TRAINING PACKAGES
DEVELOPMENT

PACKAGE II: ELECTRICAL

**Presenter:** Dr Evan Murimi Wanjiru, PhD, CEM.
Presentation structure

- Target group
- Objectives
- Expected impact
- Sources of electrical energy
- Electricity consumption
- Components of utility bill
- Modules- 8 of them

"The age we live in is a busy age; in which knowledge is rapidly advancing to perfection."

- Jeremy Bentham
Target group

• Factory electricians
  They deal with day-to-day running of factories.
  They manage electrical equipment.
Objectives

Main objective
Train, equip and sensitize factory electricians with thorough information on electrical energy saving opportunities and related cost in a tea factory.

Specific objectives
- Provide thorough understanding of the tariff structure with its components
- Enlighten on various electrical energy consumers in a factory and their impact on cost.
- Quantify the impact of efficient operation of electrical equipment
- Sensitize the electricians on importance of proper maintenance.
Expected impact

At the end of the training, the electricians shall;

• Understand the billing structure and identify ways of saving cost.

• Be equipped with knowledge on tracking and analyzing energy consumption within the factory.

• Understand efficient operation of various electrical equipment in a factory.

• Ensure proper maintenance is carried out.

• Identify various energy saving opportunities in a factory and estimate energy and cost savings.

• Identify measures to take to stop energy wastage.
Modules

1. Power factor
2. Maximum kVA demand
3. Generator operation
4. Voltage balance
5. Lighting
6. Motors and fans
7. Energy monitoring & sub-metering
8. Maintenance
Sources of electrical energy

Most tea factories rely on
- Grid from Kenya power
- Hybrid (grid+hydro)
- Diesel generators as back up

- Oil generates just below coal.
- Most expensive to use
- Hydroelectric & wind emit the least
Electricity consumption

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Average Annual Units Consumed</th>
<th>Percent</th>
<th>Average Annual Cost</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>2,029,020 kWh</td>
<td>8%</td>
<td>23,841,171 kWh</td>
<td>58%</td>
</tr>
<tr>
<td>Thermal</td>
<td>22,917,592 kWh</td>
<td>92%</td>
<td>17,302,288 kWh</td>
<td>42%</td>
</tr>
<tr>
<td>Total</td>
<td>24,946,611 kWh</td>
<td>100%</td>
<td>41,143,459 kWh</td>
<td>100%</td>
</tr>
</tbody>
</table>

Electric energy accounts for less than **10%** total plant energy but accounts for **58%** of total plant energy cost.
Sectional consumption

Withering, CTC and Driers accounts for appr. 77-82% of total plant power demand/energy consumption.

Several motors and fans

Highest energy saving potential
Components of previous utility bill-CI1 at 415V

- Fixed charge at **KSh 2500/period**

- Energy Consumption kWh (TOU)
  - peak @ **KSh 9.2/kWh**
  - Off-peak @ **KSh 4.6/kWh**

- Maximum demand kW (*Actual maximum consumed real power*)

- Power Factor kW/kVA (*Surcharge if below 0.9*)

- Maximum demand kVA (*maximum supplied power*) at **KSh 800/kVA**

- Other levies (WARMA, ERC, REP, FCC, FA, IA) and VAT

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*Must be at 100% production e.g. high crop season. Extra production can be shifted to off-peak.*
Components of current utility bill-CI1 at 415V effective from 1\textsuperscript{st} July 2018

- Fixed charge at \textit{KSh 0/period}

- Energy Consumption kWh (TOU)
  - peak @ \textit{KSh 12/kWh}
  - Off-peak @ \textit{KSh 6/kWh}

- Maximum demand kW (\textit{Actual maximum consumed real power})

- Power Factor kW/kVA (\textit{Surcharge if below 0.9})

- Maximum demand kVA (\textit{maximum supplied power}) at \textit{KSh 800/kVA}

- Other levies (WARMA, ERC, REP, FCC, FA, IA) and VAT
Other tariffs;

<table>
<thead>
<tr>
<th>Code</th>
<th>Customer Type (Code Name)</th>
<th>Energy Limit kWh/month</th>
<th>Charge Method</th>
<th>Unit</th>
<th>2015/16 to date Approved</th>
<th>2018/19 KPLC Application</th>
<th>2018/19 ERC Approved</th>
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</thead>
<tbody>
<tr>
<td>DC</td>
<td>Domestic</td>
<td>0-10</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>150</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11-50</td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>2.50</td>
<td>13.01</td>
<td>12.00</td>
</tr>
<tr>
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<td></td>
<td>51-1500</td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>12.75</td>
<td>18.90</td>
<td>15.80</td>
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<td></td>
<td>&gt;1500</td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>20.57</td>
<td>25.56</td>
<td>15.80</td>
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<tr>
<td>SC</td>
<td>Small Commercial</td>
<td>0 - 15,000</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>150</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>13.50</td>
<td>19.85</td>
<td>15.60</td>
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<tr>
<td>CI1</td>
<td>Comm./industrial</td>
<td>&gt;15,000</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>2,500</td>
<td>3,100</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>9.20</td>
<td>13.77</td>
<td>12.00</td>
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<tr>
<td>CI2</td>
<td>Comm./industrial</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>4,500</td>
<td>5,600</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>8.00</td>
<td>11.77</td>
<td>10.90</td>
</tr>
<tr>
<td>CI3</td>
<td>Comm./industrial</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>520</td>
<td>650</td>
<td>520</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Demand</td>
<td>KShs/kVA</td>
<td>800</td>
<td>1,000</td>
<td>800</td>
</tr>
<tr>
<td>CI4</td>
<td>Comm./industrial</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>6,500</td>
<td>8,000</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>7.50</td>
<td>10.93</td>
<td>10.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Demand</td>
<td>KShs/kVA</td>
<td>270</td>
<td>350</td>
<td>270</td>
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<tr>
<td>CI5</td>
<td>Comm./industrial</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>17,000</td>
<td>21,000</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>7.10</td>
<td>10.32</td>
<td>10.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Demand</td>
<td>KShs/kVA</td>
<td>220</td>
<td>280</td>
<td>220</td>
</tr>
<tr>
<td>SL1</td>
<td>Street Lighting</td>
<td>No Limit</td>
<td>Fixed</td>
<td>KShs/month</td>
<td>200</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy</td>
<td>KShs/kWh</td>
<td>4.36</td>
<td>15.91</td>
<td>7.50</td>
</tr>
</tbody>
</table>
How can you reduce your electricity bill?

• **Reduce consumption kWh**
  • Lower rated motor/appliance
  • Reduce operation hours/idle operation

• **Improve Power Factor**
  • Install PF correction/Daily check of PF control system
  • Motor capacity vs duty

• **Reduce kVA**
  • Load scheduling

• **Reduce losses**
  • Voltage balancing
  • Motor loading
Module 1: Maximum kVA demand

• **Demand** is the rate at which energy is delivered to an electrical load.
• It is expressed in either **kW** or kilovoltamperes (**kVA**).
• **Maximum (peak) demand** - maximum rate at which electric energy is drawn through the meter during a period of time.
• **For example:**

For a house with, 4.5 kW water heater, 3.0 kW lighting, 15.0 kW cooking, 1 kW iron box and 1.3 kW microwave. If they all operate at the same time, the peak demand =24.8 kW.
• Electricity consumed after generation.
• Utilities must meet **highest demand**

- kWh (A) = kWh (B) i.e. shaded area.
- Peak = 2x average demand
- Capacity (A) = 2x Capacity (B)
- Peak only for short time

**Co. A**

**Kilowatt demand**

Peak demand

Avg. demand

Co. A

**Co. B**

**Kilowatt demand**

Peak demand

**Time**

**Kilowatt demand**

Peak demand

**Time**

• Peak = average demand
• Utility can meet this demand efficiently.
Demand charges

• Are utility's costs for meeting a customer’s higher demand
• Based on the maximum kVA demand recorded in any half hour of billing period.

• Company “A” demand is 80 kW for 50 hours. \( Energy = 80 \times 50 = 4000 \, kWh \).

• Company “B” demand is 20 kW for 200 hours. \( Energy = 20 \times 200 = 4000 \, kWh \).

• Both use same amount of energy during the billing period.
• Should they pay the same?
• Required system capacity; 80 kW for Company A, 20 kW for B.
Load shifting and scheduling

- With **TOU tariff**, scheduling to process tea in cheaper off-peak periods (night) could save money.

<table>
<thead>
<tr>
<th>Day</th>
<th>Off-peak hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekdays</td>
<td>22:00 to 00:00 and 00:00 to 06:00</td>
</tr>
<tr>
<td>Saturdays and public holidays</td>
<td>14:00 to 00:00 and 00:00 to 08:00</td>
</tr>
<tr>
<td>Sundays</td>
<td>All day</td>
</tr>
</tbody>
</table>

- Extra tea (above 100%) would require **2000 kWh** to process.
- During peak, Energy cost
  \[9.45 \times 2000 = Kshs \, 18,900\]
- Shifting to off-peak, Energy cost
  \[7 \times 2000 = Kshs \, 14,000\]
Operational excellence

Do’s

• Operate withering when there is no processing
• Fully load processing lines
• Switch off unnecessary processing lines/loads
• Process extra crop during off-peak period if possible

Don’ts

• Run empty processing lines
• Minimize operating withering when processing is taking place
Peak demand reduced from 500 kVA to 400 kVA. Demand cost = Kshs800/kVA
Cost savings = Kshs 80,000
Module 2: Power factor

Power factor (PF) = \( \frac{\text{Working power}}{\text{Apparent power}} = \frac{\text{kW}}{\text{kVA}} = \cos \theta \)

= \( \frac{\text{Beer}}{\text{Beer + Foam}} \)
How do I improve power factor

• **Consumers** of kVAR- transformers, induction motors, high intensity discharge (HID) lamps- **lower PF**.

• **Generators** of kVAR- capacitors, synchronous generators, synchronous motors- **increase PF**

• **To increase/improve PF:**

1. **Install capacitors (kVAR generators):** Capacitors store KVARs and release it opposing kVAR caused by the inductor load.

\[
 kVA = \frac{kW}{PF} = \sqrt{(kW)^2 + (kVAR)^2}
\]
Energy/cost saving from capacitors

Assuming Max 600kVA recorded,
With \( \text{PF=0.78} \), \( kW = 0.78 \times 600 = 468 \) and \( kVAR = \sqrt{kVA^2 - kW^2} = \sqrt{600^2 - 468^2} = 375 \).

Correcting \( \text{PF to 0.99} \), \( kVA = \frac{468}{0.99} = 473 \text{ kVA} \) meaning \( kVAR = \sqrt{473^2 - 468^2} = 67 \).

Capacitors required to correct are \( 375 - 67 = 308 \text{ kVAR} \).

<table>
<thead>
<tr>
<th>Factory</th>
<th>Jan-16</th>
<th>Mar-16</th>
<th>Apr-16</th>
<th>May-16</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PF</td>
<td>KSh</td>
<td>PF</td>
<td>KSh</td>
</tr>
<tr>
<td>Factory 1</td>
<td>0.88</td>
<td>129,478.00</td>
<td>0.84</td>
<td>370,143.00</td>
</tr>
<tr>
<td>Factory 2</td>
<td>0.85</td>
<td>412,547.00</td>
<td>0.85</td>
<td>302,163.00</td>
</tr>
<tr>
<td>Factory 3</td>
<td>0.96</td>
<td>95,313.00</td>
<td>0.93</td>
<td>347,020.00</td>
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<tr>
<td>Factory 4</td>
<td>0.87</td>
<td>0.93</td>
<td>0.82</td>
<td>714,807.00</td>
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<tr>
<td>Factory 5</td>
<td>0.97</td>
<td>0.87</td>
<td>0.97</td>
<td>173,526.00</td>
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<td>Factory 6</td>
<td>0.99</td>
<td>1</td>
<td>0.82</td>
<td>249,665.00</td>
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<tr>
<td>Factory 7</td>
<td>0.96</td>
<td>39,524.00</td>
<td>0.94</td>
<td>970,217.25</td>
</tr>
<tr>
<td>Factory 8</td>
<td>0.98</td>
<td>281,023.00</td>
<td>0.91</td>
<td>970,217.25</td>
</tr>
<tr>
<td>Factory 9</td>
<td>0.98</td>
<td>281,023.00</td>
<td>0.91</td>
<td>970,217.25</td>
</tr>
<tr>
<td>Factory 10</td>
<td>0.78</td>
<td>681,879.00</td>
<td>0.9</td>
<td>970,217.25</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,447,291.00</td>
<td>1,335,998.00</td>
<td>1,485,018.00</td>
</tr>
</tbody>
</table>

PF 0.78, Assuming Max 600kVA recorded; Correct to PF 0.99, need additional 290kVAR; Investment cost: KSh 0.95m-1.2m; PB: 1.3-1.7yrs
Effect of switching off capacitor bank

• If the capacitor bank is switched off during processing, PF goes back to 0.78
• Demand is raised from 473 kVA to 600 kVA
• Financial losses (kVA demand)
  \[(600 - 473) \times 800 = Kshs. 101,600\]
• Additional losses due to PF surcharge
Impact of overcorrecting PF

- When PF=1, kW=kVA
- Overcorrecting increases kVA → higher cost
- Increased currents-losses!
- Increased voltage can damage equipment.

Both yield same kVA!!
More Capacitors cost more money!!
2. Proper loading of motors

Do not operate under loaded motor (empty conveyors? OR idle running

Load motor at least 50% and above

Purchase correct rated motor for duty

Low LF leads to low PF
Benefits of improving power factor?

1. **Lower cost of electricity by**;
   a. **Peak kVA billing demand**- high PF → low KVAR → low KVA.
   b. **Eliminating power factor penalty**- Utility charges for low PF (<0.9).

2. **Increased system capacity**
   For example, a 1,000 KVA transformer with an 80% power factor provides 800 KW of power to the main bus. By increasing the power factor to 90%, the kW that can be supplied are:

   \[
   0.9 = \frac{kW}{1000}, \text{Hence kW} = 900 \text{ kW}
   \]

3. **Improved voltage level**: As power factor increases, total line current reduces, meaning **more efficient, cooler motor performance and longer motor life**.
Operational excellence

Do’s
• Do not oversize capacitor banks
• Always switch on capacitor banks when required
• Properly load motors and conveyors (at least 50%)

Don’ts
• Don’t run idle or empty conveyors
• Do not overload motors
Module 3: Generator

Cost considerations

- Cost of diesel
- Energy content of a liter of diesel: 32 MJ/l
- Energy conversion: 1 kWh=3.6 MJ
- Generator electricity generation efficiency: 30%

\[
\eta_g = \frac{\text{output}}{\text{input}}
\]

- 1kWh of electricity requires how many kWh diesel?
  \[
  \text{input (kWh)} = \frac{\text{output (kWh)}}{\eta_g} = \frac{1}{0.3} = 3.33 \text{ kWh}
  \]
- How many MJ of diesel are these;
  \[
  3.33 \text{ kWh} \times \frac{3.6 \text{ MJ}}{\text{kWh}} = 12 \text{ MJ}
  \]
- 1 liter of diesel has 32 MJ energy content and costs Kshs. 96.
- Cost of generating 1 kWh electricity is;
  \[
  \frac{12 \text{ MJ}}{32 \text{ MJ}} \times \text{Kshs. 96} = \text{Kshs. 36/kWh}
  \]
Specific Fuel Consumption (SFC)

• Quantity of diesel required to generate one unit of electricity.

\[ SFC = \frac{\text{Fuel consumption per unit time}}{\text{power produced}} \]

• Lower SFC → higher efficiency
• Optimum SFC at 75-80% loading
• e.g. a 500 kVA set is observed to have 20% better SFC at 75% than at 25% loading
Generator efficiency

• Do not use a big generator to run small loads!!
• Factory can have 3 generators
  • Biggest generator- to use when at full load.
  • Medium generator- to use when at half load
  • Small generator- use when factory is not processing.

This saves on diesel cost and reduces CO₂ emissions
Generator maintenance

Use manufacturer’s recommended checklist

Service as recommended
Operational excellence

Do’s
• Where possible use the right generator for the load
• Regularly maintain generators per manufacturer’s recommendations

Don’ts
• Don’t use a very big generator for very small loads
Module 4: Motors & fans

- All induction motors have losses; constant (fixed) & variable losses.
- Full load motor efficiency varies from about 85% to 97%, due to losses;
Motor efficiency

IE1—Standard efficiency (EFF 2)
IE2—High efficiency (EFF 1). About 4 or 5% more efficient than IE1.
IE3—Premium efficiency. About 2 or 3% more efficient than IE2.
# Motor retrofitting/replacing

<table>
<thead>
<tr>
<th></th>
<th>22 kW</th>
<th>22 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td>93%</td>
<td>86%</td>
</tr>
<tr>
<td><strong>Process Hours</strong></td>
<td>4200</td>
<td>4200</td>
</tr>
<tr>
<td><strong>Load (70%)</strong></td>
<td>15.4</td>
<td>15.4</td>
</tr>
<tr>
<td><strong>Elec. Energy (kWh)</strong></td>
<td>15.4 × (\frac{0.93}{0.93}) × 4200=69,548</td>
<td>15.4 × (\frac{0.86}{0.86}) × 4200=75,209</td>
</tr>
<tr>
<td><strong>Energy Cost [KSh20/kWh]</strong></td>
<td>KSh 1,390,960</td>
<td>KSh 1,504,180</td>
</tr>
</tbody>
</table>

**For retrofitting:**
- **Energy Efficient Motor**: KSh 200,000
- **Savings**: KSh 113,220 per year
- **Pay Back**: 1.76 years

**In case of replace:**
- **EE Motor Extra Cost over Std Motor Cost**: KSh 50,000
- **Savings**: KSh 113,220 per year
- **Pay Back**: 5.3 months
Motor rewinding

• Will repaired motor retain its efficiency?
• Repair decision making process involves:
  • Suitability for application (sizing, enclosure)
  • Condition of stator and rotor
  • Assess all damages: cost of repair vs replacement
  • Efficiency; lifecycle costing
  • Availability of funds & replacement motor
  • ROI for replacement acceptable when replacing with energy efficient motor?
Good rewinding practice

• To maintain or reduce winding copper ($i^2R$) losses;
  • Ensure overall length of turns in windings does not increase (more resistance increases losses)
  • Increase wire area if slot fit allows it (larger area reduces resistance, reducing losses)

• Maintain efficiency by
  • Copy-rewinding or improving winding pattern
  • Use same or shorter average length of turns
  • Using same parts as before e.g. bearings, fans etc.

• Why could efficiency drop?
  • Damage to the stator while removing damaged windings.
  • Reassembly can cause more acute problems
Methods of starting motors/fans

• **Direct-on-line starting (D.O.L)** - high starting current that may cause interference with supplies to other consumers.
  - Low power and torque.
  - Suitable for small fans (38 inches)

• **Star-delta starting** - stator phase winding are star-connected.
  - High energy consumption
  - Higher torque
  - Suitable for larger fans e.g. 48 inches.

• **Auto transformer starting** - auto transformer reduces stator starting current - torque seriously reduced.
  - When motor is up to speed, switch is moved to direct connection.
Fans: Dampers vs Variable frequency drives (VFDs)

• Dampers used to control volumetric air flow.
  • They are like pressing car’s throttle (accelerator) and brakes together!!
  • Cheap to buy & install
  • Energy inefficient
  • Require frequent maintenance

• VSDs/VFDs
  • operate like a car’s throttle.
  • Adjusts speed of motor based on demand.
  • Most energy efficient
  • More expensive to buy
  • Pay back within the lifetime.
  • Harmonic concerns
Operational excellence

Do’s
• Consider high efficiency motors while replacing std motors
• Follow due diligence while rewinding motors.
• Use suitable connection for motors and fans based on torque required.
• Consider VFDs in place of dampers

Don’ts
• Do not connect VFDs and then fix the speed.
• Do not use VFDs and dampers together.
Module 5: Voltage balance

• Ideally:
  • Load in each phase should be the same
  • No net current flows thro neutral

• Not possible to achieve ideal situation

• Line voltage - between phases.
• Phase voltage - between phase and neutral.
Causes of imbalance

• **Unequal reactance** in induction motors → varying current in three phases.
• Connecting **single phase loads to only one phase**.
• **Unequal impedances** in power transmission or distribution system.

Control Measures

• Distribute single phase loads equally among the three phases
• Replace or rewind motors with unbalanced three phase reactance
Quantifying the losses

\[
\% \text{ imbalance} = \frac{\text{max. voltage deviation}}{\text{average voltage}} \times 100
\]

Example: average voltage = 420.8\text{V}.

\[
\% \text{ imbalance} = \frac{422.7 - 420.8}{420.8} \times 100 = 0.45\%
\]

- Up to 2\% imbalance is acceptable.
- Operation of a motor with above a 5\% imbalance condition can damage to the motor.
Effects of imbalance

- *temperature rise = 2 × %imbalance*²
- 7% imbalance = double temp rise
- 10° C rise in temp. reduces motor life 50%

- **Power losses:**
  - Low motor efficiency
  - Increased temperature → heat losses (*i*²*R*).

- **Maintenance issues:**
  - Temperature rise: decomposes grease in bearings & de-rates motor winding
  - Fluctuating torque & speed – vibrations & noise damages the motor
  - De-rating of power cables- Imbalances cause higher current→ heat losses (*i*²*R*).

- **More power loss higher → more power bills.**
Operational excellence

Do’s
• Try to equally distribute single phase loads.
• Frequently monitor motors that could cause imbalances.
• Replace/rewind such motors.

Don’ts
Module 6: Lighting

Common sources of light

• Incandescent- has a wire element. 90% heat and 10% light (100W bulb produces 90W heat and 10W light)
• Fluorescent – linear, U-tubes, CFLs. 40% light and 60% heat
• LED – Light emitting diodes
• Natural (sunlight)

Skylight and LED at a tea factory
<table>
<thead>
<tr>
<th></th>
<th>LEDs</th>
<th>CFLs</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifespan (hours)</td>
<td>50,000</td>
<td>10,000</td>
<td>1,200</td>
</tr>
<tr>
<td>Power (equiv. 60 watts)</td>
<td>6</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Energy used over 50,000</td>
<td>300</td>
<td>750</td>
<td>3,000</td>
</tr>
<tr>
<td>hours (kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity cost</td>
<td>6,000</td>
<td>15,000</td>
<td>60,000</td>
</tr>
<tr>
<td>(@Kes20/kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulbs needed for 50,000</td>
<td>1</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>hours of use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per bulb (Kes)</td>
<td>500</td>
<td>250</td>
<td>50</td>
</tr>
<tr>
<td>Cost of bulbs (Kes)</td>
<td>500</td>
<td>1,250</td>
<td>2,100</td>
</tr>
<tr>
<td>Cost of bulbs + energy</td>
<td>6,500</td>
<td>16,250</td>
<td>62,100</td>
</tr>
<tr>
<td>after 50,000 hours (Kes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For a house with 5 bulbs only, in 50,000 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy (kWh)</td>
<td>1,500</td>
<td>3,750</td>
<td>15,000</td>
</tr>
<tr>
<td>Cost (Kes)</td>
<td>32,500</td>
<td>81,250</td>
<td>310,500</td>
</tr>
<tr>
<td>Energy savings (kWh)</td>
<td>13,500</td>
<td>11,250</td>
<td>0</td>
</tr>
<tr>
<td>Cost savings (Kes)</td>
<td>278,000</td>
<td>229,250</td>
<td>0</td>
</tr>
</tbody>
</table>
## Comparing the features of common bulbs

<table>
<thead>
<tr>
<th></th>
<th>LEDs</th>
<th>Fluorescent</th>
<th>Incandescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent On/Off Cycling</td>
<td>no effect</td>
<td>shortens lifespan</td>
<td>some effect</td>
</tr>
<tr>
<td>Turns on instantly</td>
<td>Yes</td>
<td>Slight delay</td>
<td>yes</td>
</tr>
<tr>
<td>Durability</td>
<td>Durable</td>
<td>Fragile</td>
<td>Fragile</td>
</tr>
<tr>
<td>Heat Emitted</td>
<td>Low (3.16 kJ/h)</td>
<td>Medium (15.83 kJ/h)</td>
<td>High (89.68 kJ/h)</td>
</tr>
<tr>
<td>Hazardous Materials</td>
<td>None</td>
<td>5 mg mercury/bulb</td>
<td>none</td>
</tr>
<tr>
<td>Replacement frequency</td>
<td>1</td>
<td>5</td>
<td>40+</td>
</tr>
<tr>
<td>(over 50,000 hours)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Evident that LEDs have the best qualities.
Retrofitting fluorescent lamps

- **Energy Efficient Lamp (LED):** KShs 3000
- **Assume 200 lamps replacement:** KShs 600,000
- **Savings:** $(4,180 - 1,300) \times 200 = KShs 576,000/\text{year}$
- **Pay Back:** $\frac{600,000}{576,000} \approx 1 \text{ year}$

<table>
<thead>
<tr>
<th></th>
<th>Fluorescent</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>58</td>
<td>18</td>
</tr>
<tr>
<td>Hours (in a year)</td>
<td>3,600</td>
<td>3,600</td>
</tr>
<tr>
<td>Energy (kWh/year)</td>
<td>$58 \times 3600/1000 = 209$</td>
<td>$18 \times 3600/1000 = 65$</td>
</tr>
<tr>
<td>Cost (Kshs/year)</td>
<td>$209 \times 20 = 4,180$</td>
<td>$65 \times 20 = 1,300$</td>
</tr>
</tbody>
</table>
Retrofitting security lights

- Replacing 10 Halogen lamps with LED Equivalent
- Cost of LED lights @2,500= KSh 250,000
- Energy Cost Savings: \((21,900 - 8,760) \times 10 = KSh 131,400\) /year
- Pay Back: \(\frac{250,000}{131,400} = 1.9\) years

<table>
<thead>
<tr>
<th></th>
<th>Metal Halide</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W)</td>
<td>250</td>
<td>100</td>
</tr>
<tr>
<td>Hours (in a year)</td>
<td>4,380</td>
<td>4,380</td>
</tr>
<tr>
<td>Energy (kWh/year)</td>
<td>250 × 4380/1000 = 1,095</td>
<td>100 × 4380/1000 = 438</td>
</tr>
<tr>
<td>Cost (Kshs/year)</td>
<td>1,095 × 20 = 21,900</td>
<td>438 × 20 = 8,760</td>
</tr>
</tbody>
</table>
Proper lights operation

Sensitize

- Security lights should have photocells - night
- Photocells + motion sensors – night & motion

Where possible, use natural light

Consider solar security

Install occupancy sensors
Operational excellence

Do’s
• Pay attention to sensitizing materials on lights operation
• Occasionally clean the skylights.
• Automate lights operation where possible.

Don’ts
• Don’t leave lights switched on unnecessarily.
Module 7: Energy monitoring & sub-metering

• Install sub-meters in various sections of the factory.
• Periodically measure & record individual motors/fans
• Compare similar processes

You can’t manage what isn’t measured. If you don’t measure, you can’t improve it.
Why sub-meter?

• Verify utility bills
• Allocate energy costs and assign accountability
• Determine equipment/system efficiency
• Identify process problems
• Identifying future energy savings opportunities
• Compare similar processes
Potential energy savings from sub-meters

• **Increased awareness**- Employees notice energy waste e.g. lights left on when they know it is being metered.

• **Savings from increased accountability**- Measuring energy costs can show that decisions made by production staff & energy managers play a significant role in the overall cost of energy.

• **Savings from automation**- e.g. during peak electrical demand, non critical load could be shut down.

**Instrumentation**

• In case there are no sub-meters, use portable meters such as power meters to record and monitor energy consumption.
What must you do?

By themselves, meters do not save money -- they only cost money to purchase and install. To maximize savings, complement a sub metering system with appropriate procedures.

• Keep records
  Develop & maintaining a database.

• Analyze the data
  Trends, peaks, and correlation with factors such as weather, season, operating shift, and production rate.
  Make sense of the data

• Take action
  For continuous improvement & preventive maintenance
  Actions could save the factory downtime, labour and money.
Operational excellence

**Do’s**

- Take energy consumption readings occasionally for various loads.
- Record and compare the consumption.
- Analyze the data
- Take appropriate actions.

**Don’ts**

- Don’t record data just because you are asked to!
Module 8: Maintenance

- Wiring should be neat!
- Ease of troubleshooting
- Use/ensure correct cable size, colour coding and termination
- Digitize records
- Properly label the distribution panel
- Never short circuit a fuse/circuit breaker. Prevent catastrophe!

- Digitize records
Maintenance

• Power house should be kept clean
  • Close the door so as to only allow authorized personnel.
  • Ensure no water on the floor.
  • Should be well ventilated.

• Ensure all indicating devices are fully functional and properly set.

Examine insulation

NO Shortcuts!!
Follow the procedure
Energy saved is energy generated.