Preliminary Energy Study Conducted at Arrapetta Tea Factory

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INTRODUCTION

A preliminary energy analysis was conducted in Arrapetta Tea Factory of M/s Harrisons Malayalam Limited.

The aim is to identify and propose/suggest energy saving opportunities for the Factory. The study is focused in major energy consuming areas.

There are two major methods of tea manufacture:

(i) Orthodox method
(ii) CTC (Cut-Tear-Curl) method.

Orthodox is a traditional method in which the green leaves are first withered, twisted gradually by the slow rolling process, then fermented and dried.

CTC method is a high volume process. In this, the withered leaves suffer more severe cutting to strong liquors, then fermented and dried.

Some factories manufacture tea by Dual process - both orthodox and CTC methods.

ABOUT THE COMPANY & PROCESS

Arrapetta Tea Factory of M/s. Harrisons Malayalam Ltd. Is an ISO 9002 certified company and engaged in the manufacture of tea using Orthodox processing. The factory is having a capacity to process 32000kgs green leaf per day in three shift operation.

The raw materials – Tea green leaves collected from the field are first spread in withering troughs to remove the internal and external moisture content to certain level to retain the quality of green leaf and its contents to have chemical changes. The leaves are spread in the withering trough at a pre-determined thickness of about 20 to 25 cms. There are 37 withering troughs. In the wither process air is blown from the bottom of the withering beds or troughs for a minimum period of 8 to 15 hours. After withering the moisture content of the leaves is reduced to around 95%.

Orthodox: After attaining the required wither, leaf is rolled on roller table in batches of about 300 kgs. Rolling is a process of reducing the size of withered leaf into Curly dhool by the help of Conventional Crank Rollers. At the end of the batch roll, leaf is taken out and sifted (known as ball breaking) to get the required particle size of tea. One batch of withered leaf undergoes three rolling, for about 30 to 50 minutes. The rolled, sifted tea is spread on the floor for fermentation. The tea after fermentation is fed to drier to arrest the fermenting using hot air. From the drier discharge end, black tea is collected and cleaned to remove stalk and fibre. In the sifting room tea is graded, cleaned and stored in bins. The tea stored in bin is packed in packing chests and despatched for auction.

- Rolling: Process of reducing the size of withered leaf into Curly dhool by the help of conventional crank rollers.
- Fermenting: The tea after rolling is fermented for some time to have chemical changes with the help of oxygen from atmosphere air.

Drying: The fermented tea is dried in dryers to reduce the moisture content to 1.5 – 3% with the help of hot air. Hot water generators are used to build up heat. The fresh air is sucked from atmosphere passes over the hot water and the hot air thus generated is used for drying the tea.

Sifting/Cleaning: The dried tea is cleaned in machines like Fibre Extractor (Fibromat), Winnower etc., to remove the fibre as well the lighter or unmarketable tea. The tea is sieved through different meshes to extract size wise. The lighter or unmarketable tea is pulverised and taken for reconditioning.

Packing and Despatching: The tea sifted as above is weighted and binned. It is packed in jute bags with HMHDPE liners and is despatched.

A detailed process flow chart describing the tea manufacturing process is given below.

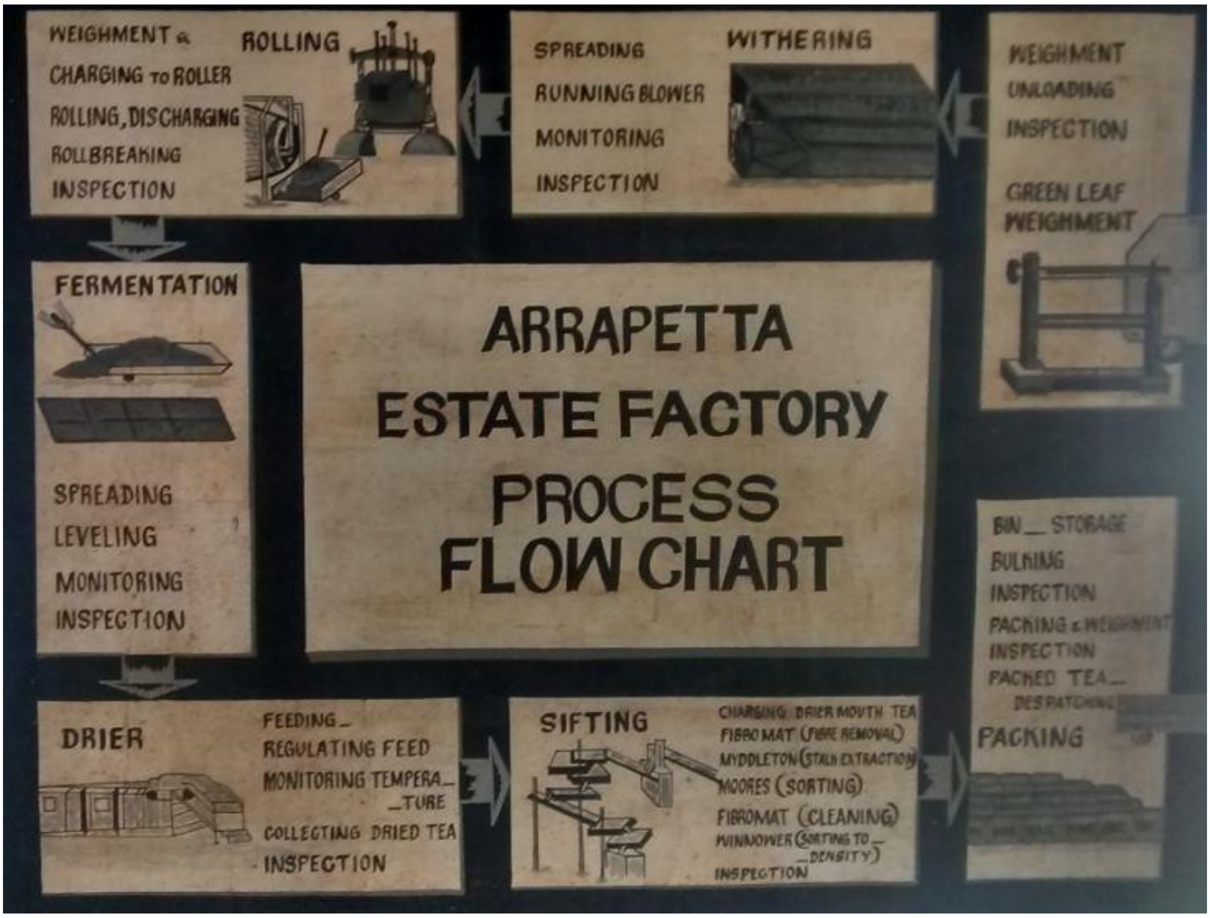


Fig 2.1 Process flow

ENERGY CONSUMPTION PROFILE

The plant utilizes both electrical and thermal energy as primary energy input for the production process. The electrical energy is being supplied by State Electricity board. The thermal energy is utilized in tea driers for drying purpose with the help of a hot water generator. Firewood and other fuels like wood waste, veneer waste etc are used in the hot water generator. Diesel is used for self-generation by DG set during supply interruptions and power cuts.

The following block diagram shows the process and energy flow.

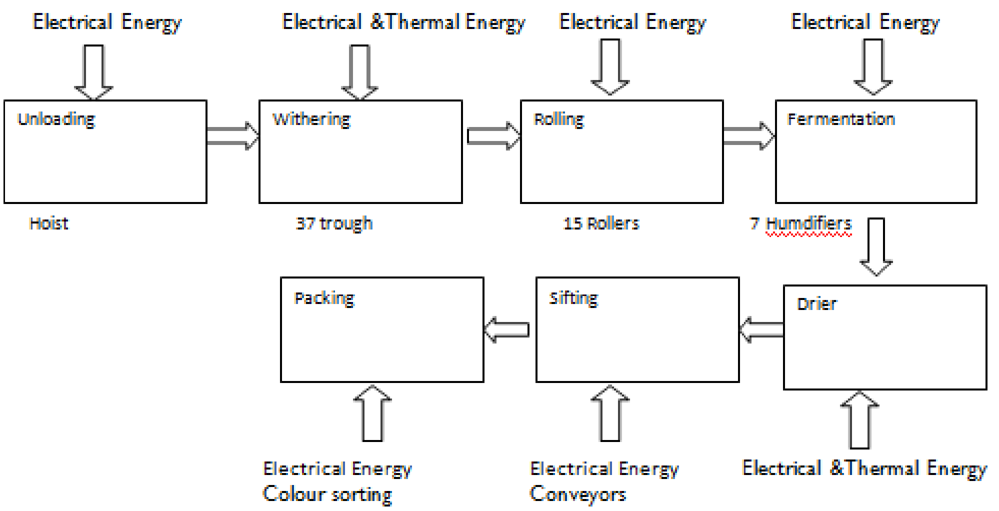


Fig 3.1 Process and energy flow

Energy Requirement in Tea Industry

Energy is a critical input for tea manufacture. Thermal energy is required to remove the moisture from the green leaf as well as fermented tea, whereas electrical energy is required at almost all stages of unit operations.

The process of tea manufacturing consists of different energy intensive unit operations viz. withering, processing (rolling/CTC cuts), fermentation, drying, sifting and packing. These make use of 3 different forms of energy i.e. electrical, thermal and human. More than 80% of the energy required is thermal energy to remove moisture from tea during withering and drying.

Every kg of made tea requires 3.5-6 kWh of thermal energy, 0.21 - 0.5 kWh of electrical energy and 0.11 kWh of manpower.

The following pie chart shows the different forms of energy required in the tea manufacturing in percentage.

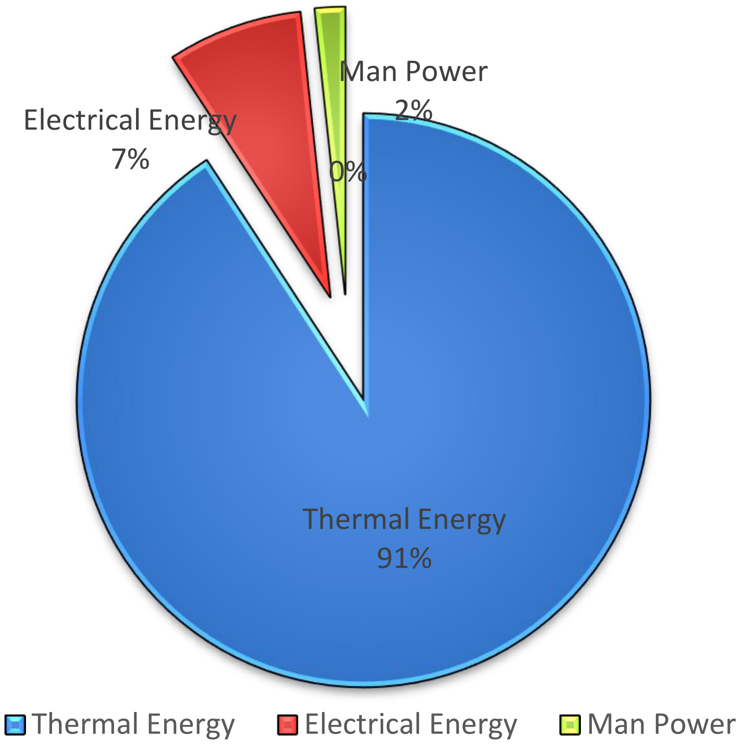


Fig 3.2 Energy requirement for tea

DATA COLLECTED

Electrical data of the industry

- The Industry is HT1 (A) type.
- The annual power consumption of the factory during the period September 2013 to September 2014 was 945912 kWh with a monthly average of 78826 kWh.
- The Contract Demand of the factory is 350 VA. The present average demand is 257kVA, 228kVA and 192kVA in Normal, Peak and Off-Peak zones respectively.
- The Connected Load of the factory is 760 kW.
- Maximum Demand of the factory is about 240 to 250kVA.
- A distribution transformer of 11/433V 500KVA capacity is installed for the electrical supply to the unit
- The factory utilizes two DG sets having capacities of 310kVA & 160kVA as alternate source for power during supply interruption, low voltage, and energy & demand cuts imposed by the State Electricity Board.
- For the purpose of power factor correction, the factory has adopted central and group compensation method. A total of 210kVAr capacitors are installed at the factory for power factor compensation of which 190kVAr (20kVAr x 5 + 40kVAr x 2 + 10kVAr) is connected in APFC panel, 20kVAr is connected as spare.

Electricity bill collected:

Bill for the month of August

August			
Contract Demand	350 KVA		
75% of Contract Demand	262.5 KVA		
130% of Contract Demand	455 KVA		
Connected Load	517.815 KW		
Average Maximum Demand	242.18 KVA		
Average Consumption	83863 KW		
	Normal	Peak	Off Peak
kWh(Units)	60350	19915	37335
kVAh(Units)	66675	20850	39510
Demand(Units)	301.14	272.62	247.9
Total Cost(Rs)	277610.00	137413.50	128805.75
pf	0.95		
Pf Incentives	4078.72		

Bill for the month of September

September			
Contract Demand	350 KVA		
75% of Contract Demand	262.5 KVA		
130% of Contract Demand	455 KVA		
Connected Load	517.815 KW		
Average Maximum Demand	240.90 KVA		
Average Consumption	78826 KWh		
	Normal	Peak	Off Peak
kWh(Units)	49140	16510	29535
kVAh(Units)	52550	16750	30460
Demand(Units)	259	219	218
Total Cost(Rs)	240915.00	121821.00	108900.00
pf	.95		
Pf Incentives	5895.45		

Bill for the month of October

October			
Contract Demand	350 KVA		
75% of Contract Demand	262.5 KVA		
130% of Contract Demand	455 KVA		
Connected Load	517.815 KW		
Average Maximum Demand	243.48 KVA		
Average Consumption	83206 KW		
	Normal	Peak	Off Peak
kWh(Units)	54585	17530	32975
kVAh(Units)	58675	17960	33970
Demand(Units)	261.75	247.25	219.45
Total Cost(Rs)	283842.00	136734.00	128602.00
pf	0.95		
Pf Incentives	6864.73		

From the Electricity bill of the three months it is clear that the company is getting additional incentive for power factor above 0.9.The power factor is maintained on an average at 0.93 to 0.95.

Bill composition for the month of October as a pie representation

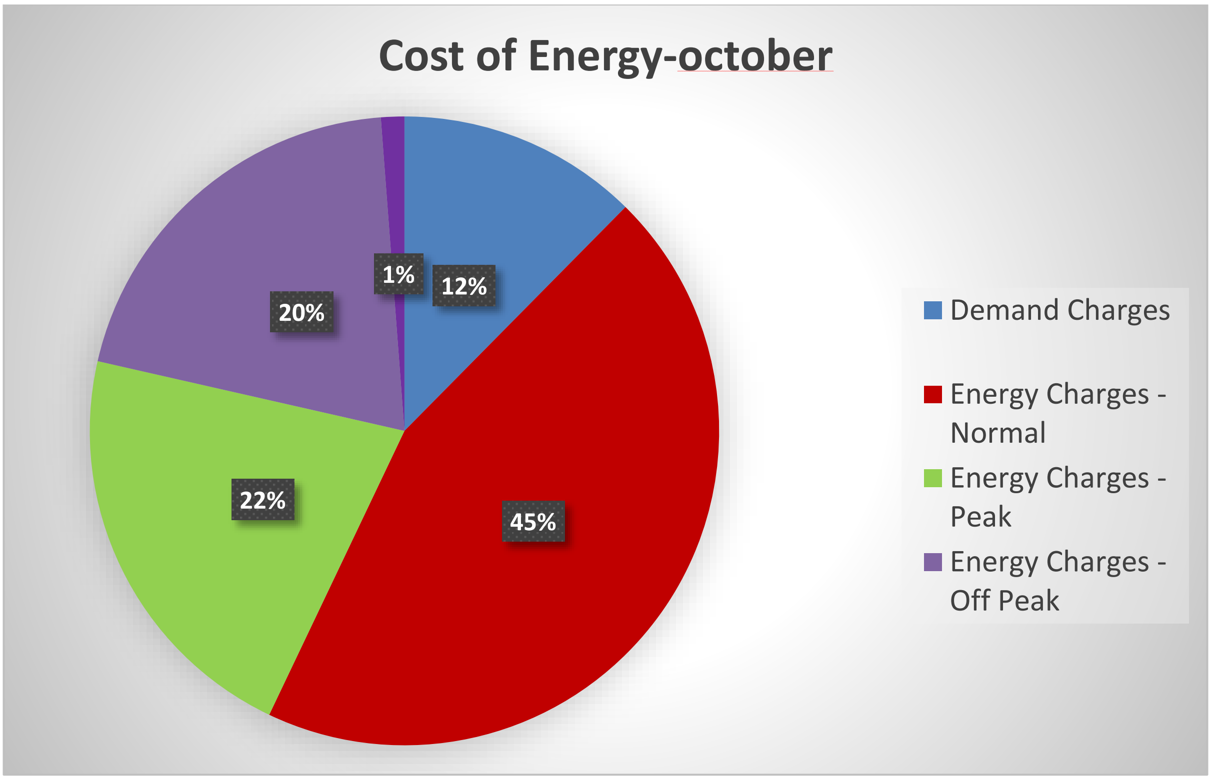


Fig 4.1 Energy bill composition

Units in kWh taken by each process during the period 10th October 2015 to 21st October 2015 is tabulated below.

ARRAPETTA FACTORY												
DATE	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
WITHERING	1496	1716	1832	1800	1784	1580	1332	1192	1436	1764	1772	1444
SIFTING - COLOR SORTER	674	642	570	656	716	504	572	546	560	630	494	532
ROLLING	232	264	200	272	208	280	216	320	216	304	312	304
DRIER	1038	1014	1022	992	904	1140	992	994	972	850	1210	940
WORKSHOP	28	20	16	12	16	24	28	24	20	20	8	24
FACTORY WATER SUPPLY	103	56	133	88	60	107	81	103	104	100	97	84
LIGHTING	331	304	330	319	308	293	328	309	282	329	320	311

ANALYSIS

1. SEC plot:

The following table shows the production and the energy consumption details for 12 days.

PRODUCTION (kg)	MANUFACTURE UNITS (kWh)	SEC(kWh/kg)
6975	3953	0.566738
7200	4280	0.594444
7200	4302	0.5975
6875	4215	0.613091
7150	4340	0.606993
6750	4104	0.608
6525	3628	0.556015
6290	3388	0.538633
6750	3619	0.536148
6865	4291	0.625055
6975	4325	0.620072
6525	3941	0.603985

SPECIFIC ENERGY CONSUMPTION:

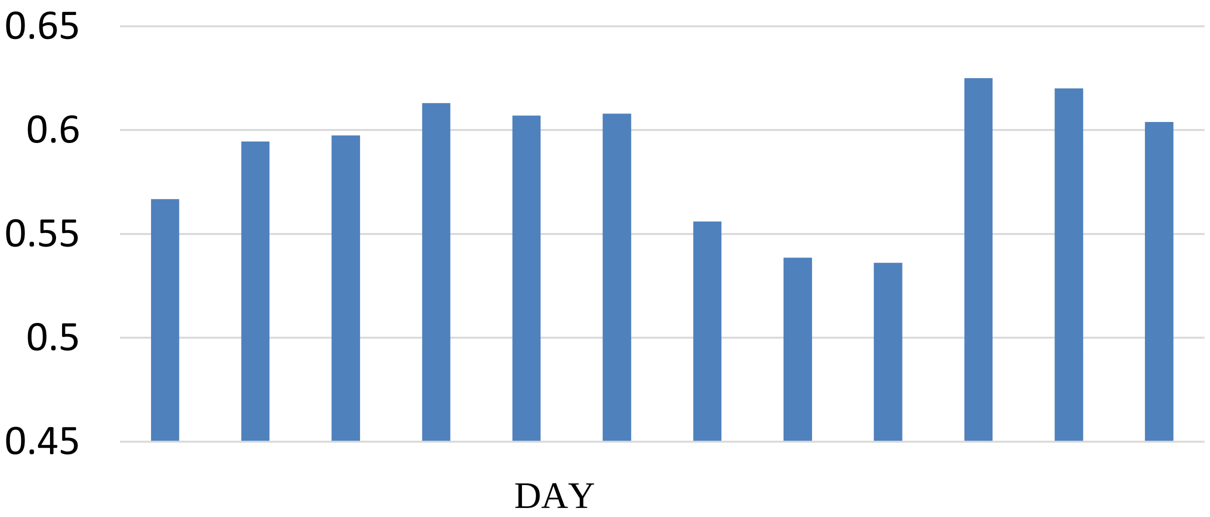


Fig 5.1 SEC plot

Motors:

Electricity consumption by electric motors accounts for the significant amount of the power consumption in the factory. Electric drives like Withering trough fans, Crank rollers, Conveyors, blowers, compressors etc

There are no oversized motors in this industry. The under loaded motors in the Arrapetta Factory is operated in star mode so that maximum efficiency is attained. Motors that are loaded below 40% are operated in star mode, provided the starting torque required is not very high. The other benefits in running in star mode are improved power factor and reduced motor heating.

From the electricity bills of the factory it is clear that the power factor is maintained at 0.93. The industry is having a capacitor bank of 190kVAr + 20 kVAr along with APFC to maintain the power factor.

The following table gives the summary of the Motor Load details of the Arrapetta Tea Factory.

Sl No	Ratings(HP)	Withering	Rolling	Drier	Shifting Room
1	0.5	---	---	---	7
2	0.75	---	6	---	---
3	1	---	---	---	5
4	1.5	---	1	---	5
5	2	---	3	3	
6	2.5	---	---	---	4
7	3	1	---	---	---
8	4	---	---	---	1
9	5	26		3	2
10	7.5	12	---	---	1
11	12.5	---	---	1	---
12	15	---	7	2	---
13	19	---	2	---	---
14	20	---	5	3	---
15	25	---	1	---	---

Lighting Loads:

The total lighting load of the factory including plant, offices and outside premises comes about to 20.72kW. The entire plant and office lighting consists of tube light fittings, CFLs and incandescent bulbs. Sodium vapour lamps of 250W are used in the factory for street/yard lighting. Some halogen lamps of 70W are also used in the trough area. The consolidated figure of light fittings provided in the following table.

Load	**FTL**	**Incandescent**	**CFL**	**Halogen**	**SVL**	**Total**
	40W	100W	12W	70W	150W	kW
Total (Nos)	340	3	3	6	5	20.72
Total(kW)	18.7	0.18	0.04	0.48	1.33	

The chart below shows the connected light load details of the entire plant.

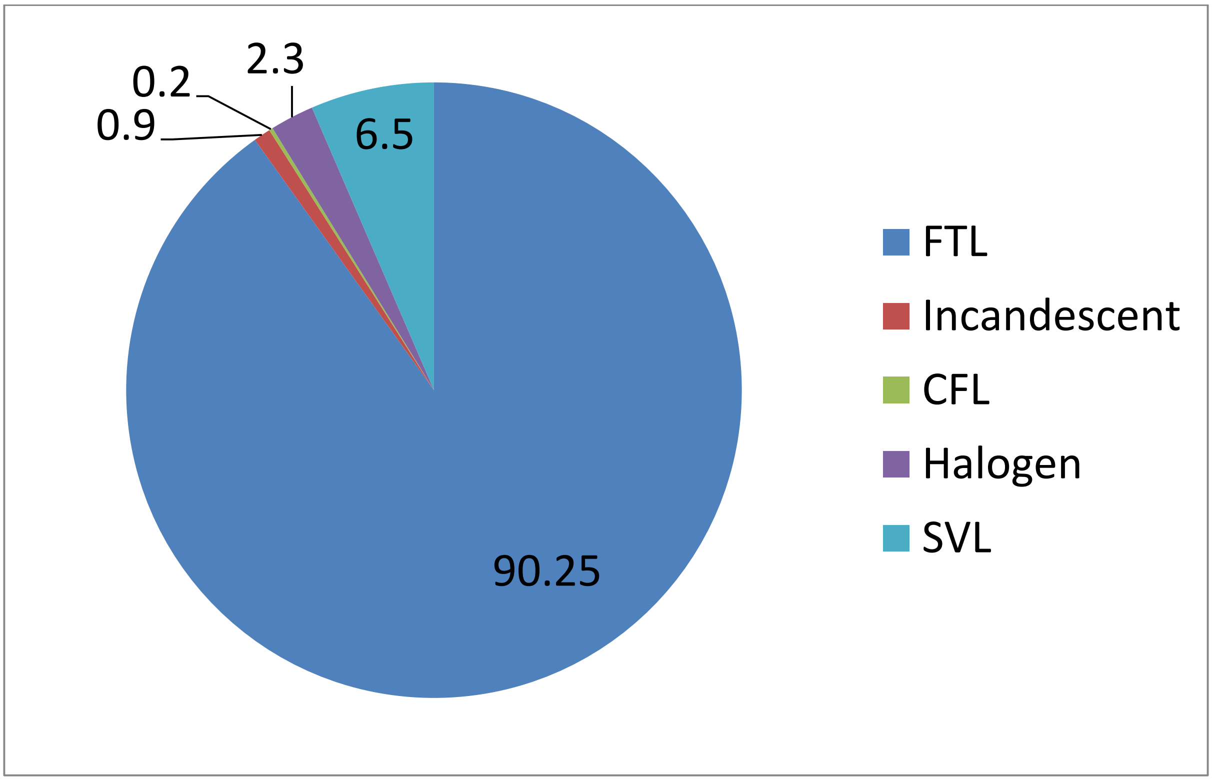


Fig 5.2 Connected light load of the plant

SUGESSTIONS

1) Replacement of Aluminium trough fan impeller with PAG fibre fan**.**

PAG stands for Poly Amide Glass. This fan consumes low power compared to the traditional Aluminium fans that are previously used. PAG fans are light weight and energy efficient. Poly Amide Glass fans are implemented in two troughs i.e. in trough 1 and trough 33as part of the energy savings.

The following tables show the performance comparison of the Poly Amide Glass fans with the traditional Aluminium fans.

Performance comparison of trough 1 and trough 2. The fan size is 965mm.

	Trough 1	Trough 2
Capacity Measured(CMH)	32711	23974
Velocity(M/Sec)	12.43	9.11
Motor Full Load Current(Amps)	7.3	7.3
Current Measured(Amps)	5.16	6.68
Motor Power(kW)	3.7	3.7
Input Power(kW)	2.58	3.23
Volts consider	400	400
Power Factor considered	0.85	0.85
Motor efficiency considered	0.85	0.85
Trough total leaf weight(kg)	1160	1200
Trough Area (Feet)	72X6	72X6
Fan working (Hours/day)	14	14
Number of days working/year	300	300
Kilowatts hours	10836	13566
Power tariff(Rs/unit)	5.50	5.5
Total spend Rs	59598	74613
Annual savings(Rs/year)	15015	

Capital cost = Rs 14,500
Annual savings = Rs 15,015
Simple Payback Period = 14,500/15,015
= 0.96 yrs

Performance comparison of the trough 32 and trough 33. The fan size used is 1200mm

	Trough 33	Trough 32
Capacity Measured(CMH)	45900	46391
Velocity(M/Sec)	7.54	8.14
Motor Full Load Current(Amps)	12.2	12.2
Current Measured(Amps)	6.8	10.88
Motor Power(kW)	5.5	5.5
Input Power(kW)	3.4	5.44
Volts consider	400	400
Power Factor considered	0.85	0.85
Motor efficiency considered	0.85	0.85
Trough total leaf weight(kg)	1800	1550
Trough Area (Feet)	129X6	129X6
Fan working (Hours/day)	14	14
Number of days working/year	300	300
Kilowatts hours	14280	22848
Power tariff(Rs/unit)	5.50	5.50
Total spend Rs	78540	125664
Annual savings(Rs/year)	47124	

Capital cost = Rs 17,500
Annual savings = Rs 47,124
Simple Payback period = 17,500/47,124
= 0.37 yrs

2) <u>Replacement of 250W Mercury Vapour Lamps (yard lighting) by 80W LED lamps</u>

The light efficacy of 250W mercury vapour lamps is nearly equal to that of the 80W LED lamps. It is recommended to replace all mercury vapour lamps with LED lamps. The detailed calculation is shown below.

Present Light Fitting – 250W Mercury vapour Lamps

Present power consumption = 265W

Power consumption by proposed of LED fittings = 80W

Approximate cost of one LED Lamp = RS 17,000

Power saving = 185W

Number of fittings = 5

Operating hours	= 12hrs
Power savings achieved daily	= 11.1kWh
Power savings achieved annual	= 4051.5kWh
Cost saving achieved @ Rs 6.89/kWh Daily	= Rs 76
Cost saving achieved @ Rs 6.89/kWh Annual	= Rs 27,915
Total investment required	= (5*17,000)
	= Rs 85,000
Simple payback period	= 85,000/27,915
	= 3.05yrs

3) Cogeneration

Combined heat and power (cogeneration) system is the coincident generation of necessary heat and power - electrical and/or mechanical - or the recovery of low level heat for power production. Two basic types of Combined Heat and Power systems are (i) Bottoming cycle in which thermal energy is produced first and

(ii) Topping cycle in which electrical energy is produced first.

The ratio of electricity to steam for tea processing is low. So, for a tea factory, a steam turbine topping cycle is recommended. Thermal match cogeneration system offers higher overall efficiency in tea manufacture.

- ***Analysis Before Cogeneration***

  Average electricity bill/month = Rs 6,50,000

  Monthly requirement of firewood = 14,62,570kg

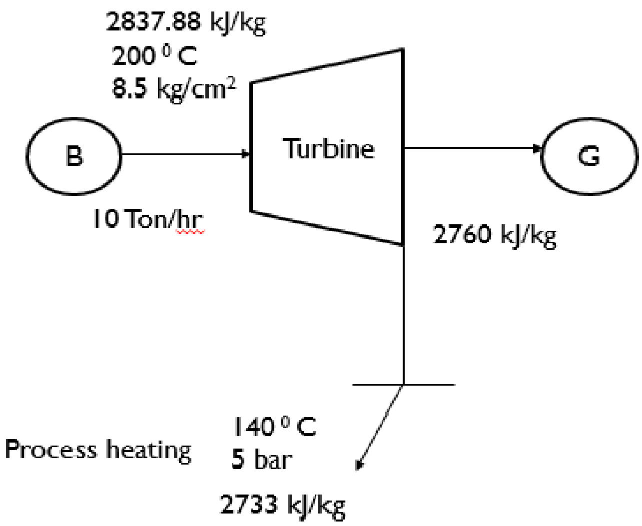
  Fuel cost = Rs 2700/ton

  Fuel cost (per month) = Rs 39,48,940

  Total expense per Month = Rs 45,98,940

❖ *Topping cycle cogeneration*

The topping cycle Combined Heat and Power system in the factory works as follows: Steam is generated in a boiler with a working pressure of 8.5 kg/cm^2, using firewood as fuel. The capacity of the boiler is 10 tons/hr. Steam temperature at boiler outlet is 200°C. Then high pressure super-heated steam expands in a steam turbine the turbine drives a generator, producing electricity amounting to 223 kVA. The exhaust steam from the turbine goes to a heat exchanger where it heats the cold air. The hot air thus produced is fed in to the tea dryer using a fan. The steam condensate coming out of the radiator is collected by a steam trap and recycled with the boiler feed water. Taking 26% losses of energy in the system and 50% use in dryer, the remaining 24% shaft output is available as bonus energy. Thus there is a scope to meet complete electricity demand of the factory after meeting the thermal energy requirement using the same amount of firewood. For the Combined Heat and Power system of the above capacity, approximate cost of the equipment is Rs. 1 crore and the payback period is around 1.218 years.



Design parameters

Selected boiler specifications (From BEE Standards):

Capacity : 10 ton/hrs.

Temperature : 200^o C

Pressure : 8.5 kg/cm^2

Process requirement

Capacity : 10 ton/hrs.

Temperature : 140° C

Pressure : 5 bar

❖ *Analysis After Cogeneration*

kVA generated per day from cogeneration – 223 kVA

Maximum demand of the industry – 240 to 250 kVA

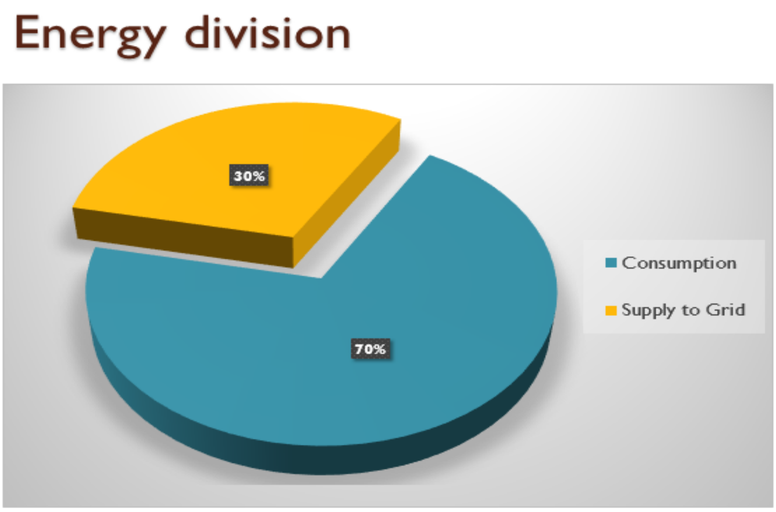
Monthly Electricity generation -1,44,400 units

Average consumption for the industry for a month – 1,00,000 units

Savings for a month – 44,400 units

Excess units generated is supplied to grid at a rate of Rs 3.5 per unit

Savings from energy supplied to grid for a month – Rs 155400



Calorific value of firewood – 4.1 kWh/Kg

Enthalpy to be supplied to generate steam- 104 KJ/Kg

Monthly requirement of fuel for boiler – 15,26,538 kg

Total monthly cost for fuel – Rs 41,21,653

Contract Demand reduction is proposed, from 350 kVA to 180 kVA

Saving per month = Rs 51,000

Annual Savings = Rs 6,12,000

Initial cost for boiler and generator setup – Rs1 crore

Annual Savings – Rs 82,04,248.7

SPP = 1.218 years

4) <u>Heat Pump For Dryer</u>

The exhaust gases from a tea dryer may have high moisture content. Since they are vented at a moderately high temperature to atmosphere, heat loss takes place. This heat can be recovered effectively by using a heat pump with a recycle system. The heat pump extracts heat from the vent gases by cooling them (some moisture is also condensed during this process) and used it for heating the air going to the dryer. Further heat economy is resulted from recycling of part of the dryer outlet gases. Energy required by using heat pump and recycle is only 185.8 kJ/s (electrical energy = 86.75 kJ/s and thermal energy = 99.05 kJ/s) whereas that required without using them is 400 kJ/s. For a dryer of capacity 200 kg tea/hour in 2 shifts, approximate net investment required for heat pump system is Rs. 4.62 lakhs and payback period is less than 2 years.

CONCLUSION

Energy analysis is carried out for the industry and various energy saving options such as energy efficient lamping, cogeneration, heat pump etc. are proposed. The economic analysis are done for the suggestions given and results are obtained.