., 2009. Multi-Year Program Plan FY'09-FY'15 - Solid-State Lighting Research and Development. U.S. Department of Energy. 193p.

