Electrical Energy Management

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Energy Audits in Industrial Small Medium Enterprises (SMES) - Training Course

Monday, 9 December 2019 – Cairo, Egypt

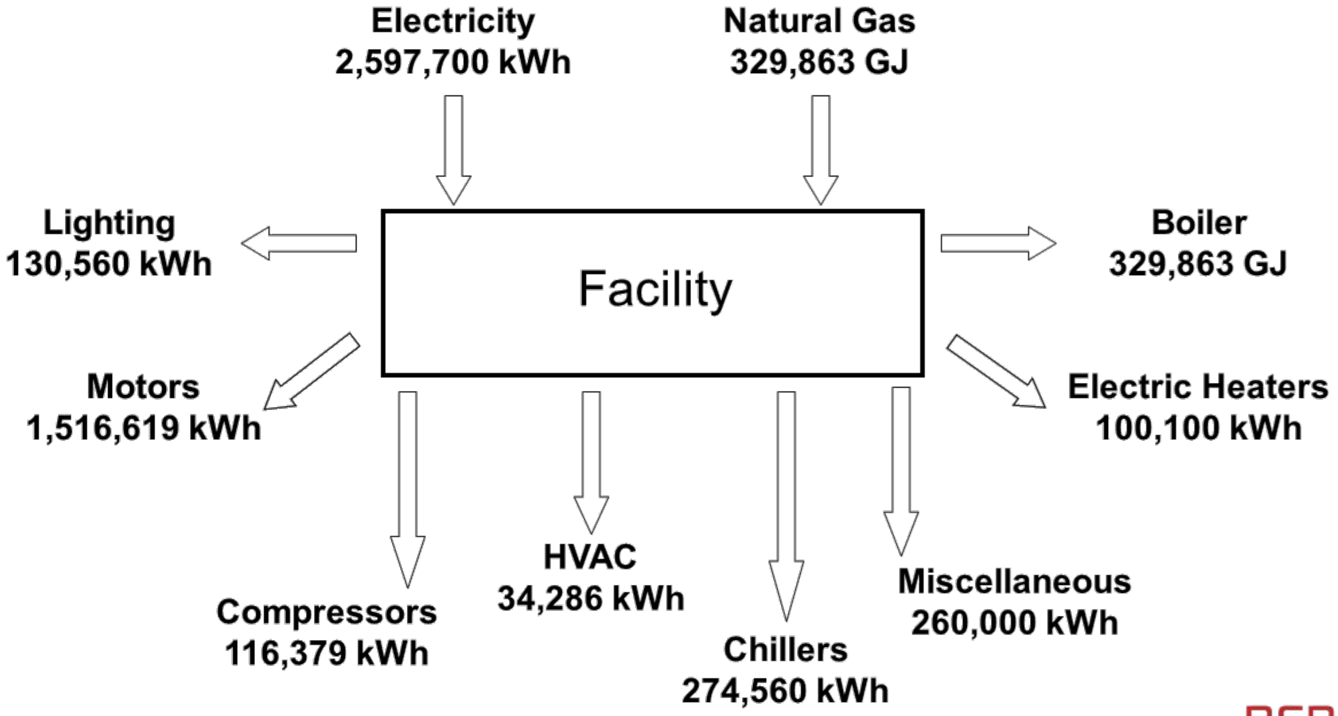
Funded by the European Union

Electrical Systems

- Electric Motors and Drives.
- Electric Fans.
- Electric Pumps.
- Compressed Air Systems.
- Lighting Systems.

Energy Basics Knowledge

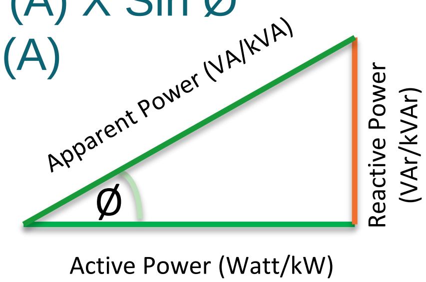
- Energy Units and Formulas of calculations.
- Energy Balance.



Electrical Basics

- Electric Power Circuits;
  - DC Power (no reactive power is present)
    - Power (Watt) = Voltage (Volt) X Current (Ampere)
  - AC Power, Single Phase
    - Active Power (Watt) = Voltage (V) X Current (A) X Power Factor (Pf)
    - Reactive Power (VAr) = Voltage (V) X Current (A) X Sin Ø
    - Apparent Power (VA) = Voltage (V) X Current (A)
  - AC Power, Three Phase
    - Active Power (Watt) = √3 X Voltage (V) X Current (A) X Power Factor (Pf)
    - Reactive Power (VAr) = √3 X Voltage (V) X Current (A) X Sin Ø
    - Apparent Power (VA) = √3 X Voltage (V) X Current (A)

Cos Ø = Power Factor (PF)



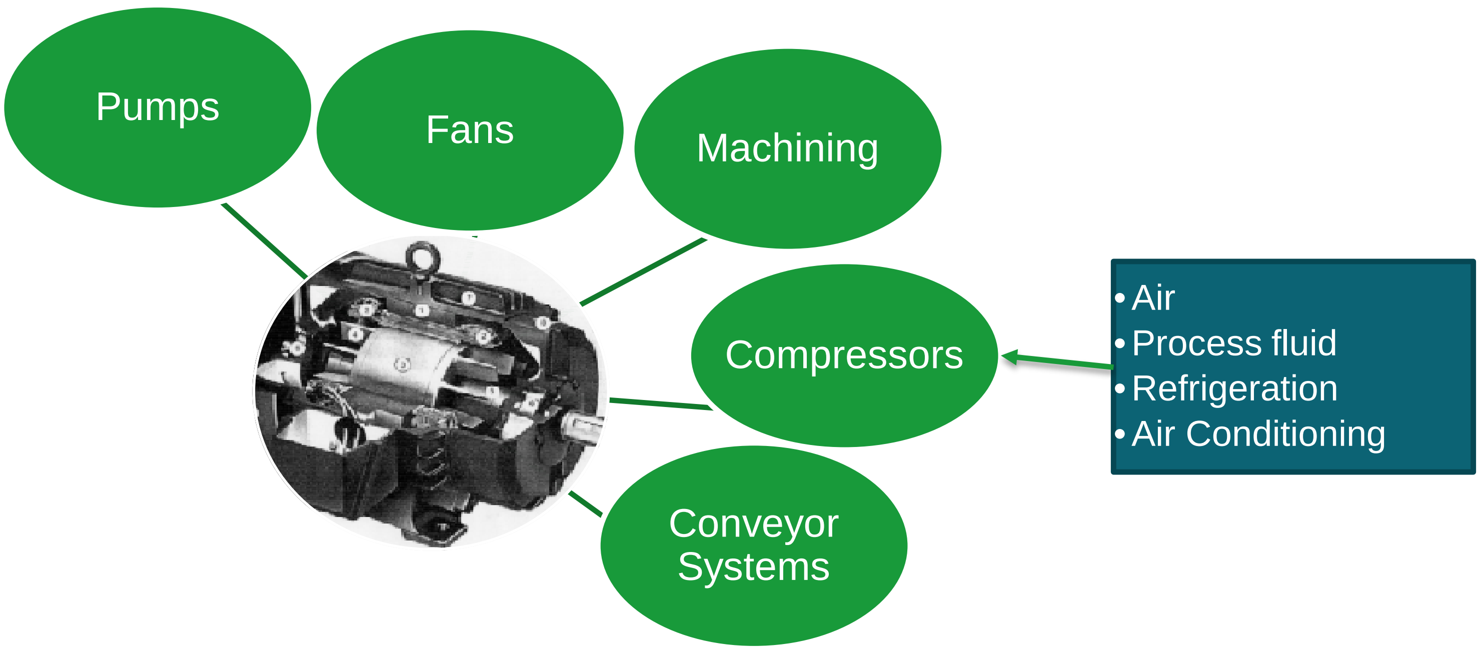
Electrical Basics

- Electrical Loads Type:
  - Resistive Load of Unity Power Factor.
  - Inductive Load of Lagging Power Factor.
  - Capacitive Load of Leading Power Factor.
- Power Factor;
  - Poor Power Factor is due to inductive loads and should be corrected in order to reduce the phase shift angle (Ø).
  - Power Factor correction could save energy upstream the location of power factor correction equipment and it improves the power quality because of reducing the reactive power demand in Power System.
    - Fg

- Power Factor Correction
  - Benefits:
    - Increase electrical distribution system capacity
    - Reduce utility charges
    - Reduce losses in transformers and feeders
  - Methods:
    - Source Correction: Capacitor is installed at the individual load or integrated into the equipment
    - Group correction: Capacitor is installed at a distribution transformer that feeds several loads

Motors and Drives

- Motors consume 55–65% of the industrial sector’s electrical energy



Motors and Drives

- The motor efficiency is expressed in the division of the mechanical shaft power (Useful) over the input electrical energy.

$$\eta = \frac{Mechanical\ Shaft\ Power\ (kW)}{Input\ Energy\ (kW)} \text{ X } 100$$

- Motor Load Factor is defined as the ratio between the actual loading to the motor and the maximum installed motor load.
- $Load\ Factor\ (LF) = \dfrac{Actual\ Average\ Load\ of\ Motor}{Maximum\ Motor\ Loading}$

Energy Efficiency opportunities in Motors Applications

- High Efficient Motors.

$$kW saving = kW rating X \left\{\frac{1}{\eta_{old}} - \frac{1}{\eta_{new}}\right\}$$

- Motors Controls;
  - Process Control.
  - Variable Speed Drives (VSD).

Efficiency of Electric Motors		
Power	Standard	High Efficiency (average value)
150 kW (200 HP)	92,5	95,4
75 kW (100 HP)	91,7	95,0
37,3 kW (50 HP)	91,4	94,1
18,7 kW (25 HP)	89,6	93,0
11,2 kW (15 HP)	88,4	92,4
7,5 kW (10 HP)	87,3	89,4
3,7 kW (5 HP)	84,6	89,5
1,5 kW (2 HP)	79,9	85,5
1,1 kW (1.5 HP)	78,0	85,5
0,7 kW (1 HP)	74,8	84,0

Affinity Law - Centrifugal

$$\frac{LPS_{new}}{LPS_{old}} = \frac{RPM_{new}}{RPM_{old}} \qquad \frac{Head_{new}}{Head_{old}} = \left\{\frac{RPM_{new}}{RPM_{old}}\right\}^2 \qquad \frac{kW_{new}}{kW_{old}} = \left\{\frac{RPM_{new}}{RPM_{old}}\right\}^3$$

LPS: Flow in liter per second.
Head: Discharge Head.
kW: Motor input power.
RPM: shaft speed in rotation per minute.
kPa: Kilo Pascal

Electric Fans

- With fans, four basic approaches for energy efficiency are feasible:
  - Reduction of hours of operation
  - Improve equipment efficiency
  - Flow reduction
  - Pressure reduction

The Same Affinity Laws are applied to fans very similar to pumps

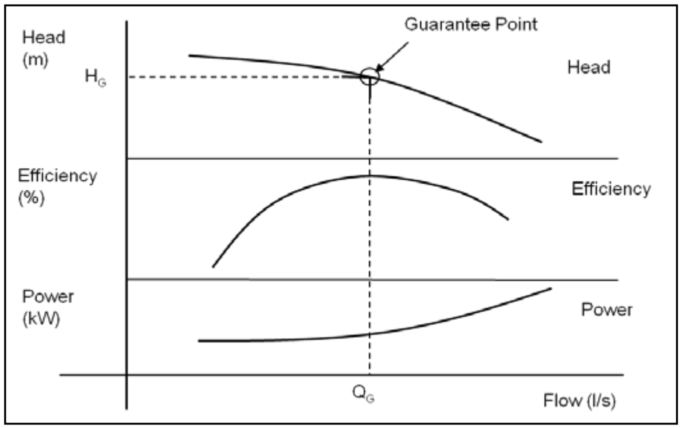
$$\textbf{Fan input power}(\textbf{Watt}) = \frac{\textbf{LPS}}{\textbf{Fan or Pump set Efficiency}} \textbf{ X } \textit{Discharge Pressure (kPa)}$$

Pumps/Fans Controls

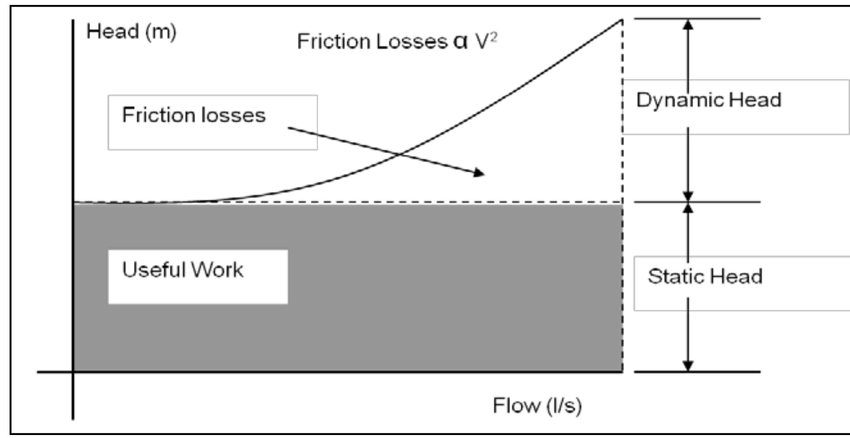
- To Control the performance efficiency, the approach is:
  - Reduction of hours of operation
  - Equipment efficiency
  - Flow reduction
  - Pressure reduction
- To control the hours of operation, the strategy is:
  - Manual control
  - Timers
  - Centralized building controls
  - Start-stop set points
  - Occupancy sensors

Pump Operation and Design Consideration

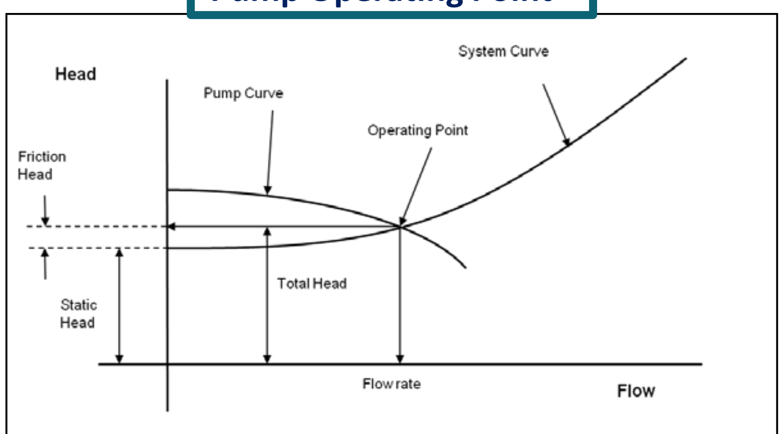
Pump Curve – Manufacturer Data Sheet



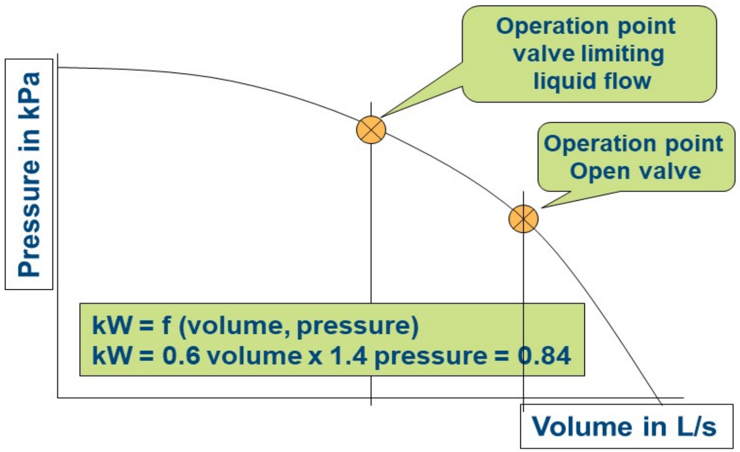
System Curve – Analysis and Study



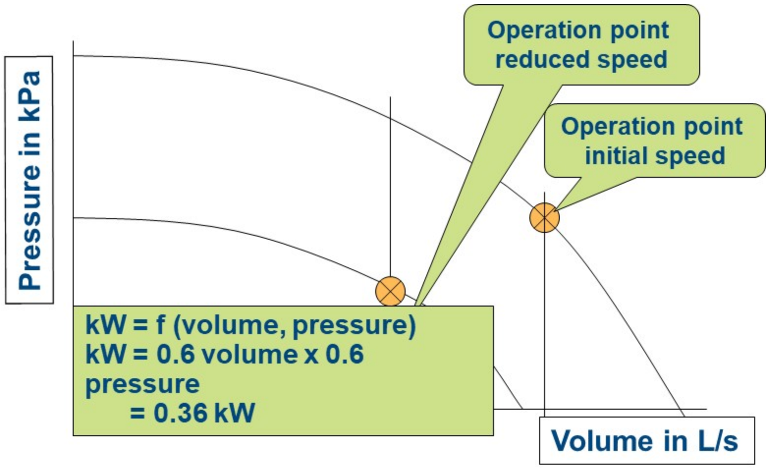
Pump Operating Point



Pump Flow Control Schemes



Flow control with throttling



Flow control with VSD

Compressed Air Systems

- Energy Efficiency Opportunities;
  - Reduction of air losses
  - Modification of distribution system
  - Modification of other systems
  - Compressor efficiency
  - Optimization of distribution pressure
  - Compressor control
  - Multi-stage compressors

Compressed Air Systems

- Potential Savings to Compressed Air Systems;
  - Leak reduction is a very cost-effective energy conservation measure.
  - The payback period is too short.

Hole diameter (mm)	Air consumption at 6 bar (g) m^3/min	Loss kW
1	0.065	0.3
2	0.240	1.7
3	0.980	6.5
4	2.120	12.0

Compressed Air Systems

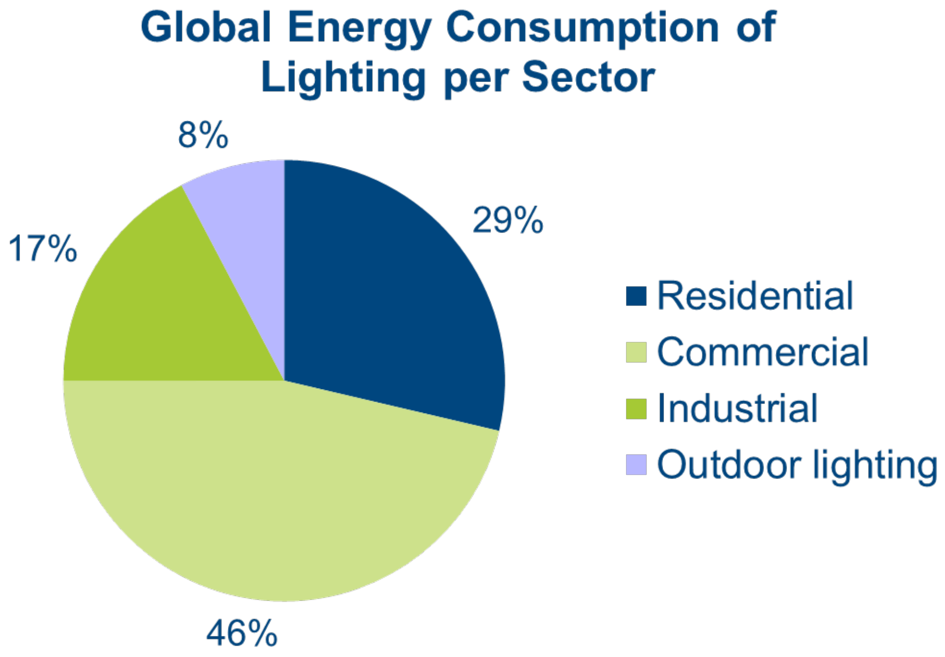
- Measures to consider;
  - Distribution system Modifications (if there are large pressure drops)
    - Pipe selection according to a pressure drop of 5% or less in initial pressure
    - Replace piping when the diameter is too small
    - Add new piping in parallel
    - Generously size filters, final coolers, air dryers and fittings
    - Replace fast fittings by fixed fittings for permanent tools
  - Compressor Efficiency;
    - Relocate inlet (colder air)
    - Replace standard motors with high-efficiency ones
    - Replace filters regularly: excessive pressure drop in filters also wastes energy
    - Choose the right air dryer; Desiccant or Refrigeration-based

Compressed Air Systems

- Measures to consider;
  - Multi Stage Compressors;
    - Two-stage flooded rotary screw compressors offer significant power savings over single-stage compressors.
    - Unless power is extremely inexpensive or the daily operational time is very short, two-stage compressors typically provide a return on the investment within the first two years of operation, and often within the first.
  - Air dryer optimization;
    - Air dryers can be a huge energy consumer.
    - The refrigeration type are usually good in terms of efficiency.
    - The absorption type used in the moisture-sensitive type should be carefully adjusted.
  - Venturi nozzles to reduce air flow;

Lighting Systems

- Lighting Systems Consumption Distribution;



Lighting Systems

- Objectives;
  - Discuss concepts and characteristics of energy-effective lighting design
  - Identify typical lighting energy conservation opportunities
  - Demonstrate lighting economics calculations and relationships

- Quality;
  - Color Rendering Index (CRI)
    - Indicates the effect on the color appearance of objects illuminated by the light source of a particular colour temperature
      - 90 – 100 CRI = Excellent color rendition
      - 75 - 85 CRI = Good color rendition
      - 55 – 70 CRI = Fair color rendition
      - 0 – 55 CRI = Poor color rendition.
  - Correlated Color Temperature (CCT)
    - The color appearance of light emitted from a light
      - < 3200 K = “warm” or red side of spectrum
      - > 4000 K = “cool” or blue side of spectrum

Lighting Systems – Definitions

- **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/m^2. (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

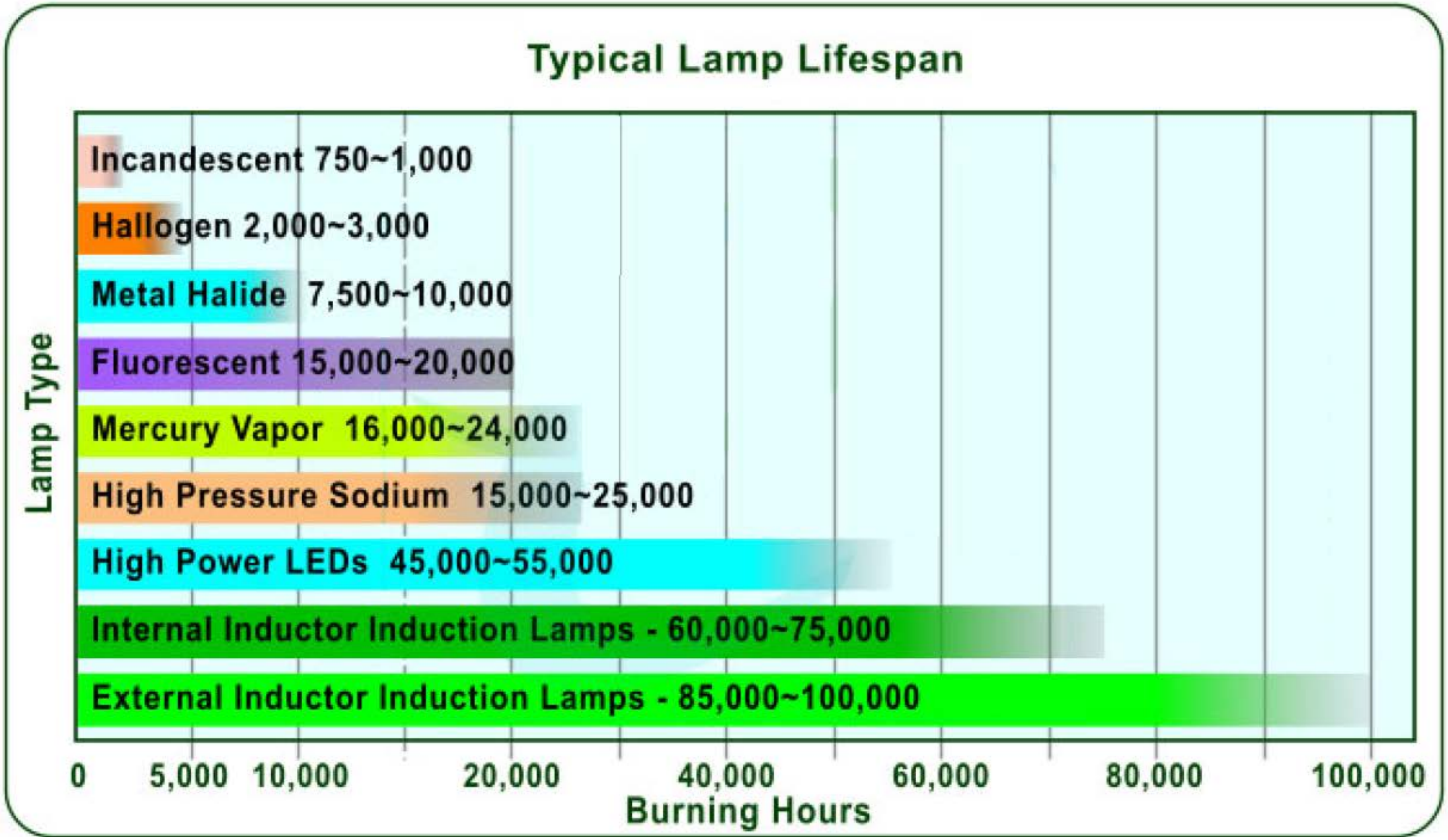
Typical Lighting Level

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

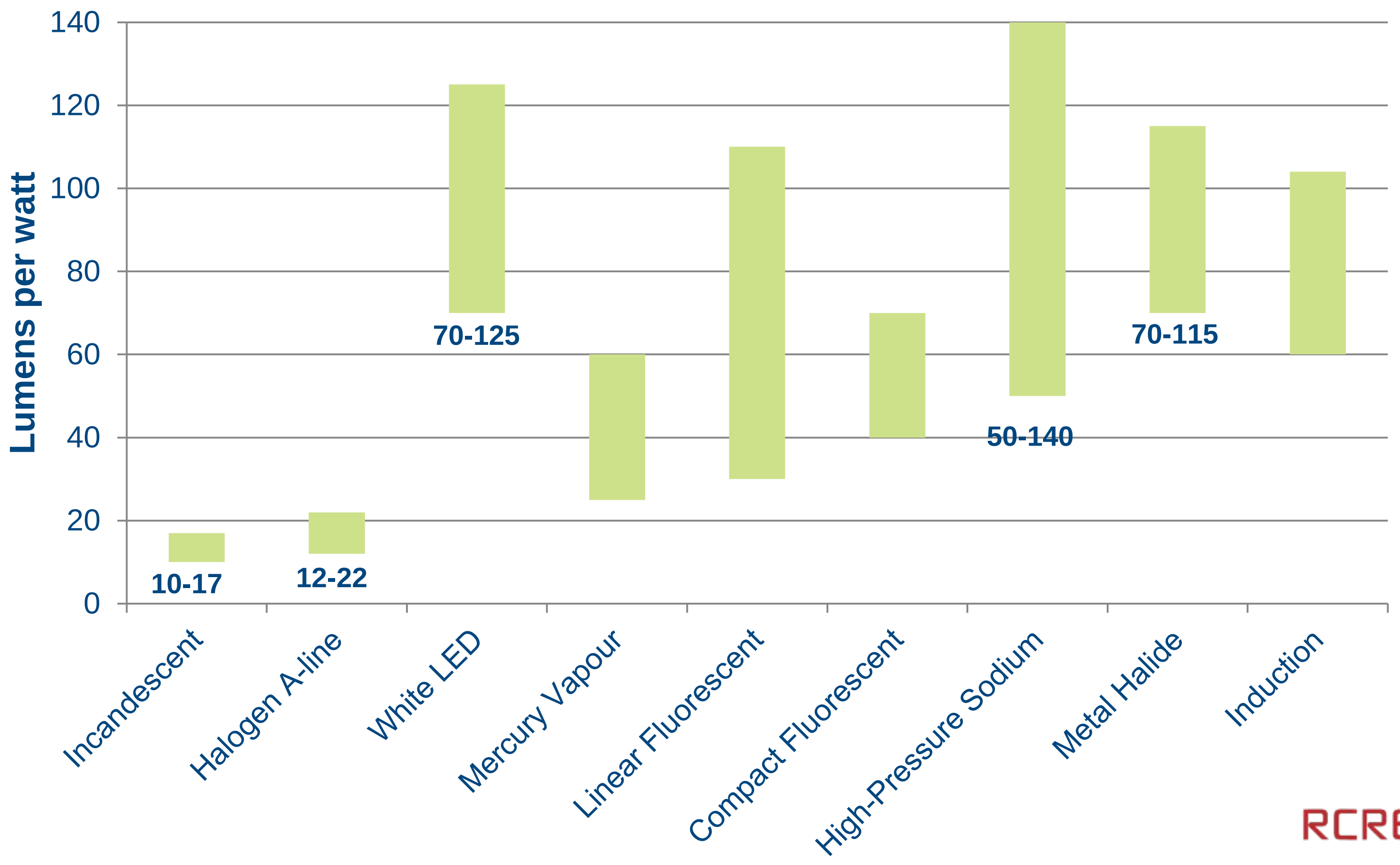
Lighting Source Technology

- Incandescent
- Halogen
- Metal halide
- Fluorescent
- Mercury vapour
- High-pressure sodium
- Induction
- LED

Typical Lifespan Of Various Light Source Technologies



Efficacy of Light Source Technologies



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