INTEGRATION OF EE IN BUILDINGS – PART 4

Lighting systems

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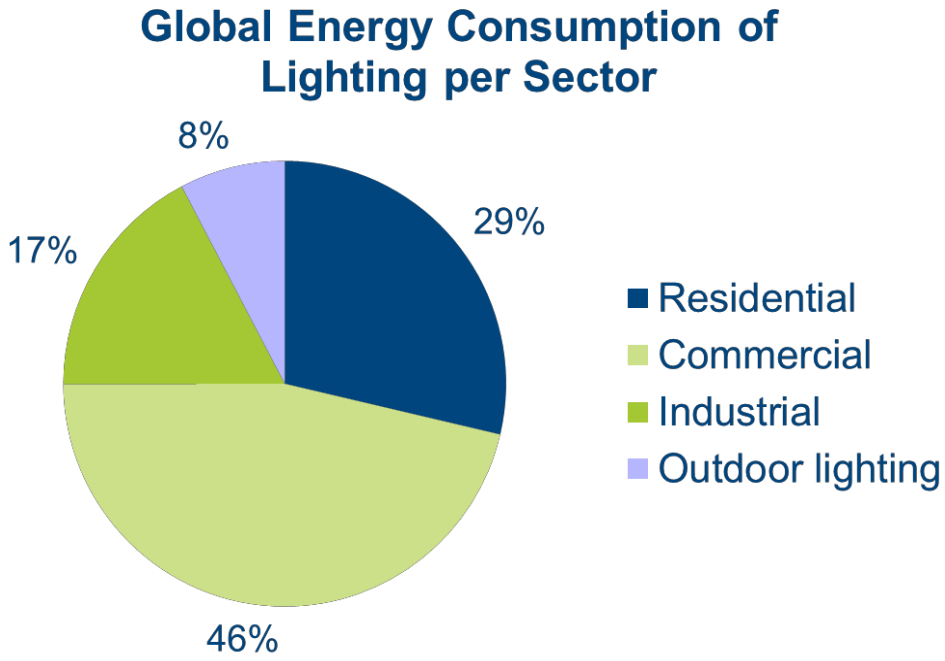
Lighting systems

Brainstorming

- What do I know about lighting systems?
- What do I expect to know about lighting systems at the end of this course?

Lighting Energy Consumption



Energy consumption of lighting systems covers between 15% and 19% of global electricity consumption (over 5% of global greenhouse gases emissions) according to a study by the United Nations Environment Programme.

Lighting definition of commont terms

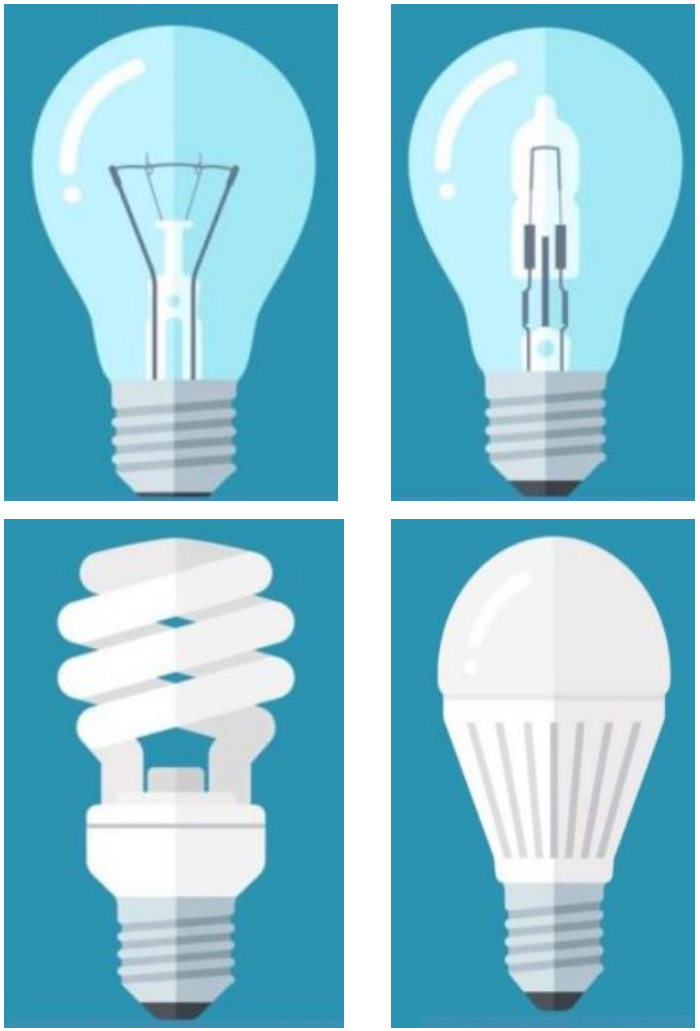
- **Lumen**: measure unit of the total "amount" of visible light emitted by a source (symbol: lm);
- **Lux**: unit of illuminance and luminous emittance, measuring luminous flux per unit area; equals 1 lm/m². (symbol: lx);
- **Luminous efficacy**: measure of how well a light source produces visible light; it is the ratio of luminous flux to power in lm/W;
- **Colour temperature of a light source**: the temperature of an ideal black-body radiator that radiates light of comparable Hue to that of the light source.

Typical lighting levels

Building area	Lux
Office – general	400
Auditorium	400
Bathroom	300
Dining room	100
Conference room	300
Corridors and stairs	50
Local roads	3 to 8
Highways	6 to 14

Light source technologies

- Incandescent (no more available in Europe)
- Halogen (partially not available in Europe)
- Metal halide
- Fluorescent
- Mercury vapour
- High-pressure sodium
- Induction
- LED (Light Emitting Diode)



Light source technologies

	Incandescent	Halogen	Fluorescent	LED
Luminous efficacy [lumen/Watt]	11 - 12	18 - 28	40 -75	40 - 90
Power [W]	5 - 1.000	5 - 450	5 - 35	1 - 15
Duration [ore]	1.000	2.000 - 5.000	6.000 - 20.000	10.000 - 50.000
Colour temperature [K]	2.000 - 3.000	2.400 - 3.200	2.500 - 6.000	2.500 - 6.500

Light source technologies

	Incandescent	Halogen	Fluorescent	LED
Power [Watt]	60	37	11	9
Luminous efficacy [lumen/Watt]	12	20	67	82
Duration [ore]	1000	3000	10000	25000
Initial Cost [€]	22	24	12	8
Cost of energy in 10 years [€]	237	146	43	35
Total cost in 10 years [€]	259	170	55	43
Economic savings %	-	34%	79%	83%

N.B: savings calculations consider a costant amount of light emitted (740 Lumen) and:

- Cost of electricity: 0,18 €/kWh
- Working hours: 6 hours per day and 365 days per year

Light source technologies

	Halogen	Fluorescent	LED
Pros	• *Good color rendering* • *Immediate ignition*	• *High efficiency* • *Different colours available* • *Long duration* • *Low heat emission*	• *Very long duration* • *More compact and robust* • *Immediate ignition* • *Different colours available*
Cons	• *Low efficiency* • *High heat emission*	• *Long ignition time* • *Presence of mercury*	• *High initial cost* • *Cold light → light pollution*
End of life	Mixed waste	WEEE	WEEE

N.B. WEEE: Waste Electrical and Electronic Equipment

Main energy conservation measures

General energy conservation measures

1. Reduce lighting demand by exploiting natural light as much as possible and also adding automatic control systems (timers and light sensors);

2. Reduce lighting demand by avoiding over-illumination;

3. Reduce lighting demand by accurately assess the position of lights;

4. Reduce lighting demand by using light colors for internal walls and ceilings;

General energy conservation measures

5. Control electrical systems' stability to avoid voltage fluctuation and control the value of the power factor;

Table 13.12 Power quality characteristics for different electric devices.

	Active Power (W)	Power Factor	Current THD (%)
Compact fluorescent lighting systems			
13-W quad-tube compact fluorescent lamp w/ NPF magnetic ballast	16	0.54	13
13-W quad-tube compact fluorescent lamp w/ NPF electronic ballast	13	0.50	153
16-W quad-tube compact fluorescent lamp w/ HPF electronic ballast	16	0.91	20
Full-size fluorescent lighting systems (two lamps per ballast)			
T12 40-W lamps w/ energy-efficient magnetic ballast for T12 lamps	87	0.98	17
T12 34-W lamps w/ energy-efficient magnetic ballasts for T12 lamps	72	0.94	22
T10 40-W lamps w/ energy efficient magnetic ballast for T12 lamps	93	0.98	22
T12 40-W lamps w/ electronic ballast for T12 lamps	72	0.99	5
T12 34-W lamps w/ electronic ballast for T12 lamps	62	0.99	5
T10 40-W lamps w/ electronic ballast for T12 lamps	75	0.99	5
T9 34-W lamps w/ electronic ballasts for T12 lamps	79	0.99	5
T9 32-W lamps w/ electronic ballast for T8 lamps	61	0.98	6
T8 32-W lamps w/ electronic ballast for T8 lamps	63	0.98	6
High-intensity discharge lighting systems			
400-W high-pressure sodium lamp w/ magnetic transformer	425	0.99	14
400-W metal halide lamp w/ magnetic transformer	450	0.94	19
Incandescent lighting systems			
100-W incandescent A lamp	101	1.00	1
50-W MR16 low-voltage halogen lamp w/ magnetic transformer	62	0.97	6
50-W MR16 low-voltage halogen lamp w/ electronic transformer	51	0.99	10
Office equipment			
Desktop computer without monitor	33	0.56	139
13" high-resolution color monitor for desktop computer	49	0.56	138
Laser printer while in standby	29	0.40	224
Laser printer while printing	799	0.98	15
External fax/modem	5	0.73	47
Electric pencil sharpener	85	0.41	33

*NLPIP measured specific products and reported their characteristics. These characteristics may vary substantially for similar products; specifiers should check with product manufacturers for specific information.
NPF = Normal Power Factor
HPF = High Power Factor

General energy conservation measures

6. Use motion/occupancy detectors where possible;

Table 13.8 Estimated % savings from occupancy sensors.

Application	Energy Savings
Offices (Private)	25-50%
Offices (Open Spaces)	20-25%
Rest Rooms	30-75%
Corridors	30-40%
Storage Areas	45-65%
Meeting Rooms	45-65%
Conference Rooms	45-65%
Warehouses	50-75%

Table 13.9 Occupancy sensor applications.

Sensor Technology	Private Office	Large Open Office Plan	Partitioned Office Plan	Conference Room	Rest Room	Closets / Copy Room	Hallways Corridors	Warehouse Aisles Areas
US Wall Switch	•			•	•	•		
US Ceiling Mount	•			•	•	•		
IR Wall Switch	•			•		•		
IR Ceiling Mount	•	•	•	•		•		
US Narrow View							•	
IR High Mount Narrow View							•	•
Corner Mount Wide		•						
View Technology Type								

General energy conservation measures

7. Use efficient lamps where possible;

Table 8.4 Savings by Use of High Efficacy Lamps

Sector	Lamp type		Power saving	
	Existing	Proposed	Watts	%
Domestic/Commercial	GLS 100 W	*CFL 25 W	75	75
Industry	GLS 13 W	*CFL 9 W	47	78
	GLS 200 W	Blended 160 W	40	20
	TL 40 W	TLD 36 W	4	10
Industry/Commercial	HPMV 250 W	HPSV 150 W	100	37
	HPMV 400 W	HPSV 250 W	150	35

Table 8.5 Saving Potential by Use of High Efficacy Lamps for Street Lighting

Existing lamp			Replaced units			Saving	
Type	W	Life hrs.	Type	W	Life	W	%
GLS	200	1000	ML	160	5000	40	7
GLS	300	1000	ML	250	5000	50	17
TL	2×40	5000	TL	2×36	5000	8	6
HPMV	125	5000	HPSV	70	12000	25	44
HPMV	250	5000	HPSV	150	12000	100	40
HPMV	400	5000	HPSV	250	12000	150	38

Table 2 ***Appropriate lamps by sector***

	Space use	Recommended lamp type
Internal	Offices	Triphosphor tubular fluorescent, compact fluorescent, low voltage tungsten halogen (use sparingly)
	Factories	Triphosphor tubular fluorescent, high pressure sodium, metal halide, inductive
	Hotels	Triphosphor tubular fluorescent, compact fluorescent, low voltage tungsten halogen (use sparingly), LED
	Hospitals	Triphosphor tubular fluorescent, compact fluorescent
	Retail	Metal halide, white sodium, compact fluorescent, low voltage tungsten halogen (use sparingly), LED
	Leisure	Triphosphor tubular fluorescent, compact fluorescent, metal halide, inductive
	Emergency directional	LED
External	Car parks	High pressure sodium, metal halide, compact fluorescent
	Multi-storey car parks	Triphosphor tubular fluorescent, compact fluorescent, metal halide, high pressure sodium
	Floodlighting	Metal halide and high pressure sodium
	Feature	Metal halide, high pressure sodium, triphosphor tubular fluorescent, LED
	Sports facilities	Metal halide (4,000K+)

General energy conservation measures

Improvement measure	Savings	Additional notes
Improve natural light use	40 – 60 %	Savings estimated considering yearly average natural illumination where available.
Use occupancy detectors	10 – 50 %	Consider the use of the building.
Use timers	10 – 40 %	Consider actual occupancy.
On/off	10 – 50 %	Savings estimated considering an initial situation where lights are always on.
Use dimmering	10 – 50 %	Consider lighting demand.
Use light sensors	10 – 40 %	Consider lighting demand during night time.

References

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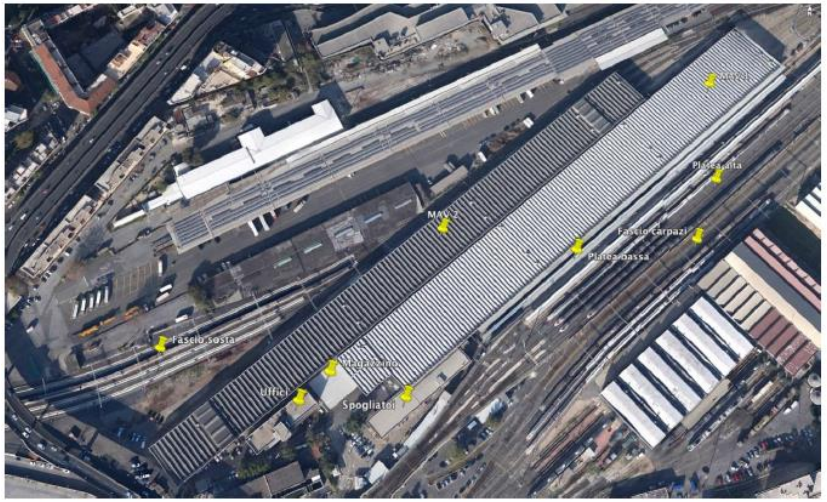
- *Barney L. Capehart, Wayne C. Turner, William J. Kennedy ” Guide to energy management” - Fourth Edition, The Fairmont Press, 2003*
- *Wayne C. Turner ” Energy management handbook” - Fourth Edition, The Fairmont Press, 2001*
- *Petrecca, “Industrial Energy Management: Principles and application” Kluwer Academic Publisher*
- Libro verde sull'efficienza energetica "Fare di più con meno" della Commissione Europea (2005)
- *Carbon Trust, Lighting Technology Overview (www.carbontrust.co.uk)*
- *http://www.elettrotecnologie.enea.it*

Lighting case study

Train maintenance workshop

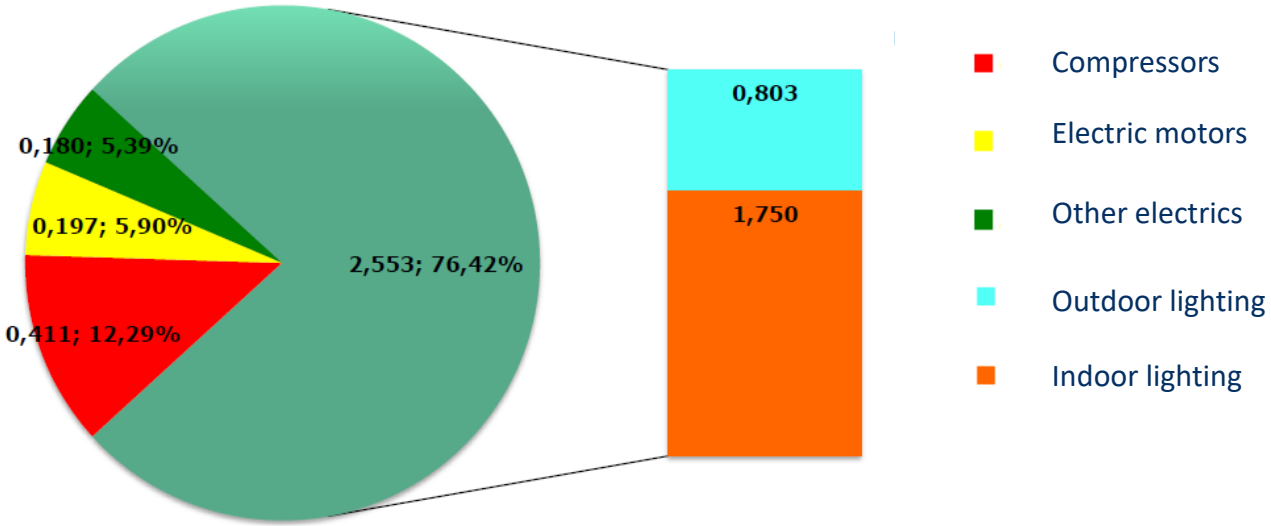
- Surface = 120.880 m2;
- 450 workers per shift;
- 3 shifts per day;
- Two sheds;
- One warehouse;
- One office buildings;
- Locker rooms;
- External tracks.



Train arrival → Cleaning → Emptying → Inspection → Corrective maintenance → Test → Train departure

Train maintenance workshop

- Energy analysis of the workshop conducted in 2011;
- Yearly water consumption = 292.000 m3;
- Yearly gas consumption = 157.300 Sm3;
- Yearly electricity consumption = 3,34 GWh

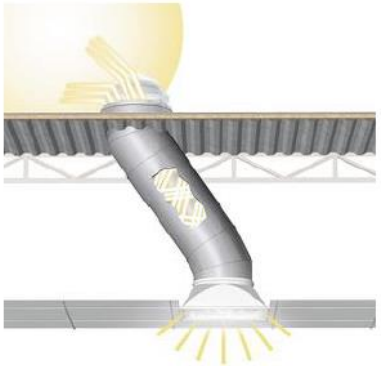


Train maintenance workshop

- Improvement of natural light use

Clerestories

Solar tunnels



Rooflight

Train maintenance workshop

Guidelines for indoor lighting – sheds:

- Optimisation of number and position of lamps;
- Selection of the most convenient lamp typology considering the Life Cycle Cost;
- Use lighting equipment allowing wide beams;
- Install separate power supplies.

Train maintenance workshop

Results– sheds:

- Initial situation: 272 mercury vapour lamps (68kW in total) always on (24/7), with a total yearly cost of energy of 90.000 Euros and a duration of 10.000 h;

- 255 High-pressure Sodium lamps with higher efficiency (124 lumen/W) and longer duration (30.000 h);
- Total cost of the substitution: 14.000 Euros;
- Total savings: 5.500 Euros/year;
- Adding the separate power supply (40 Euros/unit) savings increase to 14.000 Euros/year.

Train maintenance workshop

Guidelines for outdoor lighting:

- Check of lighting demand;
- Use of light sensors;
- Use high-efficiency, long-duration lamps;
- Use spotlights allowing wide beams;
- Install separate power supplies.

Train maintenance workshop

Results– stopover area:

- Initial situation: 80 mercury vapour lamps (250W per lamp) always on (24/7), with a total yearly cost of energy of 26.000 Euros and a duration of 10.000 h;

- 12 High-pressure Sodium lamps (150 W per lamp) with higher efficiency (117 lumen/W) and longer duration (30.000 h);
- Total cost of the substitution: 5.100 Euros;
- Total savings: 18.400 Euros/year.

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