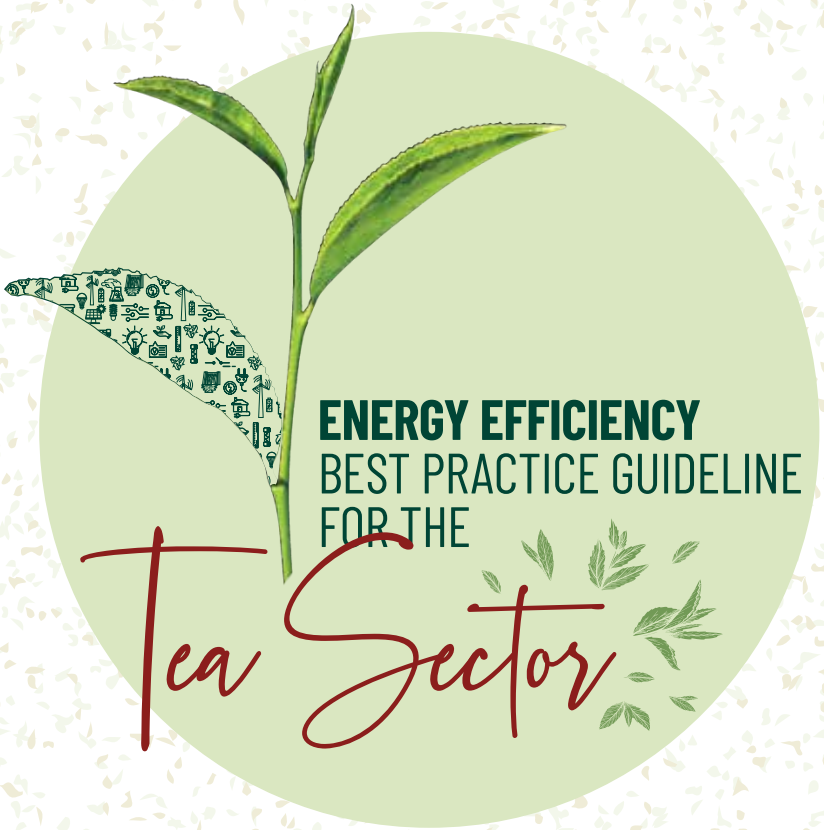


ENERGY EFFICIENCY
BEST PRACTICE GUIDELINE
FOR THE
Tea Sector



ENERGY EFFICIENCY BEST PRACTICE GUIDELINE FOR THE Tea Sector

Developed under the
" Tea Sector Energy Efficiency Improvement Programme in Sri Lanka" by the **Ethical Tea Partnership**
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Preface

This 'Energy Efficiency Best Practice Guideline for the Tea Sector' (Guideline) provides users the essential knowledge on potential energy efficiency improvement measures within a tea factory. The Guideline also includes the basics of energy management practices applicable to the tea sector. It is expected to provide valuable directions for group engineers, tea factory managers, supervisors, officers, and staff, apart from being a general reference book for all professionals dedicated to promoting sustainability in energy use in the sector. The Guideline covers both thermal and electrical energy generation, supply, and use, general maintenance practices with a focus on energy efficiency, and general energy management aspects. Interventions implementable within tea factories are presented in a simple and reader friendly manner.

This Guideline is a result of a collaborative effort by a group of experts with years of experience in energy efficiency in the tea sector, and our sincere thanks are due to all who contributed to its success. Funding for preparation of the Guideline provided by GIZ and partner organizations, and programme implementation assistance received through Ethical Tea Partnership, UK are also thankfully acknowledged.

We are confident that this Guideline will fulfil the need for fundamental knowledge to meet the energy efficiency improvement challenge in the tea sector.

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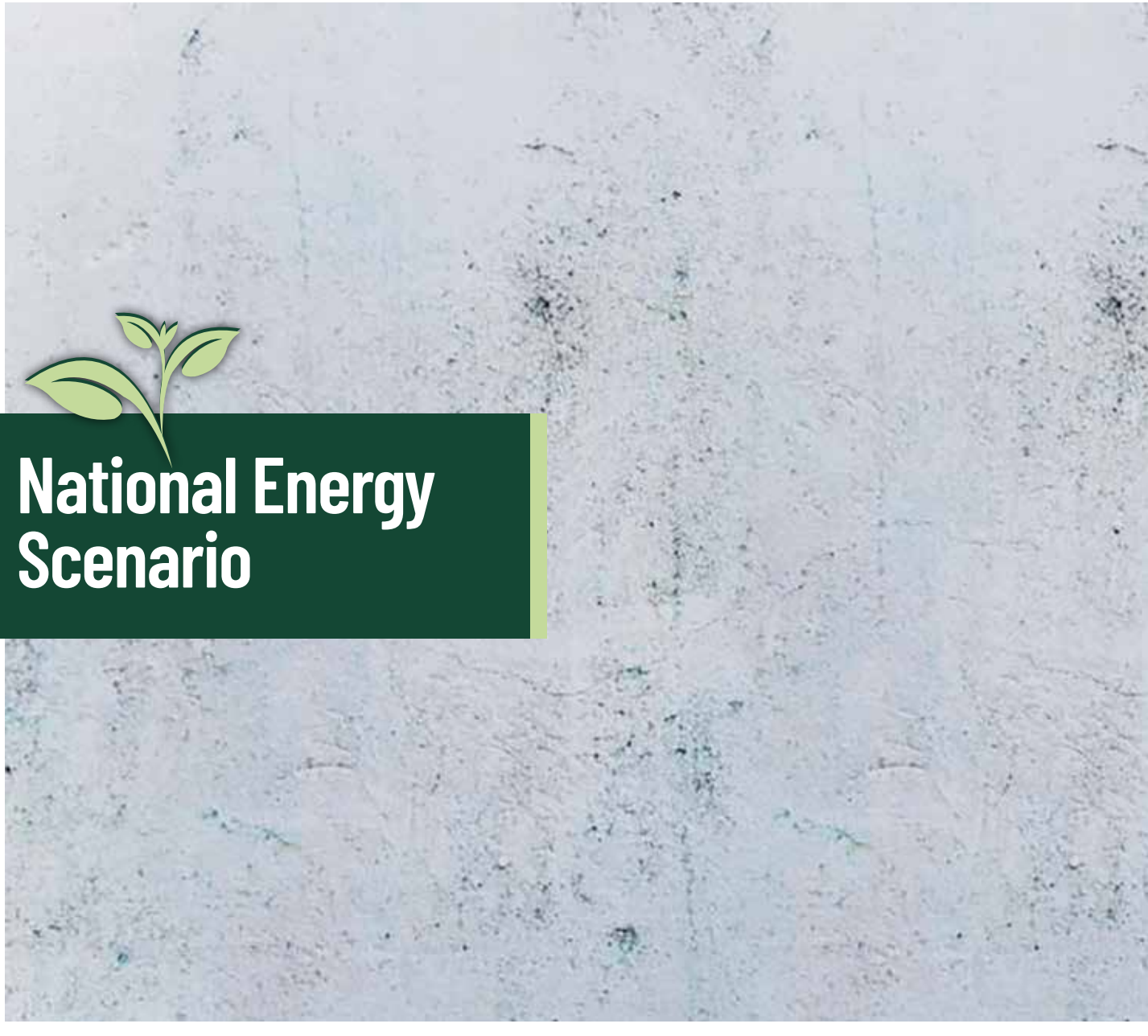
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National Energy Scenario



1 National Energy Scenario

Biomass, hydro, petroleum, coal, solar and wind are the primary energy resources utilised in Sri Lanka to meet the country's energy requirements. Figure 1.1 depicts the share of primary energy supplied by each source in 2016, with petroleum and biomass dominating the energy supply portfolio. Among the different uses, hydro, coal, solar and wind resources are used for electricity generation. In addition, a small quantity of coal is used as a thermal energy source in the industrial sector. Petroleum is used mainly for transportation and electricity generation. As shown in Figure 1.2, bulk of biomass use is for domestic cooking and industrial thermal energy applications whilst a small portion is used for electricity generation.

In 2016, the total electricity generation of Sri Lanka was 14,361

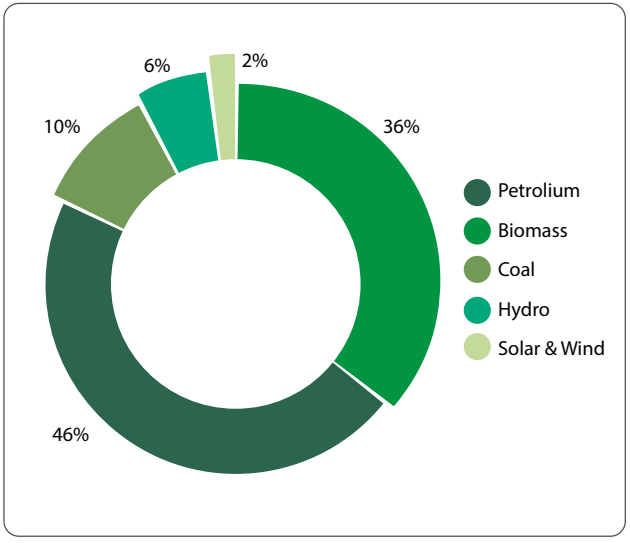


Figure 1.1: Primary Energy Use of Sri Lanka in 2016

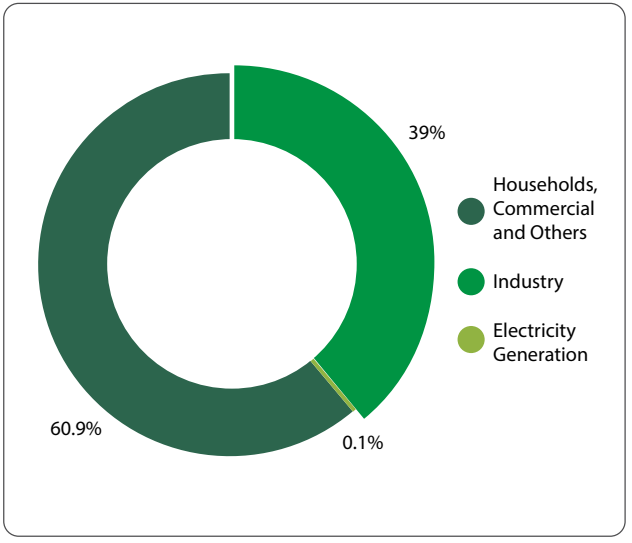


Figure 1.2: Use of Biomass as a Primary Energy Source in 2016

GWh, and the contribution to this generation by different primary energy sources is shown in Figure 1.4. Approximately 67% of electricity generation was from thermal sources. In general, two third of the energy contained in thermal energy sources is lost during the conversion process to electricity. In other words, three units of energy can be saved by saving one unit at the user point.

The "Operation DSM: National Energy Management Action Plan 2016-2020" published by the Presidential Task Force on Energy Demand Side Management established within Sri Lanka Sustainable Energy Authority (SLSEA) has a target to improve end-use efficiency of electricity and reduce 1,100 GWh by 2020, with an expected economic cost saving of Rs. 15 billion annually.

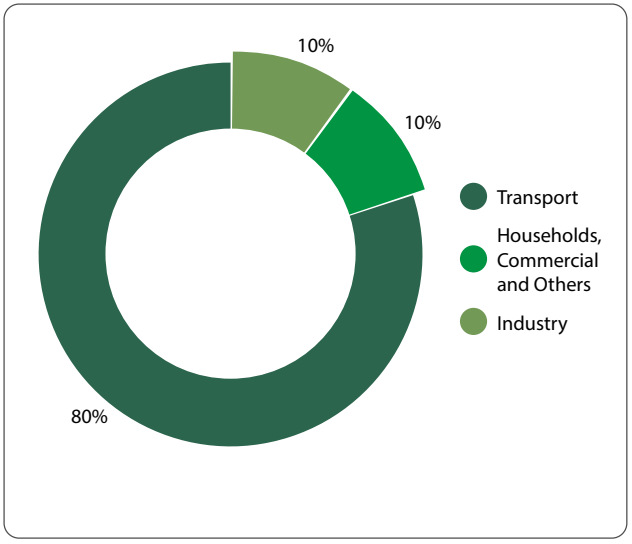


Figure 1.3: Use of Petroleum as a Primary Energy Source in 2016

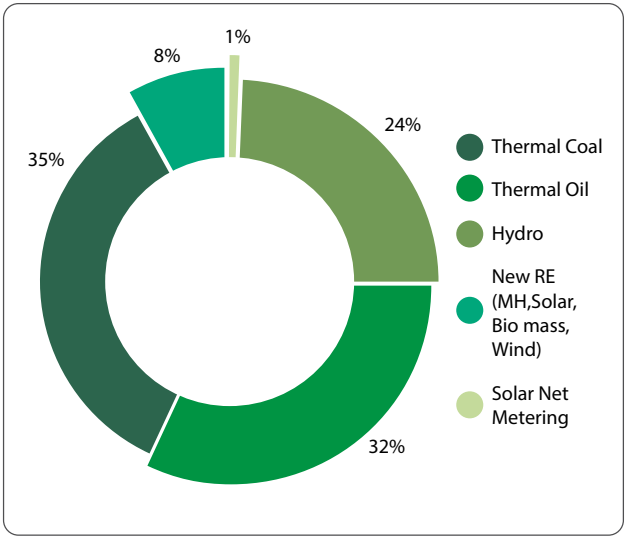


Figure 1.4: Primary Energy Supply for Electricity Generation



Tea Industry and Energy Use



2 Tea Industry and Energy Use

Contribution by the tea industry to the Gross Domestic Production (GDP) of Sri Lanka is 2% and it accounts for 65% of total agriculture sector export earnings. More than two million people, i.e. 10% of the total population of the country, depend on the sector earnings. Therefore, development of the tea industry with sustainable initiatives is an essential national priority.

"Sri Lanka shows an interesting paradox between, on paper, a wealth of programmes supporting industries to invest in energy efficiency (some of which directly target the tea sector) and, in reality, a general lack of awareness of energy efficiency issues among tea sector stakeholders. Energy audits done at two tea factories, as well as secondary data collected from the tea sector indicate the potential for substantial energy and therefore monetary savings in the tea industry. To achieve this potential, a number of measures should be implemented. Possible measures include both investments in new equipment as well as improved operation and maintenance procedures and more generally, a bigger focus on energy management and monitoring in tea factories" - Energy Efficiency & Sustainable Use of Energy in Asian Tea Sector (GIZ/ETP pre-study finding).

In 2016, tea industry used around 235 GWh of electricity for tea processing, which was about 5.7% of the total industrial sector electricity consumption.

Out of the total processing cost of Rs. 60 to 80 per kg, cost of energy in producing tea varies around Rs. 20 to 30 per kg. Biomass is the major energy source used in generating hot air required in the tea production process. For running the motors and for lighting, electricity supplied from the national grid is used. As shown in Figure 1.4, amongst the electricity uses, the trough fan motors in the withering process and the maceration machines account for a major share of electricity consumption.

According to a survey done by SLSEA in 2013, the average energy use in the tea production process was 0.63 kWh of electricity and 1.78 kg of fuelwood per kg of made tea. Within the tested sample, these energy consumption values varied from 0.54 to 1.62 kWh of electricity and 0.56 to 3.23 kg of fuelwood per kg of made tea.

Based on the above survey data, if all tea factories can be brought to their best energy efficiency levels of 0.54 kWh of electricity and 0.56 kg of fuelwood per kg of made tea, 33.5 GWh electricity and 42,300 tons of fuelwood can be saved annually within the tea industry.

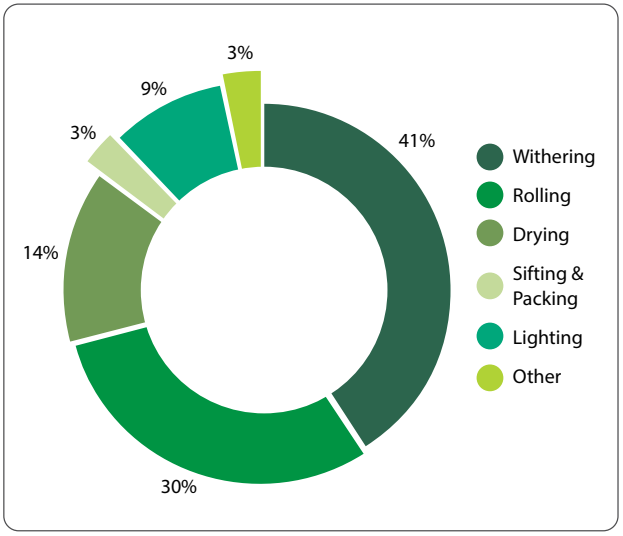


Figure 2.1: Energy Balance of a Typical Tea Factory

Electricity Bill in September

	Unit Cost (Rs.)	Units (kWh)	Total Cost (Rs.)
5.30 am - 6.30 pm	11.00	5,516	60,676.00
6.30 pm - 10.30 pm	20.50	1,755	35,977.50
10.30 pm - 5.30 pm	6.85	1,593	10,912.05
K. V. L.	1,100.00	54	59,400.00
Fuel + Statutory Charges	3,000.00		3,000.00
Total			**169,965.88**



Thermal Energy Supply



3 Thermal Energy Supply

Biomass is the major thermal energy source used in the tea manufacturing process. Since purpose-grown biomass and agricultural waste are considered sustainable energy sources, the United Nations Framework Convention on Climate Change (UNFCCC) has recognized the net emission of sustainable biomass utilization process as zero.

Use of biomass in the industrial sector is being increased day by day, due to the price differential between petroleum and biomass. Thus, the biomass market is becoming more competitive. Obtaining the quality and quantity of sustainable biomass for the tea industry is already a challenge.

It has been identified that ample amount of bare land is available in tea plantations. Making those lands available to grow biomass can be a long-term solution for the currently experiencing shortage of biomass for energy needs. Enhancement of biomass utilization efficiency and reduction in the consumption can be another solution. This chapter presents practical and workable measures to make use of the latter solution.

3.1 Fuelwood Growing

Of the total area of tea lands under estates in the 20 Regional Plantation Companies (RPCs), only 70% are under any cultivation. Within the cultivated extent, as at 2011, 16.1% or 19,000 ha is under fuelwood/timber cultivation. Out of the 30% uncultivated land extent, at least one third or 17,000 ha can be considered as the extent that could be utilized for intensive cultivation of trees to be taken for fuelwood and timber purposes. These lands are available in all tea growing regions. [01]

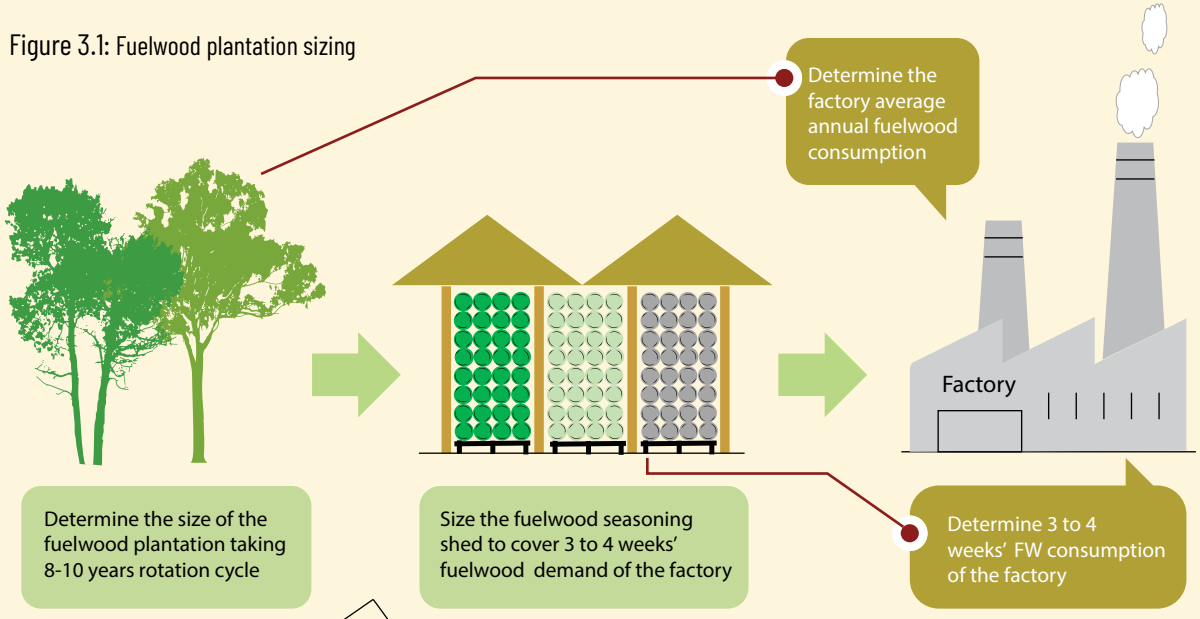
For most species grown for the purpose of fuelwood, the average growing cycle is 8 to 10 years, and the average annual yield is 12 to 20 tons per ha. Eucalyptus (Gum) and Acacias (Wattles) are currently available in fuelwood plantations and among them, Genus Eucalyptus is fairly distributed over all regions with different species. Eucalyptus Grandis, Eucalyptus Robusta, Eucalyptus Torelliana and Eucalyptus Camaldulensis are the species presently available in fuelwood plantations of RPCs. Acacia Mangium is the only species found in RPCs among genus Acacia.

Size of the fuelwood growing area requirement based on factory production capacity can be estimated as presented in the following case study.

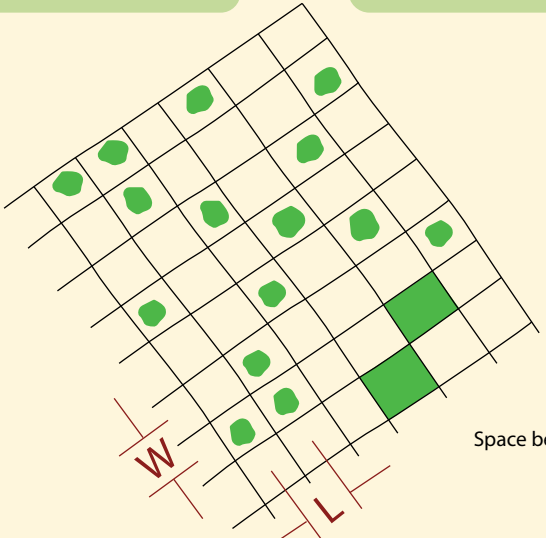
01 *Source: Agronomic Profile of the Corporate Sector Tea Plantations in Sri Lanka, Tea Research Institute of Sri Lanka, 2011.*

Case Study; 10,000 kg green leaf handling factory requires about 2,650 kg of fuelwood per day. This is approximately 8 m^3 of dry fuelwood per day and requires 2,000 m^3 of wood storing capacity for one day's fuelwood requirement. With an average 15 tons/year/ha fuelwood yield, approximately 100 ha of a fuelwood plantation is required to cater the factory fuelwood demand.

Figure 3.1: Fuelwood plantation sizing



Fuelwood shed sizing



Space between leaves (L,W) 1 - 2m

Further information on sustainable fuelwood growing can be found in the website: www.biomass.lk.

3.2 Fuelwood Receiving and Handling

- Try to receive fuelwood as dry as possible. Avoid or limit purchasing/receiving wet fuelwood.
- Green logs (fresh logs) have a moisture level of 40% to 60% and are unsuitable for use in the furnace as-received. This is because a significant amount of energy contained in the fuelwood would be wasted in driving out the large amount of moisture.

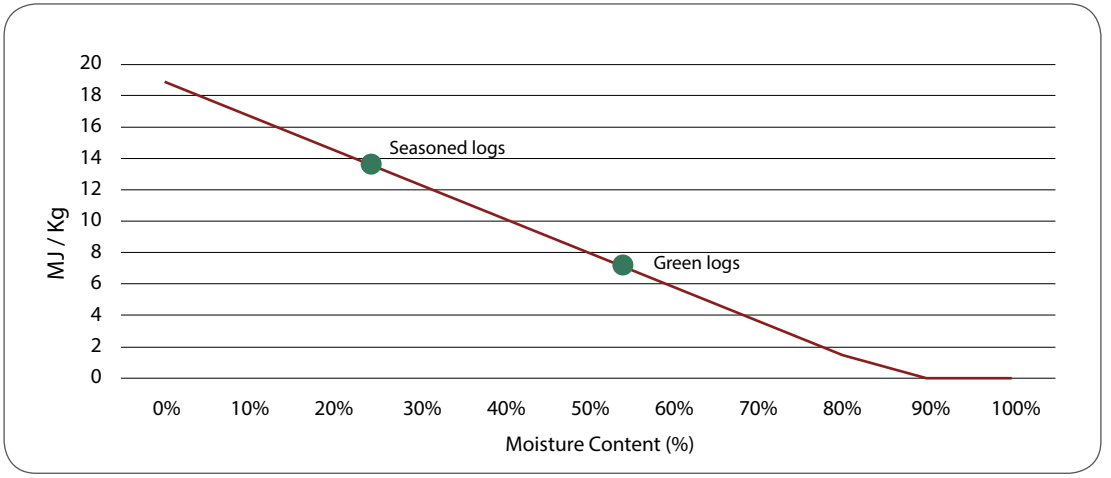
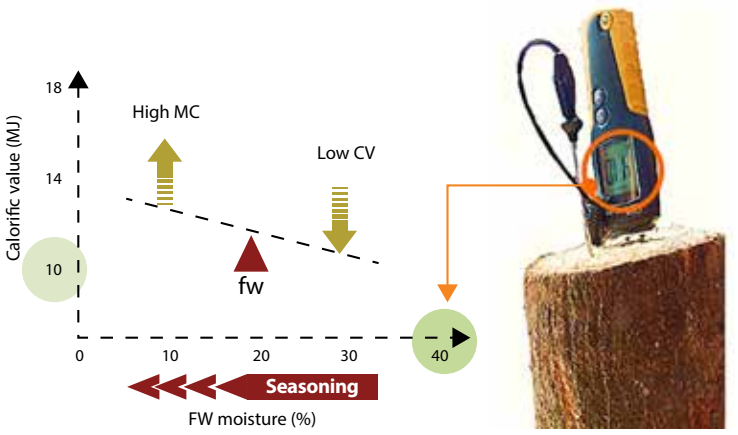


Figure 3.2: Caloric Value of Fuelwood Vs Moisture Content



- Moisture content of logs can be easily measured using a hand-held moisture meter as shown in Figure 3.2.

Figure 3.3: Measuring the humidity of fuelwood

- Carrying out moisture sampling of the fuelwood as-received and keeping records of these sample measurements is a good practice. This information can be used to track the progress of purchased fuelwood seasoning activity described in the next section.

- In case of fuelwood, if the purchase is done in terms of stacked volume, the wood logs should be arranged in approximately one-meter high rows without gaps, in a manner acceptable to both the seller and the purchaser.

- Best practice of fuelwood or any other biomass fuel purchase is to use mass instead of volume. This practice is feasible in large factories where weigh bridges are available.

- Avoid receiving mud and sand contaminated fuelwood. Sand is rich with silica and it can block the firing grates and also get deposited inside the fire tubes, resulting in poor combustion and poor heat transfer.

- Use covered vehicles when transporting biomass during rainy periods.

- If a group company has several factories close to each other, processing (splitting, drying etc.) and supplying of fuelwood for each factory is best arranged in a centralized location, instead deploying resources at multiple locations, thereby ensuring the quality of fuelwood and simplifying the logistics management. This can be done by the respective group company or even be outsourced.

3.3 Fuelwood Storing and Seasoning

- Record the bought/received fuelwood moisture content at the time of receipt and when the fuelwood is released to the furnace/boiler for combustion after seasoning.
- As shown in Figure 3.3, split the received fuelwood and store for three to four weeks for drying before using it.

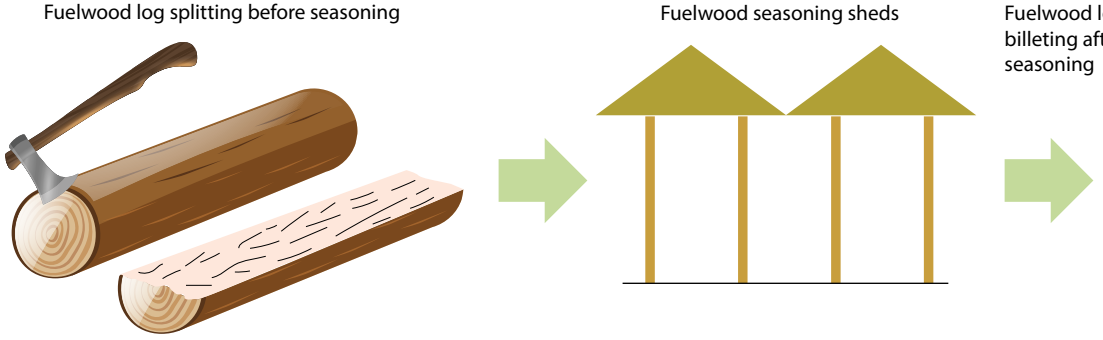


Figure 3.4: Fuelwood Storing and Seasoning

- It is recommended to split fuelwood to a size not exceeding 12-18 inches in length and 4 inches of diameter. Splitting of fuelwood increases the surface area, accelerating the rate of moisture loss, which is desirable for the seasoning process.
- Store the split fuelwood layer by layer in lateral and longitudinal directions as illustrated in Figure 3.4 to create a natural air flow through the stock.

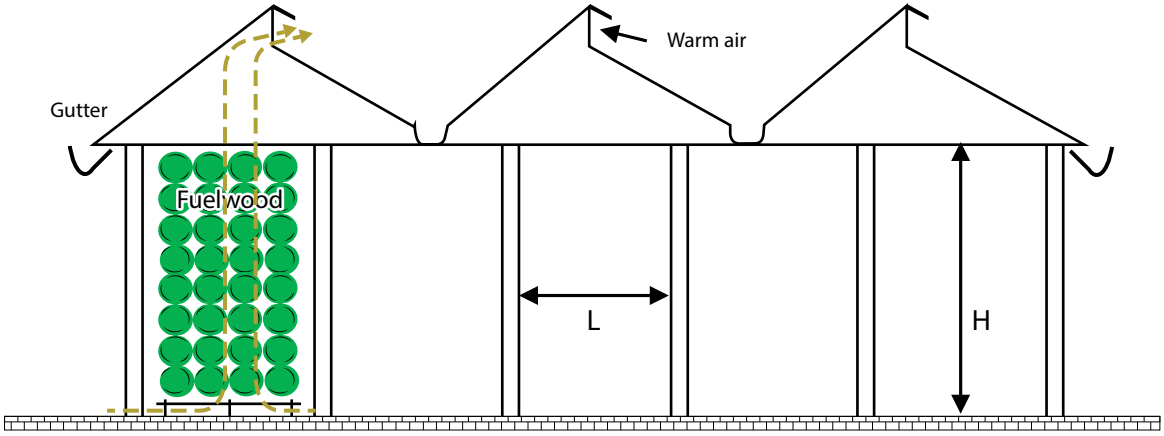


Figure 3.5: Recommended Design of a Fuelwood Shed for Fuelwood Storing

- Mark the fuelwood received date on the stock and use it on first-in first-out (FIFO) basis after drying.

- Fuelwood with 25% to 30% moisture is suitable for use. [02]

- A low cost shed for storing fuelwood can be constructed by using light weight steel or wooden structures and covering the structure with transparent 200-micron polythene.

- Fuelwood can be stacked, keeping air gaps between logs or fuelwood pieces to allow a free air flow. This system acts as a greenhouse. Openings need to be provided at the bottom and the top to create a cross flow through the fuelwood stock as shown in Figure 3.4.

- It is important to make sure that the floor of the shed remains dry even during the rainy season. Also, pathway between the shed and the furnace room needs to be paved in a simple manner to give prominence to the fuelwood feeding arrangement.

- Make necessary arrangements to prevent fuelwood getting wet during the transfer from the fuelwood storage area to the furnace room during rainy seasons.

02
Due to the high humidity levels in Sri Lanka, even when stored under cover, moisture level hardly decreases below 25%.

3.4 Fuelwood Feeding

- Feed a known quantity of fuelwood in regular intervals to the hot water heater/boiler or furnace. Feed in 25 kg to 50 kg batches (depending on the heat energy requirement of the dryer) at 15 to 20 minute intervals. The batch size can be determined through trial and error. This arrangement minimises the likelihood of overfeeding and underfeeding of fuelwood and also make it easier to maintain a uniform temperature level inside the furnace.

- Avoid the use of small and large pieces of fuelwood together in the furnace. The rate of firing with different size of fuelwood is not uniform. Small pieces get burnt quickly and release heat rapidly. It is required to maintain a higher amount of excess air for burning of large pieces of fuelwood and if heat is generated too fast by the smaller pieces of fuelwood, this heat would pass through the heat transfer area rapidly, reducing the heat transfer rate. Use of small pieces mixed with normal sized pieces is acceptable when temperature fluctuations need to be controlled by improving the firing condition.

- Avoid tightly packing the furnace with fuelwood. Feed the fuelwood, keeping free spaces in between fuelwood pieces, providing free spaces for combustion air to enter the fireplace. This increases the turbulence inside the combustion chamber and results in a uniform and better combustion.

- Avoid completely filling the furnace with fuelwood. Keep free space within the furnace. Ideally, about one third of the furnace volume should be filled to allow the flame

sufficient time in the combustion chamber to give out heat by radiation before entering the tubes. If the combustion chamber of the furnace is fully packed with wood, there is a tendency for the live flame to enter the tubes, which is a major reason for burning of tube ends.

- Always try to maintain a brilliant yellow colour inside the combustion chamber. If the system is tuned properly (with good quality fuelwood and appropriate limit of excess air), the flame will give this colour.

- Keep fuelwood for the next feeding at a close distance. This will reduce the time the fuelwood feeding doors are required to be kept open.

- Clean the bottom ash daily to ensure smooth flow of combustion air into the furnace.

- Clean the fire tubes weekly using correct cleaning utensils. The cleaning needs to be done while the air heater/boiler is slightly warm.

- For boilers with double fuelwood feeding doors, open one door at a time to reduce cold air ingestion.

3.5 Furnace Operation

- Furnaces coupled with tea dryers are equipped with two sets of fire tube bundles on either side. There are two flue gas exhaust ducts for the two tube bundles. It is important to maintain equal air flow rates through these two ducts to ensure a uniform heat transfer across the two fire tube bundles and to avoid unnecessary overheating in one segment. This can be achieved by adjusting the air control valves at the two sides.

- Fire bars and side tiles should be correctly positioned.

- The ash pit door should be adjustable and should be used properly to control the combustion air flow.

- Properly insulate the air duct between the furnace and the dryer.

- Make sure temperature gauges are working properly. Calibrate the temperature gauges annually.

- Monitor the flue gas temperature at the induced draft (ID) fan inlet. Make sure there are no air leaks in between the furnace and the ID fan.

- Maintain the flue gas temperature in the range of 120-130 oC at the ID fan inlet. This level may depend on the specific design of the furnace and the dryer. However, the aim should be to keep it at a minimum above condensing temperature, while achieving the required hot air temperature by the dryer.

3.6 Boiler Operation

- Maintain the boiler water quality at the recommended condition (refer Table 3.1) to avoid the deposition of scale inside the boiler.

Table 3.1: Recommended Water Quality Parameters for Boilers

Parameter	Recommended Level
TDS	Less than 3,500 ppm
pH	10.5 – 11.5
Alkalinity	Less than 700 ppm
Silica	Less than 125 ppm

- Install an inline water softener and maintain the recommended water quality level.

- Clean the water gauge glass of the steam boiler daily.

- Properly Insulate the hot water or steam pipes and the boiler feed water tank to minimize heat losses.

- Check the steam traps regularly and repair or replace faulty traps. If steam leaks occur at the trap, the steam could directly pass through to the feed water tank through the condensate return line. Such occurrences can be detected if water is seen boiling at the feed water tank.

- Use of variable speed drives (VSD) for regulating the combustion air can reduce the electricity wastage at the blower. Use of VSDs also can reduce the fuelwood consumption .

- Pressure inside the boiler should be maintained at desired levels. When fuelwood feeding door is opened, air should be sucked in only slightly, indicating a marginally negative pressure inside. This can be tested by holding a thread at about half-a-foot distance from the feeding door and checking whether the thread is leaning towards the door, but not being dragged into the furnace. On the other hand, the inside pressure should not be too negative either. If the inside pressure is considerably lower than atmospheric pressure, the flame will be seen being dragged towards the firetube end of the furnace.

- Generate steam at the design pressure of the boiler and utilize it at minimum possible pressure (e.g. 3 to 3.5 barg) at the heat exchanger (radiator) to get the maximum benefit of steam.

- Record the chimney temperature hourly. Exhaust gas temperature of the boiler should be around 200 – 230 0C. If the exhaust temperature increases unnecessarily, it could be due to;

    - Amount of fuelwood loaded being higher than the capacity,
    - Air is supplied in excess to the combustion chamber,

- Dirt is deposited inside or outside of the fire tubes.

- If white smoke is emitted from the chimney, it could be due to;

  - High moisture content in fuel
  - Excessive combustion air supply

- If black smoke is emitted from the chimney, it could be due to insufficient air supply for combustion.

- Clean the heat exchangers regularly. Dirt deposited on the heat exchanger surface acts as a heat insulator that reduces heat transfer between the hot and cold streams significantly, thus leading to higher fuel consumption.

- Typical boiler operating parameters are

  - 40-42% excess air (for biomass combustion)
  - 7-8% oxygen
  - carbon monoxide less than 4,000 ppm.

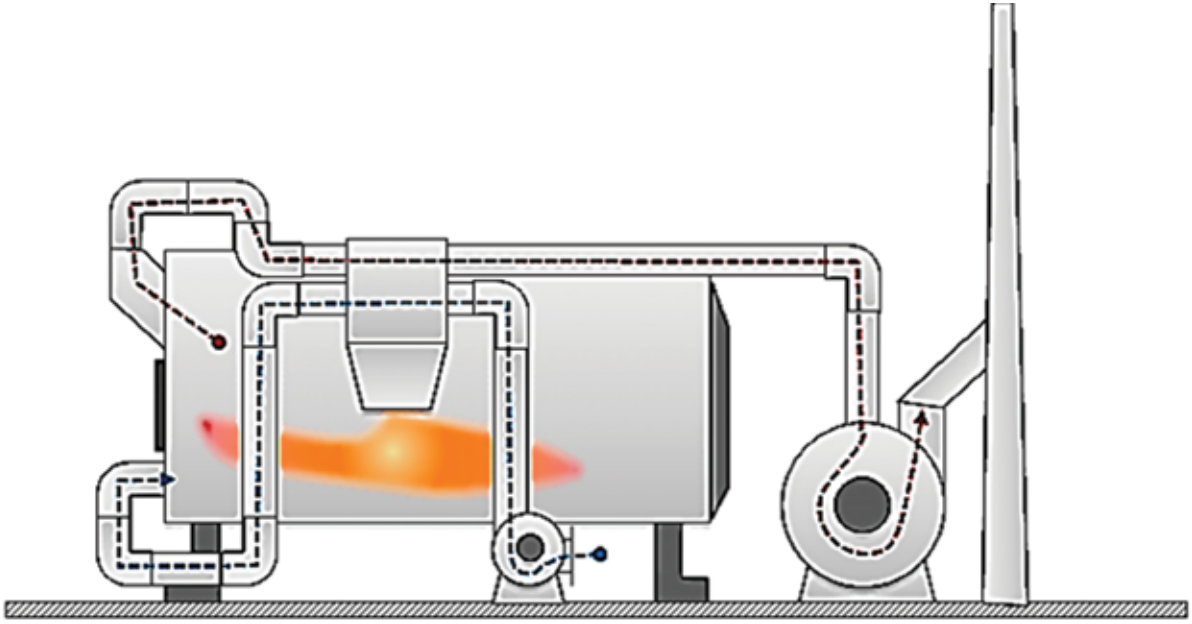


Figure 3.6: Boiler Heat Exchanger





Electrical Energy Supply


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4 Electrical Energy Supply

This chapter discusses interventions and practices in electrical energy supply (and generation), which can help the reduction of electrical energy use and maximum demand, leading to electricity bill savings. Best practices of tariff management, power factor correction, best practices of energy management such as metering & sub-metering, use of stand-by generators and renewable power are discussed in this chapter.

Electrical energy is mainly required in tea factories to drive the motors whilst a small share is used to provide lighting and for other auxiliary uses. Electrical energy use will be detailed in separate chapters with reference to end-use application (e.g. withering, rolling etc.).

4.1 Electricity Tariff Management

A Time of Day (ToD) electricity tariff is applicable for tea Factories. Currently applicable [3] ToD tariff is given in Table 4.1. Users are advised to note the large differences in energy charges applicable for different time intervals. It is noted that a very high energy charge is levied for the peak electricity demand period of the national grid. Similarly, a very low energy charge is levied during the low demand period. Users are advised to look for cost reduction opportunities through the adjustment of time periods of different processing activities.

Table 4.1: Electricity Tariff for Medium Scale Factories

Time Interval	Energy Charge (Rs./kWh)	Fixed Charge (Rs./month)	Maximum Demand Charge per month (Rs./kVA)
Peak (18.30-22.30)	20.50	3,000.00	1,100.00
Day (5.30-18.30)	11.00		
Off-peak (22.30-05.30)	6.85		

03 As of May 2019.

Since withering of tea leaves is the major processing activity occurring during the peak period, use of VFDs fitted to withering trough fans provides a significant cost saving opportunity. To reduce costs, only the minimum required air flow should be maintained by adjusting the VFDs during the peak period. If judiciously practiced, this

measure significantly reduces the electricity consumption during the peak period and save costs without affecting the quality of process.

During the peak period of the day, operation of non-essential equipment/machineries such as wood splitters, cutters etc. should be avoided and these operations should be shifted to off-peak and/or daytime.

After a power failure, a step by step/sequential switching on of withering lofts and rollers is recommended. When the sequential starting is practically impossible, use soft starters for higher capacity, constant load motors can reduce the higher starting current (maximum demand). If the load is varying, use of VSDs will reduce the starting current and the energy consumption at varying load.

Whenever possible, withering process should be planned in such a way to carry out maximum withering duty during off - peak rate period.

4.2 Metering/Sub-metering

- Implement proper electrical energy accounting system by way of introducing sub meters for major energy consuming areas and recording the meter readings daily. Monthly sub-meter data records should be compared against section-wise targets set through an energy management plan.

4.3 Power Factor Improvements & Phase Balancing

- Capacitor banks should be used to manage the factory's maximum kVA demand. Reduction of maximum demand is achieved by keeping the power factor (PF) around 0.98. The recommended place of installation of capacitor bank is the main distribution board of the factory. Capacity Bank must have a digital PF indicator showing real time PF value.

- Sudden drop in PF below 0.95 should be inspected for potential failure of capacitor bank.

- Weekly visual inspection of capacity bank for any abnormality (e.g. burnt capacitors).

- From the digital meter installed at the grid metering house, maximum demand can be read, and this must be monitored regularly.

- Factory must be aware of the time of occurrence of its peak demand, which depends on the process. It is important to make sure that the corrected power factor is as close to unity as possible during the peak demand time.

4.4 Electricity Distribution

- As much as possible, distribute the single phase loads in the factory evenly among the three phases.

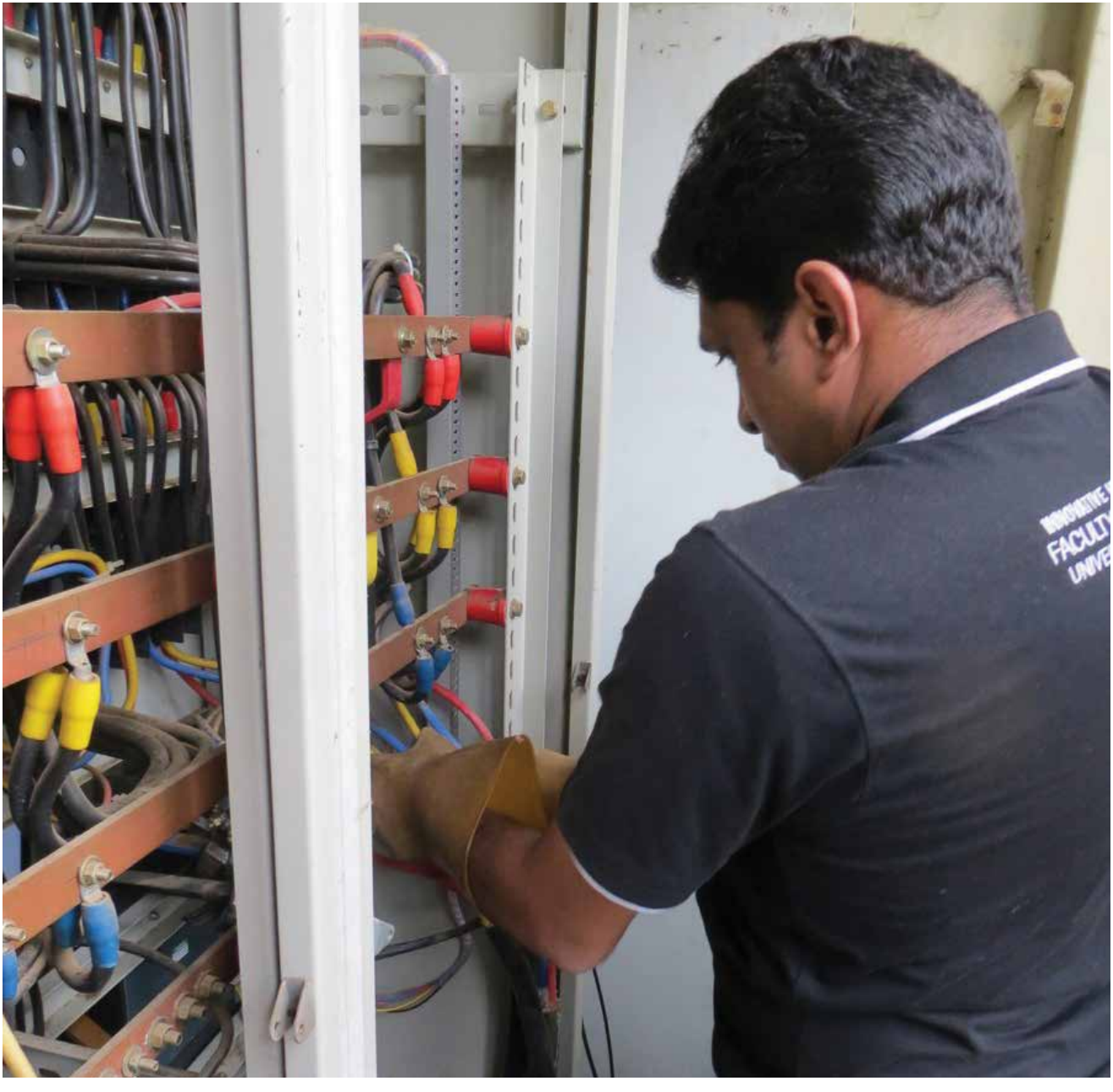
- Use correctly sized cables to supply electricity to the load. Use of undersized cables results in increased energy losses, voltage drops and can cause fires. Overheated cables indicate improper cables sizing.

- Inspect terminal connections and switchgear connections regularly for any loose connections. Improperly connected terminals result in voltage unbalance and energy losses, in addition to the associated fire risk. Measure terminal connector temperature annually, using a non-contact type thermometer or a thermal image camera.

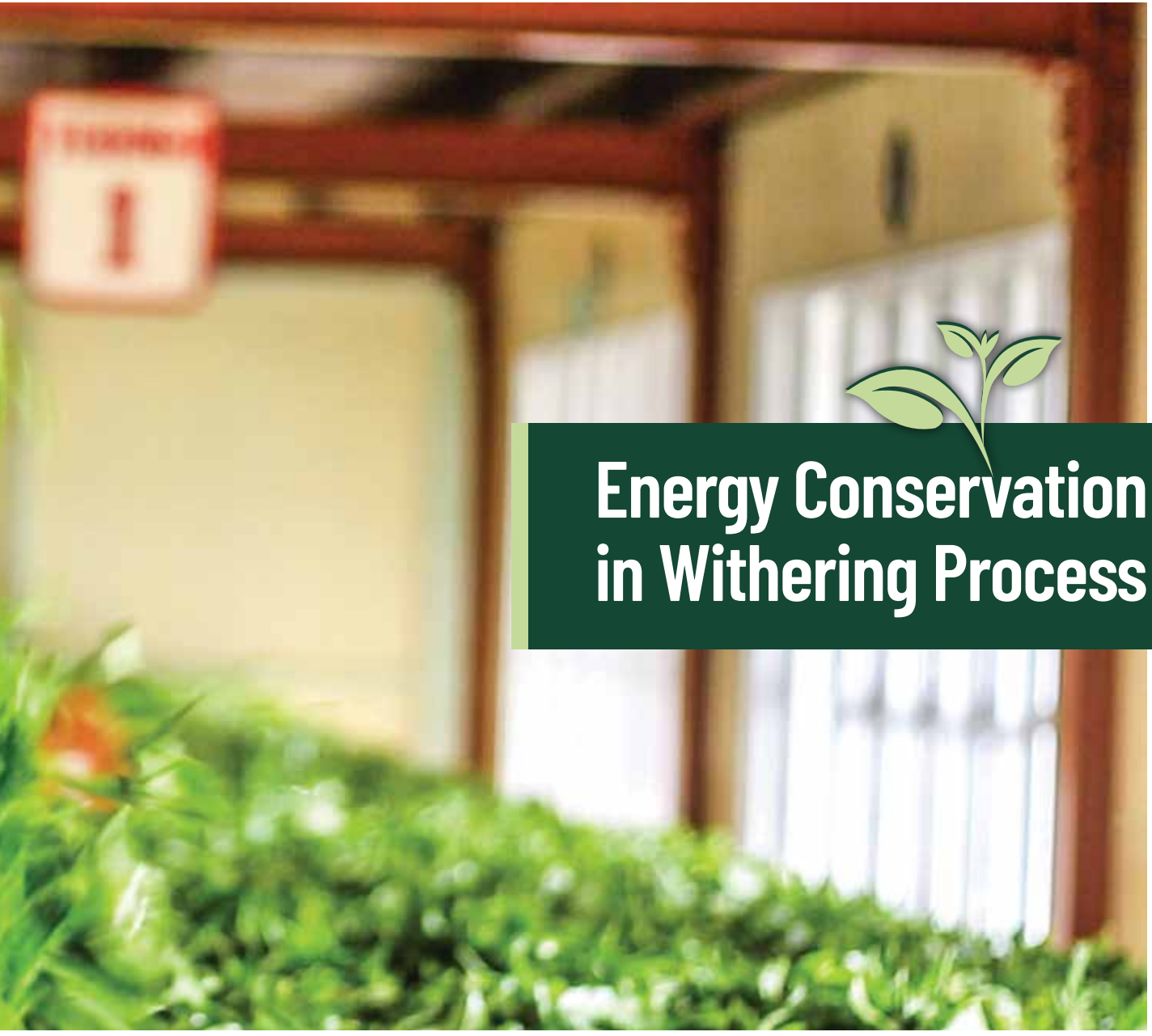
4.5 Stand-by Generation

- The factory should invest on a stand-by generator of a sufficient capacity to power at least the key processing activities such as dryers and rollers.

- Daily, weekly, monthly and annual maintenance of the generator and making sure the generator is in good working order is very important.







Energy Conservation in Withering Process

5 Energy Conservation in Withering Process

The largest electricity share of the production process is the withering operation. Typically, 40% to 45% of factory electricity use is for the withering process.

Withering is the first step of the tea manufacturing process and obtaining a quality wither is of paramount importance. Slow evaporation of moisture while maintaining air flow across a thick bed of tea leaves is the present practice of withering in Sri Lanka. In the withering process, full flow of air is required only during the initial 3 to 5 hours to facilitate fast removal of surface and easily available moisture from within green leaves. Subsequently, the air flow can be reduced for removal of moisture from within the tea leaf, which takes time to diffuse out. Normally, this change of air flow requirement is done by adjusting the dampers provided in the inlet air grill. Dampers achieve the desired outcome, but without significantly reducing the energy consumption of fan motors. In addition, as dampers are adjusted manually, it may not happen at the optimum manner. This section presents some energy conservation measures that can be implemented in the withering process.

5.1 Receiving of Tea Leaves

- Ensure only carefully transported, commercially acceptable quality leaves (tender two or three leaves and bud and tender banji) are received and minimize receiving mature leaves. Uneven standard of leaf always leads to uneven withers. While over matured leaves take a long time to wither, best quality leaf by then get over-withered. Therefore, extending the withering time to get mature leaf also withered is meaningless, both in terms of quality as well as cost of electricity used for withering.
- Use covered vehicles when transporting green leaves during rainy season to avoid wetting. If more surface moisture is present, it takes a longer time for withering and is wasteful.

5.2 Withering Trough Management

- Rank the available troughs considering the minimum electricity use for that size of trough, ease of maintaining hygrometer difference and time taken for withering. When loading the troughs, consider higher rank troughs first and utilize them more.

- Since electricity is a lot more expensive than thermal energy (hot air, steam or hot water), leverage may be made on energy usage to achieve withers by striking an optimal balance between running the fans (electricity use) and getting hot air for withering troughs. For example, during late night hours, when usually humidity is very high, either fan should be run with hot air supply or fans should run at low speed, if use of hot air is harmful.

- Maintain recommended air flow rate at the trough. At the start-up, it is recommended to provide 0.56 m^3 of air per minute per kg of green leaf. For this purpose, it is necessary to utilize a correct sized motor and an axial flow fan. (Note: Measurement of air flow rate is often very tedious and full of inaccuracies. Therefore, users may make their judgement on adequacy of air flow by comparison with other troughs. Operators are highly advised to follow industry practices like handkerchief method to ensure optimum withering airflow).

- Recommended leaf loading is 2.5 kg of green leaf per square feet of trough area to get an even wither and to optimize the energy use. Avoid thin spreading on long troughs even during low cropping seasons. During heavy cropping periods, higher loading rates are unavoidable.

- Proper green leaf opening and spreading helps in achieving uniform withers, thus reducing the time needed to achieve withers. Good withers result in better made tea and saves on both electrical and thermal energy.

- Strictly prevent air leaks from the trough box. If air leaks exist, the internal pressure of the trough and air flow rate across the trough bed reduces, resulting in longer wither time and waste of electricity.

- Sloped side plates on either side of trough bed is a must to avoid air leaks from the edges.

- To get the best wither, air temperature should be as low as possible. Ideally, to get an even wither, the dry and wet bulb temperature difference of the air flow should be maintained at 4 - 6 F. However, to get withering done within the expected time, temperature and low humidity (measured by dry and wet bulb temperatures) should be managed carefully.

    * Place the hygrometers at the middle of the trough in a manner to face the airflow.
    * Ensure there is water in the container.
    * Ensure that cloth wick is soft.
    * Make sure that thermometers are easily readable.

- Latest electronic sensors, displays, controllers and alarms can also be used to monitor the temperature and humidity level.

- Often, hot air is required to maintain the temperature difference. Generally, hot air is taken from the dryer room through a duct. Since there is not much control in this system, more attention and supervision is required to maintain the required temperature and get the best results. In hot water and steam boiler applications, this can be improved by introducing separate hot water or steam lines with heat exchangers and flow controls to the trough.

- Within the first three hours, there is a tendency for the leaf bed to get packed. Loosening of the leaf mass at that point is necessary to facilitate a proper airflow.

- Loosening of leaves in-between will further facilitate proper flow of air and reduce the withering time.

- To get an even wither, turning the leaves at the required intervals is essential. Turned leaf mass must then be loosened.

- Avoid damages to the leaf loading bed.

- Vibration of the trough due to vibration of fan impellor or other rotating machinery can also lead to packing of leaf on the trough resulting in air leakages and uneven wither.

- Provide fresh air by opening windows and minimize re-circulation of spent air (air leaving through the withering bed). Sometimes during rainy periods, some windows may be kept shut to avoid wetting of the floor.

- For best energy efficiency, introduction of fan speed control mechanisms (Variable Frequency Drives) in place of dampers or louvers is highly recommended. This is further discussed in the following section.

5.3 Fans and Motors

Controlling the motor speed in a fluid machinery is the best mode of regulating the output. These controllers are defined in different technical names viz. Variable Speed Drives (VSD), Variable Frequency Drives (VFD) or more commonly it is identified as inverters in the market. Inverter is not a newly introduced technology and is commonly available in domestic refrigerators, washing machines, air conditioners etc. to control the output. This technology has been introduced to the Sri Lankan tea industry for controlling withering fans about 15 years ago. As per the studies carried out, if it is possible to control the air flow of a withering trough through an inverter, by its judicious use, approximately 40% of electricity use for withering can be saved. This is a very attractive, technically and financially feasible investment.

- Supply frequency in Sri Lanka is 50 Hertz and fans used for withering troughs work at 960 rpm. When frequency is reduced, speed of motor too reduces proportionately.

- Additionally, in a fan, when speed is decreased, volume flow decreases proportionately whereas power consumption decreases to degree three. For example, when speed is halved, volume reduces to half and power reduces to one eighth.

- VFD saves energy, when the connected motor is running at any speed below the rated RPM, which is related to frequency.

- If VFDs are installed for withering troughs, the VFD can be used to change the fan speed while keeping louvers fully open.

- A lower air flow can be maintained during spreading, loosening, turning and collecting by reducing the fan speed while louvers are kept fully open.

- The fan can be kept at full speed for the first few hours, essential when wet leaf is to be withered and when the time available for withering is short. Once that period is over, VFD can be used to reduce the withering period.

- Adequacy of full air flow is usually checked in an international fashioned method by using a handkerchief.

- Louver control may be used only when taking hot air.

- Operate the fan at lower speed after obtaining the partial wither. Then there is no need to open rear door or to block the air intake.

- Operate fan at lower speed for long wither, and handkerchief method can be used to ensure sufficient airflow requirement for withering operation.

- Additional loosening, when one or two times loosening will help to further reduce the air flow requirement.

- Fan speed can be reduced during peak rate hours (6.30pm to 10.30pm) to reduce the electricity consumption and save cost, provided that there is no surface moisture to be removed.

- Operate a withering fan at lower speed using a VFD, if there is a need to exhaust warm humid air from the dryer room.

- Change fan blade angle setting to achieve optimal fan operation. Proper fan angle setting results in lower drag, thus lowering current demand while at the same time achieving maximum air flow rate within the capacity of the motor. Necessary technical support can be obtained from the Tea Research Institute for this purpose.

- Check on balance of fan impellors. Out of balance impellors give excessive vibrations (energy loss), higher motor loading (energy loss) and may lead to reduced motor life or burn out.

5.4 Lighting Improvement in Withering Section

- Avoid group switching of lights as much as possible.

- Use one or two lamps per loft for night-time illumination and use trough lamps only for essential works (e.g. turning, checking hygrometer readings etc.)

- LED lamps are more efficient than other types available in the market. Replace blown fluorescent lamps with LED lamps.

- Use reflectors, if CFLs/LEDs are used.

- To improve the brightness, clean the lamps and the luminaires periodically.

- Select lamps with higher star ratings.

- Use daylight as much as possible with Skylight options whenever possible.

- Eliminate over or under illumination.

- Use a colour code or numbering system to identify the switch and the respective bulb.

Roller Room Operations





6 Roller Room Operations

Use of different types of maceration machines, roll breaking, and fermenting are the next steps in tea manufacturing process. Of the total motor population in a tea factory, generally, a greater number of high capacity motors are found in rollers. The energy requirement of rollers depend on the pressure applied on the roller bed. Since this process is done manually in most of the tea factories, attention and supervision are required to reduce energy wastage.

6.1 Rolling Programme, Correct Loading and Management, Roll Breaker Operation

- Apply only the required pressure to the roller. When pressure is applied, power consumption of the roller increases.
- Load the rated dhool capacity to the roller. Avoid under loading.
- Schedule the rolling programme to avoid unnecessary and idling operation.
- When designing the rolling programme, eliminate the possibility of high pressure minutes overlapping in many units as that may contribute to peak demand of Factory.
- Automation of pressure applying system and green leaf feeding system can eliminate most human errors and can improve the quality of the product as well as reduce the energy use.
- Take out the dhools from the rollers directly to a trolley or cart and bring them to the roller breakers.
- Tension the belts properly in the belt drives. Power loss from a loose V belt can be as high as 20%.
- In multi belt drives, use the designed number of belts.
- When replacing belts, replace all the belts at once in the particular belt drive

6.2 Rotorvane

- Be aware of the condition of vanes of Rotorvane. Wasted vanes lead to poor quality rolling and waste of energy.

- Plan roller room operations to avoid idle operation of rotorvanes and other machineries.

6.3 Roller Breaking

- Evenly feed dhools to roll breakers. Maintain uniform thickness of dhool at the roll breaker without over feeding.
- Minimize manual loading and unloading and, as much as possible, use conveyors to facilitate even feeding.
- Avoid idling operation.

6.4 Fermentation

- Be aware of effectiveness of humidifiers. Avoid water droplets on floor. Instead, all water must create mist.

6.5 Lighting Improvements in the Roller Room

Refer Section 5.4 for energy conservation measures in lighting.





Firing Operation



7 Firing Operation

Drying is done to stop the fermentation and to bring the moisture level down to required 3% level. Different types of dryers are used in tea manufacturing and the drying temperature recommended vary depending on the type of dryers as well as type of processing. Obtaining the rated dryer output whilst minimizing the energy use is the main challenge. In most tea factories, both hot air generation and utilization and the dryer operations are done manually. Due to this, energy wastage in tea drying the tea industry is varying from 0.56 kg to 3.23 kg of fuelwood per kg of made tea. With the implementation of energy efficiency measures, it is possible for all the factories to achieve the best energy performance level and the corresponding total annual saving in the tea sector would be 42,300 tons of fuelwood. This chapter presents simple energy waste minimization measures, that can be implemented in the tea drying area.

7.1 Temperature Control

- Calibrate the temperature gauges and make sure the measurements are correct or else, the errors are known. Calibration can be done in-situ by checking against boiling temperature of water.

- Volume flow rate and temperature of hot air should match in both the furnace and the dryer. If expected performance is not achieved, get the units tested by a competent person.
- Furnace, Hot Water Generator or Boiler should be able to provide the required volume of hot air, at the required temperature, to the dryer.

- ECP or FB dryer should be able to maintain a steady exhaust air temperature while giving steady moisture level of 3% in tea.

- Automatic controllers for regulating the supply energy with respect to the dryer temperature is available in some of the tea factories and thereby the unnecessary use of energy can be minimized.

7.2 Dryer Management

- Maintain uniform feeding of dhools.

- Ensure all the trays are in order in the ECP dryers.

- Feed dhool across the whole tray without keeping empty spaces. Do not keep empty trays in ECP dryers. When the trays are empty, major portion of hot air bypasses through them.

- In an FBD, continuous even feeding is very important. That will facilitate optimum fluidization along the full length of

the unit. Proper fluidization is vital in relation to quality as well as cost.

- Avoid air leaks in dryer walls.
- Make sure that rolling programme can give an uninterrupted supply of correctly fermented dhools. Time gaps in feeding the dryer should be avoided nor accumulation of dhools awaiting drying.
- Do not over-fire the tea, as this will increase the fuelwood use unnecessarily.
- Minimize re-firing requirement.



Grading Room Operations





8 Grading Room Operations

Purpose of grading room operation is to prepare grades of tea to facilitate sale, for example, at the Auction. It involves sifting of fired tea using sifters (meshes), cleaning such as stalk and fibre removal, removal of sand and other impurities, separation to satisfy grade nomenclature such as removal of fine dust from larger particles and finally packing of grades of tea in standard sacks.

Different types of numbers of machines are being used in these processes and most of the operations are done manually, assisted by conveyors. Also, output of one machine could be the input to another machine and so on. If capacities do not match, one machine could be in idling operation or may have to be stopped or slowed down. Smother function of these machines are essential for obtaining an optimum output.

8.1 Machine Capacity Matching and Operation

- Pre-schedule the sorting and packing room operations and avoid idling operation of machines.
- Tighten the belt and chain drives properly to ensure the maximum energy transfer between pulleys and sprockets.
- Automation of feeding of dhools can eliminate the human errors and reduce energy waste.
- Always run the machines at capacities most desirable for quality of production.

8.2 Lighting

Please refer Section 5.4

8.3 Compressor & Compressed Air Supply

- Increased inlet air temperature reduces compressor output, resulting in increased energy consumption. Therefore, provide the air compressor with a cold, clean and dry air stream. Ensure to utilize clean air without dust.
- Clean the air intake filters regularly to minimize the pressure drop across the filters. Every 25 mbarg pressure drop reduces the compressor efficiency by 2%.
- Generate compressed air at the required pressure. Increase

in pressure by every 1 barg reduces the compressor efficiency by 8%. Operating a compressor at 120 psig instead of 100 psig, increases the energy use by 10% and increases the leakage rate.

- Maintain minimum pressure drops in the compressed air distribution system.

- Utilize the compressed air only for the essential work. Avoid unnecessary use.

- Do not use compressed air for cleaning purposes (unnecessary) or for ventilation purpose (as a fan/blower)
- Minimize the compressed air leakages in the factory. Regularly inspect for air leakages in the most likely places such as couplings, hoses, tubes and fittings, pressure regulators, condensate traps, shutoff valves, pipe joints and connectors at end use equipment.

- Adjust compressor delivery pressure by analysing pressures required by end use equipment and system pressure drop. Do not maintain high/excess pressure values as increased pressure results in more leaks and increased compressed air consumption.

- Cut off compressed air supply when the machine stops (manually or automatically) and proper adjustment/setting of compressor pressure values can also save a substantial amount of energy.

- Compressor water draining/bleeding should be frequently checked.

- Regularly clean the heat transfer surface/pins by removing dust.



General Maintenance





9 General Maintenance

Factory maintenance is a vast area to discuss and, in this section, focus will only be given to energy waste minimization aspects. Of the total electricity use of a tea factory, about 90% use is by the motors and machinery maintenance often focusses on maintenance of motors. Some of the critical aspects already covered in the above specific chapters and general maintenance aspects are covered in this section.

- Avoid oversized motors. Motors operating with low load factor reduce the efficiency and result in low power factor, both affects the cost.

- Purchase motors with the rated voltage of 230 V in Single phase and 400 V in Three phase. Operation of motors at 5% less voltage results in increases in energy consumption between 2% and 4%.

- In replacing motors at retirement or fault, use High Efficiency Motors (HEM) instead of standard efficiency motors.

- Clean motor surfaces regularly. Deposit of dust in the motor surfaces results in increased temperature, which causes shortening of motor life and increased energy consumption. Increase of motor temperature by 10^{c} results the increase of energy consumption by 0.5%.

- Do not apply paint to motor surface over and over. If motor surfaces are painted, remove old paint layer and apply a metallic spray paint. Accumulation of paints in the motor surfaces results in the increase of temperature of motor surfaces.

- Discourage the use of re-wound motors. If the motors are not properly re-wound, the efficiency may drop as much as 10%.

- Always feed the conveyors for full width. Reduced feed results in increased operational period of the conveyor belt and connected machine, resulting in waste of energy and low productivity.

- Use flat belt instead of V-Belt for power transmission wherever possible. Flat belts are more efficient than V-belts.

- When replacing belts, replace all the belts in the particular drive.

- Tighten belts properly. Loose belts can lead to losses up to 20 % of energy.





Renewable Energy



10 Renewable Energy

Renewable energy can be used to meet the demand of tea factories reducing the dependency on grid-electricity. Renewable energy application in tea factories started with estate or mini-hydro power applications, and roof-top Solar Photovoltaic (PV) applications are now in the increasing use with recent price competitiveness. This section covers solar PV, other usages of solar energy and small/mini hydro applications identified as more potential renewable energy application in the tea factory. However, biomass renewable energy use is not discussed in this section as this is covered with more details in section 3.

10.1 Solar PV

- Rooftop Solar Photovoltaic (PV) can be used to offset the electricity utility expenses incurred on tea factory electricity use. Solar irradiation from sun is converted to electricity by solar PV system.

- Tea factories can invest in rooftop solar PV capacity up to factory's contractual demand.

- Typical investment ranges from 120,000-150,000 Rs./kWp for capacity installations above 100 kWp capacities and space requirement can be approximately 700-800 m^2 for 100 kWp installation. Factory roof has to be of sufficient strength to hold solar PV installations.

- Typical solar PV generation is approximately 110 kWh/kWp/month whereas operation and maintenance cost is almost negligible.

- Factory owners can select either net-metering, net accounting or net-plus scheme of the utility (CEB). Under the net-plus scheme available at present, the factory can sell electricity (energy) at 22 Rs./kWh during the first 7 years and 15.5 Rs./kWh starting from 8 up to 20 years. Under the net-metering and net-accounting schemes, the factory can sell or carry forward any additional generations.

- Typical recovery period for investments is 4-5 years

10.2 Passive Solar Energy Use

Similar to active use of solar energy by converting to electricity using solar PV technology, the factory can maximize passive solar energy use. This can be done by;

- Loading troughs on the upper decks/lofts of the withering house. Use of passive solar energy hasten the withering process thus reducing the time the fans need to be operated and results in significant thermal energy savings.
- Use day light as much as possible with skylight and glass door/window options whenever possible

10.3 Estate Hydro/Mini Hydro

- In some tea factories, estate hydro/mini hydro have been in use for many years. Some of these hydro power plants might have already been abandoned or still in use with old and inefficient manner.

- It is advisable to invest in rehabilitation (or retrofit if it is an old/using more than 30-40 years) of these hydro power plant after initial feasibility is conducted.

- In some tea estates, there might still be some opportunity for new small hydro power plant (50-500 kWp) establishments and capacity of plant will be determined by the available height and flow rate (for an average sessional day) of the water stream.

- Typical investment requirement ranges from 250,000-500,000 Rs./kWp for height investments for complex sites (e.g. lengthy penstock lines) and technology selection





Energy Management



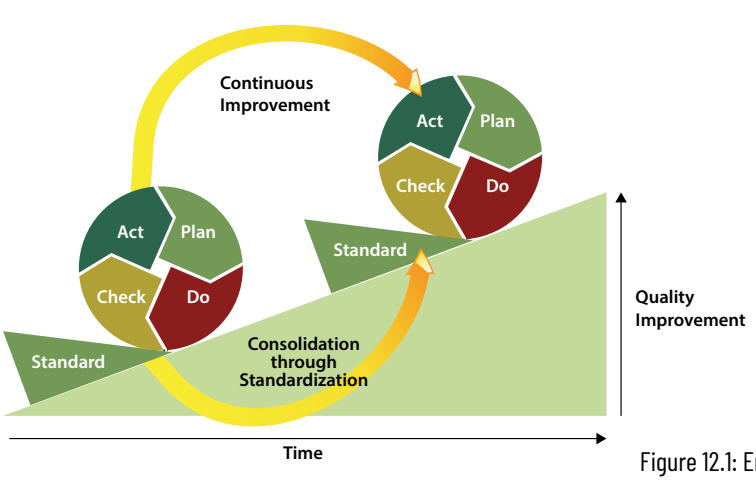
11 Energy Management

Energy Efficiency (EE), Energy Management (EM) and Sustainable Use of Energy are different to each other by definitions. EE is the input to output ratio and the objective is to maximize the useful output from certain available amount of energy. Selection of best source of energy with best technology for a particular application and practicing the use of energy efficiently is defined as energy management.

In energy management, a unique or ready-made solution cannot be recommended for all because from place to place the available systems and configuration can be different and energy type can be varying. Hence in the management of energy, certain experience is needed on available technology, type of energy, system operating parameter etc.

That is why, duty of energy manager and energy auditor has become important in the county in order to practice energy management effectively. At present, job role of energy managers is becoming compulsory in industries, and the government has published an extra ordinary gazette on 22nd July 2009, indicating the qualification and experience of an energy manager and the same defines the duties of an energy manager.

Implementation of energy management system is a continuous process, enhancing the results day by day. Energy management implementation process is clearly introduced in ISO 50001 standard. There are a few ISO 50001 certified tea factories in Sri Lanka now.



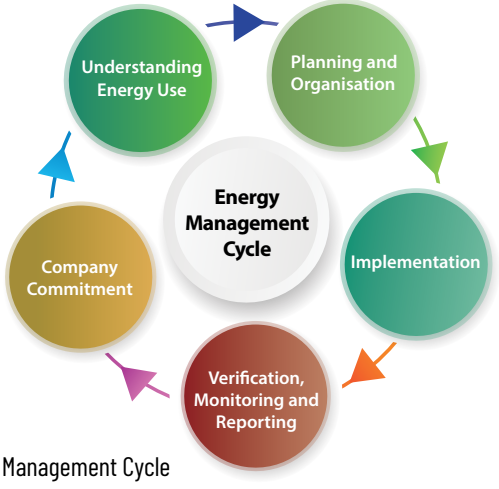


Figure 12.1: Energy Management Cycle

The energy management as a continuous process follows the PDCA cycle or a more specifically designed energy management cycle. The energy management cycle for tea industry can be discussed as follows.

11.1 Planning

11.1.1 Appoint an energy manager and energy management team:

Appointment of capable team is the first step in this process. A person having sound knowledge on both tea manufacturing process and the machine operation is the ideal person for the energy manager's position. In addition to the energy manager, at least one person representing each section could be appointed to this team. The duty of the energy manager and the team are:

- Monitoring the day to day operations of the factory with a view to reducing energy cost and maintain records pertinent to the overall energy consumption.
- Conducting training and awareness programmes for the employees of the factory relating to energy efficiency and renewable energy,
- Obtaining the services of Accredited Energy Auditors as energy advisors from time to time. This is in order to identify energy conservation opportunities available in the factory.
- Advising the factory management on the purchase of energy efficient equipment.
- Assisting the factory management in implementing its energy management plan, within specified time frames

11.1.2 Development of an energy policy for the factory:

Energy policy is a document having statements in simple and specific meanings on implementation of energy efficiency activities in a tea factory. For an example, "fuelwood having moisture content greater than 30% will not be used in the furnace". If it is a single company with multiple factories like regional plantation companies (RPCs), one energy policy can be applicable for all the factories.

11.1.3 Development of an action plan for the factory:

An action plan is developed for a specific time period with a budget for implementation of such actions. Before development of an action plan it is essential to get an idea about present energy use and the potential for improvement. If the factory staff is not capable enough to undertake this task, advice may be sought from an energy auditor and develop it.

11.1.4 Sub metering:

Most of the factories are not equipped with sub meters even for major energy consuming sections and it is very difficult to understand the sectional energy use.

Therefore, it is advisable to fix sub energy meters for major sections and analyse the sectional inefficiencies and develop action plan.

11.1.5 Set targets:

Action plan comprises actions for implementation, budget and targets. The best measurement for set target is specific energy use in terms of ***kWh/kg of made tea*** or ***kg*** of ***fuelwood/ kg of made tea.*** Targets should be realistic and achievable. Year by year, the target can be revisited and reset.

11.2 Implementation

Implementation of energy efficiency measures can be categorized in different ways. Considering the implementation cost, it can be categorized in to three levels viz. low cost, medium cost and high cost or otherwise it can be categorized considering the results/impacts. Based on payback period, it can be categorized as short-term payback and long-term pay back. Short-term payback and high impact measures are more attractive for implementation.

When selecting an energy consuming equipment, it is advisable to evaluate the life cycle cost and get the decision without considering the initial cost.

11.3 Check/Monitor Verify and Report (MRV)

Monitoring the impact of implemented energy efficiency measures is a very important event in energy management. Check the previous and present specific energy use in each section separately and get the results. Variation of weather condition directly affects the tea manufacturing process and this needs to be taken in to account when taking decisions on impact of an energy efficiency measure.

If a single owner produces tea in multiple factories, similar to regional plantation companies (RPCs), it is advisable to compare these results of each factory in a common platform and take decisions for further improvements.

11.4 Act/Sustain

Energy management is a continuous process and the results are depending on the correct decision taken through the MRV process. Also, it is equally important for the implementation process to achieve better results. So, the commitment of all the staff (from top management to low level worker) is very important to transfer a tea factory into an energy efficient or green factory.

More specifically, this can be achieved as described in Section 12.5

11.5 Energy Management

- Appoint and energy manager and energy management team comprising members in each division in the factory.
- Improve the energy accounting system in the factory as described in Section 12.6.
- Set benchmarks and annual targets for reduction of energy waste.
- Implement energy monitoring system and display the previous day/monthly/quarterly/yearly results.
- Enhancement of knowledge on energy management among factory workers.

11.6 Energy Accounting System

- Keep the energy and production data precisely in a separate record.
- Establish specific electricity and thermal energy use (fuelwood) in terms of kWh/kg of made tea and kg of fuelwood/kg of made tea.
- Compare this result with the other factories in your group or in your region.
- Set energy waste reduction targets annually and try to achieve them.
- Introduce sub-metering to at least major energy consuming areas (withering, rolling/CTC cutters, dryer and furnace/ boiler etc). Specific energy consumption of these areas can be separately calculated and is convenient to monitor deviations of the energy consumption patterns.



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