ENERGY EFFICIENCY IN ELECTRICAL SYSTEMS

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Outline

- Concept of Efficiency
- Energy Efficiency in Motors
  - Industrial and Commercial
- Energy Efficiency using Variable Speed Drives
  - Pumps, fans, blowers
- Energy efficient lighting
  - Selection of LED
  - Energy efficiency in street lights
    - Centralize and Decentralized control
- BEE Star Rating Program

Motors

- Electric motors convert electrical energy into mechanical energy. This energy is then used to drive a fan, a compressor, a pump or another rotating or oscillating part.
- A motor will draw as much energy as it requires moving the load.

$$\text{Motor Energy} = \frac{\text{(Motor Load) x (Operating Time)}}{\text{(Motor Efficiency)}}$$

- Motor Load (hp) = $\sqrt{3}$ x V x I x pf x Eff / 0.746

  Where

  hp = horsepower, V = voltage , I = current (amps)

  pf = power factor, and Eff = efficiency

Energy Efficient Motors

- Energy-efficient motors (premium) or high- efficiency motors are 2 to 8% more efficient than standard motors.
- Motors qualify as "energy-efficient" if they meet or exceed the efficiency levels listed in the National Electric Manufacturers Association' (NEMA)
- Improvement in efficiency is by reducing losses
- Reduction in losses is achieved by using high quality material and improvement in design and manufacturing process
- There is a slight variation in efficiency between part load and full load condition
- Short payback period and substantial savings after pay back period

Energy Efficient Motors - Example

- Rewinding cannot and does not improve a motor's efficiency beyond the motor's original nameplate rating.
- Assume you have a serviceable standard-efficiency (pre-EPAct), 5-hp, 1800-rpm, 208-230/460-V, with average efficiency of 84%
- Operating period is 8000 hours (11 months) per year at 75% of full load and the power costs $0.075/kWh

Source:http://www.copperindia.org/

Energy Efficient Motors - Example

- The motor will consume 26,644 kWh of energy annually
- The annual cost of operating this motor will be **[0.746(W/hp) X 5(hp) X 0.75(load factor) X 8000(h/y) X $0.075/kWh)]/0.84(efficiency) = $1998.21**
- NEMA Premium motor that has an efficiency of 90.5% at 75% of full load
- The annual energy consumption and cost savings are1914 kWh and $144, respectively, over the standard model.
- Typical cost of such motor is $302, and it hence pay back is approximately 2.10 years.

Source: *http://www.copperindia.org/*

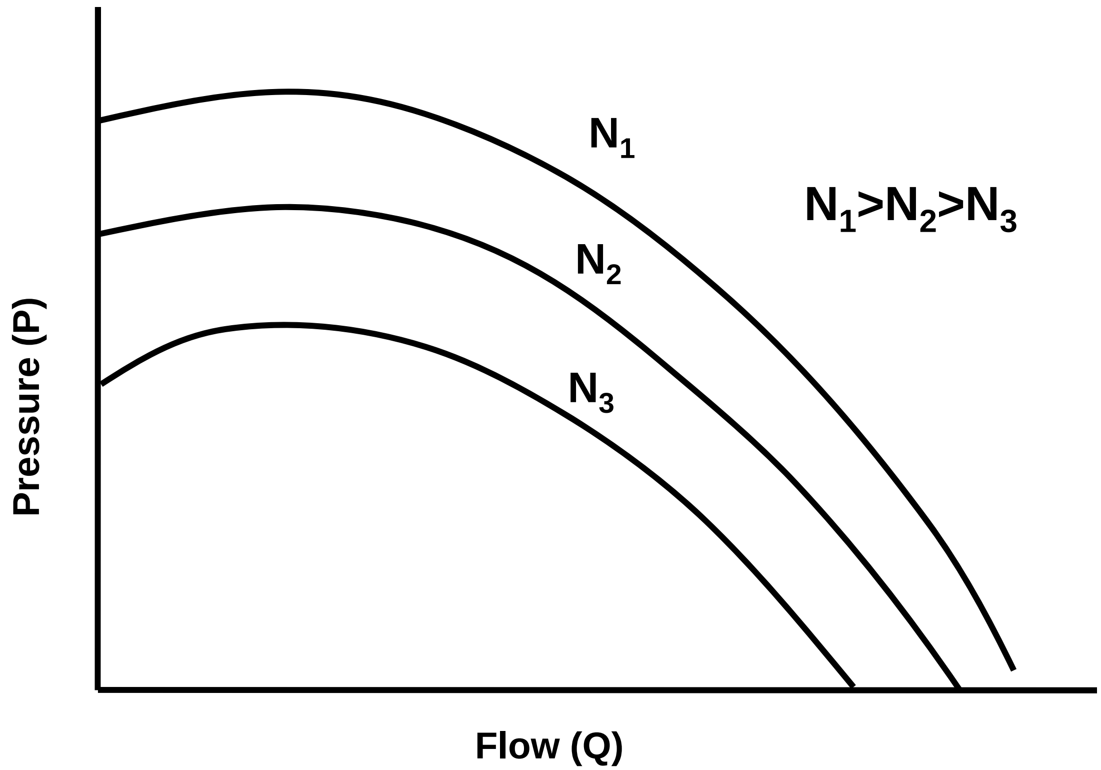
Energy Efficient Motors - Example

HP	Eff. at 75% load	Annual Energy Use (kWh), cost	% Eff at 75% load	Annual Energy Use (kWh), cost	Annual Savings, kWh, $	Payback Period
5	84.0%	26,644	90.5	24,729	1,914	2.10
		$1,998		$1,855	$144	
10	86.75	51,653	92.2	48,547	3,106	2.22
		$3,874		$3,641	$233	
15	87.55	76,771	92.6	72,815	3,955	2.11
		$5,758		$5,461	$297	
20	89.3%	100,206	93.4	95,846	4,360	2.52
		$7,515		$7,188	$327	
25	89.9%	124,457	94.0%	119,043	5,415	2.62
		$9,334		$8,928	$406	

Variable Speed Drives

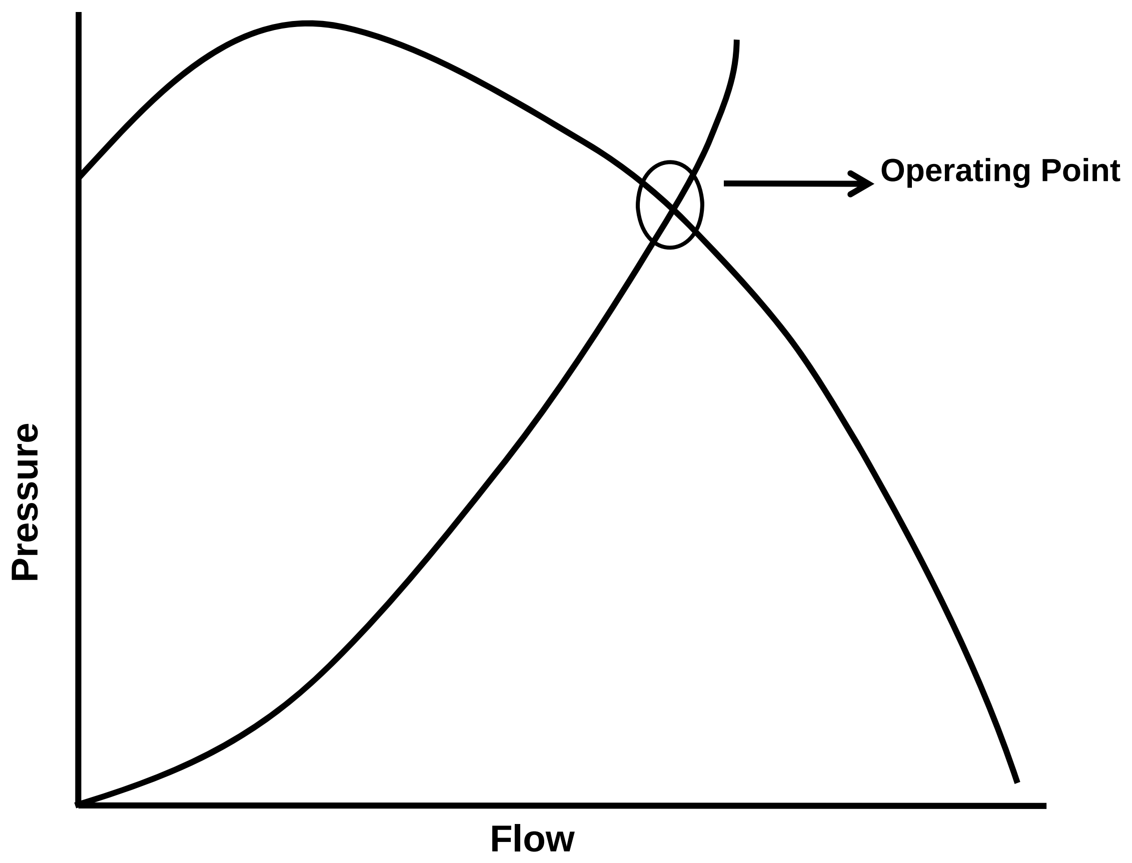
- Induction motor is the major converter of electrical energy into mechanical in industry.
- About two thirds of the electrical energy produced is fed to motors (fans, blowers and pumps).
- Fans and pumps are designed to be operate at rated demand and maximum demand of the system in which they are installed.
- It is obvious that their operating point could vary and is less than the maximum demand.
- It is possible to control speed/flow by using simple outlet dampers to fans or throttling valves to pumps.
- These control methods are effective, inexpensive and simple, but severely affect the efficiency of the system.

Fan Curve



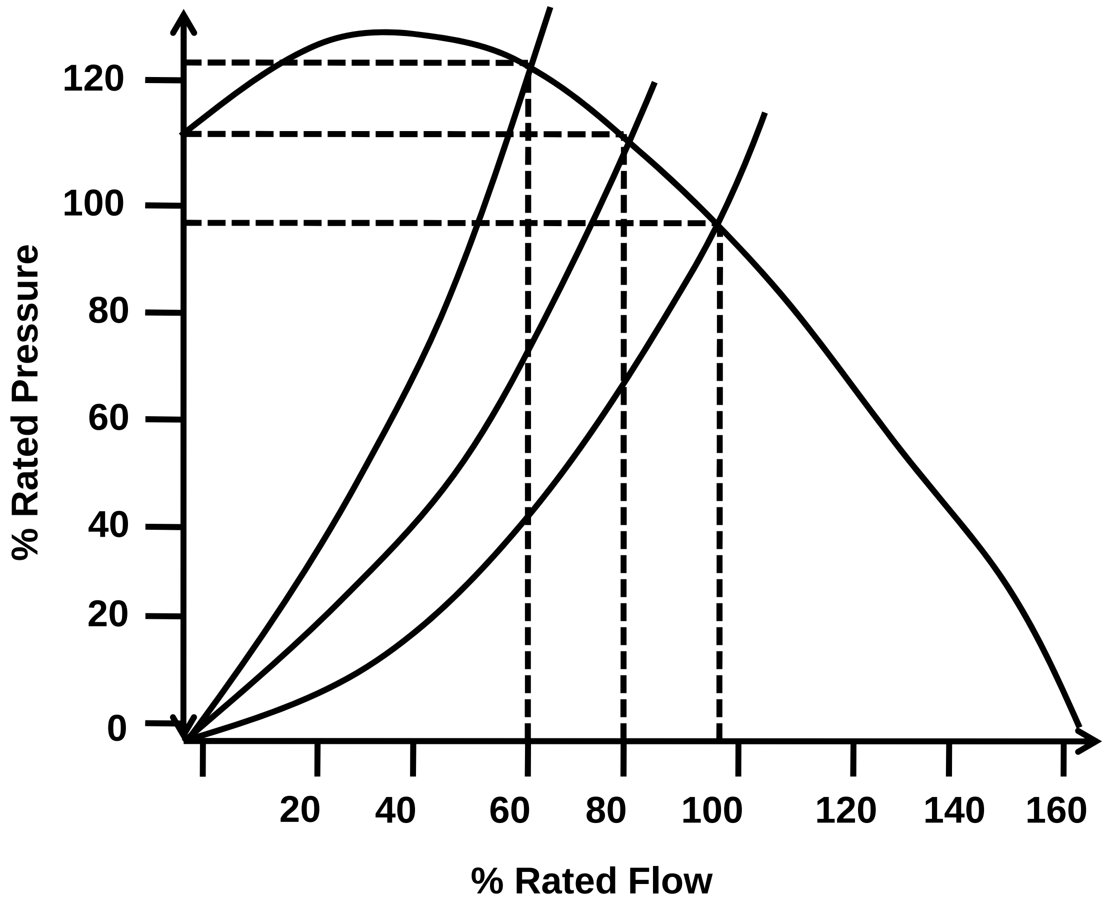
$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1} \qquad \frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^2 \qquad \frac{W_2}{W_1} = \left(\frac{N_2}{N_1}\right)^3$$

System Curve – Operating Point

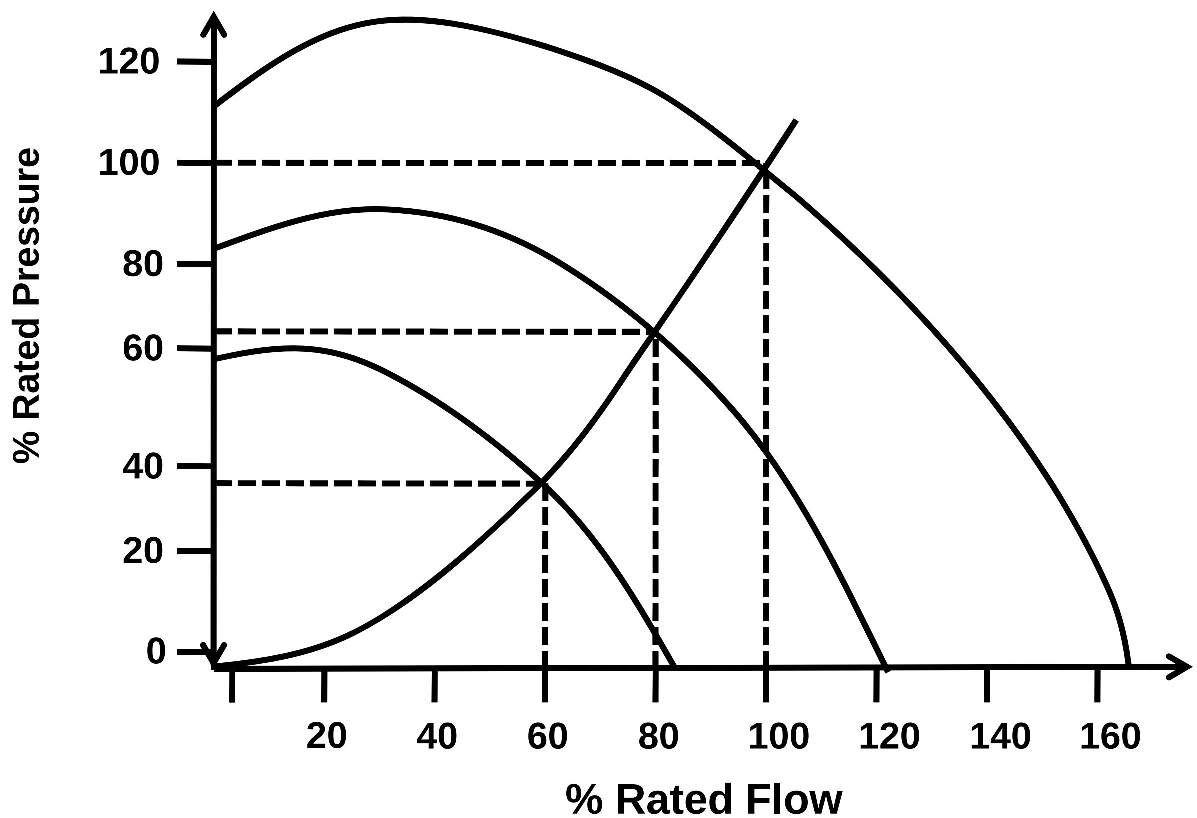


Source: http://nptel.iitm.ac.in/

Flow Control - Dampers



Flow Control – Variable Speed Drive

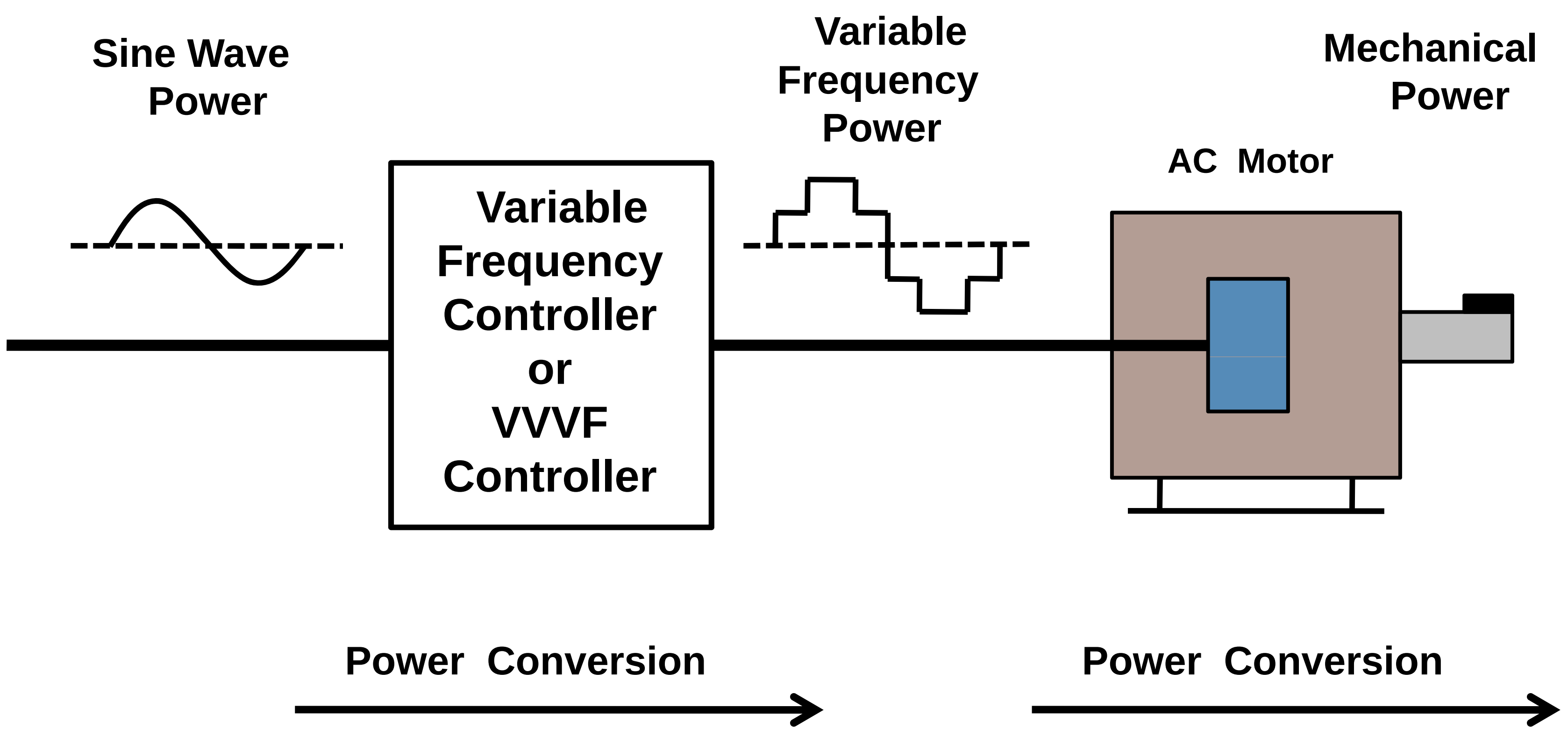


Flow Control - Example

Flow (cfm)	Duty Cycle	Power (hp)	Weighted Power(hp)	Power (hp)	Weighted Power(hp)
100	10	35	3.5	35	3.5
80	40	35	14.0	18	7.2
60	40	31	12.4	7.56	3.024
40	10	27	2.7	2.24	0.224
Total			32.6		13.948
Hr/Month			730		730
kWh/Month			17,753		7,596
Cost (Rs/kWh)			2.00		2.00
Total Cost			Rs. 35,506		Rs. 15,192

Source: ***http://nptel.iitm.ac.in/***

Variable Speed Drive



Source http://en.wikipedia.org/wiki/Variable-frequency_drive

Why study Light?

- Light is an extremely efficient way of altering perception
- Improve weight gain in premature infants.
- Increase the length and quality of sleep.
- *"Some researchers believe that even very low levels of blue light during sleep might weaken the immune system and have serious negative implications for health."*
- Bad lighting can ruin perfectly good design
- Light can alleviate seasonal depression.

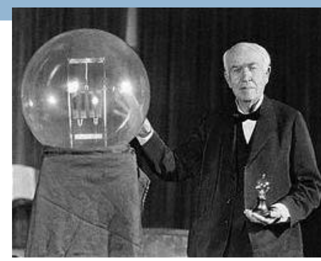
Consumption in India

- One-fifth of electricity consumption in India is through lighting
- Lighting contributes significantly to peak load
- A large portion of total lighting is used in inefficient technologies
- About 400 million light points in India today are lighted by incandescent bulbs; their replacement by CFLs would lead to a reduction of over 10,000 MW in electricity demand.
- Bachat Lamp Yojana – CFL @ Rs. 15 per piece – rest of money is claimed through CDM

Why Energy Efficiency in Lighting?

- High and rising energy prices
- Change in Global Climate
- Exhaustion of Non Renewable Sources for electricity generation
- Leads to reduction of investment for expansion of electric power sector

Types of Lighting



- Incandescent lamp
- Gas Discharge lamp
  - Low pressure discharge (Fluorescent, CFL, LPSV)
  - High pressure discharge *(metal halide, HPSV, high pressure mercury vapor)*, HID family

- Solid State Lighting
  - Light Emitting Diode (LED)
  - Organic Light emitting diode (OLED)

Comparing Commercial Lamps

	Incandescent		Fluorescent		HID	
	Standard	**Halogen**	**Full-Size or U-bent**	**Compact**	**Metal Halide**	**High-Pressure Sodium**
Wattage	3-1,500	10-1,500	4-215	5-58	32-2,000	35-1,000
Lamp Efficacy	6-24	8-35	26-105	28-84	50-110	50-120
Average Rated Life (hours)	1000-3,000	2,000-4,000	7,500-24,000	10,000-20,000	6,000-20,000	16,000-35,000
CRI (%)	99	99	49-96	82-86	65-96	21-65
Start-to-Full Brightness	immediate	immediate	0-5 seconds	0-5 minutes	1-15 minutes	4-6 minutes
Re-Strike Time	immediate	immediate	immediate	immediate	2-20 minutes	1 minute
Lumen Maintenance	very good	excellent	very good	good	fair/good	very good

Source: American Council for Energy Efficient Economy

Energy Efficiency Techniques

- Use of Day light, turn off the lights when not required
- Proper maintenance of lamps
- Replacement with energy efficient lamps
- Incorporate proper lighting controls
- **Use of electronic chokes instead of conventional electromagnetic ballasts**
- Use of dimming controls
- Use of 28 watt T5 instead of 40 watt standard FTL

How to choose in CFL?

Incandescent bulb (W)	Minimum Light Output (lumens)	CFL (W)
40	450	9 – 13
60	800	13 – 15
75	1100	18 – 25
100	1600	23 – 30
150	2600	30 – 52

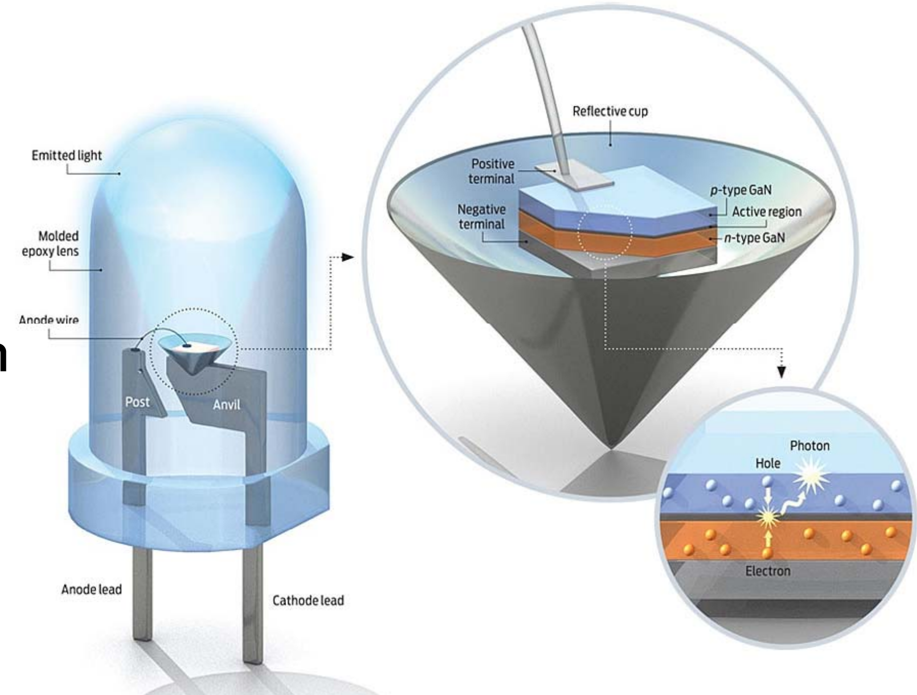
Type	Purpose	Temperature
Warm White and Soft White	Standard replacement of Incandescent Bulb	2700 – 3000 K
Cool White and Bright White	Good for Kitchen and Work Spaces	3500 – 4100 K
Natural or Day light	Reading	5000 – 6500 K

More Light from Less Power - LED

- It is essentially a semi conductor diode
- It consists of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction
- When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon (light).
- The specific wavelength or color emitted by the LED depends on the materials used to make the diode.

More Light from Less Power - LED

- Red LEDs are based on aluminum gallium arsenide (AlGaAs).
- Blue LEDs are made from indium gallium nitride (InGaN)
- Green from aluminum gallium phosphide (AlGaP).
- "White" light is created by combining the light from red, green, and blue (RGB) LEDs
- White - by coating a blue LED with yellow phosphor.



Source: Energy Star

More Light from Less Power - LED

- No Mercury
- CRI of 92, some LED lights are dimmable
- Long Life (> 50000 hrs), high efficacy (160 lm/W@350mA)
- They generally consume 80% less power than incandescent lamp and 50% of CFL.
- 12W LED can replace 65W Incandescent??

How to choose an LED? Step1

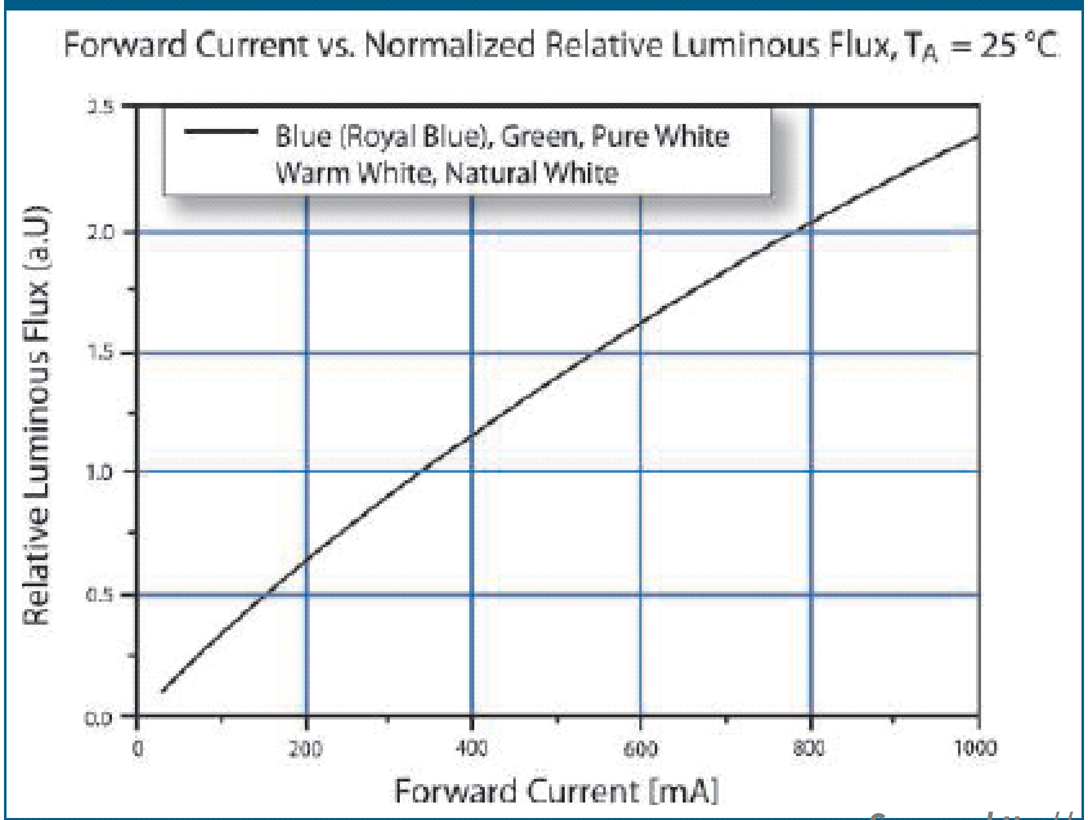
LED	lux	Drive Current	Test temp (^{0}C)
MFR 1	91 lm	350 mA	T_A 25
MFR 2	107 lm	350 mA	T_J 25
MFR 3	130 lm	700 mA	T_A 25
MFR 4	100 lm	350 mA	T_{pad} 25

- Purchase decision shall not be made on top line numbers
- Light output, light efficacy, lumen maintenance, operating temperature

How to choose an LED? Step 2

- 70% output after 50000 hours
- Maximum output at any instant

FIGURE 1: EXAMPLE OF FLUX NORMALISATION GRAPH



Source: http://www.philipslumiled.scom

How to choose an LED? Step 2

LED	lux	Normalized lux	Test temp (^{0}C)
MFR 1	91 lm	164 lm	T_A 25
MFR 2	107 lm	182 lm	T_J 25
MFR 3	130 lm	130 lm	T_A 25
MFR 4	100 lm	165 lm	T_{pad} 25

- LED from MFR 3 is the giving least lumen output at 700 mA
- We are not comparing all the LEDs at common temperature, use temperature derating graphs

How to choose an LED? Step 3

LED	Normalized lux	Data sheet T_J max	Operating T_J for T_A of 25^0C	Flux derrating factor	Actual Flux
MFR 1	164 lm	145	135	72%	118 lm
MFR 2	182 lm	150	128	78%	142 lm
MFR 3	130 lm	125	141		
MFR 4	165 lm	150	130	81%	133 lm

- MFR 3 Exceeds maximum junction temperature at this operating condition
- Check for output lumen after 50,000 hours

How to choose an LED? Step 4

LED	Actual Flux	Data sheet T_J max	Operating T_J for T_A of 25^0C	L70/50kh conditions	Current to achieve lumen maint.	Actual Flux
MFR 2	142 lm	150	128	T_J<85C	407 mA	107 lm
MFR 4	133 lm	150	130	T_J<135C	700 mA	133 lm

- MFR 2 – To achieve 50k hrs, the LED shall be operated at 407 mA at T_J at 85^0Cand it delivers a 107 lm at the end of 50000 hrs
- Off the shelf drivers are available for 350 mA and 700 mA

Source: http://www.philipslumiled.scom

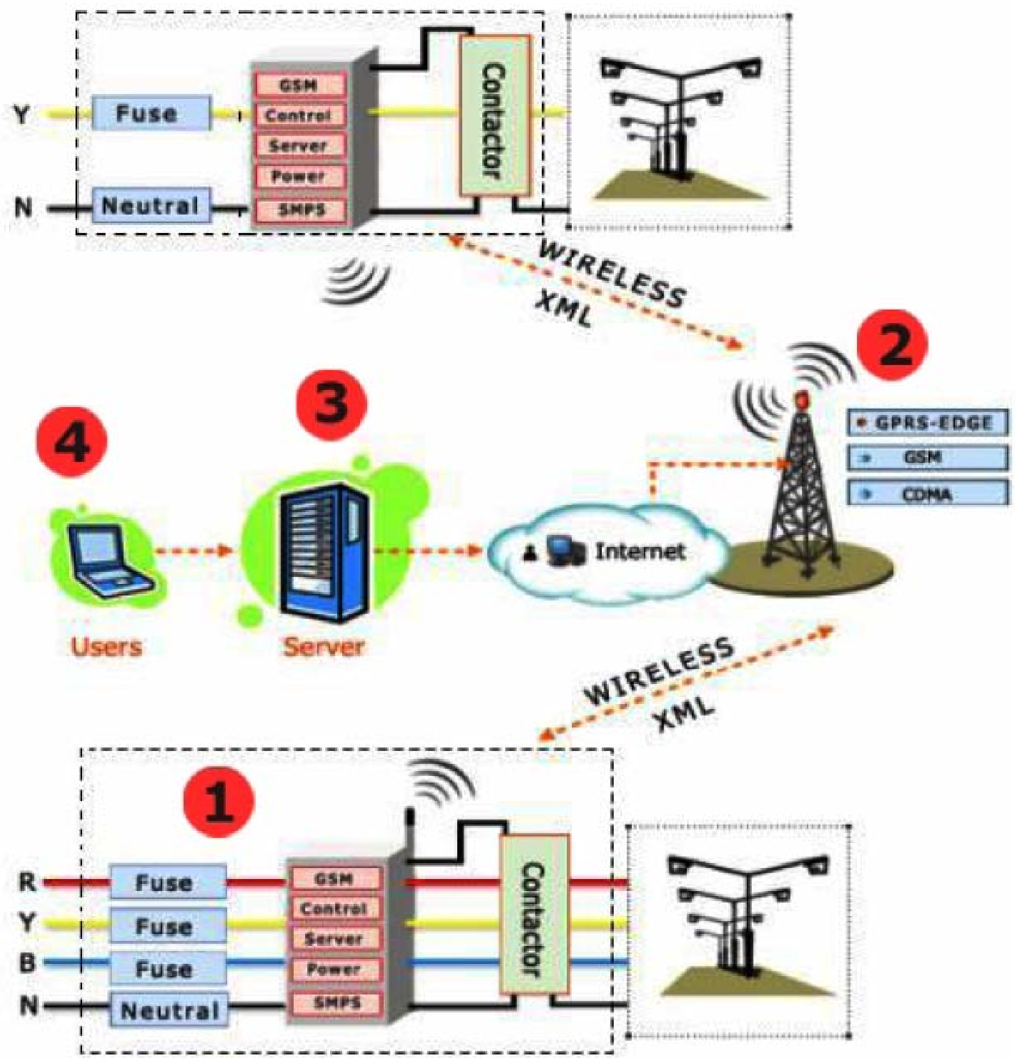
Lighting Controls

- Types
  - Infrared sensors
  - Motion sensors
  - Automatic timers
  - Dimmers
- SCADA, GSM/GPRS based centralized control system for street light
- Save energy by on/off and dimming
- Up to 40% energy saving in street lights without replacing existing fixtures

Energy Efficiency in Street Light

- Street light contribute to peak power consumption
- Replacement with high efficient bulbs and fixtures
- Electronic Timer
- Nature Switch
- Dimmable ballast or Magic Box
- Voltage regulator
- Centralized control using GSM/SCADA
- Regular maintenance of fixtures
- Power factor improvement techniques

Street light control system - Architecture



Source: M2M Brochure

Centralized control of street lights

- Load balancing information (voltage, current & pf)
- Exact identification of failure (Fuse, CB, Power failure status)
- Lamps glowing and non glowing information
- Theft and functioning of switch gear
- Twilight based
- Alternate lighting pattern is possible
- Dimming can be incorporated
- Communication via SMS/GPRS/EDGE/Radio/CDMA
- Number of hours of glowing, complete MIS

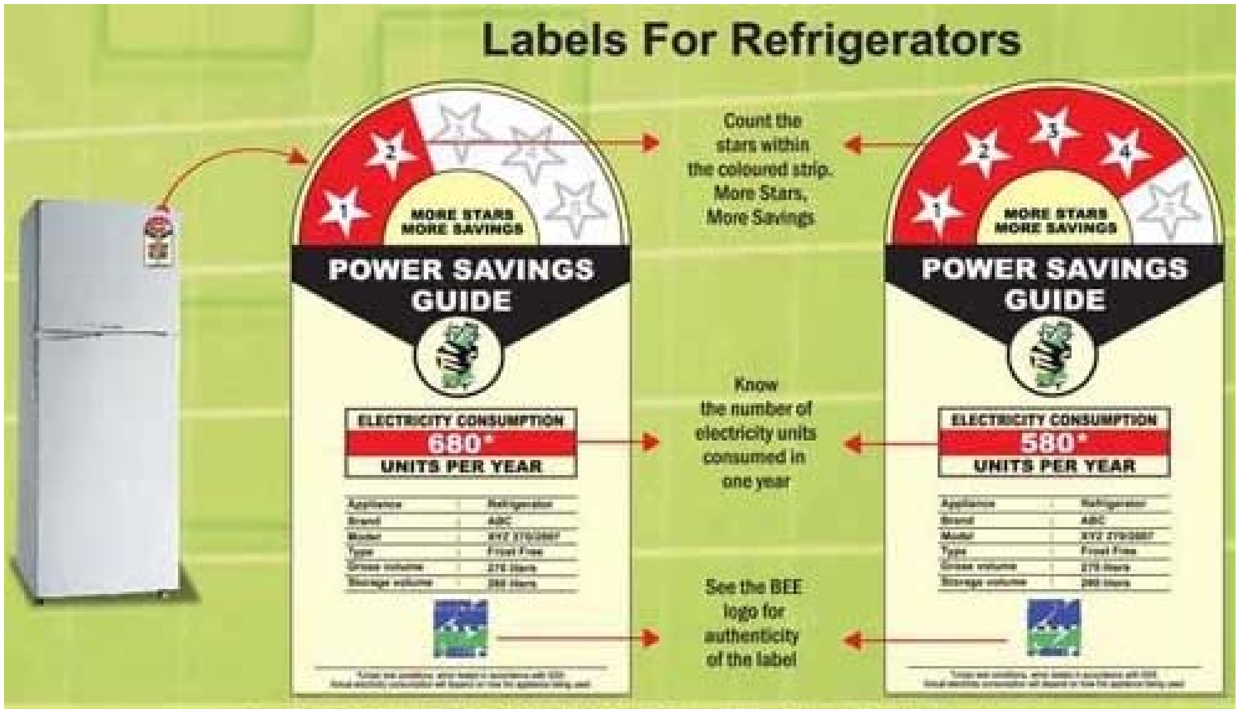
Energy Efficiency/Saving projects

- Does street light required such complex architecture? What will be the implementation cost?
- Energy Saving Company (ESCO) – BEE listed
- Investment is done by ESCO and financial risk to the municipal corporation or government is low
- Return on Investment is obtained to ESCO based on savings
- Sharing of profits on public private partnership (PPP) mode
- CDM benefits

BEE Star Rating Program

- Energy efficiency labels are created to standardize the energy efficiency ratings of different electrical appliances
- Also indicate energy consumption under standard test conditions.
- One star (lease energy efficient) to Five star (More energy saving)
- Applicable for refrigerators, air conditioners, buildings, tube lights etc.

BEE Star Rating - Refrigerator

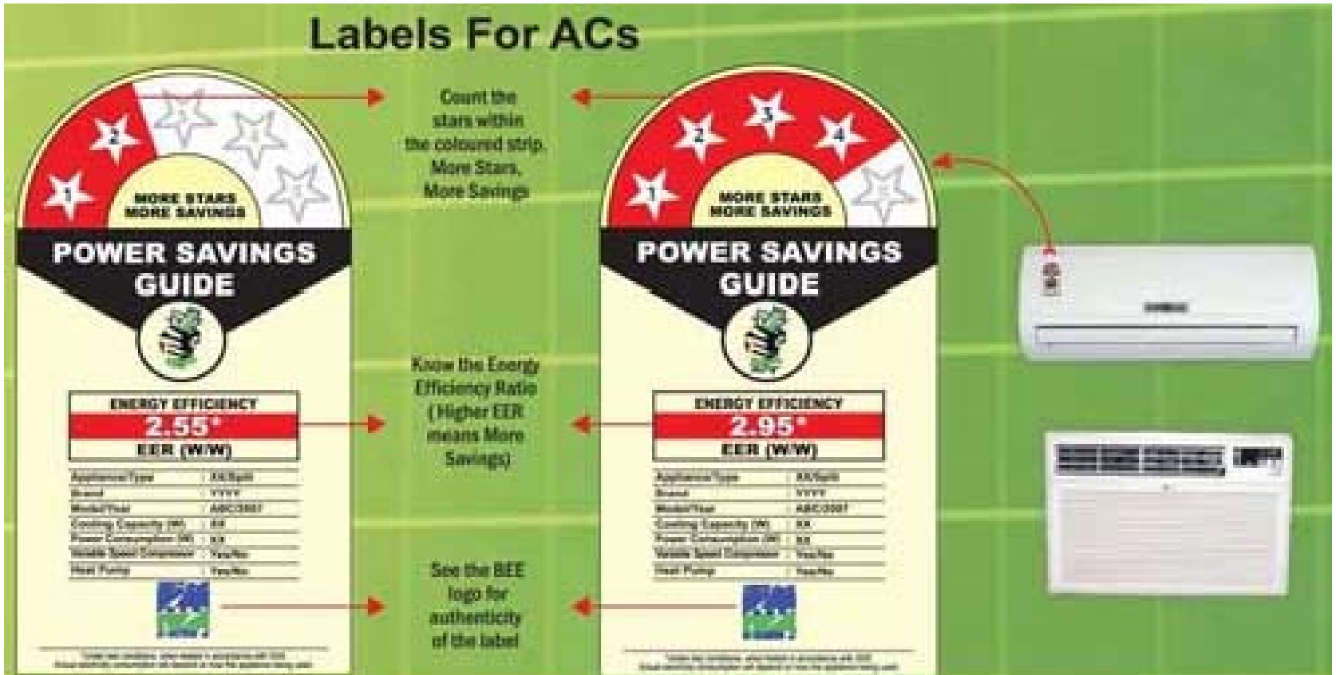


Energy and Cost saving for 250 Litres Frost Free Refrigerator at different Star Rating

Star Rating	Energy Consumption Per Year (Approx.)	Per Unit Charge Rs. (approx.)	Electricity Cost/Year in Rs.	Total Saving (w.r.t No star) Every year (Rs.)	Refrigerator Cost in Rs. (Approx.)	Cost Difference Rs.	Pay Back Period in Years
NO STAR	1100	2.50	2750	0	14000	0	0
1 (One)	977	2.50	2443	308	15000	1000	3.25
2 (Two)	782	2.50	1955	795	15500	1500	1.89
3 (Three)	626	2.50	1565	1185	16500	2500	2.11
4 (Four)	501	2.50	1253	1498	17500	3500	2.34
5 (Five)	400	2.50	1000	1750	18500	4500	2.57

Source: www.bee-india.nic.in/

BEE Star Rating – Air Conditioner



Energy and Cost saving for 1.5 Ton Windows or Split Air conditioner at different Star Rating

Star Rating	Maximum Cooling Capacity (Watts)	Minimum Energy Efficiency Ratio (EER)	Input Power (Watts)	Units consumption /Day (kWh)	Per Unit Charge Rs. (approx.)	Electricity Cost/ Month Rs.	Cost Saving Rs. Per Year (w.r.t. No star) (Approx.)
NO STAR	5200	2.20	2364	9.45	2.50	709	0
1 (One)	5200	2.30	2261	9.04	2.50	678	308
2 (Two)	5200	2.50	2080	8.32	2.50	624	851
3 (Three)	5200	2.70	1926	7.70	2.50	578	1313
4 (Four)	5200	2.90	1793	7.17	2.50	538	1712
5 (Five)	5200	3.10	1677	6.71	2.50	503	2059

Note: Assuring 8 hrs. operation per day for five months in a year

Source: www.bee-india.nic.in/

Thank You