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INTRODUCTION

This training manual has been developed for training key staff in the existing and new tea factories on the best practices in energy efficiency and energy conservation. Survey respondents reported the following indicators as potential signs that energy management training is needed in the tea factories:

- That energy management training has never been provided
- That staff were generally unaware of energy management systems
- Inexistence of energy management programs in tea factories
- Observed that inconsistencies exist between staff members in how procedures and operations are performed
- That some equipment was frequently out of service or required more than normal maintenance
- Some factories had high energy costs compared to similar factories
- Wood usage scores low efficiency level in almost all factories
- The existing energy management program has not delivered the expected results

![Figure 1 Training process for improved performance](image-url)
Objectives

The main objective of this training manual is to streamline energy efficiency in tea factories. The specific objectives are:

i. To impart knowledge on energy efficiency and energy conservation to the technical staff in Rwanda tea factories
ii. To test the knowledge of the trainees on the subject matter during the training
iii. To be used as a reference guide in implementing energy efficiency projects in Rwanda tea factories

Target audience

The target audience for this training are the key technical staff in the tea factories. These includes engineers and technicians in; electrical department, production department, operations department, workshop department, forestry department and energy procurement.

It is important to have a blend of various departmental representatives during the training so as to harmonize energy efficiency in the whole factory set up.

We can also have the top management representation/decision makers for mindset change in energy efficiency/ acceptance of the energy efficiency structure

Training methods, tools and materials

The training will be delivered using the following methods, tools and materials;

1. Conference training/classroom;
   - Hardcopy print of the manual
   - Flip charts, marker pens and highlighters
   - PowerPoint presentations including videos
   - Notebooks and pens
2. Factory visit, benchmarking and group discussions
3. Assessment and evaluation

The proposed location of Theoretical Training is preferably a Conference Hall in Kigali for 3 days

Number of Trainees; 30 pax, i.e., Maximum of 6 per factory with representation of technical departments and the decision makers.
We can also have representation of NIRDA/MININFRA concerned staff.

The Field Visits can be Either Kitabi or Nyabihu Tea Factory as they exhibited higher efficiency on both wood and electrical

A Training Report will be compiled after the training exercise and submitted to Fonerwa
### Proposed training program

**Table 1 Proposed training program**

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<th>Day 3</th>
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<td>8:00-10:00 Session 6: Forest Management to improve on wood energy efficiency</td>
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Energy management is the practice of tracking and reducing your organization’s energy consumption. It can involve small steps like regularly monitoring your energy bills. To some extent, it can also involve complex financial modelling for future years planning.

The Energy Management System (EnMS) is aimed at improving energy performance and reducing energy usage in a facility. This helps tackle climate change by reducing greenhouse gas (CO₂) emissions, improving efficiency and reducing consumption. This includes implementing efforts to monitor emissions and energy usage.

Energy management is very important as businesses look to control costs, control energy usage and attract clients that are conscious about corporate social responsibility.

Energy management system can help a facility in;

- Cutting costs through competitive procurement and strategically decreasing consumption
- Reducing greenhouse gas emissions for greater corporate social responsibility
- Tracking your utility costs to prepare more accurate budgets and gain greater insight into the operational costs
- Reducing reliance on supply chains that are inherently volatile
FORMATION OF AN ENERGY MANAGEMENT COMMITTEE

The purpose and key benefit of forming an energy management committee is to engage the various departments (e.g., procurement, production, facilities, operations etc.) within the organization in the development and implementation of the Energy Management System.

An energy committee will comprise of key staff pulled from various departments in the factory and a representative of the factory top management or ownership. The Energy Management Committee is composed of energy practitioners who work to improve energy efficiency and procurement – including the procurement of renewable and alternative energy.

Because energy concerns different departments within a firm, an effective energy management programme must involve a number of people. In many companies, a committee is formed to include representatives of important departments.

It can encourage communications and the sharing of ideas amongst various departments throughout the company.

It can serve to obtain agreements on energy conservation projects, which affect more than one department.

It can provide a stronger voice to the top management than a single manager normally could. The composition of the energy committee will vary from one company to another, depending on the existing management structure, the type and quantity of energy used and other company-specific factors.

The roles of the committee include; creating and updating the energy policy within the company. Appointment of an energy officer. Provision of the necessary resources (technical, staffing, financial) ensuring internal communication.¹

¹ Fadi AlFaris, Adel Juaidi, Francisco Manzano-Agugliaro, Improvement of efficiency through an energy management program as a sustainable practice in schools, Journal of Cleaner Production, Volume 135, 2016,
Figure 2 The context of energy committee in a facility
DESIGNATE AN ENERGY MANAGER

An Energy Manager is usually an employee already within an organization who is appointed and tasked to help monitor and reduce energy usage. For tea industries, an energy manager could be in the engineering or operations department tasked with this extra role in addition to his/her day-to-day duties.

The responsibilities & duties of an Energy Manager are:

Responsibilities

- Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energy costs
- Establish an energy conservation cell within the firm with management's consent about the mandate and task of the cell
- Initiate activities to improve monitoring and process control to reduce energy costs.
- Analyse equipment performance with respect to energy efficiency
- Ensure proper functioning and calibration of instrumentation required to assess level of energy consumption directly or indirectly
- Prepare information material and conduct internal workshops about the topic for other staff
- Improve disaggregating of energy consumption data down to shop level or profit centre of a firm.
- Establish a methodology how to accurately calculate the specific energy consumption of various products/services or activity of the firm
- Develop and manage training programme for energy efficiency at operating levels
- Co-ordinate nomination of management personnel to external programs
- Create knowledge bank on energy efficiency technology and management system and information denomination
- Develop integrated system of energy efficiency and environmental up gradation
- Coordinate implementation of energy audit/efficiency improvement projects through external agencies
- Establish and/or participate in information exchange with other energy managers of the same sector through associations
Duties

- Report to owners with information regarding the energy consumed and action taken on the energy auditors’ recommendations to improve efficiency
- Establish an improved data recording, collection and analysis system to keep track of energy consumption
- Provide support to energy auditors as conduct of energy audit for the factory
An energy management policy should set out your organization’s aims and goals concerning energy use and management. The policy should be a public statement about the business energy management goals that can appear in documents or on the website. Importantly, an energy policy doesn’t have to be long and complicated. Keeping it simple will make it easier to communicate and follow effectively.

An Energy Management Policy shall include—

- A commitment to improve energy efficiency and conservation;
- A commitment to comply with the Act and these Regulations;
- A commitment to provide resources necessary to achieve energy efficiency and conservation;
- A commitment to establish and implement a strategic plan for energy efficiency and conservation;
- A commitment to train staff to ensure competence in energy efficiency and conservation;

The owner shall ensure that the policy is endorsed by the top management

The owner shall ensure that the policy is displayed and communicated to all staff
GISOVU TEA COMPANY LIMITED ENERGY POLICY.

As part of our commitment to excellence and compliance with The Rwanda Energy Policy (REP, 2015) and the Energy Sector Strategic Plan (ESSP), Gisovu Tea Company will identify and implement improved financial and operational efficiencies relating to how we purchase and use energy, striving toward world-class status in energy management.

Commitment to Energy Management

Energy management will always play an important role in achieving our strategic objectives. Specifically, the Tea Company is committed to:

1. Improve energy efficiency and conservation in the Tea Company and associated buildings;
2. Comply with the Rwanda Energy Policy (REP, 2015) and the Energy Sector Strategic Plan (ESSP) and other statutory requirements related to energy efficiency and conservation;
3. Provide resources necessary to achieve sustained energy efficiency and conservation;
4. Establish and implement strategic plan for energy efficiency and conservation aimed at attaining energy intensities in our Tea Company of 0.55 kWh/kgMT and 300 kgMT/m³ for electricity and firewood respectively;
5. Record and maintain energy utilization and production data for a period of ten years;
6. To maintain a reporting system that gives useful, timely information to decision-makers and all other staff working at major operation areas;
7. Ensure that this policy is communicated to all staff;

In order to achieve our energy policy objectives, the policy will be implemented as per energy management strategic plan set out. This policy shall be reviewed at least once in every three years.

Name: MUKANJALU ALLAN Signature:...........................

General Manager

Figure 4 Sample Energy Policy
ENERGY MONITORING, TARGETING AND REPORTING

Energy monitoring systems provide users with data about their consumption patterns so they can make informed energy management decisions and maximize savings. Some systems are as simple as installing submeters for various utilities at each section and then reading these meters at regular intervals to verify the consumption.

Other systems are as complex that they are connected to the web such that one can view or control the real time monitored department/equipment all at once and keep historical data to compare purchases with usage hence easy to identify wastage immediately.

All the factories had a means of measuring volume of firewood for the boiler (stere/cubic metre), a key parameter that all five factories recorded in a board on a daily basis.

Figure 5 Management starts with measurements
Firewood measurements

As a further step in firewood efficiency, the factories should implement a measurement of other two below aspects of firewood;

- The weight of firewood samples from the stack before use to establish the density
- The moisture content of samples from stack to establish the dryness fraction
**Water and steam metering**

The factories can implement submetering and monitoring of water and steam utilities in the facility and record daily consumption so as to correct wastages immediately when realized.

![Figure 8 Water and steam Submetering](image)

**Electricity submetering**

The factories can implement submetering of electrical energy per department/line or

![Figure 9 Electrical Submetering](image)
ENERGY MANAGEMENT TRAINING

This training is recommended for energy managers or the specific needs as per organization goals. The training provides skills sets of the latest developments and provides the trainee with the tools to implement effective energy efficiency strategies at the area of specialization.

The training is tailored to meet specific needs at the factory level. Not investing in energy management training has cost implications. If staff do not participate in training, the energy use and costs will be higher, and product selection decisions for energy retrofit projects will be less informed, and will be less prepared for any energy regulatory changes in the industry $^2$.

![Diagram](image)

**Figure 10 Training for competencies and communication for awareness**

**Importance of staff training**

- Successfully implemented energy management trainings have been proven to deliver 4%-20% energy savings. Training is an integral part of any energy management plan.
- Operations personnel play an essential role in realizing energy savings over time. While it is understood that organizations should invest in efficient building systems to reduce energy costs, it must also be understood that the payoff from those investments is not guaranteed. Technology does not run itself – so a trained and skilled workforce is needed to operate the energy-efficient building systems.
- Investing in training creates a more knowledgeable, aware and skilled workforce, ultimately resulting in energy and cost savings for the organization.

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With the variety of technologies and operating practices available today, training helps building managers and owners identify the technologies and products they should be investing in.

Training provides participants with the broad base of knowledge and skills needed to manage and monitor the organization’s energy use, identify and implement key energy-reduction opportunities, and select and run appropriate new equipment and technologies.

Training is an opportunity to engage staff and promote a culture of energy savings throughout the entire organization.

Training is a good story to share with the greater community as an example of how the organization is taking real steps to reduce its environmental impact.

The potential risks of investing in energy can be mitigated by following training program best practices; training based on needs assessments of staff competencies; developing learning objectives for each training opportunity; hiring qualified, engaging instructors; providing a training setting that is conducive to learning; and developing mechanisms to incorporate knowledge and skills learned into new policies and procedures.
REGULAR INVESTMENT GRADE ENERGY AUDITS

An investment-grade energy audit is the most accurate and detailed energy audit that is bankable. It analyzes the lifetime financial aspects of energy savings and their return on investment from potential retrofits or upgrades. A facility manager can therefore use this investment-grade audit as a budgeting tool when planning facility upgrades/retrofits because of the level of its accuracy. The recommendations in such a high-level report can be treated as prefeasibility analysis that can be implemented with confidence.

The tea factories should invest in at least one investment grade audit every three years so that they can have the facilities and processes audited by experienced energy professionals who can then recommend areas of improvements.

An energy audit is the first investment in any energy management program, as it is the starting point in identifying energy efficiency and conservation measures. The cost is about 18,000USD per facility and would take about 6-8 weeks. The identified energy savings would be in the tune of 50,000USD per year for an average factory if implemented.
ENERGY INVESTMENT PLAN

An energy audit should come up with implementable projects, from low hanging fruits to the complex investment projects. An energy investment plan is a document that shows what the facility is planning to invest in for the next, say 3 years, and the expected level of savings targeted. All the items below can be developed through an investment grade audit and will form part of the energy investment plan.

**Checklist for energy efficiency investment plan**

- ✔ Measure baseline/benchmark current energy consumption
- ✔ Develop an energy use profile
- ✔ Complete a greenhouse gas (GHG) emissions inventory
- ✔ Build teams, get leadership support and assign dedicated resources
- ✔ Set goals and targets
- ✔ Develop strategic action plans for improvements
- ✔ Implement projects
- ✔ Measurement and verifications (track, measure and report)
- ✔ Train, educate and celebrate (awards)

This checklist is discussed in details in the paragraphs below;

a) **Measure/benchmark current energy consumption.** Establishing a baseline against which future reductions will be measured is an important first step in tracking progress. Once a baseline has been established, an organization can continue to track consumption on an ongoing basis and quantify the savings from reduction efforts.

b) **Develop an energy use profile.** An energy use profile will demonstrate how energy use is distributed among the systems as well as identify the energy source for each system (natural gas, fuel oil, firewood, electricity). Breaking down energy consumption data by discrete systems allows a more strategic approach to targeting improvement efforts. Further, including cost in your baseline and energy use profile will make it easier to recognize your best opportunities for improvement.

c) **Complete a greenhouse gas (GHG) emissions inventory.** It may be optional, but because this is a green project, we recommend that this will be a monitored indicator. GHG emissions link directly with the work you will have done to measure your energy consumption.

d) **Build teams, get leadership support, assign dedicated resources.** Create a multi-stakeholder sustainability or green team with representatives from departments that share
responsibility for energy planning, usage, and management. An energy committee described above can provide focused energy management efforts within these teams.

e) **Set targets/goals.** It is important to set both short- and long-term reduction goals for energy savings and emissions reductions and integrate them into a meaningful and achievable energy management plan. Use the data gathered during baseline-setting, energy use-profiling, and GHG inventory to help establish reasonable, SMART goals that are consistent with a basic, intermediate or advance approach. Finally, the target goals will inform which performance improvement measures to implement to achieve the goals.

f) **Develop strategic action plans for improvement.** The roadmap performance improvement measures are a comprehensive list of measures, or projects, designed to help you pick and choose those that can help you meet your goals. Note the Green Light measures, which represent the "low-hanging fruit." Consider adopting a Strategic Energy Management Plan (SEMP), which is a written plan that includes an integrated approach to ALL aspects of energy management, including short- and long-term reduction strategies.

g) **Implement projects.** Execute performance improvement measures that will result in energy and emissions reductions for your facility.

h) **Track, measure, and report (Measurement and Verifications).** It's important to begin to track your energy and GHG reductions to verify they are meeting the intended goal, to track cost and operational savings, to monitor staff satisfaction, and to report on all successes or failures in order to inform your next steps and give you traction as you prepare for the next project. Use newsletters, regular reports to keep staff and the community informed of your commitments and progress.

i) **Train, educate, and celebrate.** Effectively communicating the need for energy management and providing training and guidance on how to implement specific strategies can help an organization achieve greater reductions and gain more support for initiatives. Success is easier to achieve when users are educated on the reasons for any changes (what are the goals), trained on work practice changes (how to engage), and regularly informed on how action plan progress is matching up to goals (progress reports).
MODULE 2: LIGHTING EFFICIENCY OPPORTUNITIES

About 2-5% of electrical energy in the tea factories goes to lighting fixtures. Observing energy efficiency and energy conservation initiatives in lighting fixtures can reduce the amount of electrical energy usage in the tea factories. Below are some of the energy efficiency and conservation measures that can be recommended to improve savings on lighting.

USE OF TRANSLUCENT SHEETS TO HARVEST SUN LIGHTING DURING THE DAY

We recommend that the tea facilities utilize translucent/polycarbonate sheets as much as possible to conserve lighting during the day. Factories can use the translucent sheets to provide sky lighting during the clear sky day hence utilizing sunlight instead of electrical lights.

Skylights need to be cleaned in order to pass enough sunlight during the day hence reduce instance of switching on the lights unnecessarily.

Figure 12 Light during the day

Figure 13 Use of polycarbonate sheets to harvest sunlight
A tubular skylight as shown in the figure above, has three parts namely:

- the collector part which is direct sunlight (at the roof top),
- the transmitting part which reflective surface running through the ceiling or upper floors, and
- the diffuser part which illuminates the intended area

Building walls/facade/windows can also form an integral daylight harvesting areas as shown in figure below.
LED LIGHTS RETROFITS TO REPLACE METAL HALIDES AND FLUORESCENTS

LEDs use 60-75% less energy when compared to halogen lamps and fluorescent lights to produce equal or higher lumens than traditional lights. In addition, LEDs last for up to 50,000 hours which about 25 times longer than the incandescent/halogen lamps. Extensive use of LED lighting has the greatest potential impact on lighting energy savings due to their low wattage, high lux and longer life.

Most of the factories visited are aware of this technology and are replacing these lights gradually using highly efficient LED lights.

Figure 17 Comparison of LEDs vs Other Lights (Source: improvisedlife.com)
USE OF ALL-IN-ONE SOLAR SECURITY LIGHTS

Advancing technology, especially Lithium-Ion batteries and high efficiency solar panels, have enabled ease assembly of all-in-one solar street light. The light has a built-in sensor that enables it to light at night and go off at dawn. The light comes as a full set with solar panel, solar light and battery storage all in one package. Some lights can be programmed to increase or decrease brightness as required.

Figure 18 sample all in one solar street light
DE-LAMPING/DE-GROUPING OF LIGHT SWITCHES AS PER LUX LEVELS

It is common behaviour to find 20-30 lights wired in one switch or multi gangs switches. These lights may be spread in one floor but covering a wide area. At times, the whole floor is not in use, for instance the withering section in a factory might have 16 troughs and only 8 are in use at night. If all the lights are controlled by one circuit, half of the lights will be unnecessarily on during this period. Thus, this needs rewiring so as to have a maximum of three troughs having their lights controlled by one switch. As a rule of thumb, not more than 6 lights should be under one switch.

Figure 19 Multi light switch

LIGHTING AUTOMATION (MOTION SENSORS/PHOTOSENSORS)

Another aspect of lighting energy efficiency is automation which overrides human behaviour. It is easy to find some lights are on when no one is using the lit area. This can be overcome by installing motion sensors for places like washrooms, stores and even security lights so that the lights only operate when there is motion in the specified area. This can lead to conservation of energy during the period of inoccupancy.

For security light, photosensors and motion sensors can be combined such that the lights only light at night and when there is a motion. This is multi-level control and can be included even in solar street lights to prolong their lifetime.
MAINTENANCE OF LIGHTING FIXTURES, SHADES AND FACETS/WINDOWS

Regular cleaning of faded lighting fixtures and windows as well as facets/translucent sheets will increase illumination while improving indoor light quality. This can be a source of de-lamping where excessive lights have been installed due to shading or fading of the light source.

Before increasing or replacing lights with higher lux rating, ensure that maintenance is done well to avoid over lighting a place.

Dirty lamp fixtures make the lights look darker.
MODULE 3: MOTORS, PUMPS AND FANS
Motors, pumps, and fans present over 90% of electrical energy consumption in tea factories and companies should pay attention to these when thinking about energy efficiency.

Motors and associated drives are available in a wide range of sizes and it is often difficult to match exact output precisely to the needs of the equipment to be driven, and this leads to energy losses. In addition, the loads posed by the equipment are rarely constant, and this fluctuation leads to further inefficiencies. Below are ways to achieve high efficiencies in this equipment.

**MATCH THE MOTORS WITH THE LOAD AND DOWN SIZE NECESSARILY**
Motors are at their highest efficiency when their effective loads are equal or slightly lower than the motor rated capacity. However, in most industrial cases we find that the load fluctuates with time based on the equipment operating capacity at that instance. With this in mind, motor sizing should be always optimized and not oversized (with respect to demand) in order to achieve high efficiency’s and avoid energy losses. Below is a figure that illustrates the relationship between motor loading, capacity and respective efficiency:

![Figure 22 Motor Efficiency vs loading](image)

Selecting a properly sized motor can lead to energy efficient operations.
HIGH EFFICIENCY MOTORS

Standard motors compromise efficiency, durability, starting torque, and cost. While lower quality materials and dated designs may reduce their cost, they also prevent the motors from operating as effectively as they should. Standard motors generally compete on price, not efficiency, and they are designed just efficient enough so that they do not overheat.

High & Premium Efficiency Motors have an efficiency greater than a standard motor. It has no definitive meaning because the standard and high efficiency products vary between manufacturers. The term “super premium” efficiency is now used to define a motor which meets the highest efficiency levels on the market. Premium efficiency motors offer improved efficiencies of 2% to 8% over standard motors.

There are mainly two standards for identifying motor efficiency classes which depend on the manufacturing region of the motor; CEMEP (Europe & USA) and IEC (Worldwide). Below is a table that compares the two classes of motor identification;

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<tr>
<th>Efficiency Level</th>
<th>CEMEP (EU&amp;USA)</th>
<th>IEC (Worldwide)</th>
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<tr>
<td>Normal/Low Efficiency</td>
<td>EFF 3</td>
<td></td>
</tr>
<tr>
<td>Improved/Standard Efficiency</td>
<td>EFF 2</td>
<td>IE1</td>
</tr>
<tr>
<td>High Efficiency</td>
<td>EFF 1</td>
<td>IE 2</td>
</tr>
<tr>
<td>Premium Efficiency</td>
<td></td>
<td>1E3</td>
</tr>
<tr>
<td>SUPER Premium Efficiency</td>
<td></td>
<td>IE4</td>
</tr>
</tbody>
</table>

The premium improved efficiency of motors over the standard one is as a result of a number of means:

- Increased copper (up to 60%) in the winding reduces resistance losses and operating temperatures due to the larger amount of thermal mass
- Improved design reduces windage and other losses
- Improved quality steels in an increased number of thinner laminations reduces core losses from the stator and the rotor
- A narrowed air gap between the rotor and the stator improves the intensity of the magnetic flux so that the same torque is available at reduced power input
✓ Complex rotor bar designs improve starting torque yet maintain efficient full speed operation

Figure 23 IE2 Class motor

Figure 24 Efficiency class comparison (Source: beeindia.gov.in)
AVOID MULTIPLE REWINDING OF MOTORS

When it comes to making a decision whether to buy a new motor or rewind an old one, it should be noted that the running/energy cost of a motor is 96.7% of its lifecycle cost. The purchase cost is about 2.3% and 1% is the motor maintenance cost.

Therefore, it is better to maximize on saving motor energy cost since it is the biggest percentage, hence buying a new premium efficient motor will make sense rather than rewinding. The savings on energy cost outweighs the saving by not buying a new one.

It should be taken as a rule of thumb, that when a motor winding fails, it’s time to buy a new one. The first rewind is to give the operator the time to buy a new premium efficiency motor.

Figure 25 Motor life cycle cost analysis
The efficiency of rewound motors is extremely important. The loss in efficiency on rewinding depends on the techniques, processes and skill used to perform the rewind, and is usually between 1% and 2% loss per rewind. These are attributed to iron losses (thermal damage due to oxidation), eddy losses (due to lamination insulation damage), copper losses (flux density loss due to interference with windings pattern) and mechanical losses (hysteresis loss due to hammering) which is change in concentricity of rotor and stator.

If a choice is made between rewinding a **standard efficiency motor** or purchasing a new **high efficiency motor**, the difference in efficiency will be 4 to 5% at full load in favour of the high efficiency motor, which will also have a much longer service life. For instance, a 10kW motor would lose USD **300$**/year in efficiency terms. The sections viable include; withering section, CFU section to replace dampers, rolling and cutting sections, drier fans and boiler pumps.

*Figure 26 Motors awaiting rewind in one of the factories assessed*
A VFD/VSD is a power conversion device. The VFD converts a basic fixed-frequency, fixed voltage sine-wave power (line power) to a variable-frequency, variable-voltage output used to control speed of induction motors. By controlling speed of a pump or a fan rather than controlling flow through use of throttling valves or dampers, energy savings can be substantial.

Thus, the first place to retrofit a VFD is where there is a damper or a throttle valve, since that's a way of controlling the load, instead match the motor output with the load.

VSDs also offer an additional benefit - increased bearing and pump seal life. By maintaining only pressure needed in pump to satisfy system requirements, pump is not subjected to any higher pressures than necessary. Therefore, the components last longer.

Other benefits include, programmable soft starting, soft stopping and dynamic braking, which reduce excessive stresses being placed on the motor and, therefore, extends its life.

VSDs provide a wide range of speed, torque and power output giving a greater degree of control. For example, the electronically controlled VSD has the ability to set various parameters such as allowing differing acceleration rates for different speed changes and having the ability to increase/decrease the torque output at different speeds. There is improved efficiency since the current drawn is actually used to drive the load.
VSDs save energy by matching the motor speed to the required load. Therefore, there is no excess usage of power to drive small loads. The VSD will only allow the motor to run at full speed when at full load.

![Part Load Performance Comparison](image)

*Figure 29 Energy saving from VFDs retrofitting*

![VSD installed at Kitabi Tea Factory](image)

*Figure 27 VSD installed at Kitabi Tea Factory*
SOFT STARTERS FOR DEMAND CONTROL DURING MOTOR STARTUPS

Soft starters are used to control motor start by reducing high initial inrush currents. Soft starters only control the starting and stopping of the motor hence they only reduce peak start up demand but do not lead to actual energy savings. It is recommended that soft starters be installed for motors that have constant load and are not candidate for VSDs.

![Figure 30 Soft starter working mechanism (Source:elprocus.com)](image)

REPLACE FAN BLADES WITH LIGHTER BLADES THAT WITH EFFICIENT PROFILES

Conventionally tea withering fans are produced with impellers made of aluminium or other light metals. The problem is usually with dimensional and surface finish stability of the metallic impellers. It should be noted that the blade profile and the blade finish are most sensitive for the efficiency of the fan. Metallic blades are prone to corrosion which affects their profile and finish hence producing resistance for the flowing air. This in turn leads to high energy usage due to increased resistance and consequently high noise levels with decreased efficiency.

Fiberglass composite material is becoming a common material for withering fans due to its ease of processing so as to adopt more efficient fan blade profiles. Optimum distribution of fan blade chord and twist is difficult to generate in the metal blade, hence for this fact, hollow fiberglass reinforced plastic fan blades are rapidly being adopted for tea withering applications.
Fiberglass provides economical solution due to its special features below;

- High strength at low weight
- Good impact, fatigue, and Tensile Strength (Ultimate)
- Excellent environmental resistance
- Excellent chemical and corrosion resistance
- Superior surface finish
- Better life of the entire fan system due to low assembly weight
- Low moment of inertia helps for the selection of optimum motor and reduce over design due to higher starting torque hence the motor operates under a better range of efficiency

Efficiency of fans is affected by their weight, their profile, their number and their strength. These aspects must be maintained at all times to ensure efficient operation of withering fans.
CORRECT PLACEMENT AND PROPER MAINTENANCE OF RADIATORS

Radiators in tea factories end points of steam usage. They are found in withering troughs and in driers. It is important that proper maintenance is done on the radiators at least once a month. The radiators tend to collect dust and gets clogged with a thin film of mud on the surface which reduces heat transfer across the radiator fins. This regular maintenance would include blowing off the dust and cleaning any stuck mud on the radiator fins.

There are three common methods of bringing hot air to the tea leaves in a trough:

A. Method A - fan sucking air through a heat exchanger (radiator) at the inlet of the trough
B. Method B- fan blowing air through a heat exchanger (radiator) at the inlet of the trough
C. Method C - heat exchanger located far from the troughs and a fan sucking the hot air from the heat exchanger through a duct and pushing it to the troughs; generally, one such heat exchanger supplies hot air for a number of troughs.

All the three methods were found in the factories visited during the assessments as shown in the photos below:

Method A - Among all the methods, this is the most inefficient; i) The radiators are dirty, ii) the radiator is not enclosed with the fan hence hot and cold air sucked same time, iii) the radiator is completely outside the building hence loosing heat.
Method B was found in 2 factories and was found to be the most efficient; i) all pipes insulated, ii) located inside the building iii) fan and radiator enclosed together. The operators with type confirmed that these troughs take about 12 hours to wither, compared to another set that uses method C which takes about 14 hours.

Method C also had some inefficiencies; i) the hot air duct is covering almost 50 meters and it is not insulated hence leading to cooling of hot air inside, ii) there is a gap between the hot air outlet and the receiving fan inlet to the trough hence some hot air escapes.

Correcting these two can lead to increased efficiency of the heating system in the factory.
REPLACING INEFFICIENT TRANSMISSION BELTS BY EFFICIENT ONES

When designed and operated efficiently, conveyors streamline the movement of finished products, components, packaging, and more. A conveyor belt malfunction, however, has the potential to throw production floors and warehouses into chaos; bottlenecking workflow, piling up material, damaging valuable inventory, and potentially endangering workers. Too much spillage means that the belts are misaligned hence higher frictions or faltering which leads to tea spillage in the processing line. When this happens, check the grooves for the conveyor belt, check the motor and the pulley system, and also check the condition of the rollers for the belt. Any wear and tear should be rectified as soon as possible since those leads to high power consumption as the motor overworks to compensate the frictional losses.

Factors that should be considered when selecting transmission belts:

• Belt Loadings – The size, weight, dimensions, and other characteristics of the load your conveyor will be transporting will help determine the belt material, motor, drive, and hardware that is right for your application. Other product aspects such as temperature and material can also affect the selection.

• Set your conveyors to pull rather than push – Pulling is a lot more efficient than pushing. Your conveyor belt can lose up to 50-70% of its load capacity when pushing.

• The flow rate – How fast and how precisely materials need to be fed or removed by the conveyor may require specific equipment. For fast moving belts, you will likely need fasteners, endless splicing equipment, segmented transfer plates, and maintenance tools.

Taking the time to inspect conveyor belts and perform preventative maintenance saves money in the long run and could prevent a major failure that spoils products, puts employees in danger, or causes downtime.
The power factor of an AC power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit, and is a dimensionless number in the closed interval of −1 to 1. Power factor is the measure of how efficiently incoming power is used in an electrical installation. It is the ratio of active to apparent power. As a rule of thumb, the power factor should be maintained at above 0.9 at all times. A poor power factor is usually the result of a significant phase difference between the voltage and current at the load terminals, or it can be due to a high harmonic content or a distorted current waveform. A poor power factor due to inductive loads can be improved by the addition of power factor correction equipment, but a poor power factor due to a distorted current waveform requires a change in equipment design or the addition of harmonic filters.

An inductive load requires a magnetic field to operate and in creating such a magnetic field causes the current to be out of phase with the voltage (the current lags the voltage). Power factor correction is the process of compensating for the lagging current by creating a leading current by connecting capacitors to the supply. A sufficient capacitance is connected so that the power factor is adjusted to be as close to unity as possible.

A good power factor should be above 0.9. Utility companies will surcharge the facilities whose power factor drops below 0.9.
MODULE 4: HEATING SYSTEMS BEST PRACTICES

Heating is mainly used in withering and drying sections in the tea making process. Withering is the first stage involved in tea manufacture. The evaporation of moisture in the green leaf is brought about by blowing or moving air over the leaf in the withering trough. The current of air conveys heat to the leaves as well as carries away the water vapor through a bed of green leaves to achieve physical withering. The air temperature is kept low in order to retain the activity of the enzymes responsible for the desired changes during the subsequent fermentation process. This is the preconditioning of the leaves for further processing and it takes between 12 to 16 hours. The low drying temperatures result in fairly low thermal energy losses by convection and radiation from the surfaces of the drying troughs which may not justify elaborate thermal insulation.

The final drying process after the tea leaf has undergone fermentation is usually referred to as firing. The fermented tea at 58-60% moisture content is dried to 3-4% moisture content by bringing it into contact with a stream of hot air. It is the most expensive process in the manufacturing of tea in terms of energy inputs. The capital investment on the driers is also the highest among the different processing machines. Objective of drying are to arrest the fermentation process and to remove the moisture and to produce tea with good keeping qualities.

Heat should be recovered as far as possible from condensate streams which cannot be returned to the boiler. Adequate steam traps should be provided and maintained to minimise steam losses. Condensate tanks should be adequately lagged. Leakage of steam and condensate should be avoided. All these, and other, measures necessary to minimise energy losses in the steam and condensate systems have been discussed in this section and can lead to savings in the fuelwood used in the two processes.
ISOLATING VALVES FOR REDUNDANT STEAM PIPE

An isolation valve is a valve in a fluid handling system that stops the flow of process media to a given location, usually for maintenance or safety purposes. This valve can be used in practice to isolate the steam flow from the sections where not needed.

For instance, each withering trough should have an isolating valve so that the steam is not allowed to flow when the trough is redundant.

Isolation valves must effectively stop the passage of fluids. Gate valves (sluice valves), ball valves and plug valves are generally considered to provide tight and effective shut-off. Globe valves and Butterfly valves may not be tight shut-off due to wear on the plug or the seat, or due to their design, and may not be appropriate to provide effective isolation.

Figure 36 Steam Isolating valves
Condensate recovery and recycling system is one of the most crucial energy management Systems in any industry. The aim is to reduce the three tangible costs of producing steam: fuel/energy costs, Boiler water make-up & sewage treatment, and lastly, boiler water chemical treatment.

Condensate is the liquid formed when steam passes from the vapour to the liquid state. In a heating process, condensate is the result of steam transferring a portion of its heat energy, known as latent heat, to the product, line, or equipment being heated. As well as having heat content, the condensate is basically distilled water, which is ideal for use as boiler feed water. An efficient steam system will collect this condensate and either return condensate to a deaerator, a boiler feed tank, or use condensate in another process. Only when there is a real risk of contamination should condensate not be returned to the boiler.

Reasons for recycling and reusing:

- Financial reasons: Condensate is a valuable resource and even the recovery of small quantities is often economically justifiable. The discharge from a single steam trap is often worth recovering. Un-recovered condensate must be replaced in the boiler house by cold make-up water with additional costs of water treatment and fuel to heat the water from a lower temperature.
- Water charges: Any condensate not returned needs to be replaced by make-up water, incurring further water charges from the local water supplier.
- Effluent restrictions: Water above 43°C cannot be returned to the public sewer by law, because condensate is detrimental to the environment and may damage earthenware pipes. Condensate above this temperature must be cooled before condensate is discharged, which may incur extra energy costs. Similar restrictions apply in most countries, and effluent charges and fines may be imposed by water suppliers for non-compliance.
- Maximizing boiler output: Colder boiler feed water will reduce the steaming rate of the boiler. The lower the feed water temperature, the more heat, and thus fuel needed to heat the water, thereby leaving less heat to raise steam.
- Boiler feed water quality: Condensate is distilled water, which contains almost no total dissolved solids (TDS). Boilers need to be blown down to reduce their concentration of
dissolved solids in the boiler water. Returning more condensate to the feed tank reduces the need for blow down and thus reduces the energy lost from the boiler.

If 5ton/h of steam is supplied to equipment for a heating process, then the same amount of condensate (5ton/h) needs to be discharged from the equipment.

Assuming no condensate returned to a 5 ton/h boiler plant, 1,500,000BTU is lost (1635MJ) = 110Kg of wood = 0.2m$^3$ = 1,625 RWF/h = 14,235,000 RWF per year

The potential savings of 14,235,000 RWF per year is based on the amount of energy required to elevate the makeup water of energy content (sensible energy) to that energy level of condensate being returned in a gravity-designed condensate system.

The calculation does not take into account the savings from chemicals, water and sewer costs.

Figure 37 Condensate recovery in insulated line
AIR PREHEATING IN THE BOILER USING FLUE GASES

Air Pre-heaters are basically heat-exchangers installed in the exit flue gas duct of the boiler. The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also conveyed to the flue gas stack (or chimney) at a lower temperature.

The most common air pre-heaters are tubular preheaters consisting of straight tube bundles which pass through the outlet ducting of the boiler and open at each end outside of the ducting. Inside the ducting, the hot furnace gases pass around the preheater tubes, transferring heat from the exhaust gas to the air inside the preheater. Ambient air is forced by a fan through ducting at one end of the preheater tubes and at other end the heated air from inside of the tubes emerges into another set of ducting, which carries it to the boiler furnace for combustion. Installation of an air preheater can lead to recovery of heat from the exit of the heating chamber to pre-heat the air required for combustion. The pre-heated air can either be utilized in the thermic fluid heater or the boiler.

Preheating of combustion air can raise boiler efficiency about 1% for every 5°C in temperature increase. Up to 35°C can be recovered from the flue gas resulting to over 5% efficiency improvement. The best way to preheat this air is by use of a heat exchanger fitted on the flue exhaust. The heat exchanger can be either air-to-air or air-to-liquid-to-air. Most of the tea factories have done this for at least one boiler.
In most cases, the drier flue gas temperature after drying tea leaves is about 80 ~ 90 ℃ hence energy recovery is meaningful. The air exhausted from the dryer is often much warmer than the outside air. Capturing and re-using this air will reduce energy use. There are two distinct types of heat recovery systems:

- Heat recirculation. A heat recirculation system guides warm exhaust air directly back into the dryer fan inlet. Heat recirculation works best on continuous flow horizontal or tower dryers operated to dry and cool simultaneously. May be factory-installed or custom-built.
- Heat exchangers- A heat exchanger separates exhaust air and fresh air with a waterproof divider. Heat travels through the divider from the hot exhaust air to the cold fresh air. The two airstreams do not mix, and no moisture or fines can pass through the divider. Unlike heat recirculation, the heat exchanger recovers heat from all of the exhaust air (even the most humid air), and can be used on any type of dryer.
PROPER BOILER OPERATIONS AND REGULAR MAINTENANCE OF THE BOILERS

Ensure boiler blow down is done as per manufacturer directives. Blow down keeps the boiler water TDS levels under permissible limits. Blow down prevents corrosion and scale formation in boiler tubes. It also prevents the carryover of contaminants in steam. Manual boiler blow down is currently practiced in most factories. Too much blow down can lead to energy wastage.

Scales and Soot insulates the tubes and inhibit heat transfer leading to energy loss through the flue gas. Thermal conductivity of scale is about 1/100 of that of steel. Scales forms on the water side of a fire-tube boiler. To control this, boiler water treatment and de-scale must be done often. Soot forms inside the tubes of a fire-tube boiler and the control method is a weekly cleaning.

Effects of poor maintenance is more firewood consumption, tubes become distorted or deformed due overheating, and life of equipment reduced. Tube replacement costs money and production loss due to downtime.

![Figure 39 Scaling and soot on the boiler tube](image-url)
**PROPER STACKING OF THE BOILER**

One of the easiest ways for a facility to reduce operating expenses is to increase boiler efficiency. The majority of heat lost in a boiler is in the stack or boiler water. The goal is to create conditions that generate the smallest possible amount of flue gas at the lowest possible temperature. This results in increased boiler efficiency. Boilers stack temperatures range between 170 - 200 degrees Celsius and an increase by every 15 degrees above that equates to a 1% efficiency loss. After operation for a long period of time, significant rise in flue gas temperature and hence stack losses may be observed. The reason behind this is, as a boiler is operated, scales are formed on the boiler tubes. As the thickness of the scales increases, the coefficient of heat transfer goes down. As a result, heat from flue gases is not transferred to the water side and it is carried away by the flue gases. If you notice these numbers going above this range, then it’s time to schedule for cleaning. Do not under stack nor over stack the boiler with firewood.

**INSULATING HIGH TEMPERATURE PIPES, JACKETS FOR VALVES AND FLANGES**

Insulating process piping components such as pipes and valves provides many benefits for the facility. There is a cost benefit when increasing the profitability of a product. If the process is steam heat related and the piping is uninsulated, lower quality steam is being delivered to perform the required function within the process.

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (kg/m³)</th>
<th>Thermal conductivities (W/m °C)</th>
<th>Maximum temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0°C</td>
<td>100°C</td>
</tr>
<tr>
<td>Polystyrol</td>
<td>20-50</td>
<td>0.032</td>
<td>0.032</td>
</tr>
<tr>
<td>Cork</td>
<td>100-200</td>
<td>0.032</td>
<td>0.032</td>
</tr>
<tr>
<td>Glass wool</td>
<td>40-60</td>
<td>0.031</td>
<td>0.050</td>
</tr>
<tr>
<td>Glass wool (non fiber)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long fiber</td>
<td>80</td>
<td>0.031</td>
<td>0.048</td>
</tr>
<tr>
<td>Short fiber</td>
<td>100</td>
<td>0.036</td>
<td>0.051</td>
</tr>
<tr>
<td>Rockwool &amp; glass wool</td>
<td>40-250</td>
<td>0.028</td>
<td>0.039</td>
</tr>
<tr>
<td>Asbestos</td>
<td>80-250</td>
<td>0.042</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 40 Insulation materials and their thermal conductivities*
Once insulated, the steam is now at a higher temperature and has less moisture entrained. As a result, the process takes less time. The same holds true for cooling process piping. By insulating the process piping and components, the cooling effect of the cooling medium is faster and more exact than putting uninsulated fluid into the process. Less process time results in increased profitability from that process.
Most of the factories have steam pipes well insulated and attaining levels of 90% insulation. Some network of pipes in some sections of the factories lacked proper lack of insulation. Generally, insulation improves workplace safety and boosts energy savings.

Figure 42 Some uninsulated steam section
REGULAR CHECKS OF STEAM TRAPS AND REPLACE ANY WORN OUT

Steam traps are a type of automatic valve that filters out condensate (i.e., condensed steam) and non-condensable gases such as air without letting steam escape. Various types of steam trap mechanisms (operation principles) have been developed to automatically discharge condensate and non-condensable gases.

The most widely used mechanisms are those that rely on differences in temperature, specific gravities, and pressure. Each of these types of steam traps has its own advantages and applications. In case it is leaking steam in very large amounts, it needs to be replaced or serviced.

In selecting a suitable steam trap, system conditions determine the minimum trap specifications for pressure, temperature, discharge capacity, material, and connection type.

To help prevent premature trap failure and identify failures in a timely manner, every steam-using plant should establish a steam trap management program. Such programs help optimize the steam system and minimize costs.

Figure 43 Types of steam traps
Figure 44 Commonly used steam traps

Figure 45 Working principle of thermodynamic steam trap
Figure 46 Working principle of mechanical steam trap

Figure 47 Working principle of a thermostatic steam trap
INSULATING FEED WATER TANK

Feedwater tanks are heated storage tanks that do not have a specific deaerating section and operate at atmospheric pressure. These tanks act as condensate receivers, cold-water makeup locations and as a point for chemical injection. Given the functions the tanks perform, a properly designed feedwater tank will help reduce thermal shock and decrease oxygen scavenger usage.

Therefore, temperatures of the feedwater tank should be maintained at high temperatures to reduce the amount of oxygen in the water. The feed water tank for the boiler should be properly insulated to retain the efficiency gains of condensate water and to prevent thermal shocks.

Figure 79 Feed water tank
CORRECT ALL STEAM LEAKAGES

Steam leakages have multiple negative effects on plant operations, including energy losses, increased emissions, loss of reliability, production issues, and safety. Steam leakages can lead to severe wastages and costly operations. Some causes of steam leakages include pipe erosion, failures of valves, water hammer.

Steam flow through a leak can be estimated using a graph which is based on the diameter of the orifice, pressure at the inlet of the orifice, and pressure at the outlet (atmosphere). The graph below estimates the steam leakages through orifice sizing ranging from 1/2" to 1/32".

![Steam leaks/loss diagram](engineeringtoolbox.com)
Some steam leaks identified in a factory. This needs to be rectified as soon as possible to avoid steam wastages.

Figure 49 Steam leaks on site
PROCESS OPTIMIZATION

Process optimisation is the practice of enhancing processing efficiency through process improvement. Achieving an ideal processing operation means observing and considering the current process, developing and implementing improvement strategies, then returning to observation to start the improvement cycle anew.

First, ensure line is running at recommended throughput. To optimize the CTC energy utilization index (EUI), ensure the line operates close to the manufacturers recommended throughput. For example, significant energy savings can be achieved when a line operates at an average throughput of 2500kg/hour instead of 2000kg/hour over one year.

Figure 83 CTC lines in one of the factories visited
MODULE 5: FOREST MANAGEMENT TO IMPROVE WOOD ENERGY EFFICIENCY

Forest management is the process of planning and implementing practices such as silviculture, protection. Management objectives can be for conservation, utilization, or a mixture of the two. In this training the focus will be on the forest management with objective of conservation and utilization in tea factories in Rwanda.

Sustainable forest management (SFM) is a key concept that should be utilized to ensure perpetual availability of wood for energy in tea factories. The principles for SFM include to maintain biological diversity, forest productivity, increase forest regeneration capacity, enhance forest health and their potential to fulfil, now and in the future, maintain ecological economic and social functions values of the forest at local, national and global level. The aim of sustainable forest management (SFM) is to ensure that forests supply goods and services to meet both present-day and future needs and contribute to the sustainable development of communities.

There are over 700 species with variety of hybrids and varieties. Majority of Eucalyptus tree species flourish in Rwanda. The species can be planted in wood lots and in plantations. The advantages of the species are many including have short rotation age, fast growing with high calorific value. In addition, there are various hybrids available for planting. The greatest positive contribution of eucalyptus is in replacing indigenous species for fuel-wood, thereby reducing natural forests degradation and deforestation.

For several decades now, forests in Rwanda have been constantly threatened by anthropogenic activities such as harvesting for tea processing and cultivation. To alleviate this situation, a number of measures are required for sustainable forest management practices. One of the most important instruments for sustainable forest management is a functional Forest Management Plan (FMP).

The FMP for tea production should describe appropriate management strategies that will depend on the development of an integrated approach to management which incorporates both utilization and conservation. The FMP should have five main parts: (i) Description (Location, Size, Boundaries, Physical features, Geology and soils, Hydrology, Climate, Rights and privileges, Species composition (Flora and Fauna), Socio-economic situation, Adjacent local communities and Activities related to forest reserve management in the area) (ii) Registration (Review of previous plan, Survey of existing resources, Forest protection, Forest restocking, Nurseries, Management of buffer zones, Watershed areas management and soil conservation, Physical...
resources, Human resources etc.), (iii) Prescriptions (Management Directives and Management Prescriptions) and (v) Annual Plan of Operations (period for a management plan). Therefore, it is very important for the factory forests to have forest management plan.

During planting, good quality seedlings should be used. If possible, use of hybrid Eucalyptus should be considered. Plant Spacing between is very important as it affects tree growth and the wood properties. There is high correlation between plant spacing, wood density and energy properties in Eucalyptus wood. Eucalyptus seedlings should be planted 2.0m X 2.0m in good site class. Farmers should use the correct species, for the desired management objective (fuel wood).

![Eucalyptus planting](http://www.kenyaforestservice.org/)

Figure 50 Eucalyptus planting

Silviculture is about tree tending. It is a practice of controlling the growth, composition/structure, and quality of forests to meet values and needs, specifically for fuel wood production.

Harvesting should enable coppicing. Proper harvesting will enable healing of the scar and improve coppicing rate. Regeneration by coppicing (means during harvest cutting it at ground level to stimulate growth) reduce planting costs. When new growth emerges, select the best-looking shoot or the shoot with high vigor and allow it to grow, the rest should be cut at the ground level to limit them to regenerate. Protect the stand of Eucalyptus against wildfire. Fire reduce growth and kill many Eucalyptus tree species. Harvesting of the wood should ensure aim to minimize
disturbances of the undergrowth and nearby trees. They should also ensure that harvesting is done at the recommended age for the different products. Eucalyptus will have better calorific value at the age of 8 years and above.

Wood seasoning is drying of the wood before used as energy. Drying wood increase its calorific value. The calorific value is reduced by 2 MJ/kg for each 10% decrease in wood moisture content (see also Swithenbank et al., 2011)\(^3\). Therefore, proper drying is very crucial to attain higher calorific values. Firewood should be dried and stored in a well-ventilated covered area away from dampness. The wood should be season well for at least 6 months to reach a moisture content of less than 20%. A well staked Eucalyptus billets (e.g. Figure 80) increases moisture reduction efficiency

Introduce wood chipper when harvesting and modify combustion chambers for them to run on wood chips, with adapted chip feeder and grate. Wood chips burn much more efficiently compared with wood logs and are much easier to dry.

The following are tips that can be used to increase wood usage efficiency score when used as source of energy for tea production: air preheaters, ash management, handling leakages in the steam and condensate system, Insulate steam systems, lines, valves and flanges, use float valve in the condensate tank to regulate water addition and monitoring of feed water, monitor flue gas to ensure correct air-fuel mix, use air flow control dampers and flue gas readings, stack the boilers, use driers heat recovery, enhance proper boiler operations and management, use steam traps and frequently identify inefficiencies and treat them.

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Figure 80 Storage of firewood in one of the factories visited