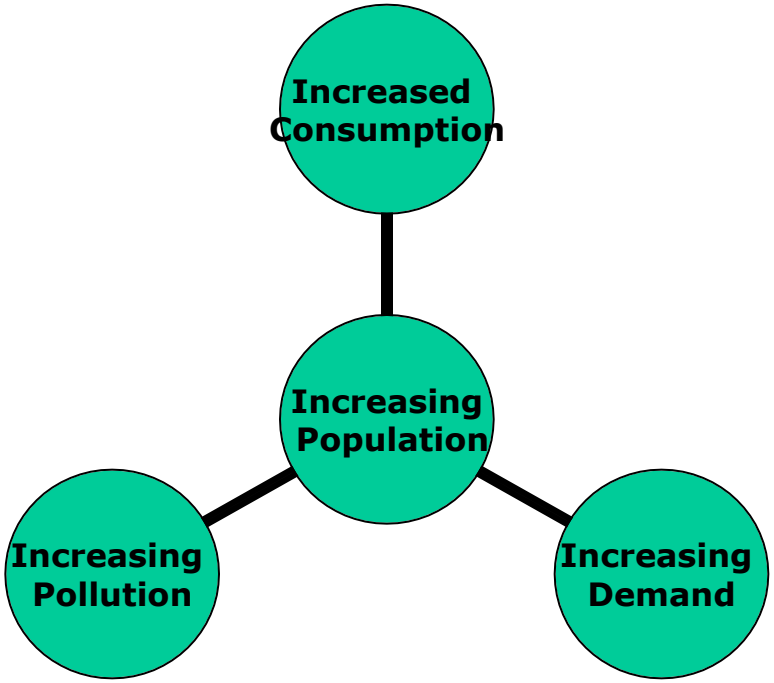
ELG4126
Sustainable Electric Systems in Building



What is Sustainable Development

- Sustainable Development (SD) is a simple way of ensuring a better quality of life for everyone, now and for generation to come. It refers to a perspective that considers all three aspects which are **social**, **economics** and the **environment**.
- Designing an electrical system with sustainability refers to an approach that considers the use of renewable energy, energy efficiency, conservation and minimising usage of natural resources.
- SD implementations can be grouped into four main areas, namely:
  - Supplementing consumption with renewable energy
  - use of high energy efficiency equipment.
  - by design and also
  - Adopting SD awareness among employees.

The Three “R”s

- Sustainable Development is elaborated on the three ‘R’s strategies in order to achieve its goal.
- The three ‘R’s are ‘Reduce’, ‘Reuse’ and ‘Recycle’.
- ‘Reduce’ is the main part being targeted with the aim of reducing consumption of energy and resources. And by virtue of reduced consumption, there is also less waste being generated which needs to be disposed of.
- Next is ‘Reuse’ which is targeted for waste materials which are unavoidable by-products of industrial processes or human consumption. Waste materials which cannot be reused will be recycled.
- Among the three, recycling is the least emphasized because after substantially reducing consumption, and reusing the wastes and by-products, there would be very little left to recycle. Moreover, recycling is not completely an environmental friendly process because it requires energy to convert it into another form.

SD Implementation in Buildings

- Solar water heater system for shower room.
- Use of high energy efficient lighting system, for example fluorescent light fittings with electronic ballasts, mirror reflectors, high output and long life lamps.
- Use of high efficiency equipment and minimise power distribution losses; e.g. high power factor motors; high efficiency transformers; larger conductor size and good power supply quality.
- Variable speed drives system for air compressor motor control which could improve energy saving.
- Monitoring of electrical energy consumption by installing meters at selected feeders for buildings and high energy users.

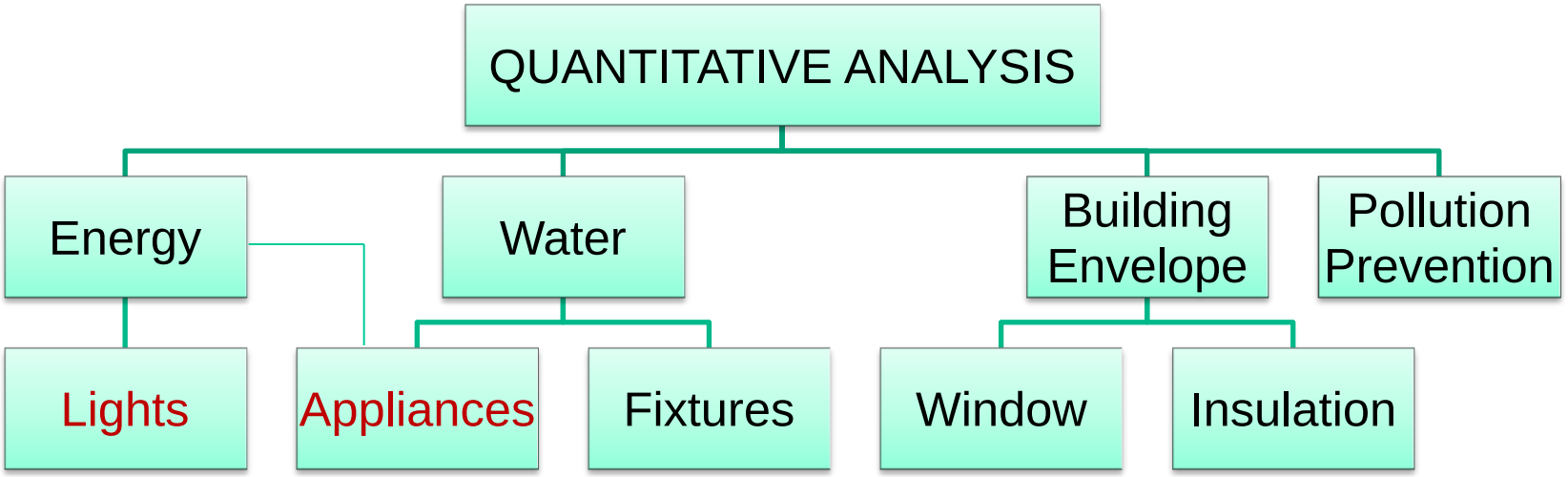
- Building design to have low thermal mass and reduce solar heat gain, e.g. use of insulating bricks for outer walls, double-glazed windows, insulated roof with natural ventilation or wind driven ventilators., etc.
- Use dynamic UPS as a reliable power source to the extruder machine instead of a continuously running diesel generator.
- Make provisions to allow future installation of photo-voltaic solar panels when their costs are more attractive.
- Incorporate designs which allow some electricity usage to be shifted to off-peak hours.

Facts: From the United States

Buildings in the United States account for:

- 36% of total energy use and 65% of electricity consumption.
- 30% of raw materials use.
- 30% of waste output which is 136 million tons annually.
- 12% of potable water consumption.
- 49% of sulfur dioxide emissions.
- 25% of nitrous oxide emissions.
- 10% of the particulate emissions.
- 35 % of the carbon dioxide emissions.

Loads in Various Building Systems



Lighting

Lighting energy use can be substantially reduced by:

- **Day Lighting**
- Installing **efficient lighting devices** such as LED, CF, and fluorescent lights).
- **Task Lighting**
- **Controls:** Developing habits of turning off lights when not needed (or using motion, heat or light sensors to control when lights are on or off).

Type of Bulb; Number of Bulbs; Wattage; and Usage

$$\text{Annual Energy Consumption} = \frac{\text{Number of Bulbs} \times \text{Wattage} \times \text{Usage per day} \times \text{Days used}}{\quad}$$

(Source: DOE FEMP)

Efficiency Recommendation			
To Replace Incandescent Bulb Rated at	**Necessary Light Output (Lumens)**	**Typical CFL Replacement Wattage**	**Recommended CFL Lumens per Watt (lpW)**
Bare Bulbs			
40 watts	495 or more	11 - 14 watts	45 lpW or more
60 watts	900 or more	15 - 19 watts	60 lpW or more
75 watts	1200 or more	20 - 25 watts	60 lpW or more
100 watts	1750 or more	≥29 watts	60 lpW or more

Estimating Electrical Energy Consumption

Electric meter reads **energy** in units of kW-hr or kWh.

Energy = Power x Time

kW-hr or kWh = kW x hours

To find **energy consumption:**

Read the power off the device in watts, divide by 1000 to find kW, and then multiply by the hours of use.

Example: Lighting Energy Use

Example: Two 100 watt light bulbs left on for 8 hours every day for a month (= 30 days)

Energy = Power (kW) x Time (hrs)

Step 1: Convert to kW

200 watts (1 kW / 1000 watts) = 0.2 kW

Step 2: Calculate energy

0.2 kw x 8 hrs = 1.6 kw-hr of electricity per day

30 times 1.6 kw-hr = 98 kw-hr per month

Step 3: Calculate the cost

What did you pay? At 15 cents per kw-hr, the cost is $14.70/month. Over a year, it costs $176.40

Day Lighting

Place most used rooms in the daytime on the **south side.**

Provide light from **two or more sides** of the room.

Open curtains and shades in the heating season.

Light-colored surfaces reflect light better (walls and ceilings).

Best Practices in Lighting Systems

- Installation of energy efficient fluorescent lamps in place of conventional fluorescent lamps.
- Installation of Compact Fluorescent Lamps (CFLs) in place of incandescent lamps.
- Installation of LED panel indicator lamps in place of filament lamps.
- Installation of high frequency (HF) electronic ballasts in place of conventional magnetic ballasts.
- Use of high efficacy light sources for reducing the energy consumption for lighting .
- Solar Lighting Systems are providing to be a viable option in rural India because it involves no moving parts, low maintenance, and are simple to operate.

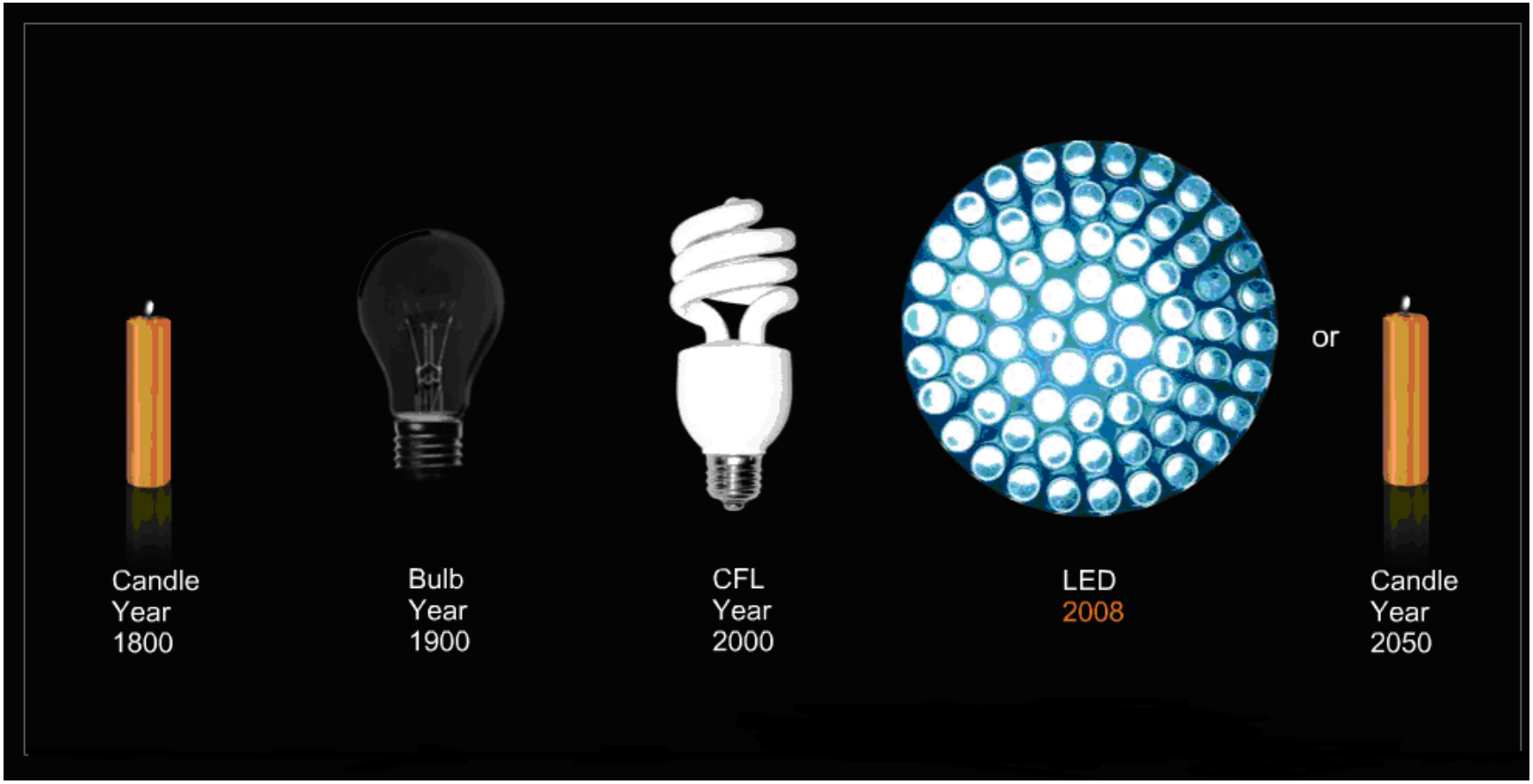
High Frequency Electronic and Magnetic Ballasts

- Energy savings about 30 to 50 %.
- Lights instantly.
- Improved power factor (more than 0.90 power factor).
- Less heat dissipation, which reduces the air conditioning load.
- No audible humming sound.
- No stroboscopic effect.
- Operates in low voltage.
- Less in weight.
- Increases the life of lamp.

LEDs

- LED is a light emitting semiconductor diode that emits light in forward direction or in the direction it is pointed towards.
- LEDs are most often used in the form of an indicator light in electronic devices, traffic signal lights, musical instruments and dashboards in cars and in houses, etc.
- The color of the light produced by LED depends on the composition of the semiconductor material used out of which producing a blue color light is the most difficult process.
- The nature of the light emitted can be visible, infrared or ultraviolet.
- Most modern LEDs are undergo superior design and manufacturing process that gives them a lifespan of up-to 1,00,000 hours, compared with 10,000 for a compact fluorescent and 1,000 for an incandescent bulb.
- Lifespan of a LED bulb could come down due to the amount of heat a LED produces. This directly depends on die temperature and ambient temperature of the LED.
- Some LED light bulbs show sign of age after a couple of years of use and may produce only 50% of the light output when compared to what it used to produce when it was new. However new technologies are in process to enhance its performance over its life span.

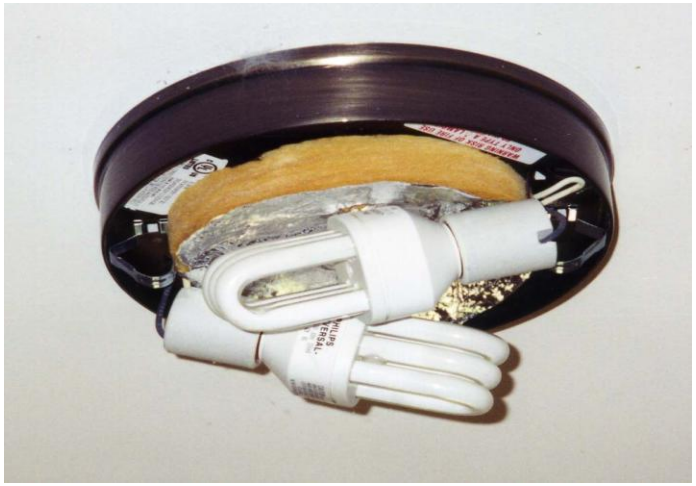
Changing Scenario of Lamps



Fluorescent Fixtures

Fluorescent fixtures are especially important in places where the lights are used extensively, like kitchens, playrooms, and living rooms. CFL’s, and LEDs are the most efficient.

Compact Fluorescent Bulbs



CF bulbs are 4x as efficient as incandescent lights. Many are equivalent in size to standard incandescent bulbs.

How to Choose Your CF bulbs?

- Energy Star rated CF's must meet higher standards and will last longer
- Choose the right size (follow recommendations)
- Choose the right color (daylight, cool white, warm white) for your application (try one and see if you like it)
- Make sure it has a flicker-free, electronic instant -start ballast

Types of Fluorescent Lights

- **Ballast:** It activates the low pressure gas inside the bulb by varying the current (used in all fluorescent bulbs). Better choose electronic ballasts and instant-start flicker-free bulbs.
- **Integral compact fluorescent:** Single unit (most common)
- **Modular compact fluorescent:** Separate ballast and tube
- Ballasts can last 50,000 hours while bulbs may last 10,000 to 20,000 hours.

Energy and Environmental Savings

- A single 18 watt CF bulb replacing a standard 75 watt incandescent bulb saves over its lifetime of 20,000 hours
- 570 kw-hr of electricity.
- $85.50 of electricity at 15 cents per kw-hr.
- 500 lbs of coal.
- 1300 lbs of carbon dioxide.
- 20 lbs of sulfur dioxide.

Lighting Controls

- Save energy and reduce peak demand.
- Cut maintenance costs by increasing lamp life.
- Integrate daylight and electric light with control systems/photocells.
- Increase productivity in building with personalized control in private areas.
  - Simplest and cheapest strategy; turn off the lights manually when not in use.
  - Heat sensors (occupancy).
  - Motion sensors (occupancy).
  - Light sensors (for outdoors).
  - Dimmers.

How much would you save?

Replace a 100 watt incandescent bulb with a 25 watt CF bulb at 8 hrs per day use and 15 cents per kWh.

Incandescent = 292 kWh/yr and costs $43.80
CF bulb =73 kWh/yr and costs $10.95.

The CF bulb lasts 10-20x longer

The CF savings is $32.85 per year for each bulb you use.

Payback time is extra cost ($3) divided by monetary savings of $32.85 = .09 years or 1 month.

The return on investment is 1095%/year!

Bulb lifetime =7 years @8hr/day

Lifestyle and Lighting

Lights that are on in unoccupied spaces do no one any good, and waste electricity, money, and cause environmental damage.

Develop good habits by using lights only when and where they are needed.

Also rethink the need for **outside lighting at night**. Studies show most neighborhoods are equally safe without extensive lighting.

Outside lighting also creates "**light pollution**," reducing the ability to enjoy the night sky, and negatively impacts wildlife, and even plants.

High Power Factor/ High Efficiency Motors

- Motors consume approximately half of the energy used in the commercial and industrial sectors. Electric motors use 66 % of electricity in a typical factory.
- Motors consume the largest power in any building or plant. The utility loads such as compressor, air-conditioning and water pumps are rated 100s kW in
- total. The machine for production is in 1000s kW.
- When high efficiency motors are used, with typically 2 % more efficient than standard motors, there is a saving of energy by 2.4 %.
- High efficiency motors are 2 % to 8 % more efficient than the standard motors.

High Efficiency Transformers

- The conventional transformer efficiency for building transformers is typically 97 %.
- A slightly higher efficiency transformer of 99 % is available in the market.
- Transformers operate most efficiently when fully loaded, and the least efficiently when operate lightly loaded. Also, transformer losses increase with increase in kVA capacity. Therefore, transformers should not be too oversized. \
- As a guide transformers should be loaded at least 70 % of their rated capacities.

Minimize Losses through Conductors

- The losses through the conductors (for example, cables, busbars) could be reduced by installing slightly larger size conductors since larger size conductors have lower impedance.
- Typical conductor losses are 1.5%.
- The losses in the conductor can be calculated as well. For example, cable resistance is 0.0984 Ω/ km, while the estimated cable length is 160 m which means that resistance is 0.0157 Ω.
- Cable losses can be obtained by the I^2R formula.

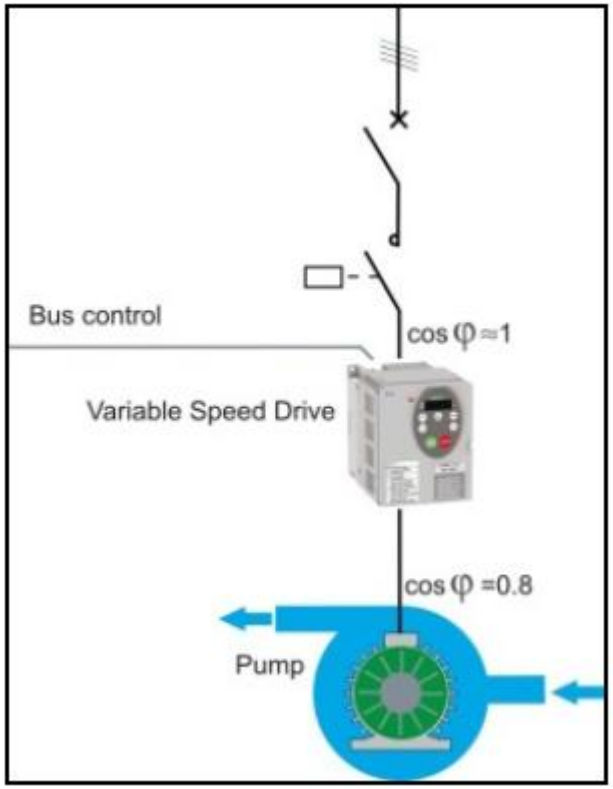
Improve the Power Supply Quality

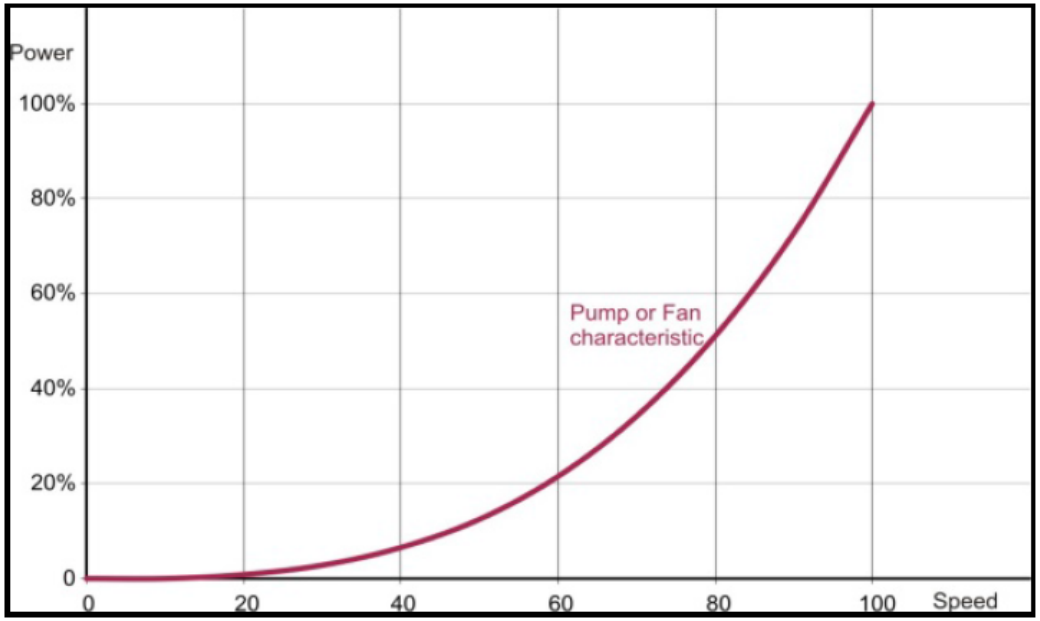
- Power quality is the relative frequency and severity of deviations in the incoming power supplied to electrical equipment from the usual 60 Hz, sinusoidal waveform of voltage or current.
- Poor power quality of electrical supply can contribute to additional losses and it affects the reliable operation of computer-based equipment.
- It is necessary to ensure that the building's electrical system and electrical equipment are not affected by low the power quality within the building. In this respect, the building's voltage and harmonics level are kept within acceptable limits, where there are no voltage dips/ sags, spikes.

- Typically, the total harmonic distortion (THD) for a building should be kept below 5 %.
- The sources of harmonics are the variable speed drive system (VSDS), switching power supply (e.g. in computers), overhead cranes and electronic ballast.
- The VSDS is equipped with harmonics filter so that the harmonics generated are not transmitted or injected into the distribution system. However, to achieve high energy efficiency within the plant, all equipment should be operated with high power factors.
- Equipment with low power factor have to be fitted with power factor correction devices so that the losses in the power cable (due to higher current) can be minimised.
- For the process area, the power factor should be above 0.85, while for non-process areas, the power factor should be above 0.90

Use of a Variable Speed Drives

- The VSDS in motor control could further improve energy saving. The motors of pumps, fans and air compressor represent an important item of energy consumption in the plant.





- Incorporating VSDS into applications such as fans, pumps, and air compressors can reduce energy usage up to 50 % at partial loads by matching motor speed to the changing load and system requirements.
- When an AC motor starts, it draws an inrush of as much as 300 % of rated current while developing only 50 % of rated torque.
- When a VSD starts a motor, it applies a very low frequency and very low voltage to the motor, gradually ramping up the frequency and voltage at a controlled rate. This allows the motor to develop 150 % torque while drawing only 50 % of rated current.
- The energy savings achieved by the variable speed drives can result in the investment to install drives being recovered in as little as a few months.

Energy Efficient Appliances

- Focus on majors appliances such as refrigerators, freezers, cook stoves, dishwashers, televisions, stereos, computers, washing machines, clothes dryers, air conditioners, and microwaves.
- Choose an energy efficient appliance when you purchase it, and then operate it as efficiently as possible.

If Wattage is Not Listed

- Read the volts and amps and multiply them together to get watts.
- P(in watts) = V(in volts) x I (in amps)
- P = 120 volts x 3 amps = 360 volt-amps
- P = 360 watts or 0.36 kW
- E = Power x Time = 0.36 kW x 10 hours
- E = 3.6 kWh

Cycle Factor

- For many appliances, you just multiply the kW by the hours to find energy use. But some appliances (those run by thermostats) cycle on and off to keep a fixed temperature.
- Examples: refrigerators, ovens, coffee makers, air conditioners, dryers, dehumidifiers.
- Some even have a different cycle (a refrigerator with a defrost cycle) at a different wattage.
- Appliance use charts will usually give the cycle factor, often 0.5 to 0.9 for applicable appliances.

Cook Stoves

- Natural gas or propane vs. electric stoves.
- For gas stoves, use electric ignition (not pilot lights) and be sure to vent gases.
- Electric stoves types (most efficient to least efficient) are induction, exposed coil, ceramic glass, halogen, and solid disk.
- Flat pans for ceramic glass and solid disk stoves are important for good heat transfer

Potential Causes of a High Electric Bill

- High parasitic loads.
- Meter read wrong.
- The addition of major appliance.
- Additional occupants.
- Faulty appliances (pump or thermostat).
- Seasonal appliances (pool pump, heat tape).
- Bad connection causing leakage to ground.
- Dueling thermostats.

Ways to Find Consumption

- Calculate: $E = P \times T$ to give kWh
- Estimate from an Appliance Use Chart (correct for different power rating and different time of use, if necessary).
- Buy a watt meter, plug the appliance in, and measure kWh directly
- Use your electric meter as a power meter (look for calibration, for example, Kh 7.2 watt-hour/rev)

  Kh value x (3600 sec/hour) divided by the time (sec per rev) is the total watts.