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STATUS REVIEW OF ENERGY UTILIZATION BY THE TEA INDUSTRY IN SRI LANKA

W. C. A de Silva
(Tea Research Institute of Sri Lanka)

INTRODUCTION

Sri Lanka is mainly an agricultural country and her economy is largely dependent upon her agricultural performance and in this scenario tea is by far, the most important export crop and it could be said that the earnings from tea is the backbone of her economy.

Sri Lanka's tea production fluctuates around 200 million kilograms of which around 90-95% is exported and this production output originates from about 650 tea factories, with production levels varying from 100,000 kg made tea/annum for the smallest viable units to over 1,000,000 kg made tea/annum for a few of the largest production units. For most factories the annual production level averages in the range 300,000 to 500,000 kg made tea.

Energy Situation in Sri Lanka

Fossil fuel resources in Sri Lanka are very limited. The two main indigenous sources of energy in Sri Lanka are hydro power and biomass(fuelwood). The balance of the energy demand is met by imported oil.

Electricity generation in Sri Lanka is based mainly on hydro power. At present the total installed capacity of hydro plants is 995 MW. This is augmented by thermal plants having a capacity of 216 MW. Upto 1990, 99.8% of the energy demand was met by hydro energy. The share of the total demand met by hydro power is rapidly dwindling and from about 1995 the share met by thermal generation is expected to be very significant.

Fuelwood/Biomass

The forests of Sri Lanka together with other sources of fuelwood (e.g. Rubber wood from Rubber Plantations) constitute very important energy resources and as at now this resource seems to be the only *viable indigenous* source of energy. Yet, according to the Forestry Master Plan fuelwood shortages would occur around 1995(Haskoning, 1989) and the defficiency might be met by sustained efforts of forestation only after the year 2000. To meet this situation, efficient usage of fuelwood has acquired a sense of urgency

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Energy Demand by the Tea Industry

From an energy point of view the tea industry in Sri Lanka is the largest fuelwood consumer utilizing approximately 33% of the industrial consumption. At the same time it is the largest consumer of electricity and one of the major consumers of oil (Haskoning, 1989). These trends are illustrated in Figures 1 & 2.

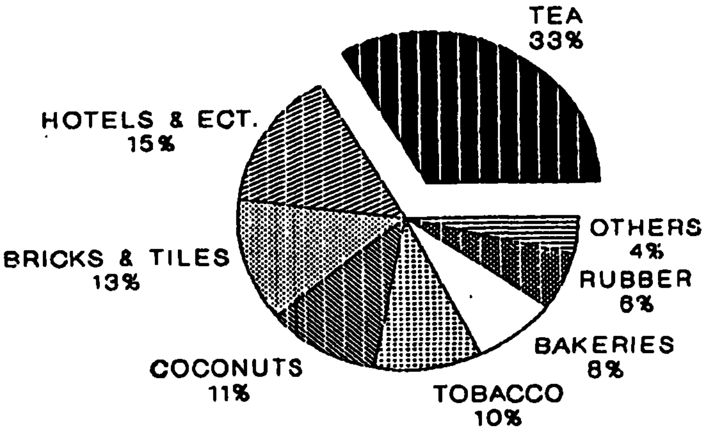
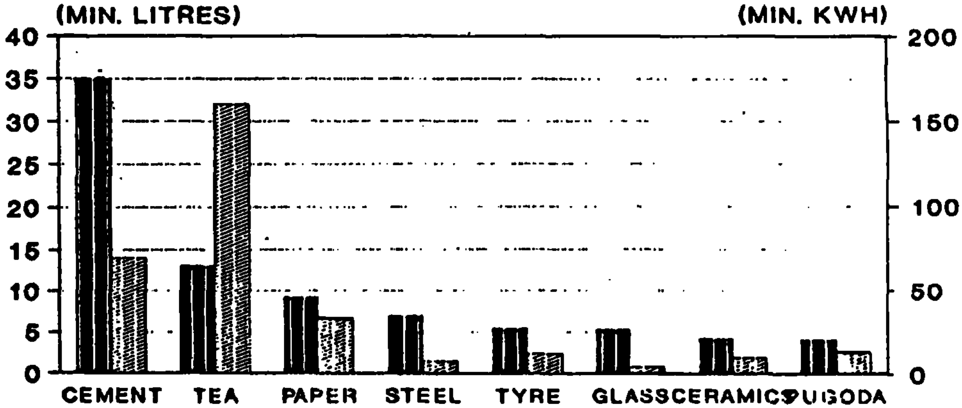


Fig. 1 – *Fuelwood consumption in Sri Lanka by Industries*



	CEMENT	TEA	PAPER	STEEL	TYRE	GLASS	CERAMICS	PUGODA
OIL	35	13	9.2	7	5.4	5.3	4.2	4.1
KWH	70	160	33.5	7.5	11.8	4	9.6	12.7

OIL KWH

Fig. 2 – *Annual oil and electricity consumption by the major Industries in Sri Lanka*

Production Process

Post-harvest manufacture consists of the following unit operations:-

a) Withering
b) Rolling/Roll Breaking
c) Fermentation
d) Drying or Firing
e) Sorting and Packing

These have variations depending on the method of manufacture (Orthodox/CTC) as well as on the type of tea produced (High/Mid Growns manufactured with accent on liquoring characteristics and Low Growns manufactured with accent on dry leaf appearance).

In Sri Lanka the commonly adopted method of manufacture is referred to as the Orthodox Process which is quite different to the CTC process adopted in East African countries and in the Indian subcontinent.

The moisture content of harvested leaf lies in the range 70-80% (wet basis) and in withering operation the moisture content is reduced to a level that lends itself to the unit operations viz. Rolling/Roll Breaking. During this operation, in addition to moisture reduction, desirable chemical changes occur and these changes require a minimum period of about 12 hours (Chemical Wither) to optimize on chemical constituents of tea.

In the case of CTC rolling the accepted level of moisture is 30 ± 2% (wet basis). For Orthodox rolling the desired level of moisture varies considerably depending on the type of tea produced. For production of teas with leaf style (Low Growns) desired level of moisture is 41 ± 2% (wet basis) and in the case of High and Mid Growns, rolled for liquoring characteristics, the level of moisture corresponds to 46 + 1.5% (wet basis).

Rolling is a process of particle degradation to produce teas of particle sizes and styles that are in demand by the World Tea Trade. At the same time this process initiates the enzymic reactions which continue upto the drying stage and which are so essential and necessary in making "Good Tea". In CTC processing, this is achieved in one single multi-pass operation, obviating the necessity to seperate fines. In Orthodox rolling particle degradation is carried out in either 4 or 5 stages and after each stage the fines(desired particle sizes) are seperated in the next unit of operations viz. Roll Breaking which is basically a "Wet Sorting" process.

Fermentation is essentially an oxidation/polymerization process brought about by enzymic reactions. Here the tea polyphenols undergo complex changes to bring about what is desirable in a"Cup of Tea".

Drying is not only a process of reducing moisture to the desired level (3%) but also a process whereby enzymes are deactivated and fermentation arrested. Thus drying does not rest with only the aspects of reducing moisture. It is an integral part of the process of making good tea in the chemical sense.

Energy Consumption in Tea Processing

Energy requirements for processing of tea, Unit Operation-wise are descriptively listed in Table 1.

TABLE 1 - *Descriptive listing of energy requirements unit operation-wise in tea manufacture*

Unit Operation	*Thermal*	*Motive Power (Electrical)*
Withering	For reduction of moisture content of raw leaf.	For fans supplying air
Rolling	–	For rolling machines
Roll Breaking	–	For roll breakers
Fermentation	–	For continuous fermenting units
Drying	For reduction of moisture content to 3% and deactivation of enzymes	For drier fans
Sorting/Packing	–	For sorting and packing machines

Electrical Energy

In Sri Lanka's Tea Industry, electricity enters into the energy equation mainly in the unit operations of Withering, Rolling and Drying. Electricity consumption in sorting and packing operations is rather small.

The actual energy consumption in typical High/Mid and Low country factories observed by analysis of historical data and by actual measurements during energy audits is given in Table 2 and illustrated in Fig. 3.

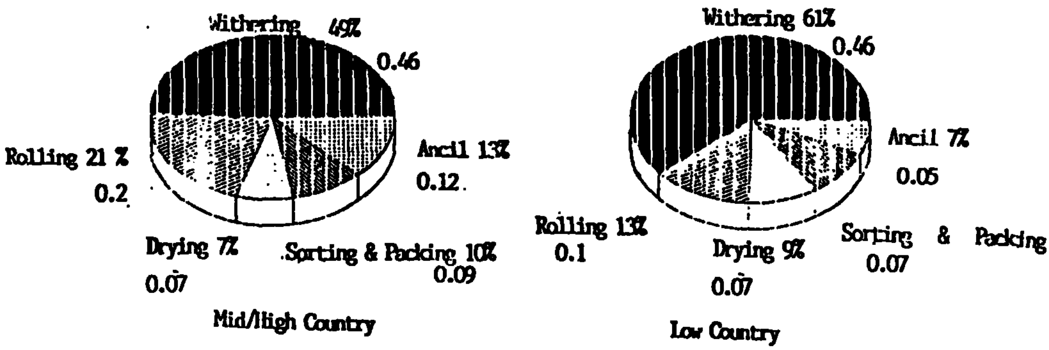


Fig. 3 – *Energy consumption in Tea Processing Unit Operation-wise*

TABLE 2 - *Energy consumption in Tea Processing Unit Operation-wise*

	Mid/High Country		*Low-Country*	
	Kwh/kg MT	%	Kwh/kg MT	%
Withering	0.46	48.9	0.46	61.3
Rolling	0.20	21.3	0.10	13.3
Drying	0.07	7.4	0.07	9.3
Sorting & Packing	0.09	9.6	0.07	9.3
Ancillaries (Including domestic use)	0.12	12.8	0.05	6.7
Total	0.94	100	0.75	100

From the above it will be seen that the bulk of electricity consumption takes place in the unit operation of withering and as the following analysis shows considerable energy savings could be effected by R + D relating to withering operations.

In withering, electricity is consumed entirely by the Fan Motors operating continuously for about 12 hours in the case of Up/Mid Country Factories and 18 hours in the case of Low Country Factories.

For trough withering units the following design features could be considered appropriate

Rate of spreading	- 30 kg/m²
Air Flow Requirement	- 0.6 m³/min/kg G.L.
Required Pressure Head in Trough	- 15mm wg
Estimated Pressure loss in Fan Housing	- 5 mm wg
Fan Head	- 20 mm wg
Assumed Fan Motor efficiency	- 65%
Safety Factor for Motor Capacity	- 25%

Based on the above the electrical energy requirements of a trough of 1,000 kg (G.L.) capacity is 3 KW and the corresponding specific electrical energy consumption applicable to troughs of any size (based on an outturn of 22.2% MT/G.L) is only 0.16 Kwh/kg MT for withers lasting 18 hours, as against observed specific consumption of 0.46 Kwh/kg MT.

This clearly illustrates that the electrical consumption of Trough Fans are far too high in relation to design figures. Contributory factors often are incorrect fan ducting design, lack of air flow distribution measures, use of oversize fans(capacity being adjusted by fan blade angle), air leaks and the use of oversize motors. This is partly the outcome of the introduction of troughs as a replacement for the older tats. Trough designs have been based on actual space vacated by tats than on aerodynamic principles.

The extent of using oversize motors could be assessed by comparing the usually installed motor capacities(Samaraweera, 1986) with those calculated to confirm to the design features given above. This is illustrated in Table 3.

By improved designs for troughs it should be possible to reduce electricity consumption in withering by at least 50% i.e. from 0.46 Kwh per kg of made tea. At a national level this represents a saving of 460,000 Kwh(460 Mwh). At factory level this represents a reduction of Rs. 0.65/kg in the cost of production.

TABLE 3 - *Usually installed motor capacities compared with design calculations based on an air requirement of 0.6 m³/min/kg G.L. for troughs of varying capacities.*

Trough size(ft)	60	72	84	100	120
(m)	18.3	21.9	25.6	30.5	36.6
Capacity(kg)	988	1183	1382	1647	1976
Air flow required(M3/min)	593	710	829	988	1186
Air power at 20 mm total pressure(kw)	1.93	2.31	2.70	3.22	3.86
Calculated fan motor capacity(kw) *	3.0	3.6	4.2	5.0	5.9
Calculated motor rating(kw) **	3.7	4.4	5.2	6.2	7.4
Usual motor rating	3.7	5.5	7.4	11	11
Oversize (%)	0	25	42	77	49

* - at an assumed efficiency of 65%

** - providing for a safety factor of 25%

Thermal Energy

Prior to the oil crisis in 1974, most up-country factories and to a lesser extent factories in other areas resorted to the use of oil for thermal energy, for the obvious reason that oil lends itself to better control of operating parameters and the additional cost was not of much significance. With the oil crisis this situation changed and the Industry by and large sacrificed control over process parameters to achieve cost savings. Today, other than a few factories producing high quality teas (corresponding to say, about 15% of total production), use of fuel wood for the generation of thermal energy is the common practice.

The scenario is once again changing with Sri Lanka heading for enhanced production of CTC teas, a process which requires stringent control of operating parameters if she is to be competitive in the World Tea Trade. As at now, in practically all CTC factories currently operating, oil is used for the generation of thermal energy, reason being the non availability of a satisfactory wood fired Heat Exchanger for operation with Fluid Bed Driers which are a *sine qua non* for the CTC method of manufacture.

Thermal energy is consumed in the unit operation of withering and drying both of which depend, as at now, on highly inefficient systems of heat generation. Even though the thermal energy component in the cost of tea production is only about 10%, savings can be achieved by the adoption of more efficient systems and improvements of process control in both withering and drying.

In the unit operations of both withering and drying, assuming that the drying capacity of ambient air is zero and that there are no heat losses, the maximum theoretical energy requirement to remove 1 kg of moisture is about 2.5MJ. However, in actual practice the calculated energy requirements depend very much on the design values of withering units used in withering and Air Heater/Drier combinations used in drying.

In withering, the drying capacity of ambient air is used to varying extents and the actual requirement of hot air supply (solely for withering) is dependent on the DB/WB difference. In both Up/Mid country and Low Country, hot air supply duration, on the average, could be taken as 06 hours (i.e. 50% of a total duration of 12 hours withering). It could also be assumed that only an increase of 5.5°C in dry bulb temperature is all that is required for satisfactory withering (Keegel, 1965). On the basis of these criteria the following energy requirements in relation to recommended air requirements can be concluded (Table 4).

TABLE 4 - *Air and thermal energy requirements in withering(theoretical model)*

	Up-country	*Low-country*
1. Air flow rate (M^3/min per kg G.L.)	0.6	0.6
2. Air density (kg/M^3)	1.05	1.05
3. Specific heat (KJ/kg/°C)		
4. Temperature rise(°C)	5.5	5.5
5. Hot air supply duration(hours)	6	6
6. Energy requirement		
(a) MJ/kg G.L.	1.25	1.25
(b) MJ/kg M.T.	5.6	5.6

In Table 6 these calculated energy requirements are compared with actual thermal energy usage observed during energy audits.

In drying operations, even though the theoretical energy requirement to remove 1 kg of moisture is also about 2.5 MJ, the actual requirements depends on air heater efficiencies, drier efficiencies and the operating parameters of these driers and these parameters set a theoretical limit to energy efficiencies that are achievable.

The recommended operating parameters for conventional driers (ECP) and Fluid Bed Driers (Samaraweera, 1986) are as follows:

	Conventional Driers		Fluid Bed Driers
	Up-country	*Low-country*	*Up-country*
1) Air flow rate(M^3/kg/ moisture removal)	117+3	117±3	45±6
2) Inlet air temp(°C)	90±2	95±1	127
3) Exhaust air temp(°C)	52±2	52±2	88 – 93

Air heater efficiencies depend on the design as well as on the type of fuel utilized (fuelwood as against diesel oil) and the efficiencies of wood fired air heaters used in Sri Lanka range from 55 to about 70% even though an efficiency of 90% has been reported for an experimental unit and the observed efficiency of air heaters coupled to Fluid Bed Driers mostly operated on oil is around 80%.

To satisfy the recommended operating parameters of driers, the following air and energy requirements with the resultant drier and overall efficiencies could be concluded, as given in Table 5.

TABLE 5 - *Air and thermal energy requirements in drying theoretical model*

	Conventional Driers		Fluid Bed Driers
	Up-country	*Low-country*	*Up-country*
1) Desired air flow rate(M^3/kg/of moisture removal)	117	117	45
2) Operational air flow rate(M^3/kg/ moisture removal- 75% of designed value)	88	88	34
3) Moisture removal (kg moisture/kg MT)	1.22	1.38	1.22
4) Air density(kg/M^3)	1.05	1.05	1.05
5) Specific heat of air(KJ/kg/°C)	1.0	1.0	1.0
6) Assumed ambient temperature(°C)	15	25	15

7) Inlet temperature	90	95	127
8) Nett Energy requirement(MJ/kg/MT)	8.5	8.9	4.9
9) Drier efficiency% (maxm that could be conceived)	35.5	33.6	61.5
10) At 80% air heater efficiency			
a) gross energy requirement(MJ/kg/MT)	10.6	11.2	6.1
b) overall efficiency(%)	28.4	26.9	49.2
11) At 65% air heater efficiency			
a) gross energy requirement(MJ/kg/MT)	13.0	13.7	Not applicable
b) overall efficiency(%)	23.1	21.8	

From Table 5 it will be seen that in accordance with operating parameters, whilst maximum conceivable efficiency of conventional driers centre around 35%, the efficiency of Fluid Bed Driers centre around 61%.

Fluid Bed Driers are only suited for small leaf grades and cannot be used in the low-country which sector accounts for nearly 50% of Sri Lanka's production. Fliud bed drying accounts only for about 15% of this production.

The overall efficiencies of drier/air heater combinations computed at 65% air heater efficiencies as illustrated in Table 5 are in very close agreement with actual air heater and overall efficiencies observed during energy audits(Haskoning, 1989; Van der Knijff, 1990) and the corresponding gross energy requirements of 13.0 and 13.7 MJ/kg/MT in up-country and low-country factories respectively are almost in perfect agreement with average usage observed during these audits. Thus whilst these values could be taken as representative of actual energy usage by the Industry, the gross energy requirements computed at 80% air heater efficiency could be taken as the best theoretically possible limit to which energy requirement could be reduced in accordance with recommended operating parameters of driers used in Sri Lanka.

Against the theoretical considerations discussed so far, the actual thermal energy usage observed in high/mid and low-country factories by analysis of historical data and by analysis during energy audits conducted in 6 factories (3 in each category) are presented in Table 6.

TABLE 6 - *Thermal energy consumption in tea processing unit operation-wise (MJ/kg/MT)*

	Mid/Up-country		*Low-country*	
	Actual	*Lowest calculated limit*	*Actual*	*Lowest calculated limit*
Withering	9.0	5.6	9.0	5.6
Drying(conventional)	13.0	10.6	13.7	11.2
Total	22.0	16.2	22.7	16.8

Thermal energy and mass flow during withering and drying per unit of made tea for up-country and low-country factories using theoretically possible and observed values are depicted in Figure 4.

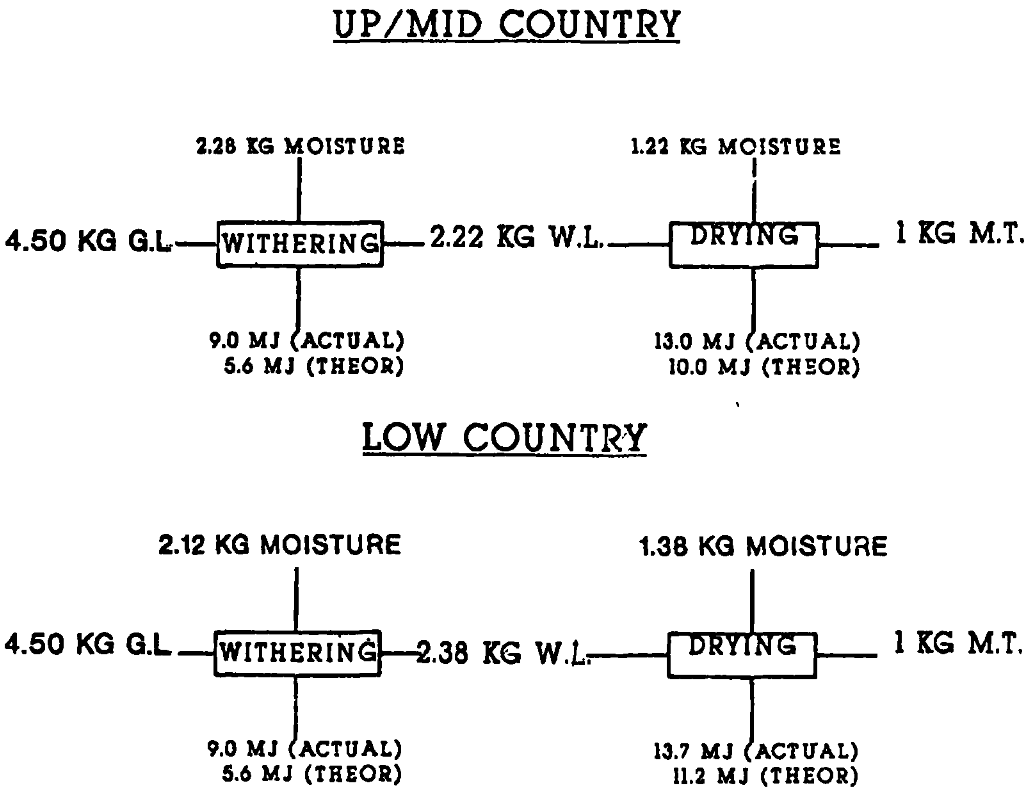


Fig. 4 – *Thermal Energy and Mass flow for typical Up-country and Low-country Factories (Theoretical and actual basis)*

Total Energy

From data presented in Tables 2 and 6, the total energy usage is strangely about the same for both up/mid and low - country teas; and is equivalent to 25.4 MJ per kg of made tea, consisting of about 3 MJ (12%) of electrical energy and 22.4 MJ(88%) of thermal energy. On the basis of a production figure of 200 million kg/annum, the total energy usage by the Tea Industry in Sri Lanka is about 5080 tera Joules/annum consisting of 4480 tera Joules of thermal energy (88% of total) generated mainly by the use of fuelwood (85% of total requirement) and 166.7 Gwh of electrical energy taken by and large, from the main Grid.

In terms of energy resources, utilization per annum is as follows:

Hydro power (electrical)	- 166.7 Gwh
Fuelwood (thermal)	- 3808 tera joules
Diesel oil (thermal)	- 672 " "

Fozzil Fuel Utilization

Use of fozzil fuel by the Tea Industry for generation of thermal energy is rather limited by force of circumstances. Its limited use is due to the non availability of satisfactory wood fired air heaters for operation in combination with Fluid Bed Driers. The estimated use correspond to about 15% of the Island's production as indicated above. Taking LHV of diesel oil at 36 MJ/l, the total consumption of diesel oil is about 4145 x 10^3 gallons per annum.

With the development of satisfactory wood fired air heaters for use with fluid bed driers which are in the offing and the introduction of wood fired steam boiler/ radiator systems for generation of thermal energy, the use of fozzil fuel will altogether disappear and this is anticipated to occur before year 2000.

Fuelwood Utilization

As at now estimated fuelwood utilization by the Tea Industry for generation of thermal energy corresponds to about 85% of the Island's production(3808 tera joules/per annum). Moisture content of fuel used varies from 25% to 40% and the average is estimated at around 35%. At this moisture content the LHV of fuelwood is about 10.4 MJ/kg.

Corresponding to this calorific value, the total fuelwood used by the Tea Industry in its unit operation is about 366 x 10^3 metric tons/annum.

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