Interreg
CENTRAL EUROPE
European Union
European Regional Development Fund

Dynamic Light

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Cost comparison of different lighting systems

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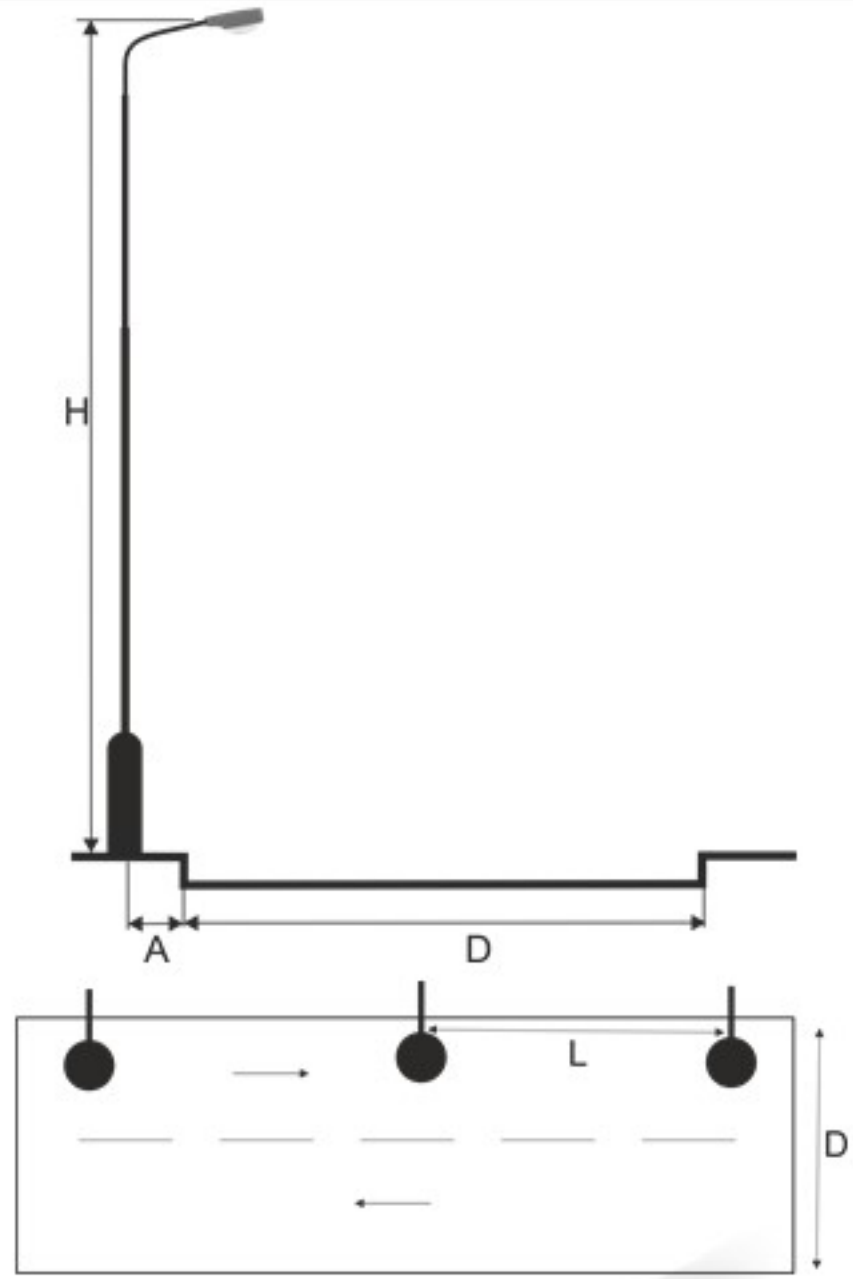
PORSENNA

1. Introduction

Design of road lighting system

Road & poles geometry

- road width (D) = 8m
- light pole height (H) = 10m
- roadside distance (A) = 1m
- light pole arm = 0,9m
- pitch of poles (D) = 29m



Light performance requirements

EN 13201- 2 Road Lighting

-Performance requirements

- Lighting class M4
  - average luminance L: 0,75 Cd/m^2
  - overal uniformity U_0: 0,4
  - longitudal uniformity U_l: 0,6
  - threshold increment f_{TI}: 15%

1. Introduction

Proposal of lighting system

A) Standard lighting system

- only ON/OFF mode
- no light control
- no remote monitoring

B) Autonomous regulation (preset dimming)

- possibility of dimming control
- no remote monitoring
- no remote adjustement

C) Dynamic lighting system

- luminance level control in-time
- remote adjustemnet
- remote monitoring
- immediate adaptation
- safety - ensuring sufficient light parameters

Compared variants of lighting system

Lighting system equipted by different luminaires & control

- HPS lamps - ON/OFF mode
- HPS lams with preset dimming control
- LED lamps - ON/OFF mode
- LED lams with preset dimming control
- LED lamps with dynamic control (dimming)
- LED lamps with dynamic control of illuminance and color temperature

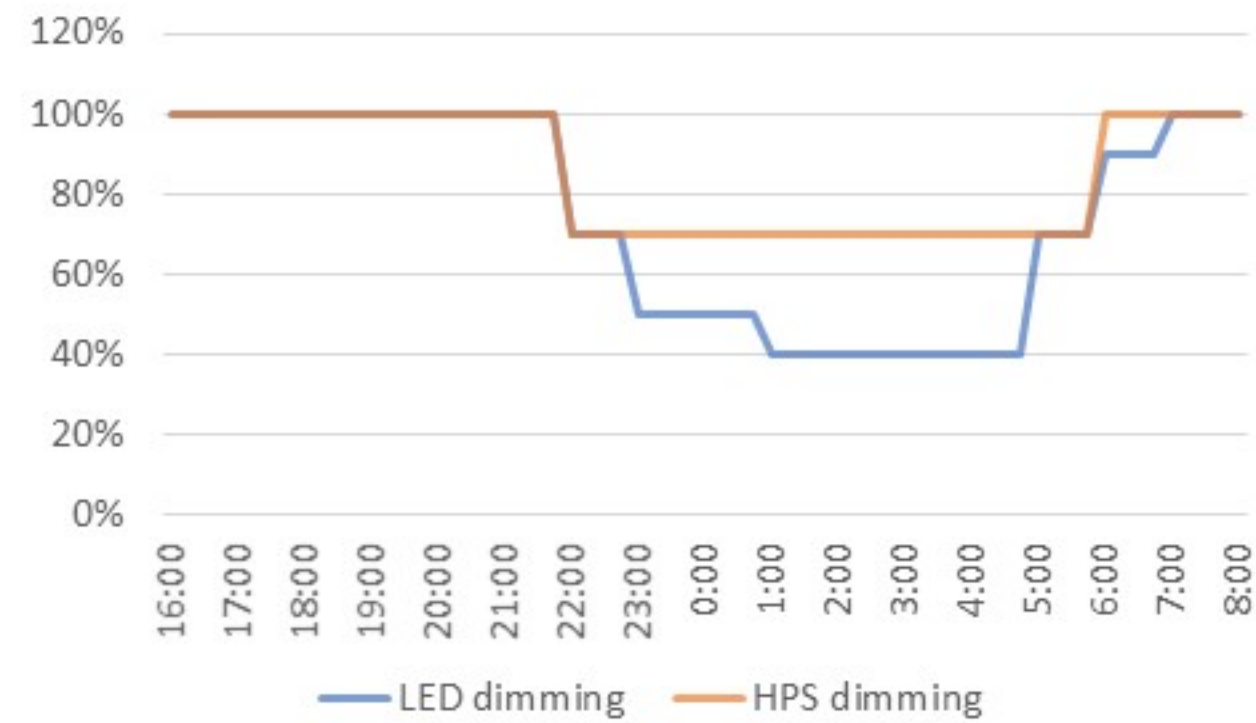
by regulation of luminance level (dimming) must be to ensure parameter of the lower lighting classes given by EN 13201-2

1. Introduction

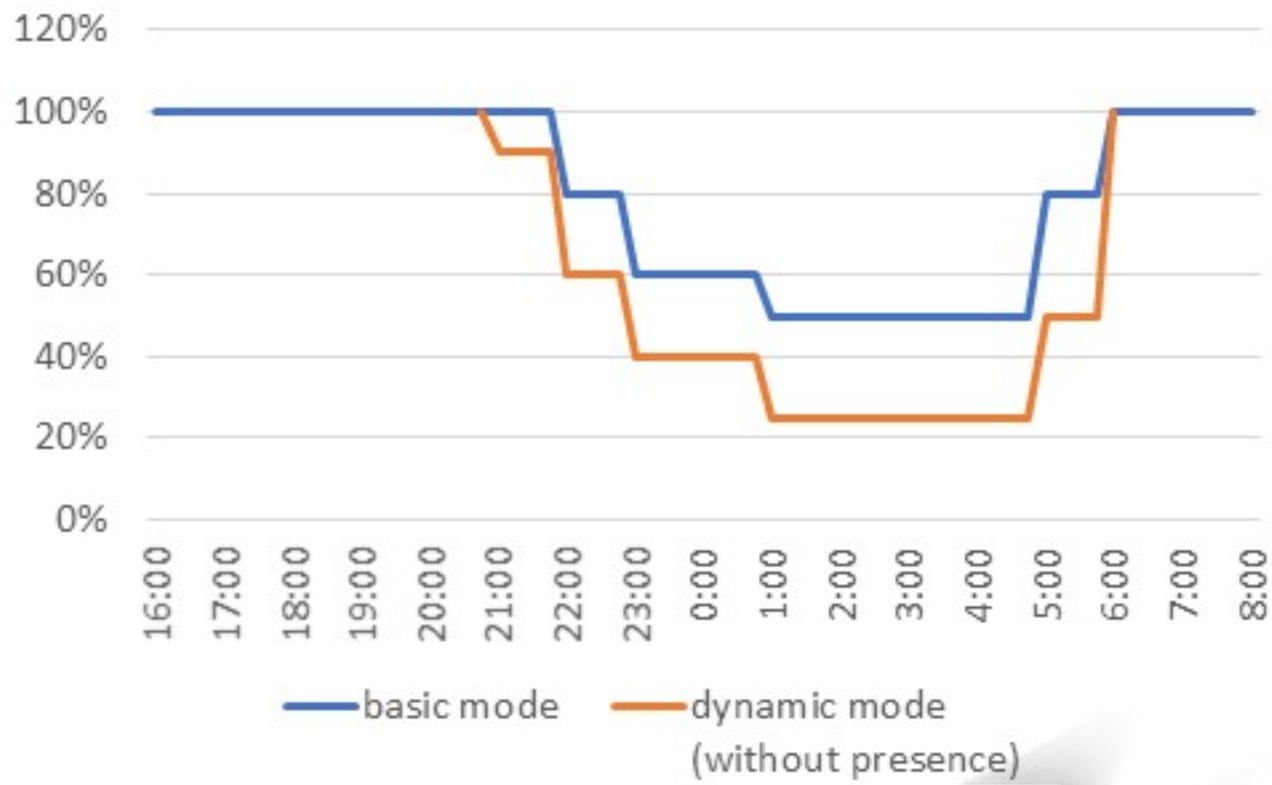
Control solution

- examples of varous cotrol system - function principle

Autonomous regulation - preset dimming



Dynamic light control



1. Introduction

Dynamic control of lighting system according traffic volume

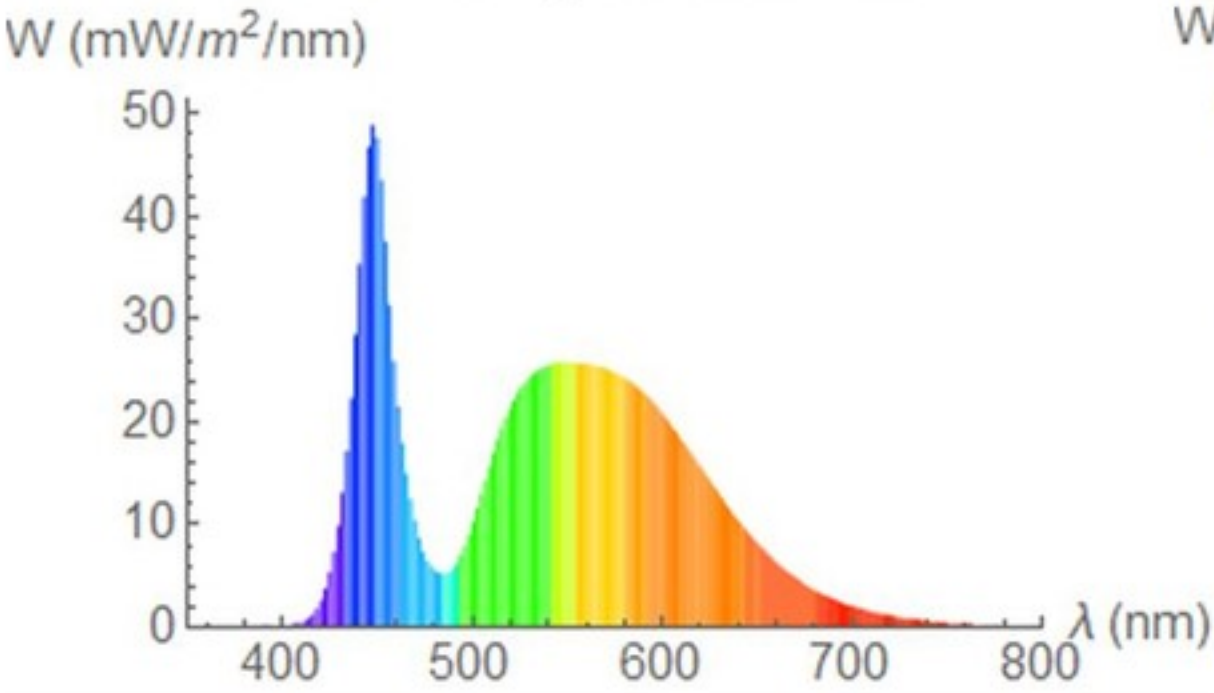
- function principle
- in facts, the curve shape of traffic volume and luminance are continuous and smooth

2. LED versus HPS - efficiency

Picture	Description	Luminaire efficiency	Luminous flux		Total input power (W)	Total luminous efficiency (lm/W)
			Source (lm)	Luminaire (lm)		
	HPS P=100 W Φ=10 700 lm T_n=2200 K R_a =20	86,6%	10 700	9 266	114	81,3
	LED P=58 W Φ=9 680 lm T_n=3000 K R_a=70	99,5 %	9 680	9 632	83,7	115,1

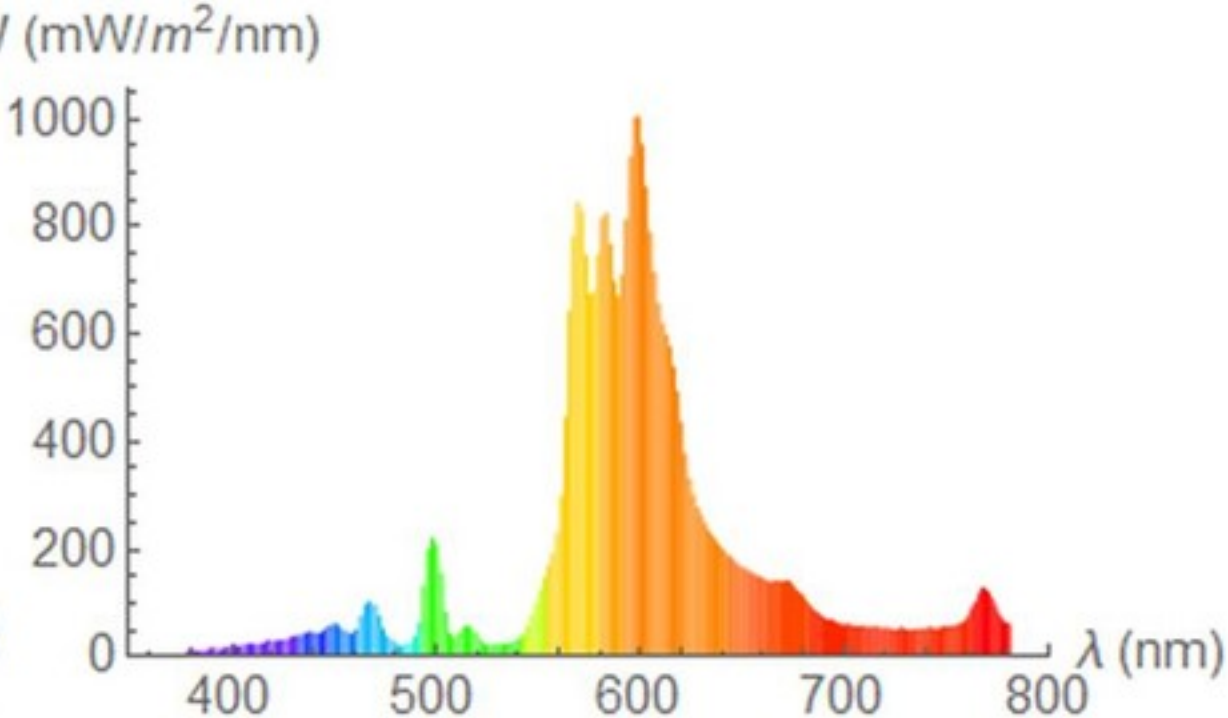
2. LED versus HPS - spectral proporties

Spectrum of the LED



- 6000 K
- Ra > 60
- λmax = 447 nm

Spectrum of the high pressure sodium lamp

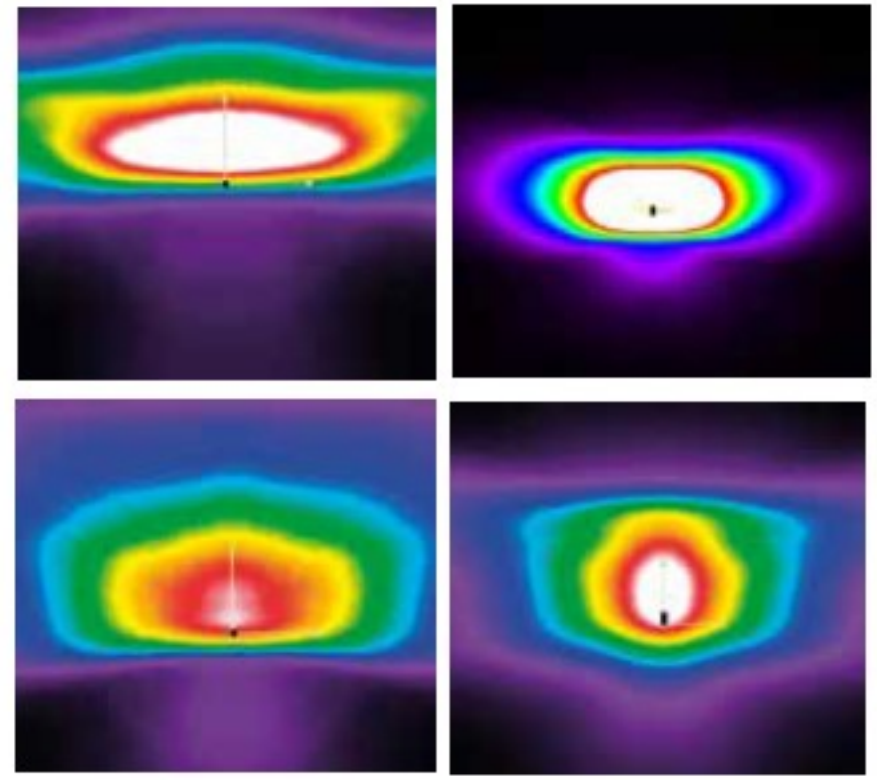


- 2000 K
- Ra > 20
- λmax = 599 nm

2. LED versus HPS

The efficiency and utilization

Light source:	HPS	x	LED
luminous efficiency η (lm/W):	80 - 120	×	120 - 220
Life t (hrs.) :	35 000	×	100 000
Regulation :	limited	×	full



LED

- selection of different optical systems
- increase of the luminous flux utilization factor
- higher luminous efficiency of luminaries

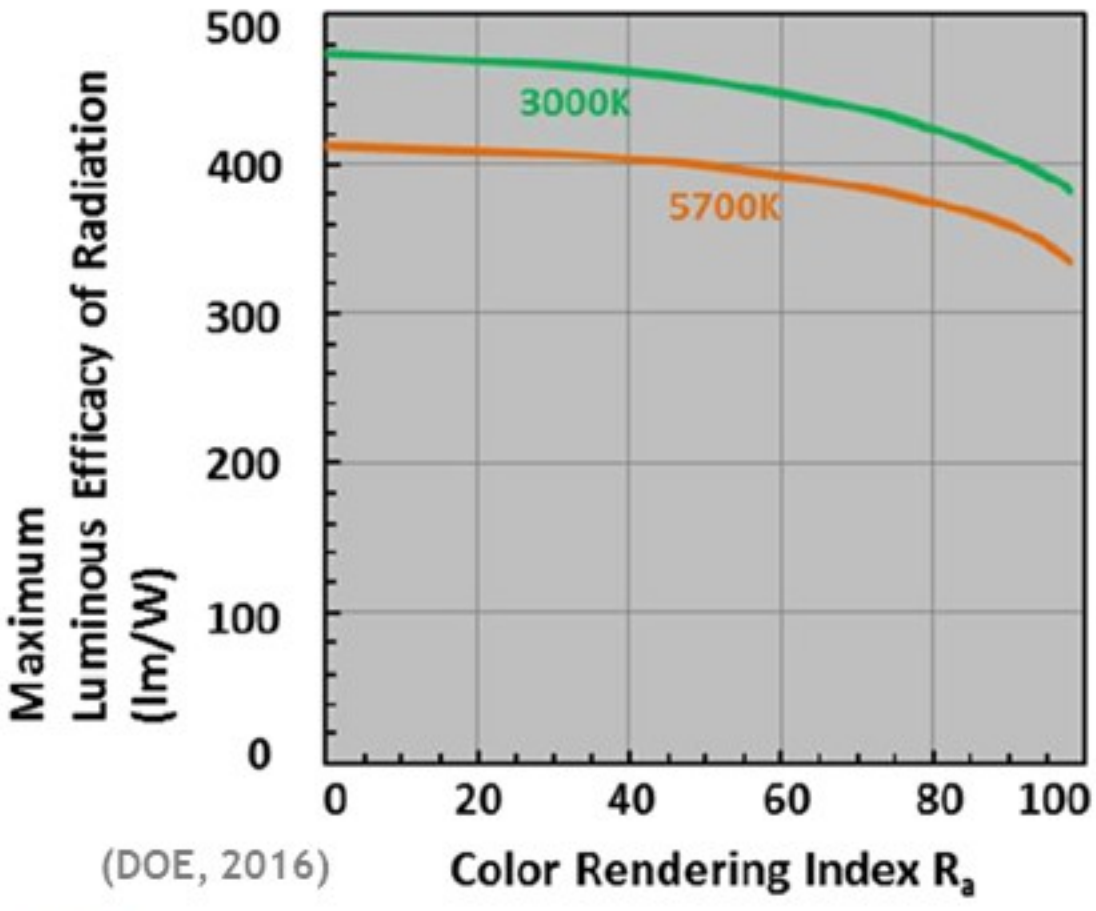
Utilization factor of luminous flux

3. LED

Parameters affecting LED efficiency

Color rendering index (R_a)

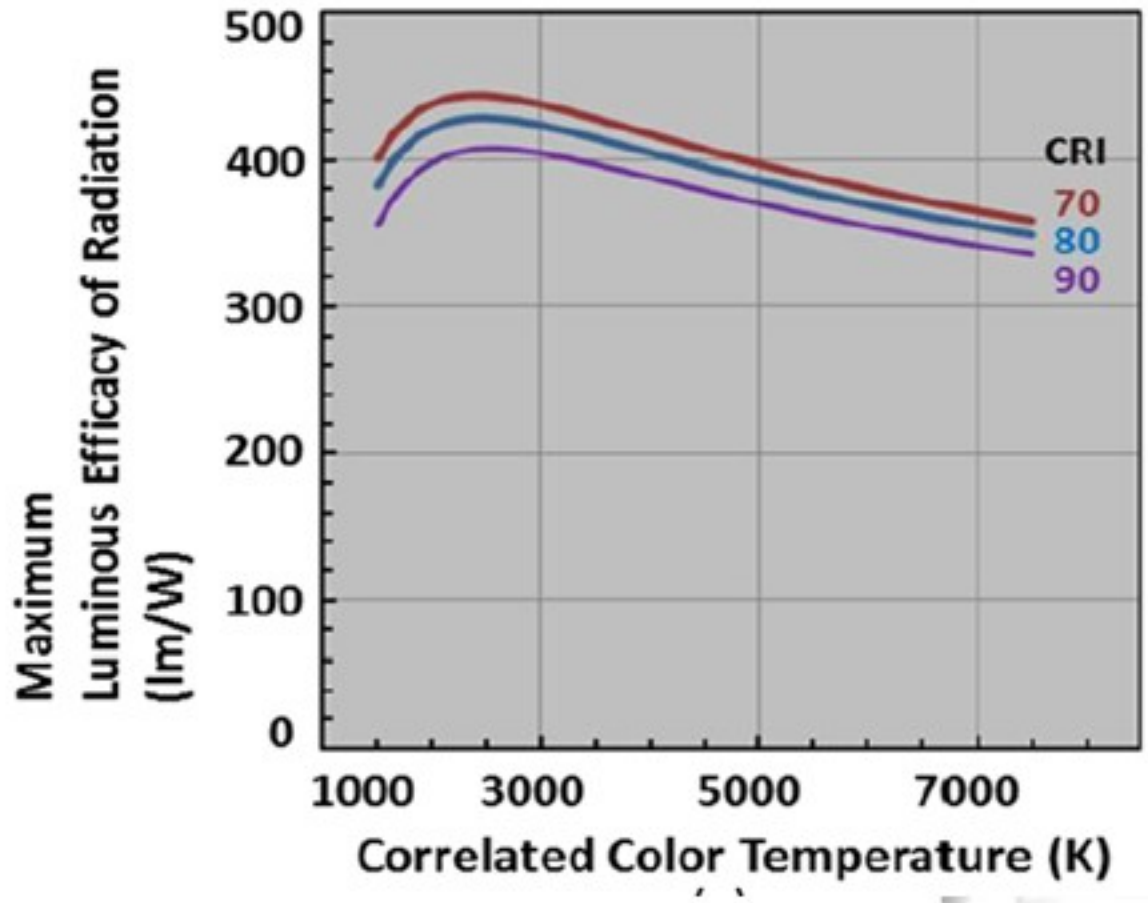
- Achieving higher luminous efficiency is (currently) more demanding for warm white LEDs than cold white



(DOE, 2016)

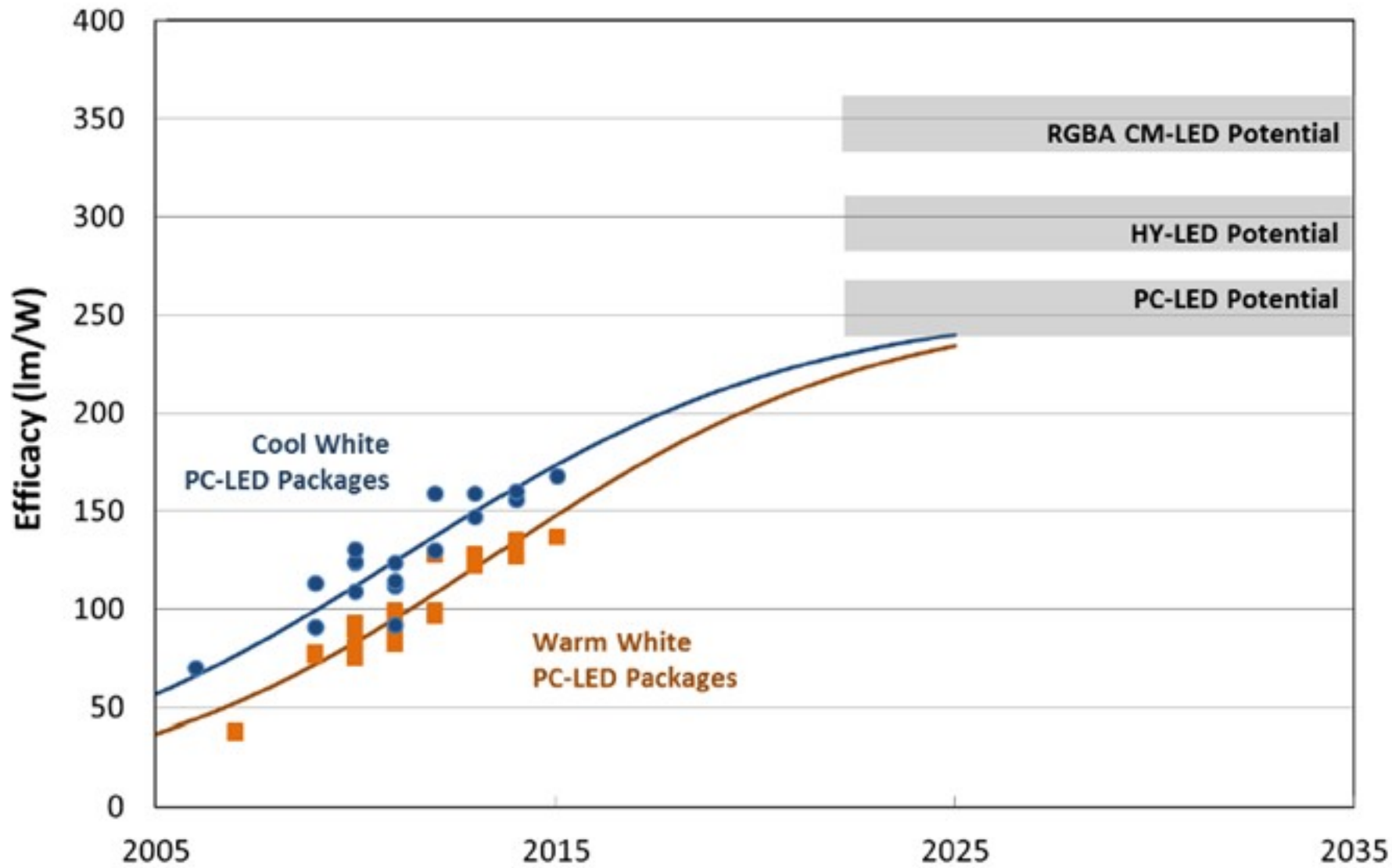
Correlated color temperature (T_c)

- it affects the luminous efficiency
- increase of Ra means a decrease of the luminous efficiency by 5 - 20%



3. LED

Estimation of specific luminous efficacy development

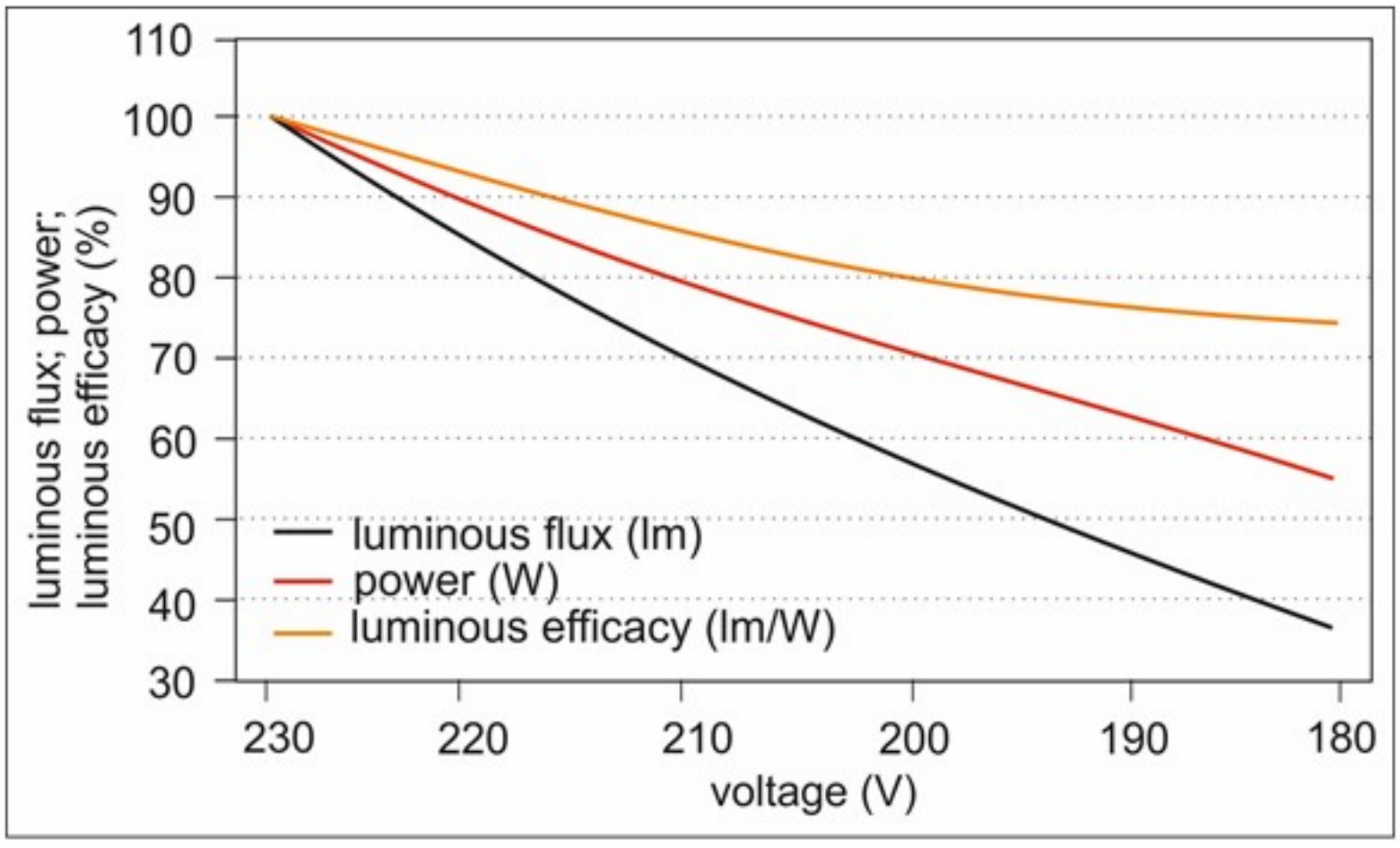


(DOE, 2016)

4. Luminous flux control - dimming

High pressure sodium

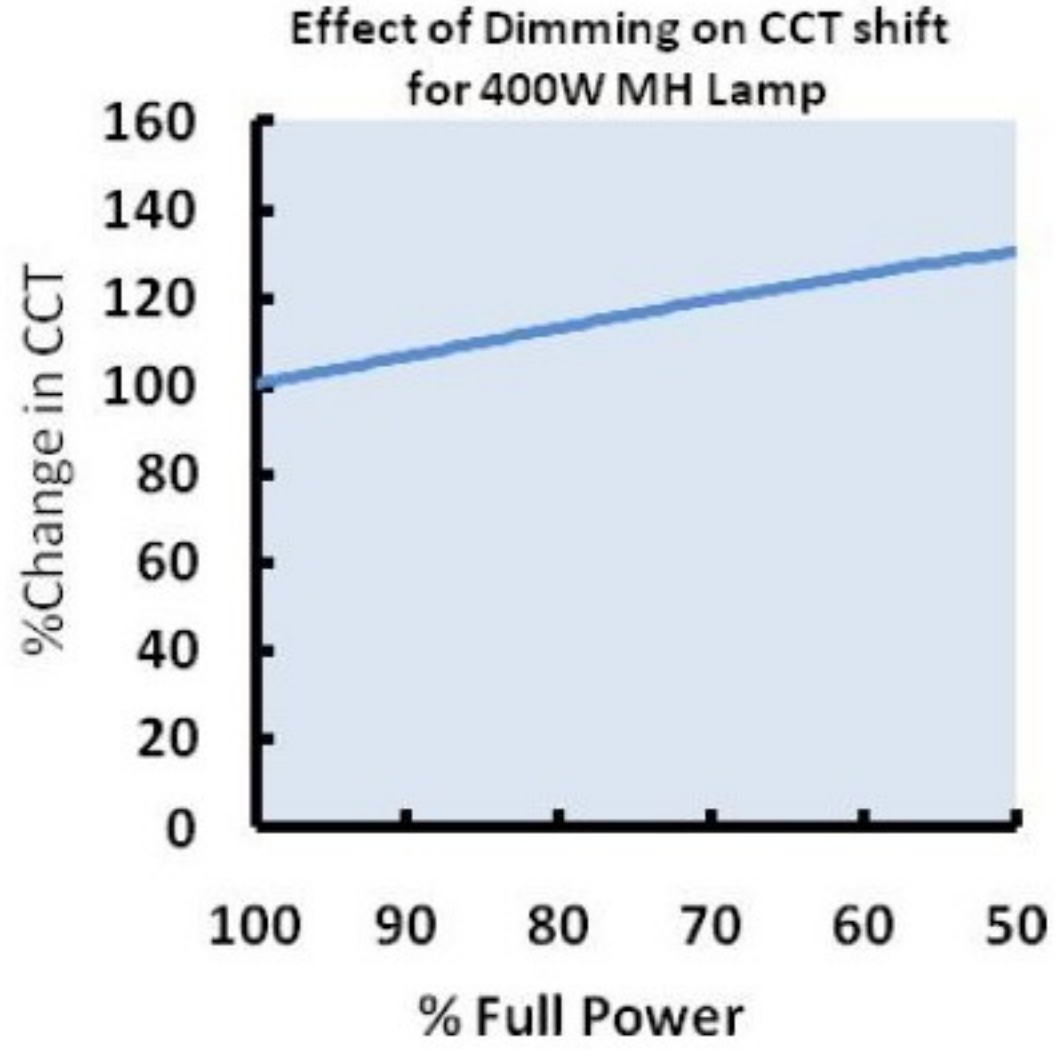
- nonlinear, limited control
- reducing the flow by 50% means a decrease in power consumption by 30%



4. Luminous flux control - dimming

Metal-halide lamps

- dependence of luminous flux on circuit values is simmilar to HPS lamps
- by dimming is changed correlated color temperature

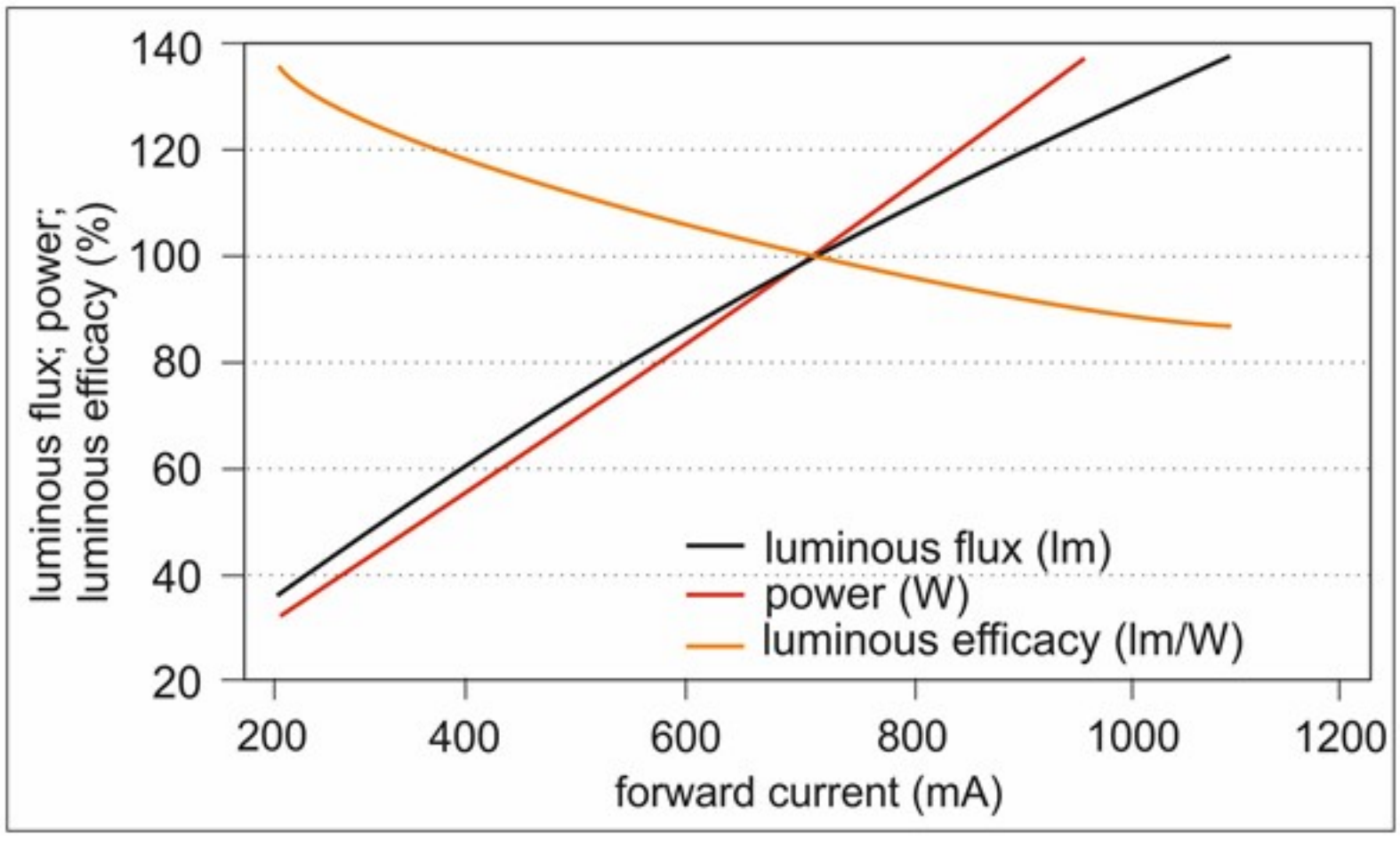


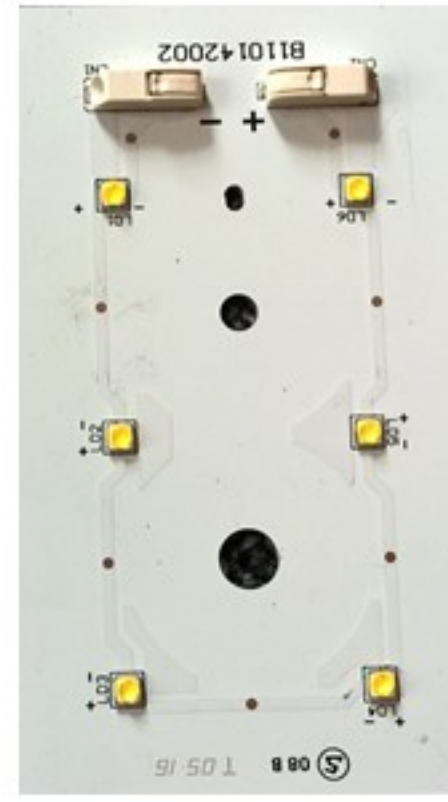
National Electrical Manufacturers Association

4. Luminous flux control - dimming

Light emmiting diode

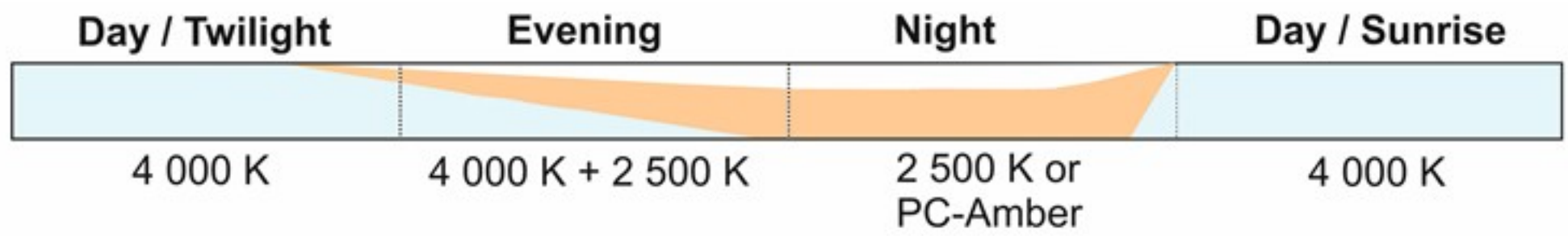
- full flux control in wide range
- possibility to increase luminous flux over nominal parameters

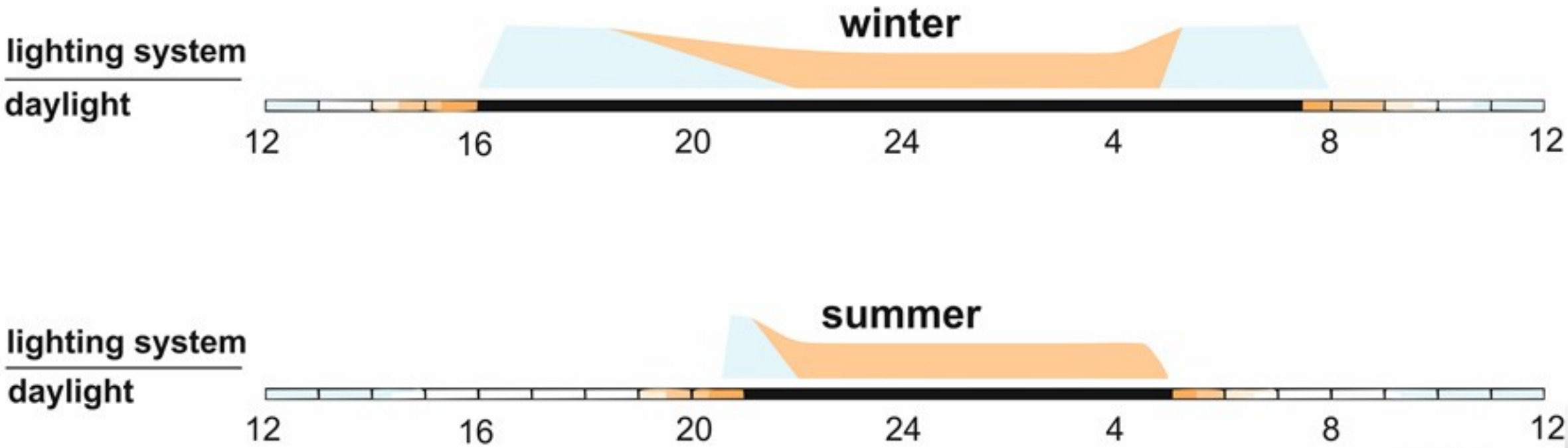




5. Color temperature control model (tunable white)

- example of mixing two color temperature during daytime
- tunable white, mix color, human centric lighting and other business names

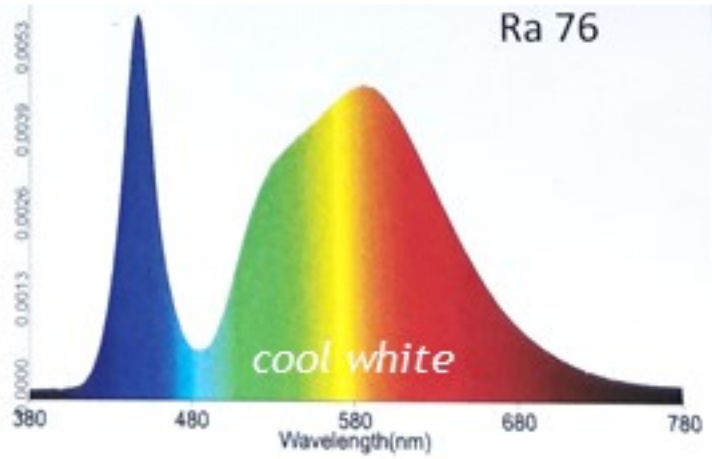




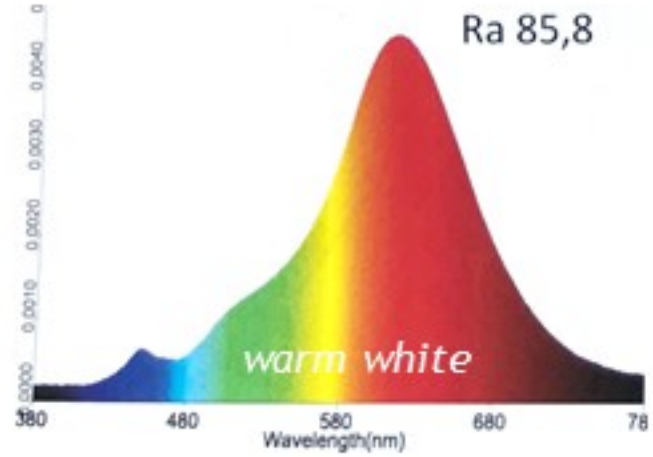
5. Color temperature control (tunable white)

Light emmiting diode – spectrum examples

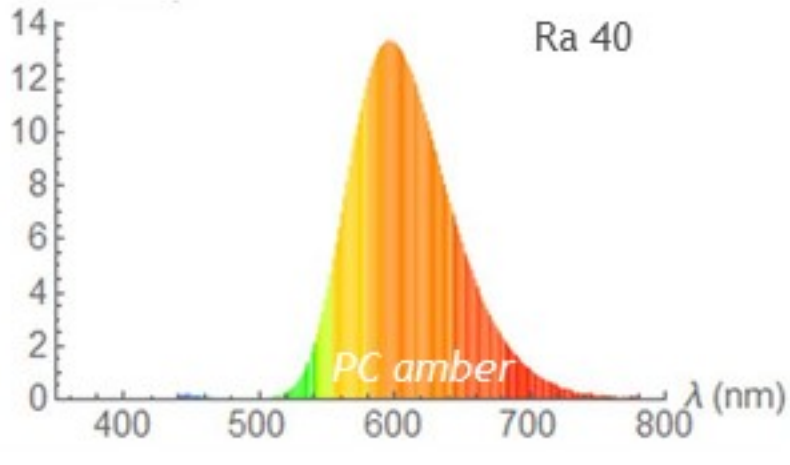
- achieving lower correlated color temperature will cause a decrease in luminous efficiency
- achieving higher CRI will caused decrease of luminous efficiency



- Tc = 4 000 K
- η: 125 - 145 lm/W



- Tc = 2 500 K
- η: 80 - 100 lm/W



- Tc =1 900 K
- η: 70 - 100 lm/W

➢ general rise in input power of LED by decreasing color temperature in relation to 4000K LED

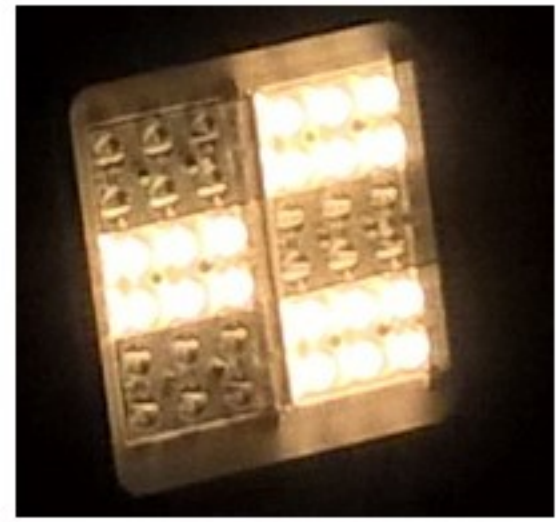
- 2700K -> power input ~ +5%*
- 2500K -> power input ~ +15%*
- 2000K -> power input ~ +20%*

)*number is dependent on specific type of LEDs

5. Color temperature control (tunable white)

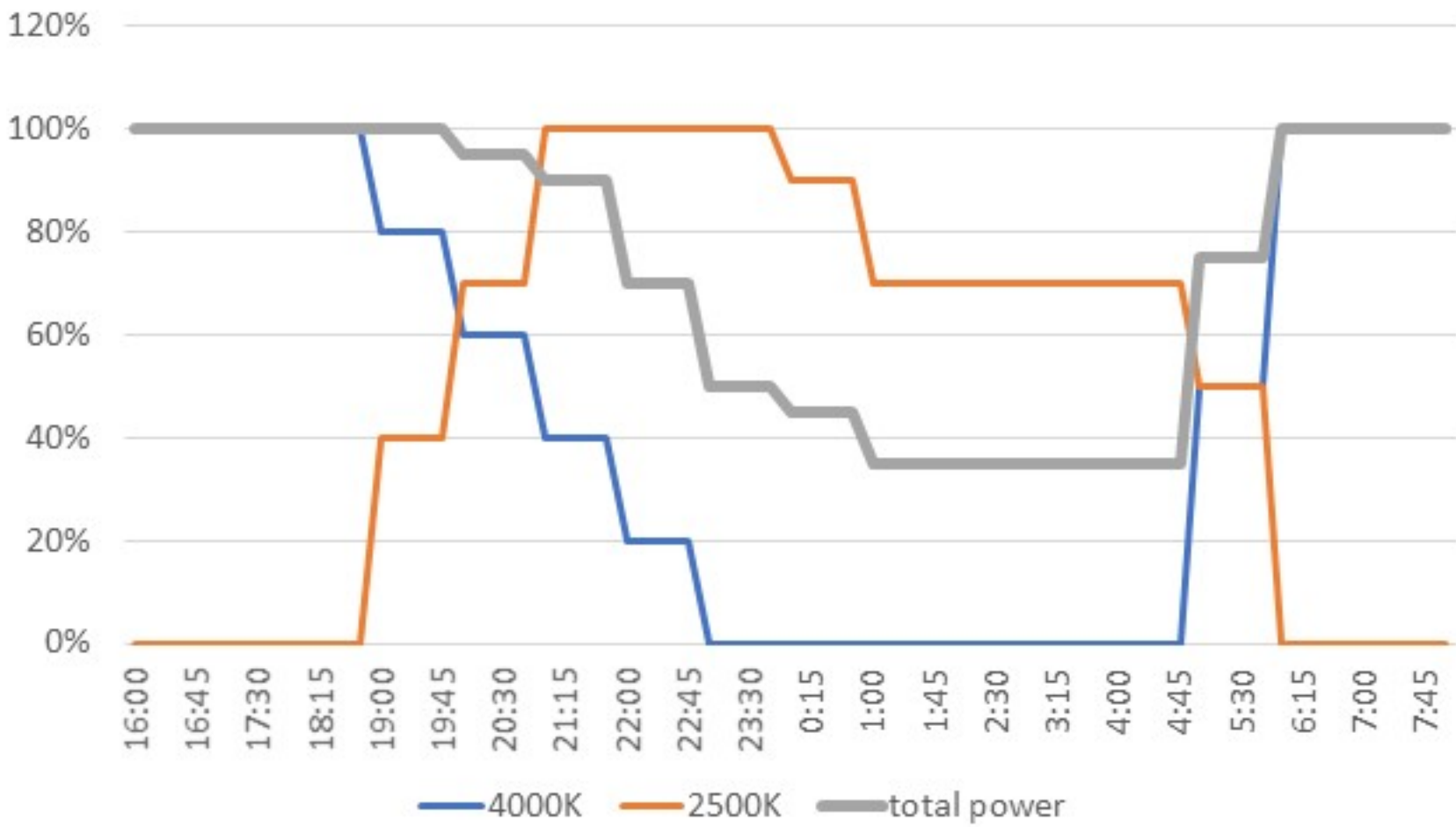
Technical solution

- color temperature is mixed according daytime and social needs
- different construction options are available



5. Color temperature control (tunable white)

- example of dynamic control of illuminance and color temperature
- LED power input in dependence of changing luminous output and color temperature



) function principle - in facts, the curve shape of the plot are continuous and smooth*

6. Cost

investment

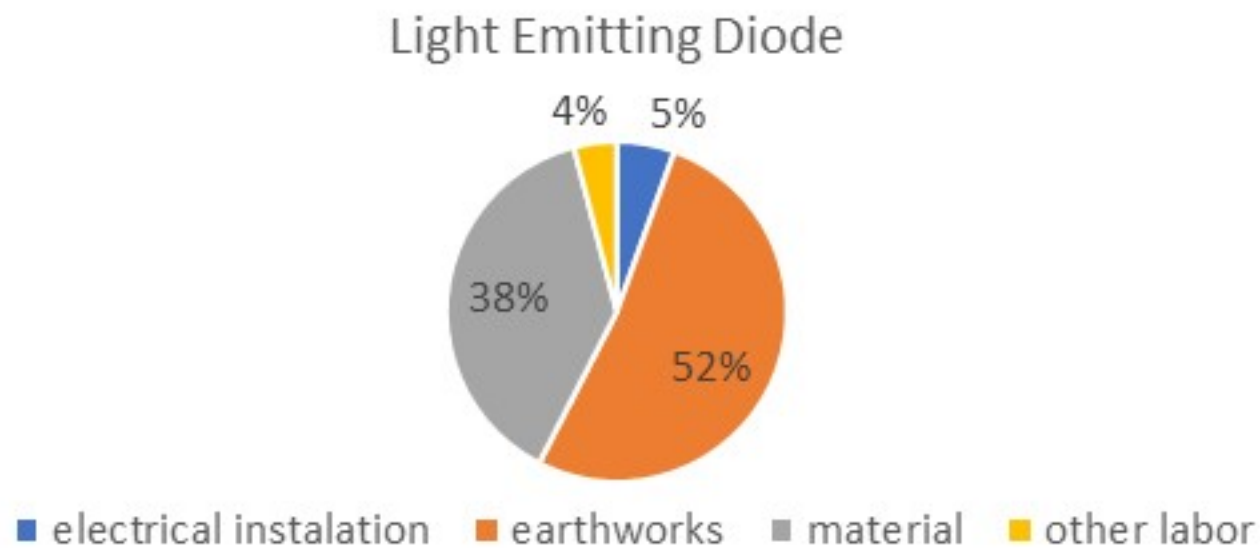
- investment to build up of 50 light places

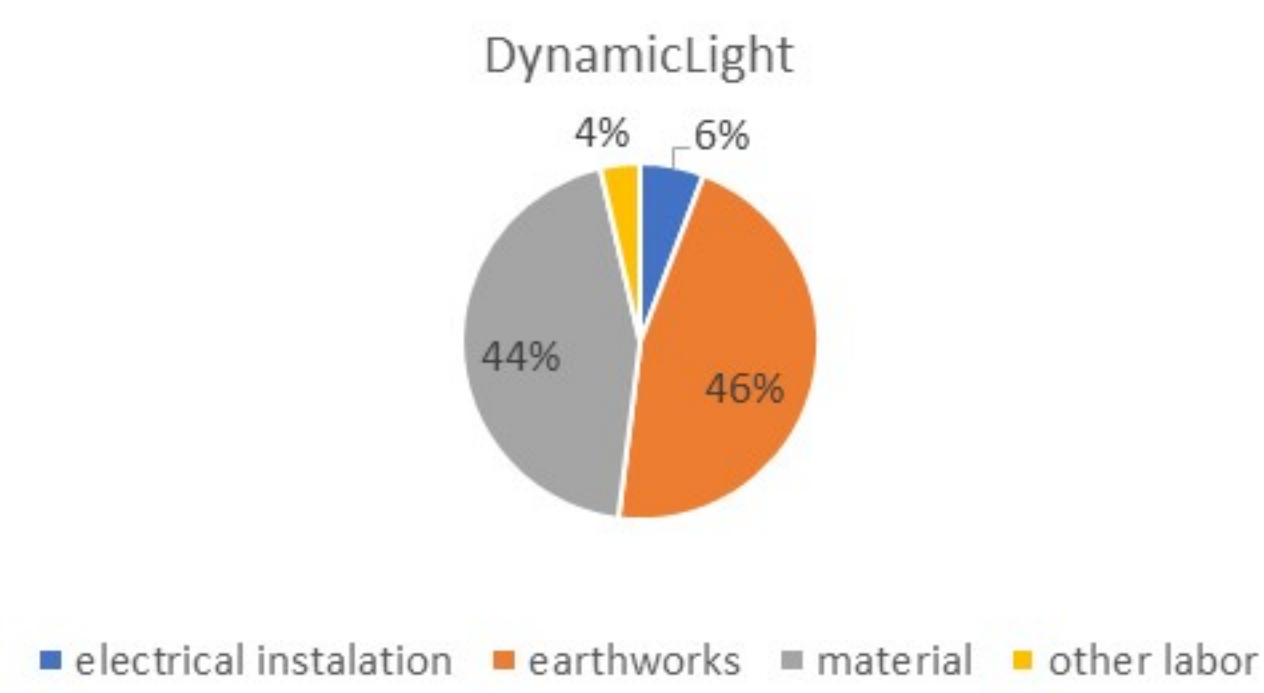
	HPS	HPS + dimming	LED (on/off)	LED + dimming	LED + dynamic	LED + tunable white
Cost of electrical instalation	8 549 €	8 549 €	7 895 €	7 895 €	9 387 €	9 387 €
Cost of earthworks	74 900 €					
Material - structural material (masts, wires...)	38 444 €					
Material - electrical devices (luminaries, sensor...)	9 700 €	12 388 €	16 732 €	16 732 €	32 398 €	34 758 €
Support works (disassembly, revision, mechanization)	2 976 €					
Engineering activities	2 874 €					
Fund	2 920 €					
TOTAL	**140 362 €**	**143 050 €**	**145 161 €**	**145 161 €**	**162 320 €**	**164 680 €**

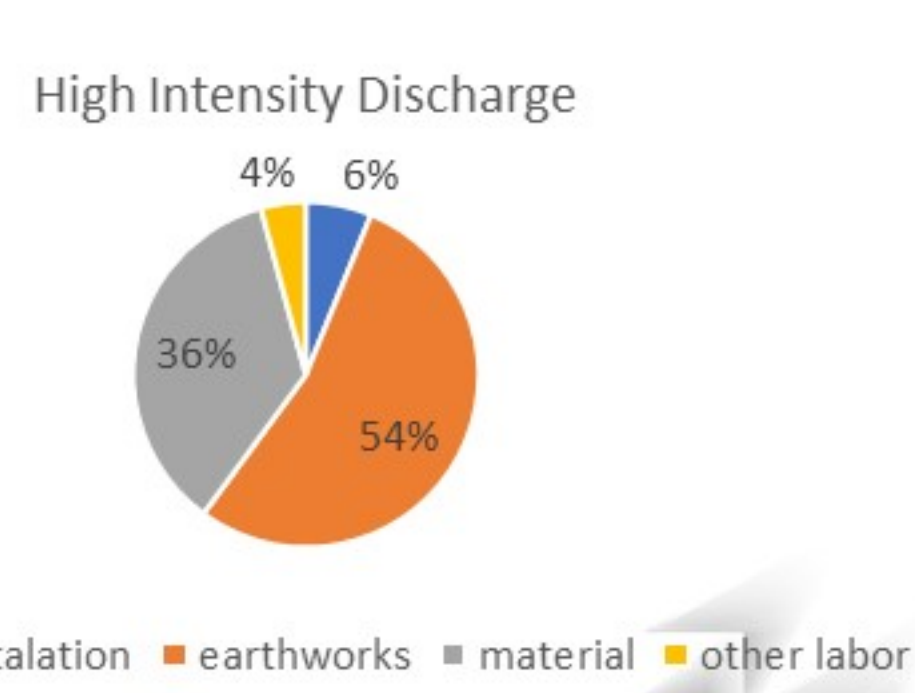
6. Cost

Investment

	lighting system equipped by:		
cost type	HID	LED	DL
electrical instalation	6%	5%	6%
earthworks	54%	52%	46%
material	36%	38%	44%
other labor	4%	4%	4%







6. Cost

electricity cost (50 light places)

	HPS	HPS + dimming	LED (on/off)	LED + dimming	LED + dynamic	LED + tunable white
Luminaire nominal power (W)	120	111	71	71	71	113
Average power of luminaire per year (W)	120	89,8	71,0	48,5	41,4	52,6
Number of luminaries (pcs)	50	50	50	50	50	50
Electricity consumption in year (operation 4 254h) MWh	25,52	19,10	15,10	10,32	8,80	11,19
Fixed operating costs per year	0 €				96 €	
Total price for annual operation	**1 950,75 €**	**1 460,10 €**	**1 154,19 €**	**788,70 €**	**768,40 €**	**950,98 €**

Electricity cost	EUR
Power electricity CZK / MWh	38
Electricity distrubution CZK / MWh (C62d)	13,52
Regulated components CZK / MWh	24,908
price per MWh	**76,428**

6. Cost

average annual cost per 1 light place

	HPS	HPS + dimming	LED (on/off)	LED + dimming	LED + dynamic	LED + tunable white
System operation	39,01 €	29,20 €	23,08 €	15,77 €	15,37 €	19,02 €
System maintenance	38,40 €	38,40 €	37,68 €	37,68 €	39,12 €	40,88 €
Fund for system renewal			40,00 €			
TOTAL annual cost / 1 lighting place	117,42 €	107,60 €	100,76 €	93,45 €	94,49 €	99,90 €

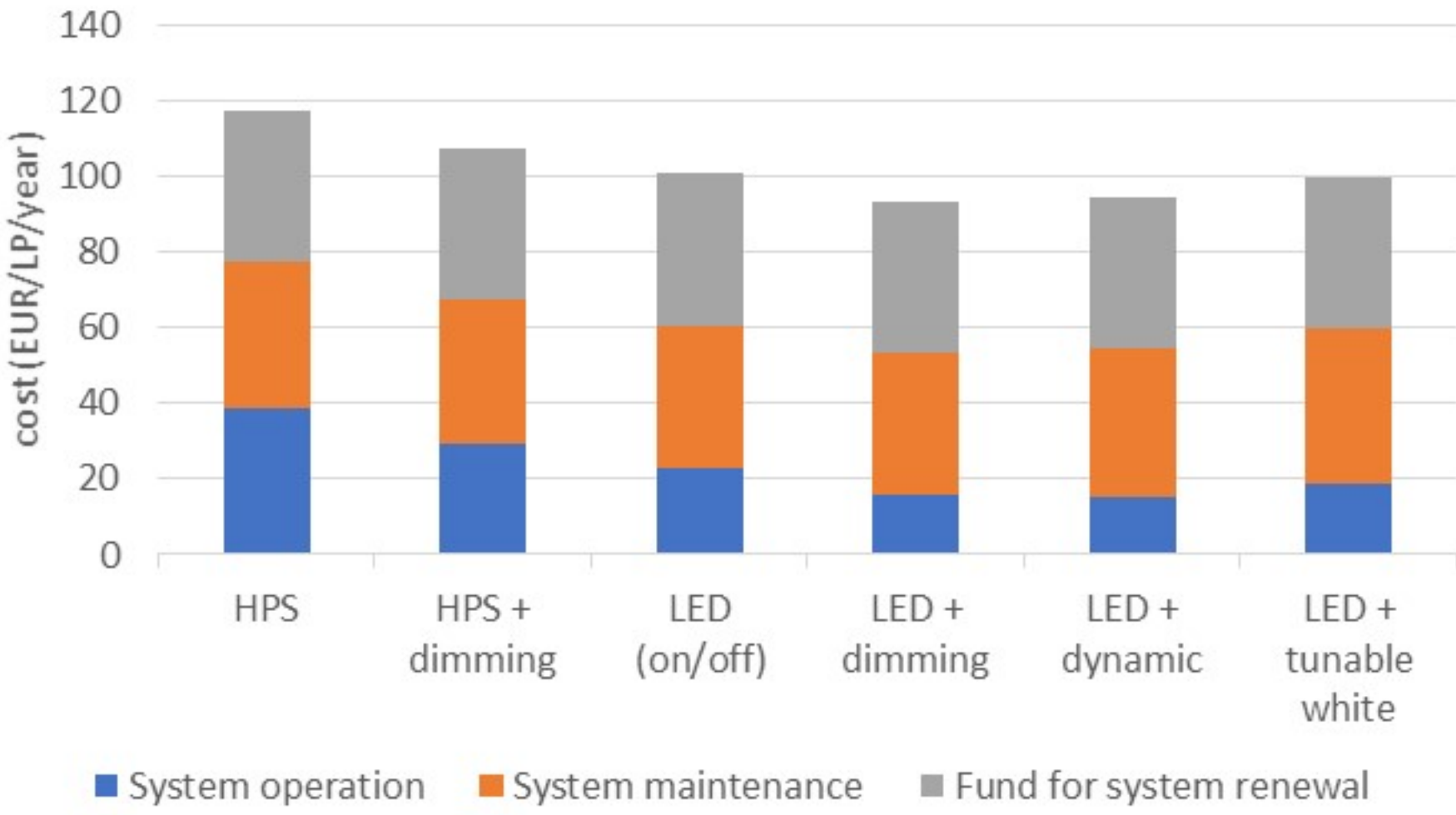
Maintenance

- periodic replacement of lamps
- replacement of electronic devices depending on functional reliability
  - igniter, driver, LED modul, overvoltage protection...
- periodic cleaning of luminaires

- annual maintenance cost is based on the operating time of 20 years

6. Cost

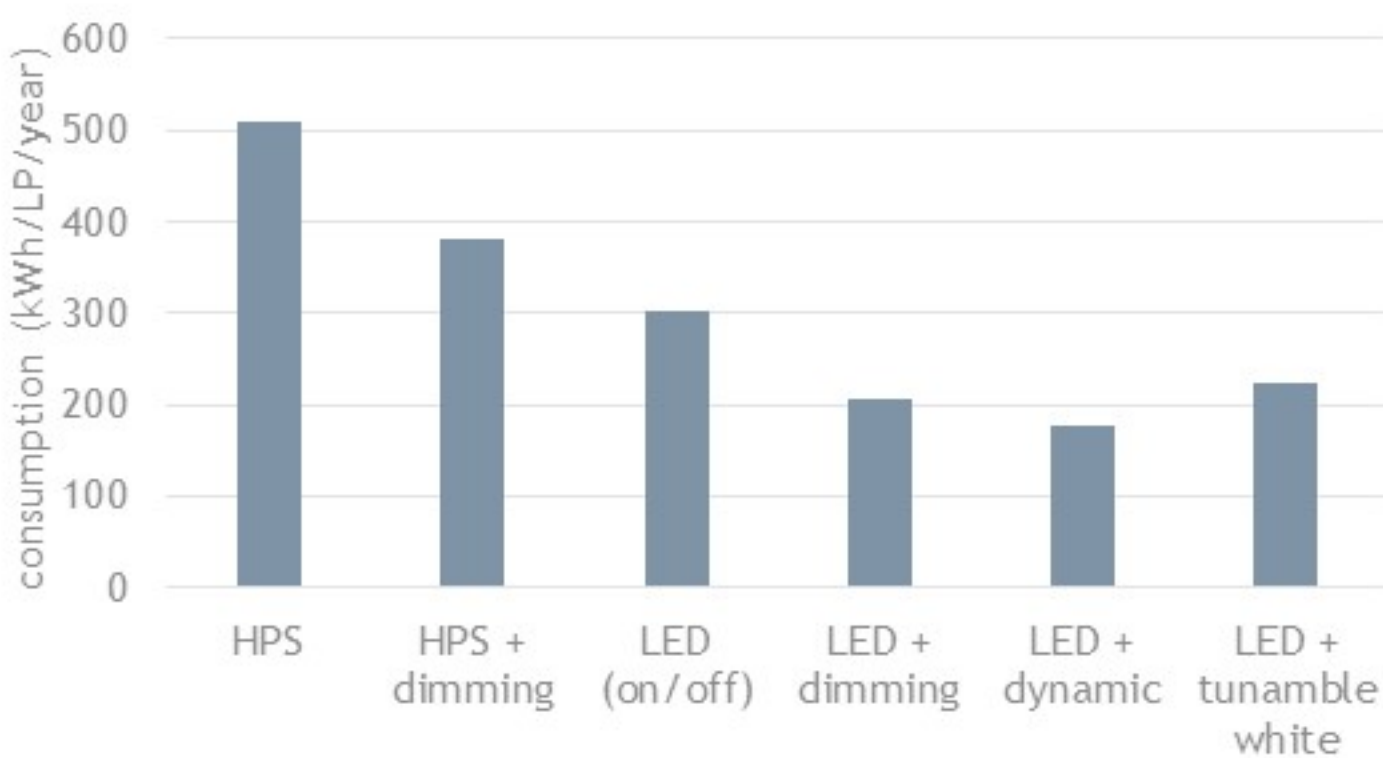
average annual cost per 1 light place



6. Cost

electricity consumption - compare

electricity consumption	HPS	HPS + dimming	LED (on/off)	LED + dimming	LED + dynamic	LED + tunable white
related to HPS	100%	75%	59%	40%	34%	44%
related to LED	169%	127%	100%	68%	58%	74%

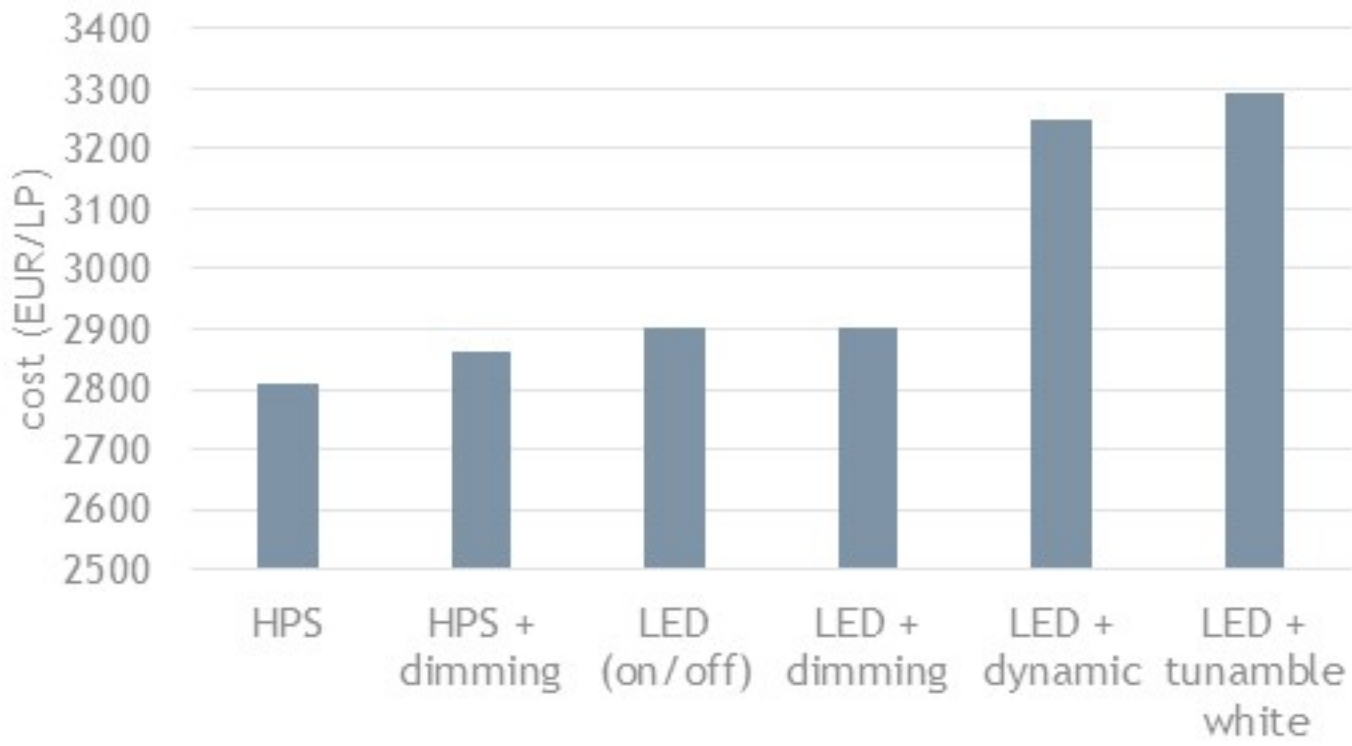


annual electricity consumption per 1 light place (kWh/year)

6. Cost

construction investment - compare

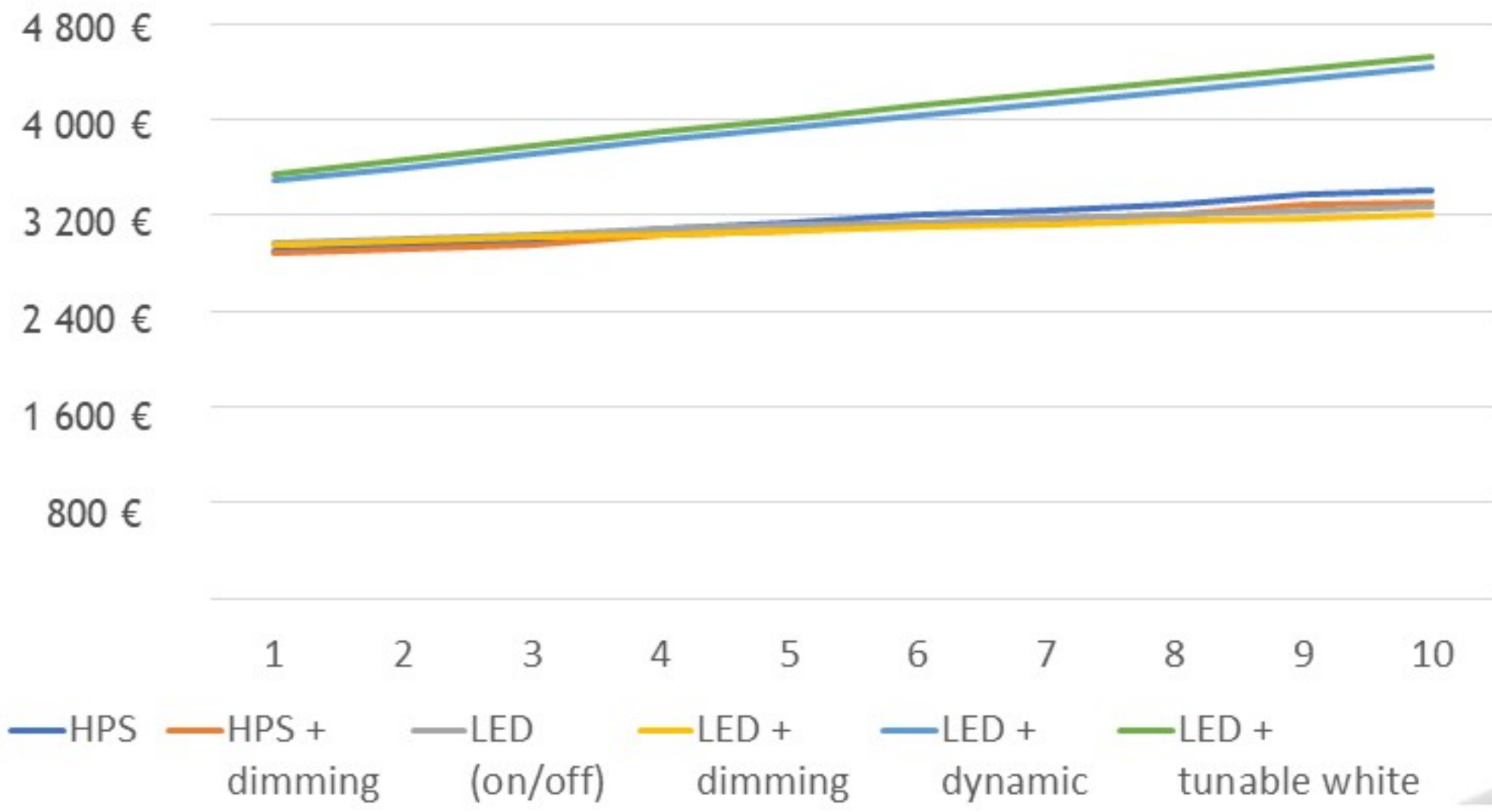
construction investment	HPS	HPS + dimming	LED (on/off)	LED + dimming	LED + dynamic	LED + tunable white
related to HPS	100%	102%	103%	103%	116%	117%
related to LED	97%	99%	100%	100%	112%	113%



construction investment per 1 light place (EUR)

7. Conslusion

Cumulative cash flow



7. Conslusion

pros and cons

HPS	HPS + dimming	LED (on/off)	LED + dimming	LED + dynamic	LED + tunamble white

cons

- limited control
- limited input power range
- poor color rendering index
- limited utilisation of light
- significant part of light in blue spectrum
- insufficient unification of electronical parts
- high invesment & maintenance cost
- limited aplication
- a lot of add-on devices
- decrease in functional reliability

pros

- low color temperature
- robust & realible system
- consolidated types
- low price
- ful light control
- various optical systems
- various performances
- various color temperatures
- adjusting light parameters
- remote control
- human & nature friendly
- light according to needs in time

in general, at dimming the light the average luminance and the overall uniformity must be kept (EN 13201-2) according to ambient conditions

Thanks for your attention

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