SUSTAINABLE OPM - OPERATING PROFIT MARGINS BY ENERGY CONSERVATION MEASURES & BEST OPERATING PRACTICES IN TEA INDUSTRY CLUSTER

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I. Introduction:

Tea is one of the most widely and most popularly consumed beverage in India. Tea industries plays important role in Indian economy and provides more than two million people in India both directly and indirectly. Based on the type of tea production, Indian tea industries are mainly classified into two category namely i) CTC (Cut-Turn-Curl) and ii) Orthodox. However most of the industries are majorly producing CTC type tea production.

This paper describes various energy conservation methods to be adopted in the CTC based tea manufacturing industries categorized into Low, Medium and High Cost investment. Also this paper deals with best operating practices to be followed along with the performance indication showing their best outcome. The authors conducted nearly about 15 energy audits in various tea industries in Nilgiris District, Tamilnadu in 2018-19 and a sample annual energy consumption details along with made tea production is also presented for ready reference.

II. Fluctuating Operating Profit Margins:

The tea industry cluster is deeply suffering from the poor Operating Profit Margins, the OPM, in spite of producing the tea output in a mass scale. Having done Energy Audits in more than dozens of tea factories in Ooty Region of South India during 2018-19, we have analysed the tea industry's production, quality aspects based on the industry's energy consumption performance.

From our energy study in the field and based on our field observations done in the tea making process, we put forth our findings that the energy conservation measures if done with professional approach by the tea industry on the Thermal and Electrical areas in the Production machine and in the utility, the industry can flatten the wild fluctuations in their OPM, reduce their energy bills in Electrical and thermal Fuel side, improve the productivity for the same energy consumption and improve the quality of the tea product simultaneously.

III. Process Flow Diagram:

Made tea manufacturing process starts with green tea leaf crushed by rotor vane and feed into CTC machines. After CTC, the tea leafs are then fed in to fermentation drum to make it granular and remove the moisture and then fed to Continuous Fermentation Machine (CFM) to remove the additional moisture and then passed to Dryer. Dryer fries it at specified temperature using hot air passed through the duct. The required hot air is being produced by a hot air generator by burning mostly wood. Then it passed through the shifter for grading and the gradedtea is again passed through Fibro mate to remove the fibre content and clean them. The process flowchart of making the made tea from leaf is shown in Fig. 1.

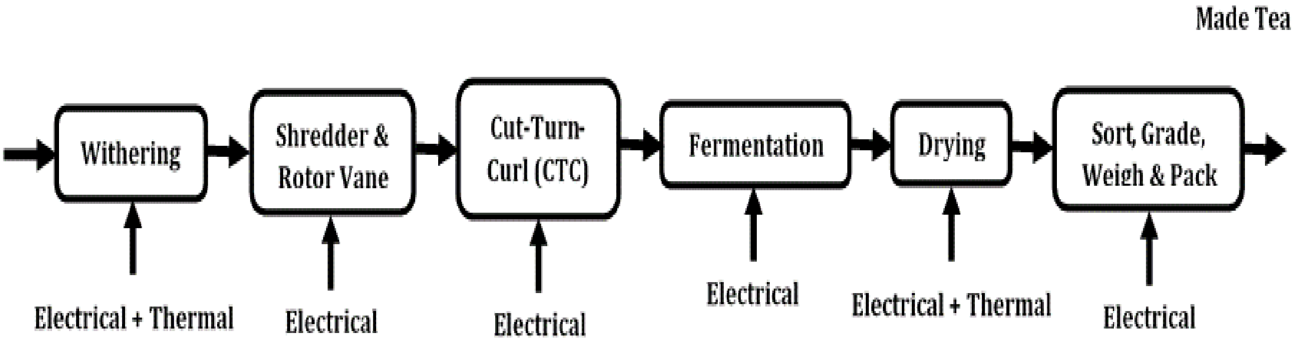


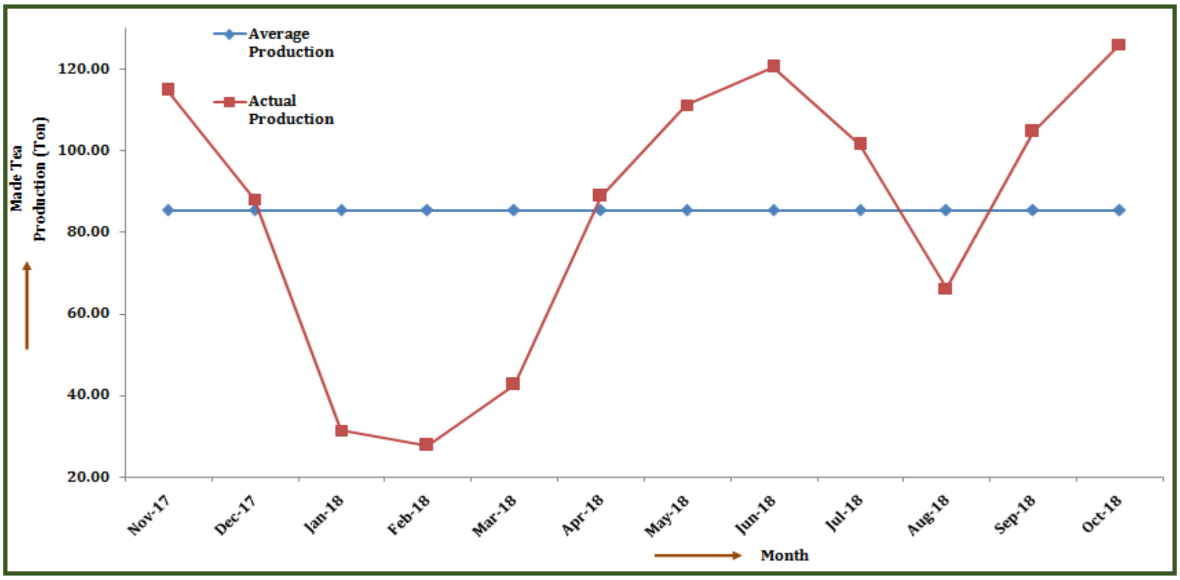
Fig.1: Process Flowchart of Made Tea from Leaf to Useful Commodity

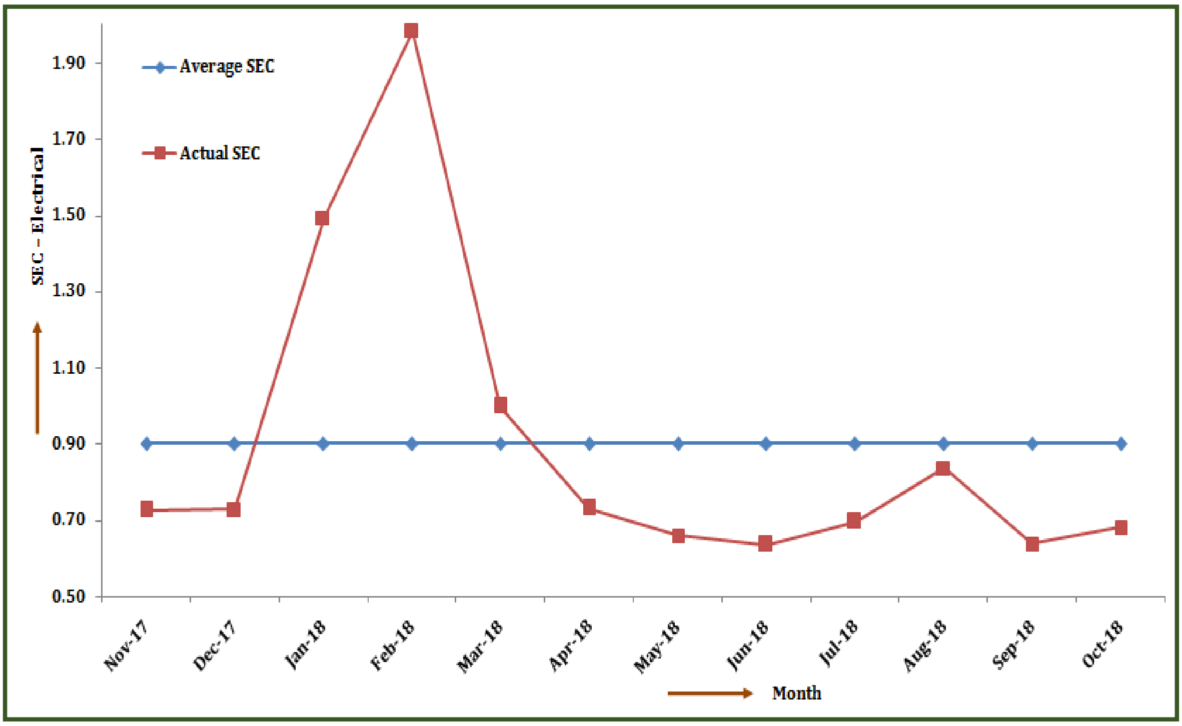
IV. Energy Carriers and their Variations:

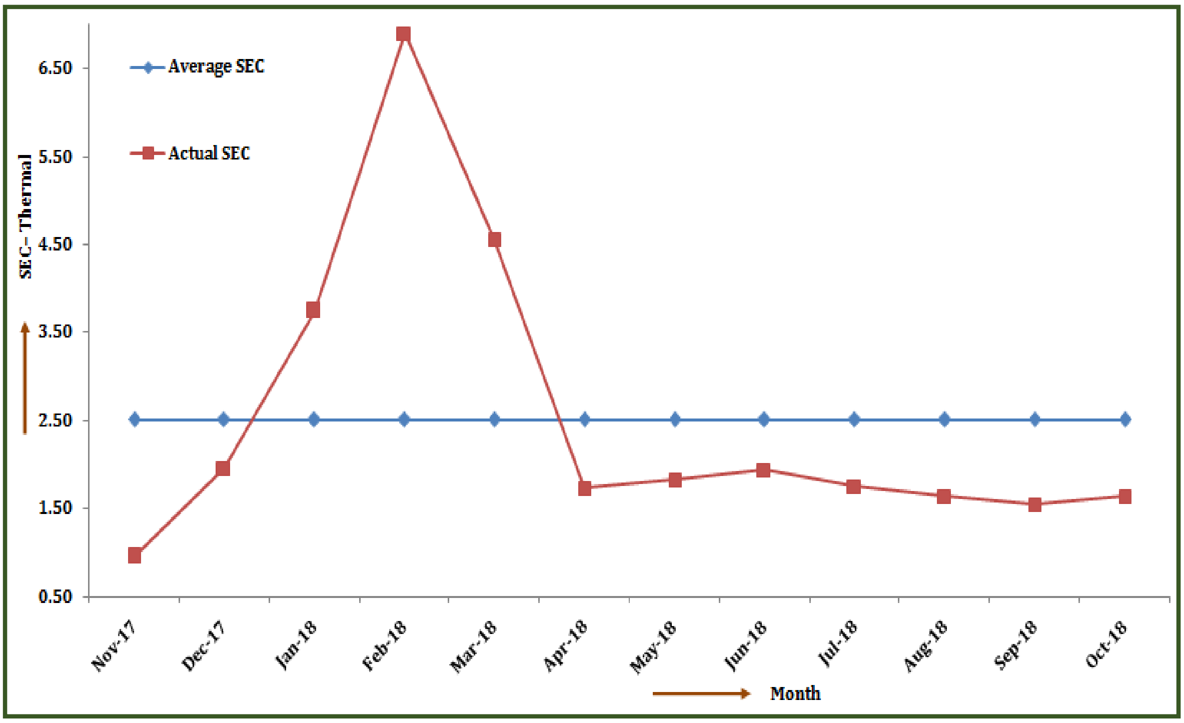
For the entire tea making processing, two types of energy carries are used namely i) Electricity and ii) Thermal. Electrical energy requirement is being supplied mostly by the utility grid and private tea industries are having LT (Low Tension) supply having connected load of maximum 150 HP. They have one set of tea making process (From CTC to Sorting). Whereas Government tea factories (even private owner having large tea production units) are having HT (High Tension) supply and might have more than one tea making process.

V. Analysis of Energy Utilization:

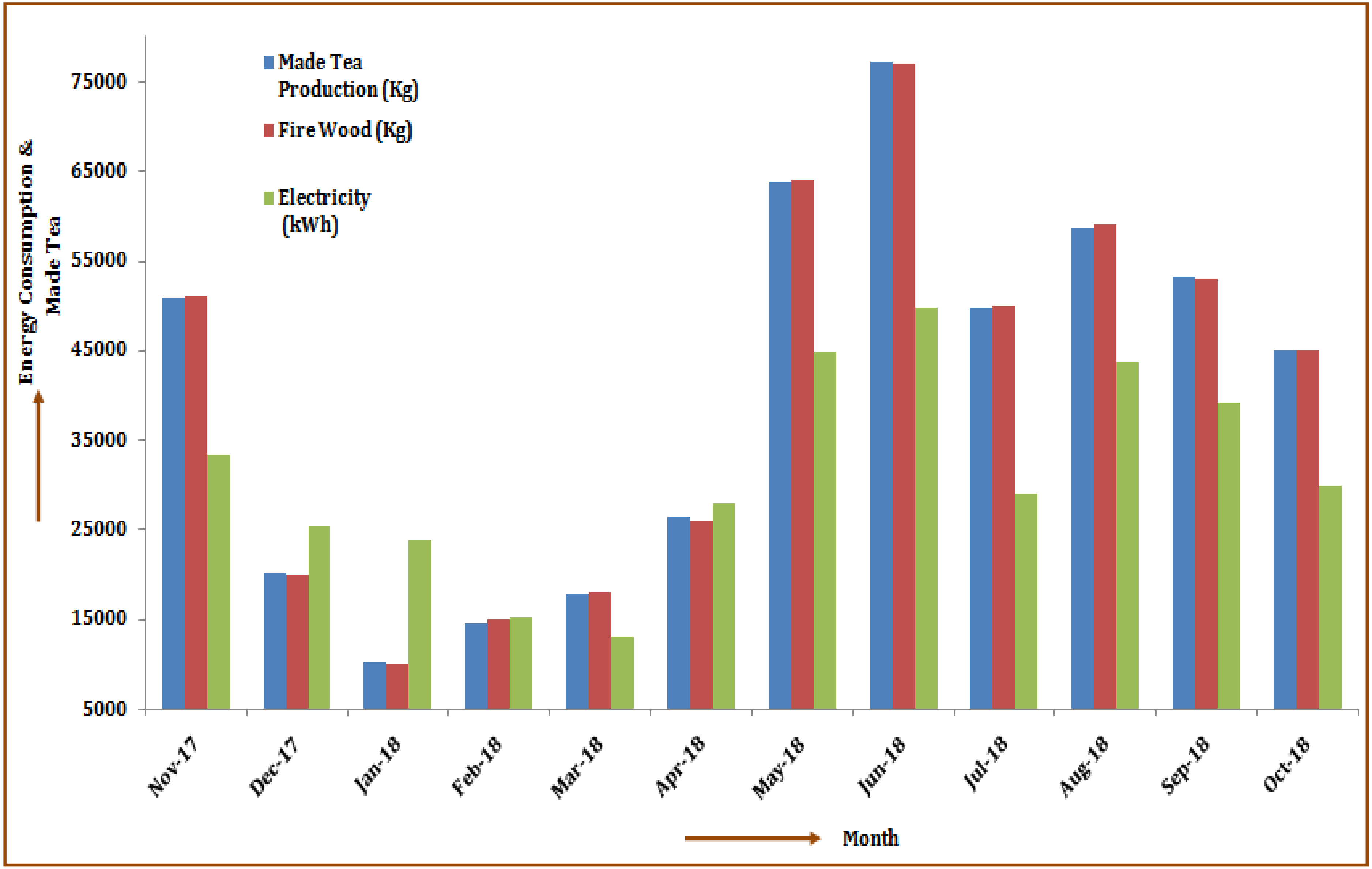
Cost of the electrical energy is almost same during the year, whereas the wood cost is slightly varying (mostly increasing). Variation of Specific Energy Consumption (SEC) is a right measure to identify energy usage in the tea industry and Graph-1 is showing the annual variation of SEC-Electrical and Thermal as against the made tea production.





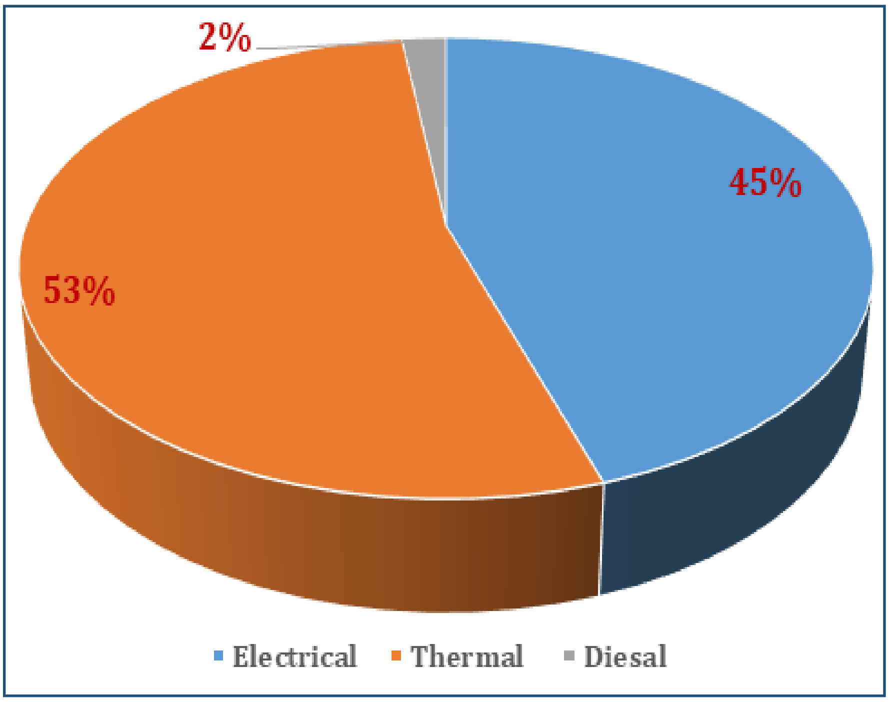


Graph-1: Representation of Specific Energy Consumption (SEC) of Electrical and Thermal


Made Tea Production (Kg)
Fire Wood (Kg)
Electricity (kWh)
Energy Consumption & Made Tea
75000
65000
55000
45000
35000
25000
15000
5000
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Month

OBSERVATIONS ON THE ABOVE PRODUCTION & SEC ANNUAL GRAPHICAL STUDY:-

- From Dec-17 to Mar-18, the made tea production is low, whereas the utilization of both energy carriers are higher than their average value. This winter period is usually is considered to be lean for the production; however the base value of energy is being utilized for the producing less quantity of made tea. Obviously the production cost of made tea per kg is also higher in this period.
- This variation has to be checked with the following parameters like utilization of wood, quality and energy content of the wood, fuel storing and charging practices, the HAG efficiency variations, and dryness factor of the wood. These input data to be analysed to arrive at uniform or narrow band variations in thermal SEC for the given production kgs.
- Graph – 2 represents the utilization of difference energy carriers in a sample tea industry.



Graph - 2: Distribution of Energy Carriers of a typical Tea Industry

This article focuses on three important areas in a tea industry namely

i) Possible energy conservation from the existing energy usage,

ii) Improvement of production with same or less energy usage

iii) Sustainable improvements in the quality of the made tea.

VI. Possible Energy Conservation Proposals (ENCONS):

Existing Conditions of the running Tea Industry:

1. The Incoming voltage fluctuations is high and fluctuating from season to season and between day and night
2. Many of the LT and HT industries are not able to maintain the PF; as the APFC functioning is not in sync with the process load variations.

3. Even during part loading operations, the load end PF compensation is not done and hence the industry may suffer due to Low PF penalty. The same can be cost effectively solved using the Load end PF correction as per case study below:-

Now we understand, why Load End Compensation is required for our 3-Phase motors rated above 3 HP?

Our motors are always around 50 to 75 % loading only except our overloaded compressor motor.

Output		Power factor			
kW	hp	¼L	½L	¾L	FL
3.7	5	0.44	0.55	0.62	0.7
7.5	10	0.58	0.64	0.72	0.76
15	20	0.6	0.62	0.7	0.75
18.5	25	0.62	0.64	0.72	0.77
45	60	0.68	0.75	0.77	0.79
75	100	0.72	0.8	0.85	0.87

KVA IMPROVEMENT IN THE Electrical Load End PF Compensation

Improved Power Factor Correction on typical 50HP Motor gives significant results.

50 HP motor Without Cap	50 HP motor (with Cap)	% Change in parameters
37.3 KW	36.2 KW	3% Decrease
28 KVAR	15.1KVAR	46% Decrease
46.6 KVA	38.4 KVA	17% Decrease
0.8 PF	0.92 PF	15% improvement

4. Motor to machine transmission losses are heavy and slippage is more. This is power loss and for productivity loss due to low friction / grip in transmission.
5. The tea industry premises are old but they can look bright with the LED tube light installations, CFL is still working in many mills. The background reflection is poor and the whole premises is in dark region only.
6. Dryer area is very hot to stand, move and difficult for workers to work. The insulation levels are so bad.

7. If insulation is done pucca, then no need to overshoot the drying temperature from the optimum 130 to 150^{0}C, overshot temperature will reduce quality of tea.
8. Environmental pollution due to excess air through chimney – flue gas not controlled
9. Any deviation in process handling practices.
10. The load is fluctuating heavily and industry has to have buffer space and equipment's to handle the momentary overloads over few days run if not done the quality of tea product is lost

The objective of the energy audit and energy monitoring to assess the viability to upgrade the energy efficiency measures prior to invest in extensive resources. After considering the above situation, the following are the possible ENCONS that may be classified into three different category (mainly based on initial investment) that are;

i) **Low cost**

ii) **Medium cost and**

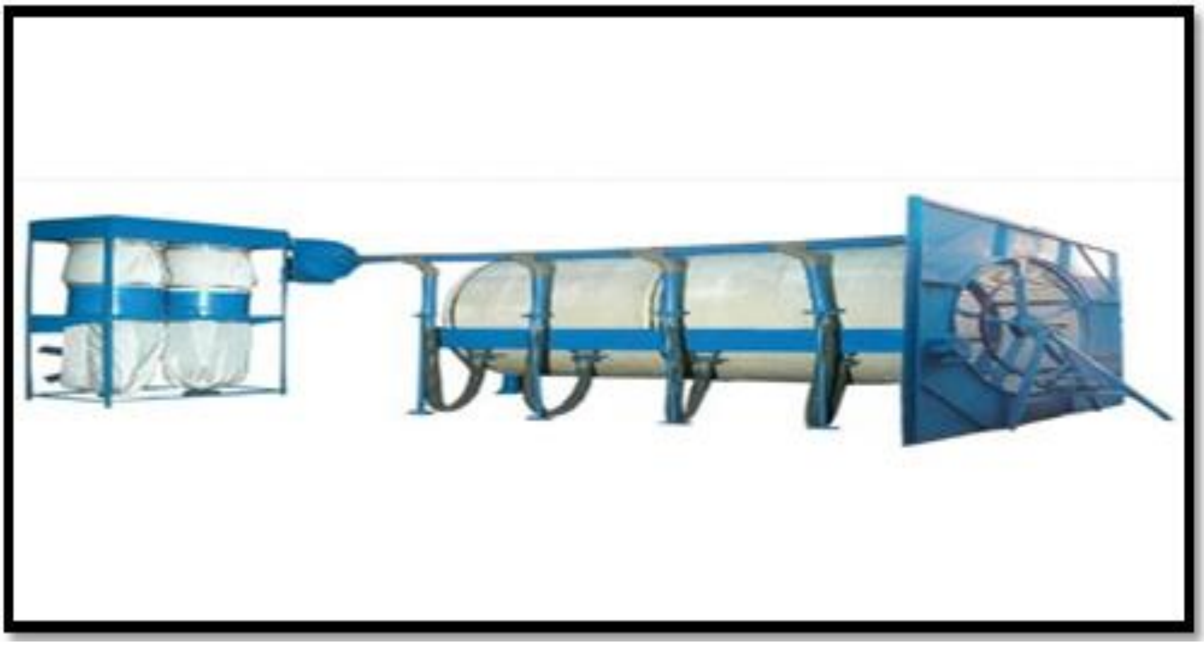
iii) **High cost investments**

- Reduction of **belt-pulley transmission losses** between the motor and machines, it is possible to reduce the electrical energy consumption nearly by 6% average, and in some places, this could restore the productivity by 20 % under specific site conditions.
- **Connecting right size of fixed capacitors** (to be selected based on the loading pattern), reduces i) nearly 1 % of the electrical distribution loss and ii) reduced the kVA demand further. Additionally this improves the system power factor.
- **Replacement of conventional lighting (FTL & CFL)** in to Energy Efficient LED lighting will save nearly 50 % of the lighting energy consumption. Care must be taken to select the lighting with higher initial CRI and light loss over the period of time.
- **Suggestion to install Lighting servo stabilizer Unbalanced type with added protections like Surge Protection Devices to protect the lighting in unmanned areas.**
- **Reduction of heat losses** exposed in the dryer by providing suitable insulation will certainly reduce the thermal utilization nearly by 3 %.
- Controlling the existing **Hot Air Generator (HAG) motor by closed loop VFD** and maintain the desired temperature inside the drying chamber. This step has two benefits like i) saving on electrical energy nearly by 20 % and ii) 6 % saving in the fire wood (thermal).
- Similar to the **HAG, dryer ID fan motor** can also be retrofitted **with O_2 based closed loop VFD** control system. This saves nearly 10 % of electrical energy along with 4 % of fire wood. – In automation, this will catalyse the productivity based on the thermal output made available fast and steady combustion achievable with ID fan VFD control based on automatic flue gas oxygen control.

- Optimize the **dust collector motor** using **moisture control based VFD** retrofit system. This step saves approximately 10 % of the electrical energy and 4 % of fire wood.

VII. Sustainable Improvement in Quality and Production Rate:

- **Condition Monitoring of Green Leaf during Cultivation:** Green leaf is the major input to manufacturing the tea and should always with good quality. It is highly recommended to procure the green leaf like two leaves with one bud. It must ensure the quality of the final product and reduce the content of the Re-Conditioning (RC). Reduction of adding RC also reduces the power cost per kg of made tea, as the RC should be considered as a value added product in the first cycle.
- **Condition Monitoring of Green Leaf during Withering:** Most of the tea industries are using trough type withering practices in which the evaporation of moisture in green leaf is being done by blowing air using a fixed speed blower. In most of the industries, the volume, pressure of the air passing through the trough and moisture content in the tea leaf is not measured and monitoring.
- The best practice in withering is to monitor the moisture level and maintain the hygrometric difference slightly above 3 ^{0}C and at the same time the dry bulb temperature of the movement air should not exceed 35 ^{0}C. Hence in withering process, it is highly recommended to monitor i) moisture content in the leaf and ii) temperature. These parameters should be monitored at least three different locations in a trough and averaged.
- **Uniform Withering using Rotating Drum Type Withering Setup:** The upward passage of air through the trough bed of leaves usually results in the bottom of the bed being withered first and the upper leaves last. To achieve a more even withering, turning over the leaf carefully once or twice is suggested. However, turning over may be practically difficult in wider open troughs.
    - Replacing the conventional withering with Rotary drum to rotate by 360^0 and ensure that the leaves are withered uniformly first before going for crushing. This will ensure uniformity of tea drying process further.

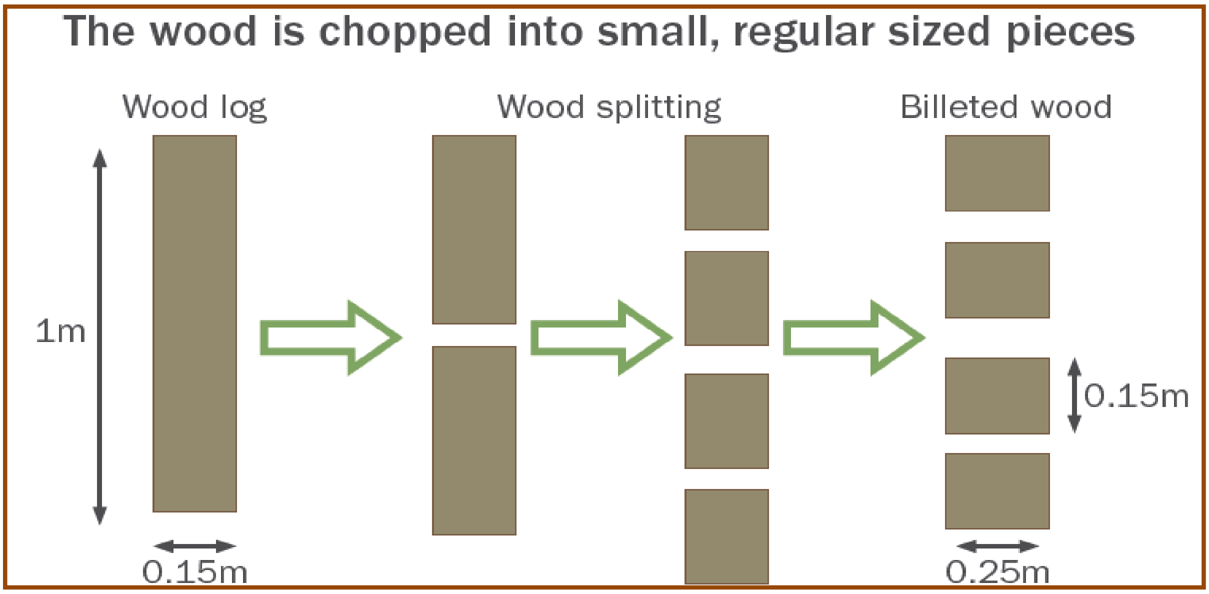


- **Tea Leaf Withering using Solar Direct Drying Method:** Similar to the above solar direct drying can be used to remove the moisture in the tea leaf. Thermostatically control hot air to be blown to the withering leaves chamber, thus the withered tea leaves at a steady temperature of say 40 ^{0}C irrespective of any time of the day, will improve the quality of tea, make the rejection less and this type of two stage drying initially at the Withering stage and finally at the tea dryer chamber, improves overall productivity.

The working is in such a way, that the raw tea leaves are dropped to the above chamber from the top. The chamber also is allowed to rotate at very low speed, for toppling the leaves to receive the forced air in the cylindrical chamber. Finally after withering, remove the leaves from the bottom of chamber.

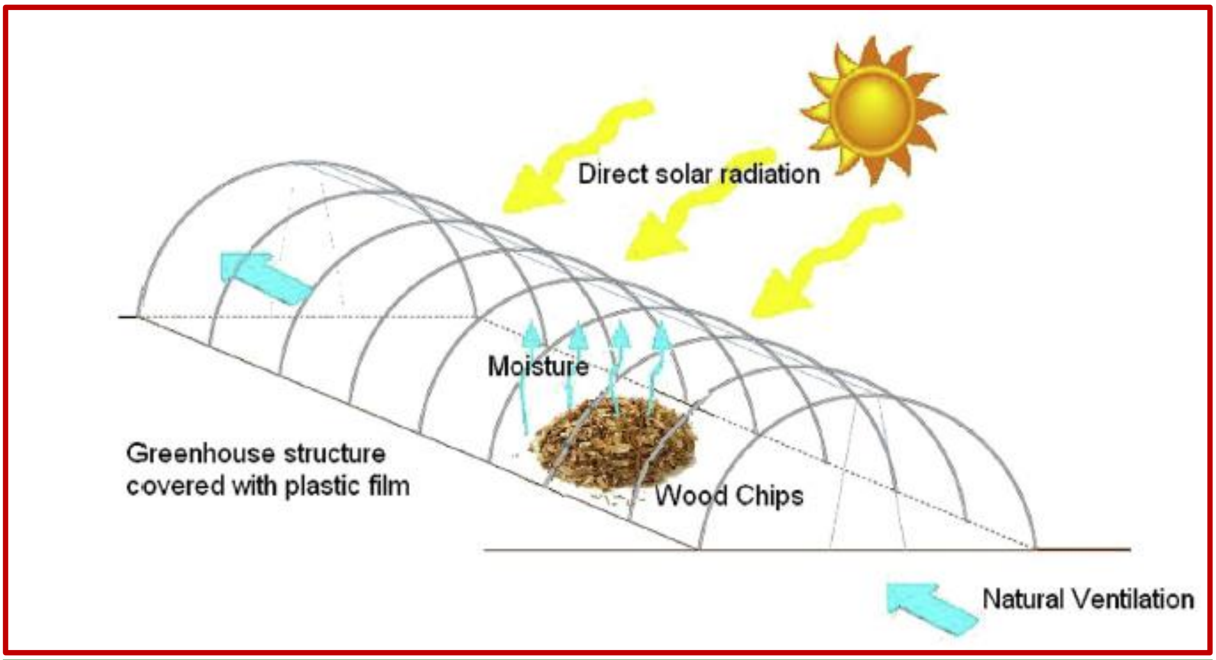
These types of solar dryer technologies reduces the fuel consumption and storage costs as well as associated problems from climatic effects. Solar dryers are a cost-effective solution. Implementing the use of solar drying system will result in significant savings to the reeling entrepreneurs.

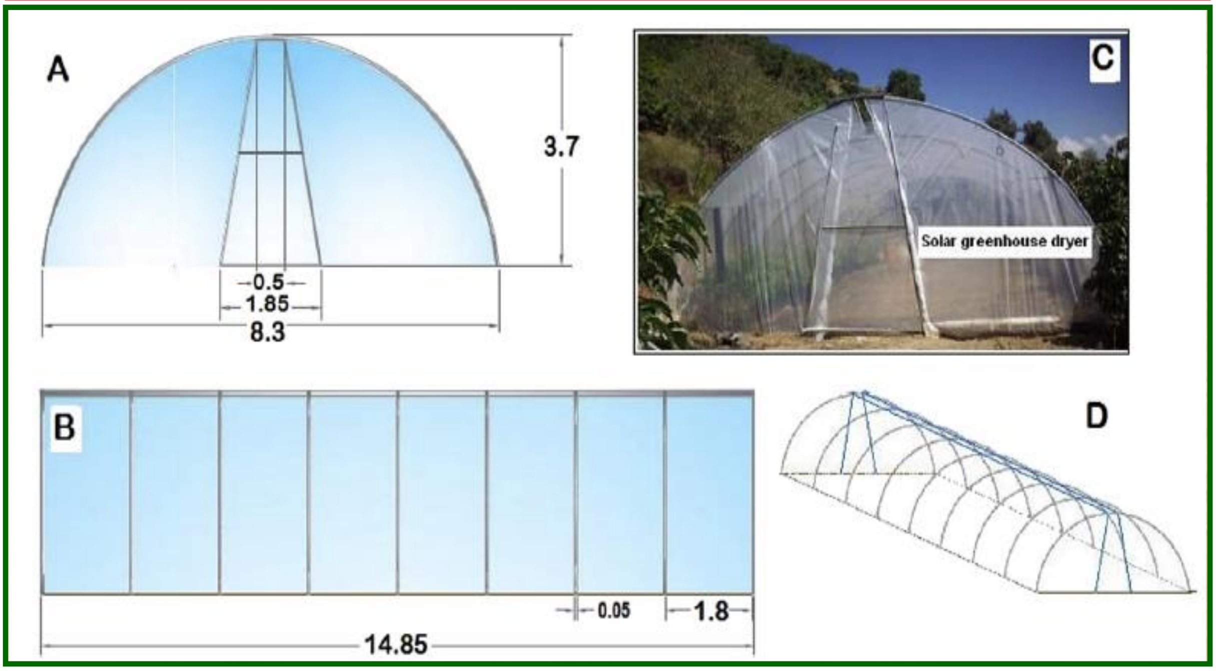
- **Wood Billeting:** Billeting is the process of chopping wood (instead of whole wood) into smaller, regular sized pieces with increased surface area. HAG with properly billeted wood to achieve efficient combustion, regular and consistent supply of hot air.
  - This will quickly catches the fire on all areas rather than firing on the circumference of the full wood.
  - Hence cut the wood into at least four pieces, keep the pieces for some time around the dryer (since it is worm) and feed into the dryer. This method removes the moisture content available inside the wood assisting to quickly burn the wood.



- **Removal of Wood Moisture using Solar Dryer*:***
  Timber drying is an energy intensive process of removal of moisture from the wood to a specified value so that the final product was improved in usage of energy intensity. Any industrial dryers operate under the principle of Heat and Mass transfer where the water (or water particles) of the wood has to be removed. The easiest method of drying the wood (and other agro-commodities) was the solar drying. Solar drying is a technological process and works on the principle of greenhouse effect. Two types of solar drying systems are available namely low temperature and high temperature dryers.
  - Instated of placing the wood openly, cover the entire place (or a portion) with solar tunnel dryer as mentioned in the below diagram and place the pulverized woods at least one day inside the dryer.

- This must remove considerable amount of moisture content of the wood and assist the burning process effectively thus attain required temperature in the dryer chamber with less fuel input.
- The tunnel has two opening (feed in and feed out) in which the feed out is close to the HAG. Design the dryer with i) fresh air let and ii) hot air outlet. Check the moisture level both at inlet and outlet of the dryer and analyse these values with daily fuel consumption. Map the same parameter with the production (made tea) and observe the reduction of fuel cost as against the made tea.





Also it is noted that, the hot air from the dust collector has nearly 80-90^{0}C (completely depends on the weather condition). Some industries recovers the heat content in the hot air through a well-designed duct system feeding to withering section. The same concept can also be used to feed the hot air in the solar dryer chamber which assist to remove the moisture content in the wood quickly.

- ***Restoring the working of CTC machines:-***

  Many industries have taken up the replacement of CTC motors of around 20 HP to IE 3 motors. But before planning to replace the existing motor, they have to first replace their existing pulley which has been running since decade. Pulley life is only 40,000 hours and the pulley has become totally worn out, dished out resulting in the slip of RPM between the motor and the machine.

  To restore the productivity of the machine, the industry has to plan to resize the pulley of motor and machine, replace the V belts with cogged belts and restore the CTC productivity of the machine by just improving the grip of the belts over the motor and machine pulleys. We are sharing a case study of sand mixer from the foundry the torque load application is similar to our CTC machine only. Please find the case study and plan to restore the losses in the prolonged workings of the CTC machine. Also the old the grease in the gear chamber is again and again packed with excess Multipurpose grease only. The same can be replaced with the speciality lubricant Polyurea thickened Lithium complex grease which can withstand the extreme pressure and high temperature arising inside the chamber.

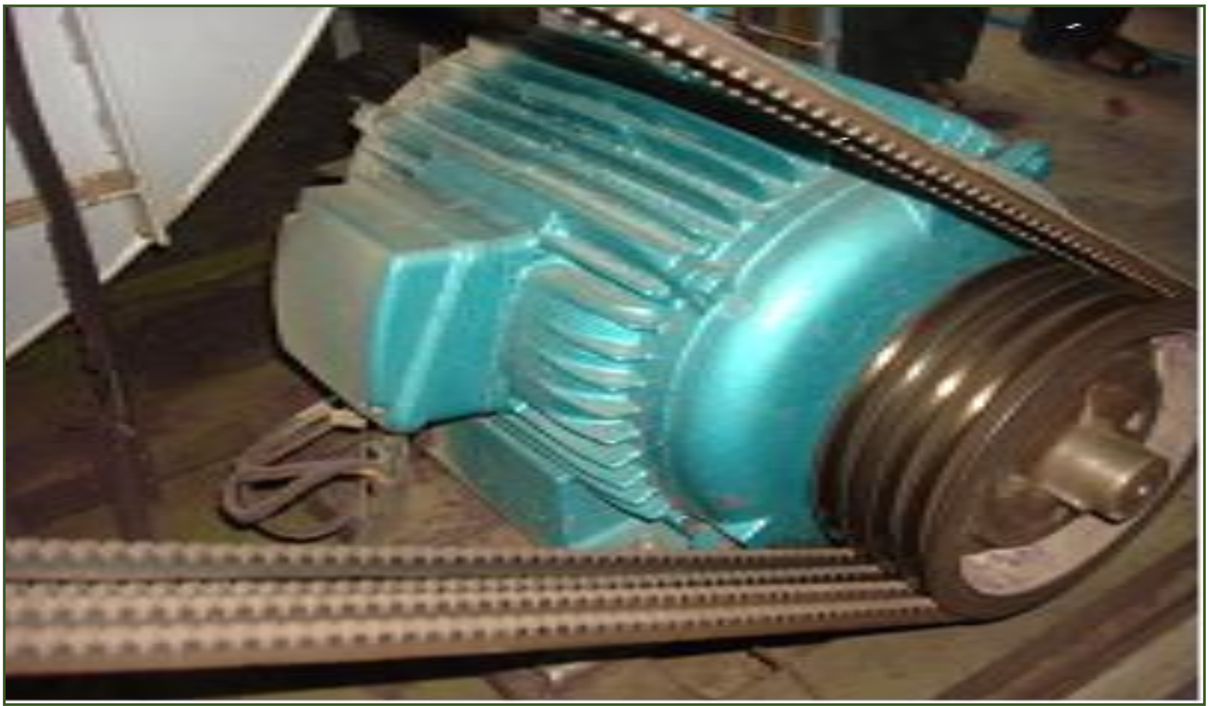
Machine details	SAND MIXER - 250 Kg Rated Capacity	
Customer	BLUEMOUNT CASTINGS P Ltd., Coimbatore	
Description	Before Changing Pulleys and Belts	After changing Pulleys and Belts
Motor HP/KW	20/15	20/15
Motor RPM	1440	1440
Type of Motor drive	Star Delta	Star Delta
Motor Pulley Dia. In mm	6.5 Inches	6. 0 Inches.
Machine Pulley dia. In mm	7.5 Inches	6.9 Inches.
Belt Specification	B 64	MITSOBOSHI XPB 1600
No-Belts (Mitsoboshi make	4	3
Sand Mixing per Batch	180 Kgs	215 Kg.
Power consumption	SAME KWH	SAME KWH
Productivity Restored		20 % More.
Results Observed since	Dec-18	Dec 2019.

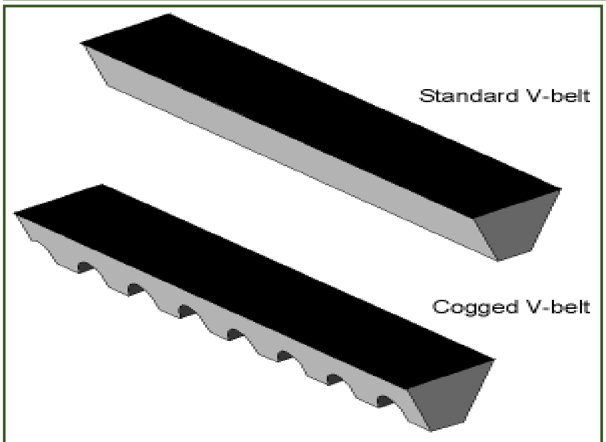
Motor drive transmission efficiency :-
Visible Losses seen in Belt Losses from motor to load

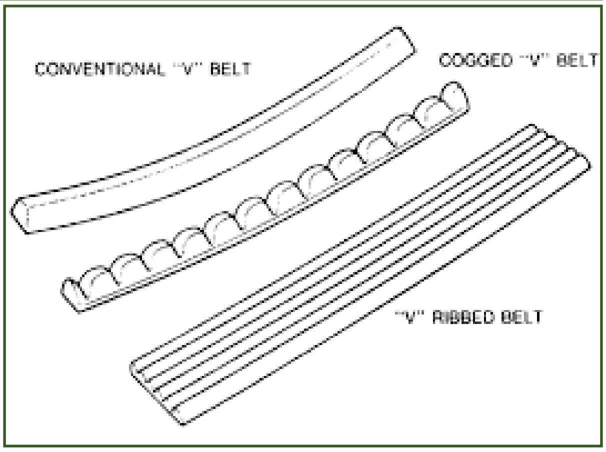
The efficiency of mechanical power transmission depends on grip between pulley and belt,, further depends on µ (Co-efficient of friction) and strength (Tensile) of the belt. In case of

Table 3.4: Losses in V Belts

Sr. no.	Motor HP	Losses %
1	2	8-15
2	3	7-13
3	4	6-12
4	6	5.5-10
5	8	5-9
6	10	4.5-8.2
7	20	3.5-7
8	30	3.2-6
9	40	3-5.5
10	60	2.8-5
11	80	2.5-4.5
12	100	2.5-4.5







- **Cleaning of Heat Banks in the Dryer:**
  - Dryer efficiency may go down if the heat bank in the dryer formed with fouling (accumulation of unwanted material on solid surfaces to the detriment of function). Hence it is recommended to clean (with wire brush available in the company) the heat banks regularly (even daily cleaning practices gives good results). This must certainly reduce the wood consumption of the dryer per kg of made tea.

Best Practices for Improve HAG Efficiency:

- Feed HAG with billeted wood to aid combustion
- Do not unnecessarily open boiler door as this disrupts combustion
- Open only 1 door when feeding boiler
- Remove ash daily
- Fully insulate the HAG system inside and outside to eliminate heat loss
- Continually monitor flue gas to ensure correct air-fuel mix
- Use air flow dampers and flue gas readings to regulate the amount of fresh air entering the combustion chamber
- The flue gas for the Hot Air Generator, even though Return on Investment may be more, this needs to be done to improve the productivity based on the thermal fuel, reduce the pollution to the surrounding environment, and with less KWH power saving in the ID fan control of the HAG.

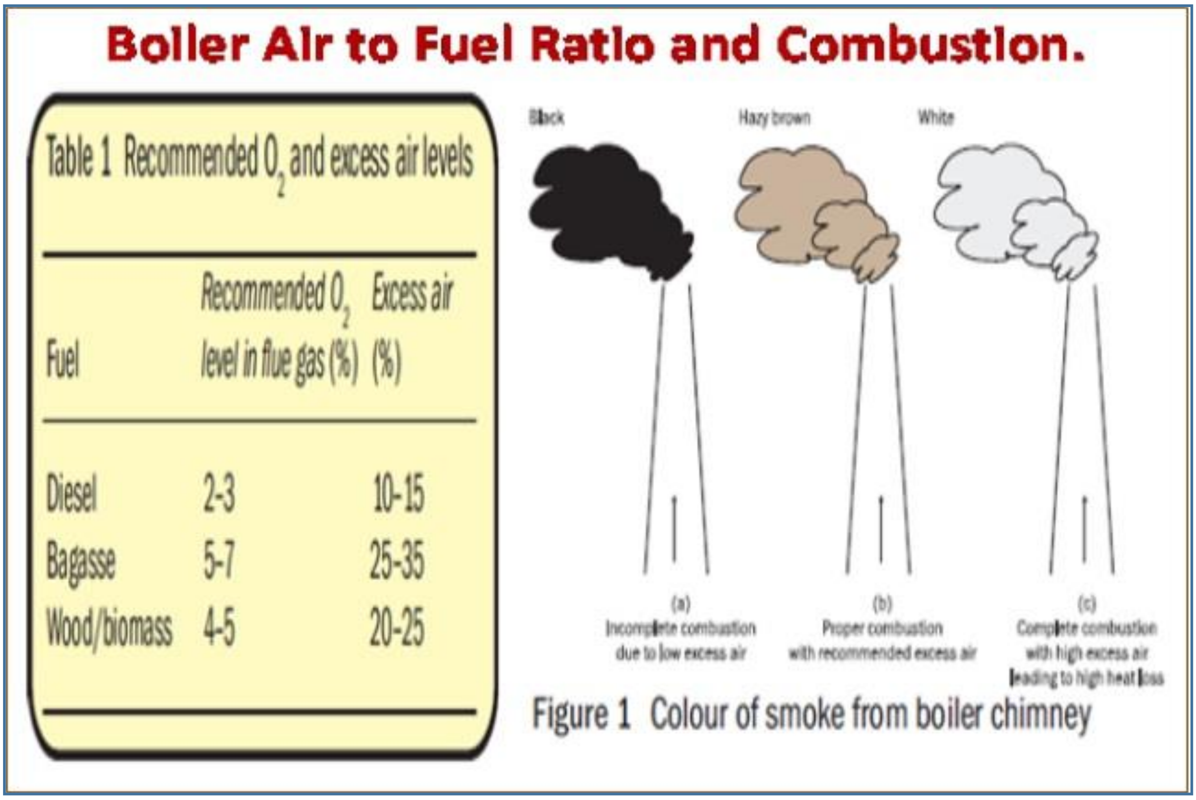
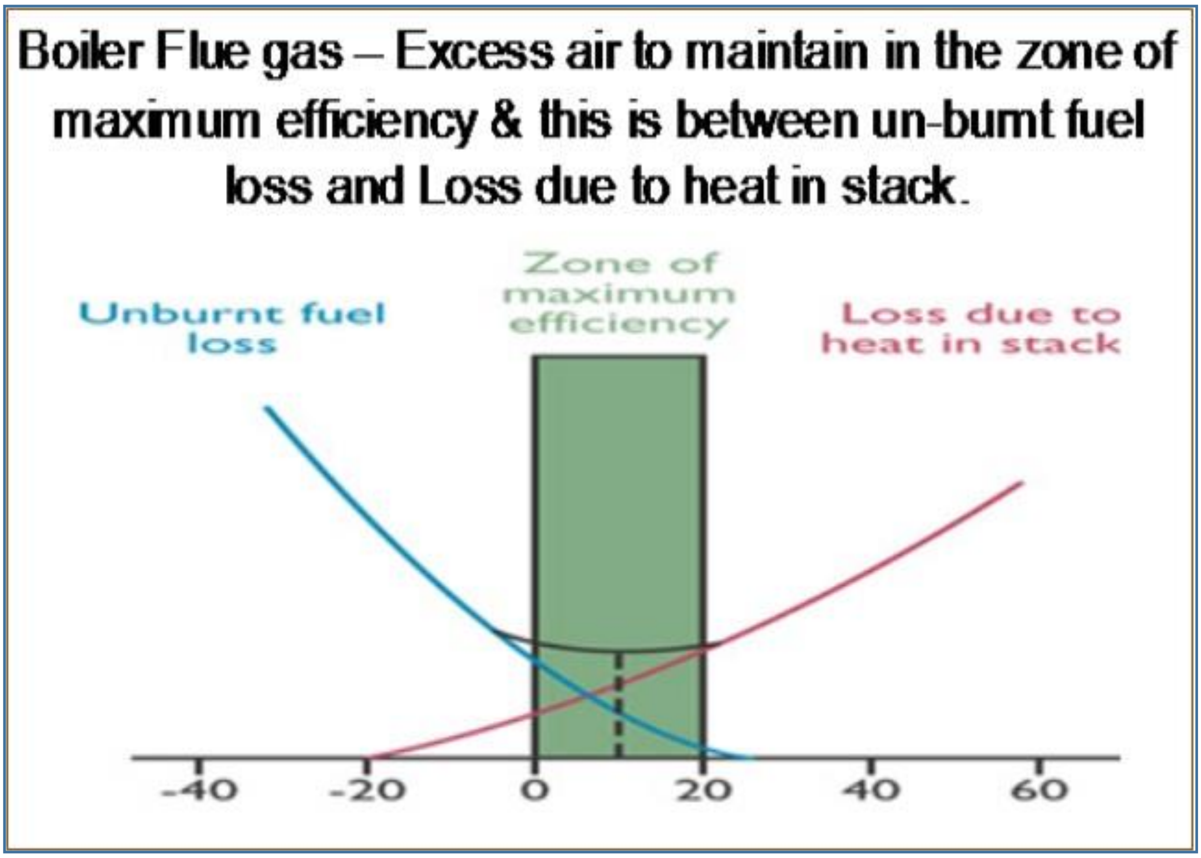


Table 1 Recommended O_2 and excess air levels

Fuel	Recommended O_2 level in flue gas (%)	Excess air (%)
Diesel	2-3	10-15
Bagasse	5-7	25-35
Wood/biomass	4-5	20-25



VIII. Condition Monitoring and Process Improvements:

- **Installation of kWh and Run Hour Meters:**

  Good practice to monitor the kWh consumption of each machine above 10 HP. The observed data must be used to compute the Specific Energy Consumption of each machine for the produced item.

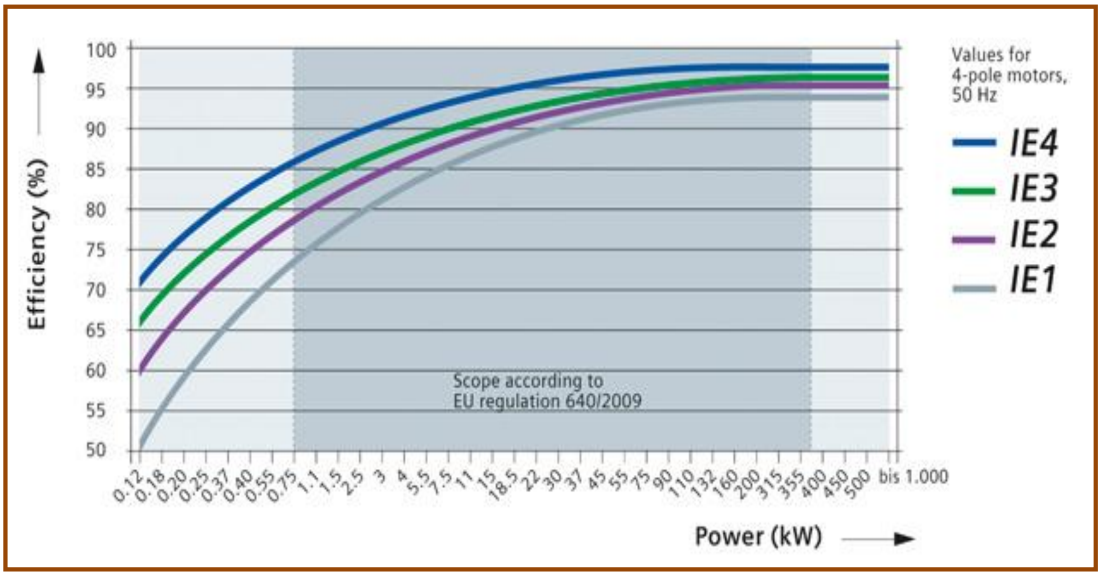
  - The recorded data from these meters must be used to compare the energy consumption pattern as against the running hours (also the respective quantity of the production) by weekly, monthly or even annual span of interval. Hence the top management knows the judicious utilization of energy in their plant.

- **Motor Failure Monitoring:**

  In tea manufacturing industries, 90 % of electrical energy is being utilized by electrical motors in different section with wide variety of power ratings. Hence maintenance of each motor with proper motor management plan is will appreciable. Similarly installation of Digital Motor Protection Relay (DMPR) for all three phase motors (Initially with higher HP motors) must prevent against over/under current, phase unbalance, phase reversal, single phasing, stall, lock, phase, phase to phase and earth faults.

- **Possible Replacement of IE-3 Motors:**

  At present the motors used for general applications is EFF 1 (Which is obsolete now) class motors. Currently the process industries are moving to IE-3 category having an increased efficiency of up to 94 % (ensures 2 % energy saving). Hence the audit team recommends the concerned authorities to insist the supplier supply any new installations with IE-3 motors (Premier Efficiency). Also if the existing motor fails (coil failure, frequent bearing failure and any other mechanical failures), it is better to replace with IE-3 motors.



Possible replacement of IE-3 Motors:

IE-3 motors are better energy efficient class even for 60-70 % loading and possible areas for replacement of IE-3 motors are as follows,

- All CTC motors (as some motors are re-winded more than twice)
- Impact Pulveriser, Hot Air Fan Motor, Trough Motors, Leaf Shredder
- Small motors in Fermentation, shifting and conveyors

Comparison of Efficiency

Output Power (kW)	Efficiency (%) IE-1 motor	Efficiency (%) IE-3 motor	Efficiency Gain (% pt)
1.1	75.00	84.10	9.10
1.5	77.20	85.30	8.10
2.2	79.70	86.70	7.00
3.7	82.70	88.40	5.70
5.5	84.70	89.60	4.90
7.5	86.00	90.40	4.40
11	87.60	91.40	3.80
15	88.70	92.10	3.40
22	89.90	93.00	3.10

- **Maintaining Input Voltage Level:**

  Maintain the input voltage level (mainly for HT consumers) and reduction of voltage stress on the electrical equipment's. In order to main the specified voltage at the input side, the LT consumes may think of a Servo Stabilizer. This step ensures the reduction of failure rate.

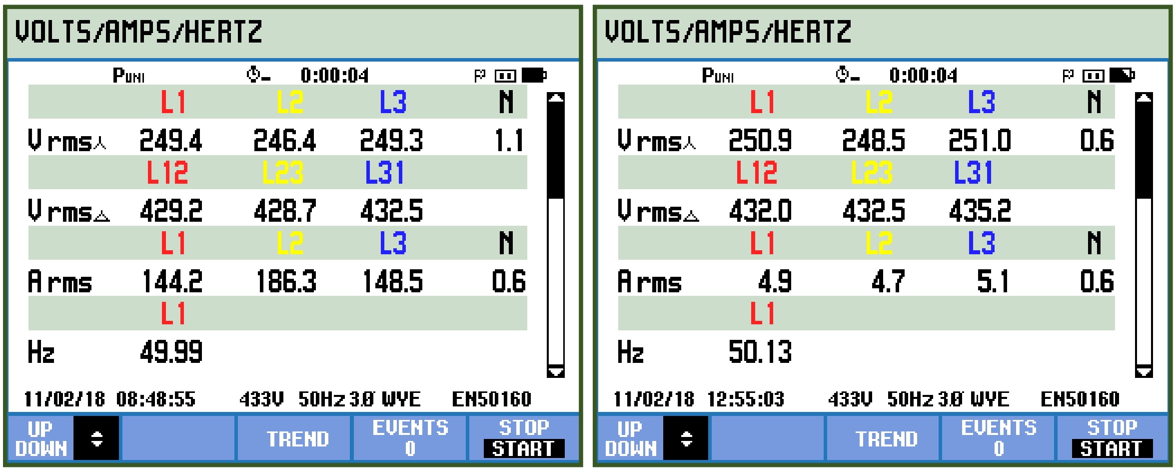


Fig.2: Higher Input Voltage (Line to Line RMS) than the specified level of 400 V.

IX. Conclusion:

Ever increasing energy bills, growing concerns on environmental impacts and shortage of natural resources has forced many tea industries to reduce their present energy consumption by implementing systematic energy management plan. This paper provides an insight about various areas where reduction of energy possibilities along with their approximate simple payback analysis.

Further this paper discussed some of the best operating practices to be followed in the industry either to improve the productivity or to reduce the energy consumption or sometimes both. Apart from the above study, one has to conduct a special analysis on Specific Energy Consumption (SEC) in order to know the effective utilization of energy per unit ton of made tea production.

This study must be compared with the existing benchmarking value and assess how far this present value. If the benchmarking value is not available (or not done so far) then, this will be treated as the first value of benchmarking. Understanding the SEC provides effective ways to reduce the present SEC without affecting productivity. Any energy management system should either;

i) Reduce the present energy consumption or

ii) Increase the productivity or

iii) Both.

Note: Detailed energy audits were done under Promotion of Energy Audit and Conservation of Energy (PEACE) - A subsidy program promoted by Government of Tamilnadu. This energy audit facilitated the MSME to build their energy efficiency awareness by funding/subsidizing need based energy studies and giving Energy Conservation Recommendations including Technology up gradation opportunities. Energy audit initiated this diagnostic studies in the tea industry segment covering the specific energy consumption norms, energy efficient process and technologies, best operating practices and the case studies in Energy conservation.

Keywords: *Energy Conservation Proposals (ENCON), Cut-Turn-Curl (CTC), Energy Carriers, Process Improvements, Sustainable Improvement in Quality.*

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