ENERGY CONSERVATION IN THE TEA INDUSTRY OF SRI LANKA

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Abstract:- This paper presents the results of an energy survey in the Tea Industry of Sri Lanka, carried out under the Netherlands-Sri Lanka Energy Programme in the period 1986-1988. The survey focussed on the energy use of the tea process, the efficiency of the machineries and the possibilities to reduce the energy costs of the tea process. Also the energy consumption of the estate labour was investigated. The effects of the environmental conditions of the different tea producing districts on the energy consumption were analysed. It is concluded that while the energy component in the Cost of Production (COP) is only a smaller part, main savings can be achieved by better house keeping and additional savings can be achieved by optimal lay-out of the withering and drying system and improvement of the process control. More savings are possible by lager investments in the manufacturing system and replacement of diesel oil by firewood or furnace oil. Introduction of more efficient airheaters at the prevailing energy prices, is viable only when manufactured locally. For the same reason the application of alternative energy sources has a limited scope. The domestic energy consumption of the estate labour is high, due attention should be given to the introduction of efficient cooking stoves and water heating equipment.

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INTRODUCTION

Under the Netherlands Sri Lanka Energy Programme a project was carried out on energy conservation in the tea industry of Sri Lanka. In the period September 1986 - March 1987 detailed energy surveys were undertaken at several tea estates of SLSPC and JEDB by a team of local consultants (EMC-NERD Centre) and foreign consultants (HVA-Crone and HASKONING). The project was coördinated by the Ministry of Power and Energy and sponsored by the Netherlands Government through the Directorate General for International Cooperation in The Hague. The results of the surveys were presented in individual reports by EMC-NERD Centre (1), statistical data and recommendations were presented in the HVA-Crone report (2) and the conclusive results were summarised in the HASKONING report (3).

The Tea Industry: The tea industry is one of the main pillars of the Sri Lanka economy, in 1985 it contributed to 33.1% of the total export earnings. In the World, Sri Lanka is the third producer of tea, with India and China on the first and second place, followed by Kenya and Indonesia on the fourth and fifth place respectively. Together with Malawi, Sri Lanka exports the major part of the produced tea, nearly 99%. The International Market therefore is one of the most important influence factors of the Nett Sales Average (NSA).

Tea Production: Sri Lanka used to produce othodox tea, the high quality tea is grown in the Up Country region and partly in the Mid Country. The Low Country and the remainder of the Mid Country produces the "black tea" for the North African and Middle East countries. In 1985 the more efficient way of CTC manufacturing amounted only to 1% of the total tea production. However the tea corporations are changing over to more CTC manufacturing in order to reduce the COP and to achieve a better competetive position on the World Market. The larger part of the COP is consumed by the labour costs (plucking of tea). Mechanisation of plucking has been considered but experiments have shown lower total and acceptable leaf yields against a higher productivity per labour unit. Efficiency improvement in organisation and manufacturing seems the only way to reduce the COP. Recently (between October 1989 and December 1989) a re-organisation has started with the restructuring of the management of the tea estates. Estates in the High Country were transferred to the JEDB, whereas the Low Country estates were shifted to the SLSPC.

Energy Consumption: The tea industry in Sri Lanka is the largest industrial consumer of fuelwood. This is indicated in figure 1 in which the fuelwood consumption by industry and zone is presented.

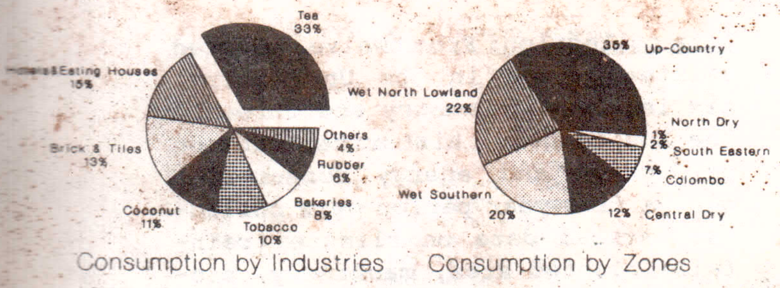

Fig.1. Industrial Fuelwood Consumption (total 1133 ton/year).

The tea industry also is the largest consumer of electricity and one of the largest consumers of oil. This is illustrated in figure 2.

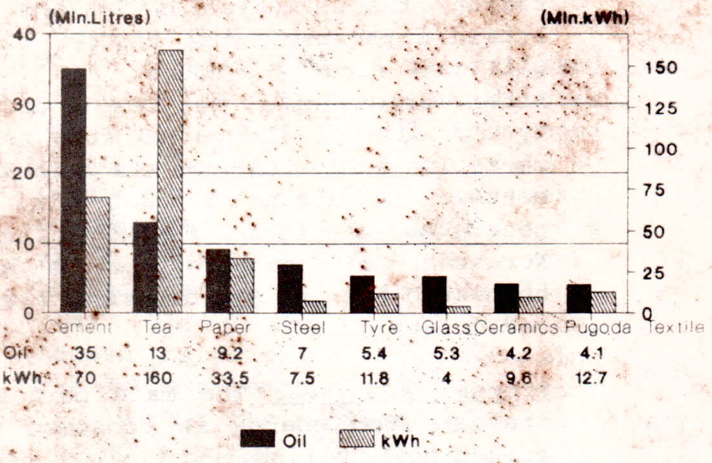

Fig.2. Largest Industrial Energy Consumers.

PRINCIPLES OF TEA PROCESSING

Production process: The tea production process is characterized by a few main steps:

- Hand plucking of the leaves;
- Transport of the green leaves to the factory;
- Withering of the green leaves;
- Rolling of the withered leaves;
- Fermentation of the rolled tea in batches;
- Firing (drying) of the tea;
- Grading of the dried tea, sorting of the tea into several grades and packing.

During the withering process, the surface moisture of the wet leaves is removed by a current of air blown through a bed of leaves. The leaves are stored in large troughs in the upper part of the factory. When the moisture content of the ambient air is too high, the air is pre-heated a few degrees. After withering, which may last 6 to 10 hours in Hill Country estates and up to 14 - 18 hours in the Low Country, the withered leaf is sent down for rolling (about

30 - 40 minutes). Rolling is done to wring out the juice from the leaf. Bringing the broken up leaves in contact with air will start fermentation. The fermentation is done to attain a palatable tea liquor, this will take about two hours.
After fermentation, the tea is dried by hot air (90-120 C) to stop fermentation and bring down the moisture content to about 3%. Hot air is generated by oil or fuelwood fired furnaces (air heaters), which are connected to tray type driers or fluid bed driers.

Process analyses: The main part of the required energy is consumed by withering, rolling and drying tea, while the thermal input during withering and drying is the largest component. The manufacturing of tea is characterized by the region where the tea is cultured:

- Hill grown : Quality tea (colour and flavour).
- Medium grown: Mixture between high and low.
- Low grown : Appearance of tea (black).

From the energetic point if view, the two different types of tea (high and low grown) are basically manufactured in the same way. A difference however is found in longer withering periods for low grown tea and adapting less pressure on the rollers.The longer withering periods for low grown tea leads to day manufacturing. This means that the plucked tea is withered from 12 am upto 8 am the next morning and followed by rolling, fermentation and drying. The production will go on upto 12 to 1 pm that day, depending on crop quantity. For high grown tea the withering period is shorter and manufacturing (rolling, fermentation, drying) often starts at night between 1 and 3 am. Another difference is the fact that in the Up Country often more heat has to be applied to the withering process in order to maintain the required dry-wet bulb difference of the withering air.

Factory design: Nearly all factories are built according to the design of the 1920's, using the so called tat withering on lofts in the factory. This lead to the high factory buildings with windows which could be opened to make use of the free ambient air to flow through the lofts. In case the dry-wet bulb difference was too low, hot air was drawn from the drier room through a big loft fan into a central bulking chamber. During the last 10 -20 years the tat-withering system was replaced by the more convenient and less labour intensive trough system. Located on the ground floor are the rolling room and fermentation room, the furnace and drier room and the grading, sorting, sifting and packing room (figure 3).

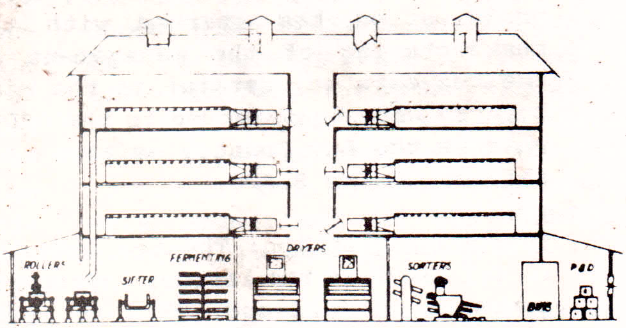

Fig.3. Cross section tea factory

METHODOLOGY

Data collection: From twelve selected estates, three in the Up Country, six in the Mid Country and three in the Low Country, historical data on production and energy consumption over a five year period were collected. Actual data on climate (rainfall),planted area, machinery, production costs and labour were collected during the audits. All data were processed at the computer facilities of the Ministry of Power and Energy.

Measurements: At six estates a detailed energy audit was carried out during a 2 to 3 day period by continuous monitoring of the energy parameters. The measurements were mainly focussed on the withering and drying process and electrical machinery in the rolling room. In every factory the following measurements were carried out:

- The input/output parameters of a withering through.
- The input/output parameters of a furnace/drier combination.
- The condition of the electrical equipment.
- The electrical consumption and load pattern of the factory over a 12 to 24 hours period.

RESULTS OF THE HISTORICAL DATA COLLECTION

Statistics: Data collection and data processing sometimes appeared to be difficult as no adequate accesible data system was available. With the today computer facilities which recently also were introduced in the plantation main offices in Colombo, it will be much easier to keep up to date records and to make maximum use of the data. The figures were converted to typical ratios, like made tea/green leaf and unit consumption on oil, electricity and fuelwood. Sometimes these results showed unrealistic figures, however on the average the data give a realistic view of the energy performance of the factory. A typical data record is presented in table 1.

Relation climate versus energy consumption.

The available data on rainfall and the (thermal) energy input figures are summarized in table 2. From these figures no direct relation could be derived between rainfall and energy consumption. In high rainfall areas about the same energy input seems to be required as in lower rainfall areas. The difference in climate, however is not only rainfall but also the ambient temperature. It is more likely that the ambient temperature has more influence on the energy consumption because of the following reasons:

- In the Up Country region the ambient temperatures are on the average 10 C. lower than in the Mid and Low Country.
- For tea drying, the higher elevation and the resulting lower boiling point does not completely compensate the lower energy input requirement.
- For tea withering the energy input requirement is ruled by the evaporation capacity of the air, which depends on the dry-wet bulb difference. At higher temperatures at the same relative humidity the air is capable to absorb more moisture than at lower temperatures.

	TEA PRODUCTION			ELECTRICITY CONSUMPTION				FUEL WOOD					LIQUID FUEL					ENERGY CONSUMPTION			
MONTH	A GREEN LEAF(kg)	B MADE TEA(kg)	B/A RATIO (kg/kg)	C M D (kVA)	D UNITS (kWh)	E COST (Rs)	E/B RATIO (Rs/kg)	F F/WOOD (kg)	G COST (Rs)	G/F F/WOOD (Rs/kg)	F/B RATIO (kg/kg)	G/B RATIO (Rs/kg)	H F/OIL (l)	I COST (Rs)	I/H RATIO (Rs/l)	H/B RATIO (l/kg)	I/B RATIO (Rs/kg)	(G+E+I)/B EN/COST (Rs/kg)	TOTAL HEAT INPUT(MJ)	HEAT INPUT (MJ/kg)	EFF (%)
JAN	172094	43047	0.25	145	43380	79590	1.85	2100	1101	0.52	0.05	0.03	19440	157824	8.12	0.45	3.67	5.54	720840	16.7	39.4
FEB	262984	66721	0.25	180	54590	100728	1.51	35250	17869	0.51	0.53	0.27	22683	184933	8.15	0.34	2.77	4.55	1169088	17.5	36.9
MAR	188748	47052	0.25	180	41420	79249	1.68	17400	9402	0.54	0.37	0.20	20715	169050	8.16	0.44	3.59	5.48	919740	19.5	33.9
APR	281225	70982	0.25	180	55740	99023	1.40	30000	13869	0.46	0.42	0.20	25445	207754	8.16	0.36	2.93	4.52	1216020	17.1	38.0
MAY	296360	71749	0.24	181	61400	108333	1.51	26250	8743	0.33	0.37	0.12	25500	208275	8.17	0.36	2.90	4.53	1180500	16.5	41.9
JUN	130945	30829	0.24	132	49630	85903	2.79						20820	170064	8.17	0.68	5.52	8.30	749520	24.3	29.4
JUL	101149	25433	0.25	120	37330	66329	2.61						10890	88960	8.17	0.43	3.50	6.11	392040	15.4	42.5
AUG	231763	57222	0.25	139	46320	85831	1.50	51000	22795	0.45	0.89	0.40	19270	157426	8.17	0.34	2.75	4.65	1203720	21.0	31.9
SEP	288285	70436	0.24	150	64440	109359	1.55	93300	44825	0.48	1.32	0.64	12270	100218	8.17	0.17	1.42	3.61	1374720	19.5	34.9
OCT	186010	45147	0.24	143	50200	89793	1.99	43800	16985	0.39	0.97	0.38	11320	97361	8.60	0.25	2.16	4.52	845520	18.7	36.7
NOV	218835	52424	0.24	140	51230	90691	1.73	62700	24252	0.39	1.20	0.46	14430	117879	8.17	0.28	2.25	4.44	1146480	21.9	31.9
DEC	311511	73577	0.24	145	67930	116535	1.58	85950	30564	0.36	1.17	0.42	16130	131736	8.17	0.22	1.79	3.79	1440180	19.6	36.3
TOTAL	2669909	654615.			623610	1111364		447750	190405				218913	1791481					12358368		
AVG	222492	54551	0.25	153	51968	92614	1.81	44775	19041	0.44	0.73	0.31	18243	149290	8.20	0.36	2.94	5.00	1029864	18.99	36.1

Table 1 Typical data record on production/energy parameters

Estate	Energy Rainfall	1981	1982	1983	1984	1985	Average
Pedro	MJ/kG	16	23	15	16	19	18
	mm	1498	1891	1326	2036	1950	1740
Great Western	MJ/kG	27	17	20	24	20	22
	mm	2422	2698	1697	3430	3596	2769
Balangoda	MJ/kG	15	20	17	17	18	17
	mm	1886	2009	2517	2584	2399	2279
Pettiyagala	MJ/kG	21	24	24	22		23
	mm	2369	3733	2313	2605		2755
Stellenburg	MJ/kG	44	38	40	38	32	38
	mm	2525	2589	2832	3700	3299	2989
Hapugastenne	MJ/kG	20	21	17	20	19	19
	mm	4136	5277	3496	5150	5432	4698
Lellopitiya	MJ/kG	29	29	26	26	25	27
	mm	3095	4195	2782	4537	4753	3872
Lelwela	MJ/kG		17	18			18
	mm		2242	3582			2912
Katandola	MJ/kG		21	21	18	16	19
	mm		3684	2840	4717	5345	4147

Table 2. Summary of historical data on energy input and rainfall.

Besides the regional difference, there is a seasonable difference also, as is illustrated in figure 4. In the wet season the evaporation capacity of the air decreases considerably and more energy has to be added to achieve a good withering condition. This particular case was calculated for the situation in Ratnapura (4) and based on meteorological data collected over a 30 year period. It illustrates that the most difficult withering conditions exists in the month of June, when additional heat has to be supplied during the whole withering period.

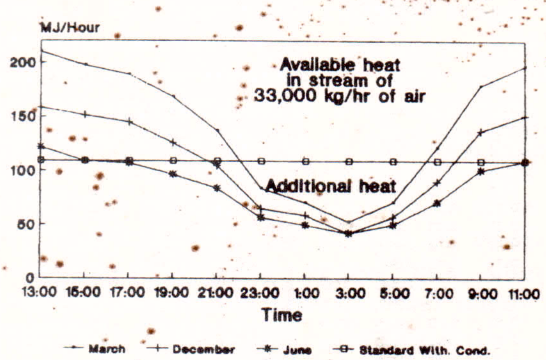

Fig.4. Seasonal variation in withering heat requirement.

Energy consumption per region: In table 3 the historical data are summarised indicating the unit consumption of electricity, fuelwood and oil. The relatively high unit consumption of electricity for the Up Country is imperative. This is most likely caused by the higher use of electricity for the withering process and for domestic use.

Estate	Elev. (m)	Annual Rainfall (mm)	Thermal Input MJ/kG	Eff. %	Electr. Cons. kWh/kG	Fuelwood Cons kG/kG	Diesel Oil Cons l/kG	Equ[illegible] Fue[illegible] kG[illegible]
Hill Country								
Pedro	1884	1740	18	34	0,92	0,99	0,24	2,[illegible]
Great Western	1463	2769	22	32		1,68	0,16	2,[illegible]
Liddlesdale	1585		28	26	0,94	2,20	0,16	3,[illegible]
Aislaby	~1500		24	32		2,13	0,09	2,[illegible]
Average			23	31	0,93	1,75	0,16	2,[illegible]
Mid Cntry High								
Stellenburg	1067	2989	21	38	0,82	2,10		
Carolina			19	43	0,95	0,96	0,30	2,[illegible]
Average			20	41	0,89	1,53	0,30	2,[illegible]
Mid Cntry Mid								
Balangoda	527	2279	17	42	0,67	1,74		
Pettiyagala	540	2755	23	31		2,28		
Average			20	37	0,67	2,01		
Mid Cntry Low								
Hapugastenne	311	4594	20	41	0,62	1,96		
Lellopitiya	300	4024	22	30		2,20	0,13	
Average			21	36	0,62	2,08	0,13	
Low Country								
Lelwela	60	2870	16	48		1,74		
Katandola	64	3965	20	39	0,65	1,87		
Average			18	44	0,65	1,81		
Overall Avg.			20	37	0,75	1,84	0,20	2,5[illegible]

Table 3. Summary historical data on energy consumption.

The high costs of thermal energy in the Up Country is related to the application of diesel oil for firing the tea. To compare these thermal energy consumption figures with the Low Country figures, an equivalent energy figure was calculated, based on the combustion efficiency and heating values of fuelwood and diesel oil.

Energy costs and the relation to the COP: A comparison between two different factories, one producing high quality, Up Country tea and one producing a Low/Mid Country tea is presented in figure 5. The Up Country estate Pedro was classified in 1985 as the estate with the highest profit per hectare, the Hapugatenne estate, one of the largest estates, was classified having the highest yield per hectare. In 1985 the energy costs for Pedro amounted to about 14% of the COP whereas for Hapugastenne this figure was 5% only.

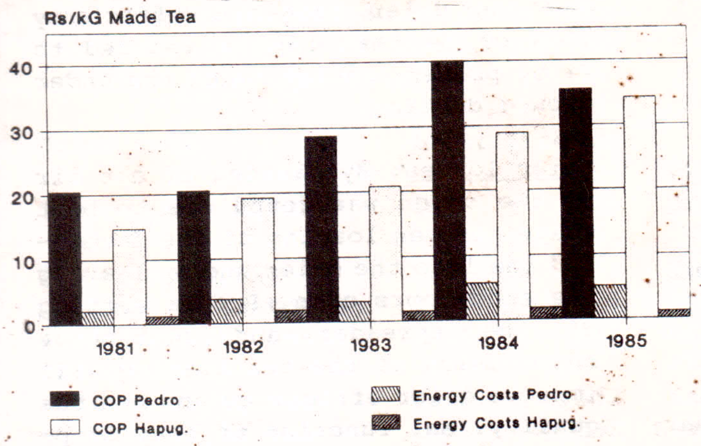

Fig.5. Cost of production and energy.

RESULTS AND INTERPRETATION OF THE ENERGY AUDITS

<u>The withering process</u>: By measuring the input/output parameters of the withering troughs it was possible to assess the energy used for withering. These data were compared with the theoretical required energy and the design data of the through system. However it should be realised that throughout the withering period the heat source is operated under two different conditions and also depends on the type of manufacturing; daytime manufacturing in the Low Country and manufacturing at night in the Up Country. In general during the first part of the withering (in the afternoon and evening), the heat is generated by firing an empty drier. In the Up Country this will be between 5 pm (when the dry-wet bulb difference decreases) upto 2 or 3 am. At this time the drier is loaded for drying the tea and the heat source for withering becomes waste heat from the drier, however with a higher moisture content. In the Low Country the drier will have to be fired unloaded until morning (8-9 am) when day manufacturing starts.

<u>Results</u>: From the measurements it appeared that in about 60% of the cases the required dry-wet bulb difference was not achieved while more than the required energy was added. Also it was found that the electricity consumption of the fans was higher than required according to the design value. The reasons for this waste of energy can be summarised as follows:

- Inproper air distribution in the troughs, especially the troughs with a length over 20 m.
- No adequate air temperature control possibilities; the application of a thermocouple system with a display in the factory office would considerably improve the process control.
- No proper hot air ducting between drier outlet and trough fan inlet.
- Fan sizes are not in accordance with the trough system design, sometimes an over-rating of 80% was found
- The troughs are not loaded according to the design parameters.

It was found that the withering process consumed about 50% of the total electricity consumption of the tea process, about 0.45 kWh/kg tea, and that with an improved design the consumption could be reduced by about 50% resulting in an annual saving of Rs 200,000 for a factory producing 500,000 kg of tea. In table 4 a summary is given of the measurement results in several factories.

<u>The drying process</u>: The reviewed drying systems are of an old design, but even with this design a considerable improvement can be achieved by good house keeping. Regular maintenance and operating the airheater and the drier at the design conditions will reduce the energy losses. Other improvements can be achieved by the application of more efficient airheaters and better process control.

Region	Hill Country			Mid	Low Country	
Estate	Pedro	GR.West.	Aislaby	Hapug.	Lelwela	Katan.
Altitude (m)	1884	1372	1220	350	60	64
Trough size (m)	18*1.8	31*1.9	17*2	33*1.8	19*1.8	18*1.8
(ft)	60*6	100*6	56*6	120*6	63*6	60*1.8
Fan Power						
rated (kW)	5,5	11,0	5,5	11,0	6,0	4,0
measured (kW)	3,6	8,7	5,3	5,4	5,6	4,0
Trough Load						
(kG)	374,0	970,0	1060,0	1669,0	897,0	987,0
(kG/m2)	11,3	16,7	31,2	27,3	26,1	29,9
Inlet Air Flow						
(kG/s)	11,1	16,4	13,6	16,6	20,0	14,0
(Kg/s/kG GL)	0,0296	0,0169	0,0128	0,01	0,0223	0,0142
With. Period						
Total (hrs)	12	13	12	15	18	14
Heatinput(hrs)	8	7	12	11	6	14
Avg. WB Depr.						
Mixed air (C)	1,9	1,5	3,0	2,7	1,0	2,5
Ambient air(C)	1,2	0,4	1,8	1,3	1,1	0,8
Heat input						
Actual (kW)	23,2	52,5	33,7	39,4	18,8	47,7
Required (kW)	9,3	17,1	18,1	25,1	14,0	16,9
Design (kW)	11,0	37,3	21,6	44,2	29,8	29,4
Specific Energy						
Elec. (kWh/kG)	0,45	0,46	0,28	0,16	0,46	0,24
Therm. (MJ/kG)	10,40	9,90	6,40	4,20	5,60	10,30

Table 4. Withering process - Summary of results

<u>High stackloss</u>: A considerable amount of energy is lost by operating the airheater under fouled conditions and without a proper combustion air - and fluegas draft control. A fouled heat-exchanger reduces the heat transfer efficiency and increases the fluegas temperature leaving the stack. A proper installed fluegas temperature indicator will indicate the progress of fouling. High excess air is usually caused by improper control of the opening of the air louvres. Especially the wood fired airheaters are difficult to control as the fuel loading doors are opened and closed manually. Introduction of a special air control device will improve the combustion efficiency. Also the flue gas draft control was found to be in a neglected condition; fluegas dampers could not move and the installation of a full height stack resulted in a higher draft than required. In one factory the firewood consumption went up by 25% after a new full height stack was installed.

<u>Wet firewood</u>: Stocking the firewood for about three months will reduce the moisture content by about 20% resulting in an improvement of usable energy of 7% per kg of purchased wood. Also drying of firewood by the hot fluegasses should be considered.

<u>Heat losses</u>: At a fluid bed drier an air temperature difference of 10 C was measured between outlet furnace and inlet drier, causing an efficiency loss of 8% that can be reduced to 2% by proper insulation of the under ground ducting.

<u>Drier losses</u>: By-passing of hot air in the drier was found due to bent trays, uneven loading of the fermented tea into the drier and by leaving the side doors open. Proper setting of the spreader and continuous supervision of the tea loading will improve drier efficiency and the tea quality. Mal function of tray dropping was common to all driers which were studied and lead to an underfired tea mix.

<u>Oil firing</u>: At one factory the diesel oil burner was adjusted at a lower excess air ratio, resulting in a combustion efficiency improvement from 67% to 80%. Changing over to furnace oil will reduce the firing costs by about 0.8 Rs/kg tea, however the measures required to capture the sulpher dioxides from the fluegasses may cost about 0.2 Rs/kg tea.

<u>Efficient airheaters/driers</u>: A comparison was made of the effect on the tea manufacturing costs by the application of more efficient airheaters and driers. The information was used from several foreign suppliers of drying equipment and from the results of the Netherlands project on the introduction of efficient air heaters at Great Western and Dessford estate. It was found that the energy costs could be reduced considerably, but due to the higher capital costs of the imported equipment, the total costs with the efficient equipment will be higher than with the local manufactured equipment. It proved to be more useful to update existing local designs and implement simple

efficiency measures than to import complete new systems. Foreign technology transfer to the local manufacturers should be encouraged. In table 5 the differences in energy- and capital/maintenance costs are illustrated for a local and an imported fluid bed drier.

Drier make	local	foreign
Tea output: kg/hr	286	325
Fuel consumption:		
Wood kg/kg tea	0.78	0.6
Oil l/kg tea	0.144	0.1
Energy costs:		
Wood Rs/kg tea	0.59	0.53
Oil Rs/kg tea	1.27	0.97
Capital costs:		
Rs/kg tea	0.71	1.66
Total specific costs:		
Wood Rs/kg tea	1.3	2.19
Oil Rs/kg tea	1.98	2.63

Table 5. Tea production costs of local and imported efficient furnaces and fluid bed driers.

The figures in this table are based on the information provided by the manufacturers. It should be realised however that to achieve these efficiency figures will depend also on good house keeping. Even a very efficient system will operate inefficient if not the necessary attention is given to the operation and maintenance.

Utilisation of electricity: The installed capacity for a tea factory ranges between 250 to 500 kW per ton of manufactured tea per year depending on the location of the factory and the production capacity. The distribution of the installed capacity per processing step is illustrated in figure 6.

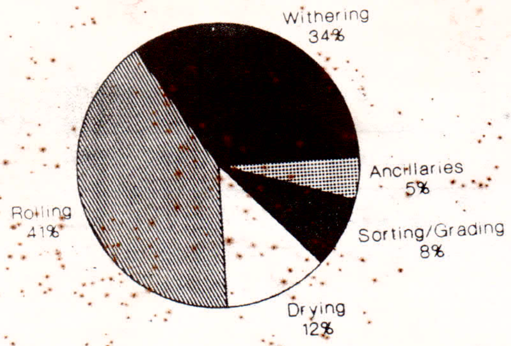

Fig.6. Installed electrical capacity per processing step.

Demand pattern: During the audit a continuous recording of the electrical off takes was taken. At the same time the operation schedule of the individual motors was recorded and with these data the electrical demand picture could be produced. Also in some instances the continuous recording unit was connected to individual motors of the rolling equipment. In the figures 7 and 8 typical load curves are presented of a complete factory and of a single roller. The load fluctuations of the rolling process are considerable and especially when two or more rollers coincide on load this will cause high peaks and a costly maximum demand reading. The factory load curve shows the ups and downs caused by production interruptions and coinciding processes like withering and rolling.

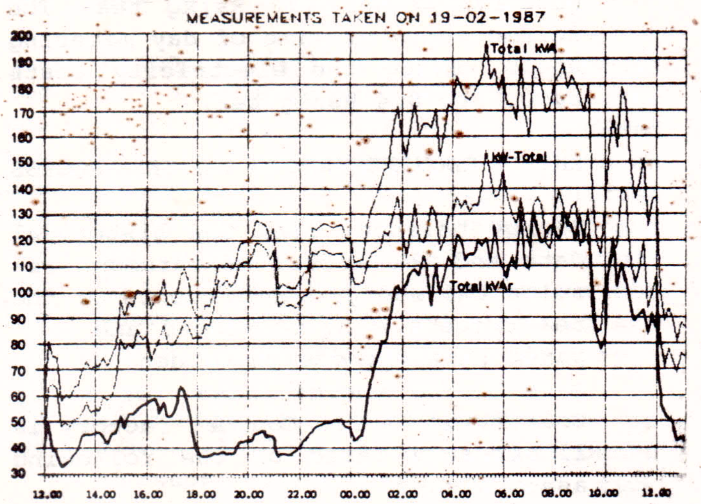

Fig.7. Typical factory load curve

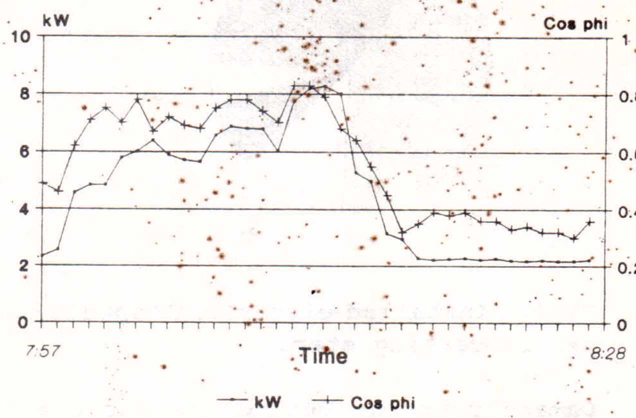

Fig.8. Electrical load pattern roller

Electrical distribution: A separate survey dealt with the condition of the electrical equipment and the energy and cost saving measures. It was found that a lot of equipment was not maintained very well and was overloaded sometimes, due to factory extension. The systems were difficult to trace as no circuit and lay-out diagrams were available. The lighting equipment was mainly equipped with a central switching system, thus preventing switching off of unnecessary lights. The power factor equipment was often found not to be working or not having the required capacity. It was estimated that by introducing more efficient and selective lighting systems the electricity costs could be reduced by 0.02 Rs/kg tea. The introduction of time of day metering would reduce the electricity costs by 0.2 to 0.4 Rs/kg tea.

ENERGY REQUIREMENTS OF THE TEA PROCESS

Energy balance: From the historical data and the actual measurement results the energy requirements of the tea process were concluded and compared with the design values. In figure 9 the energy input for an Up Country and a Low Country factory is illustrated based on the following assumptions:

- Made tea/green leaves ratio: 0.23
- Made tea/withered leaves ratio: 0.45
- Green leaves moisture content: 80 %
- Withered leaves moisture content: 65.3 %
- Made tea moisture content: 3 %

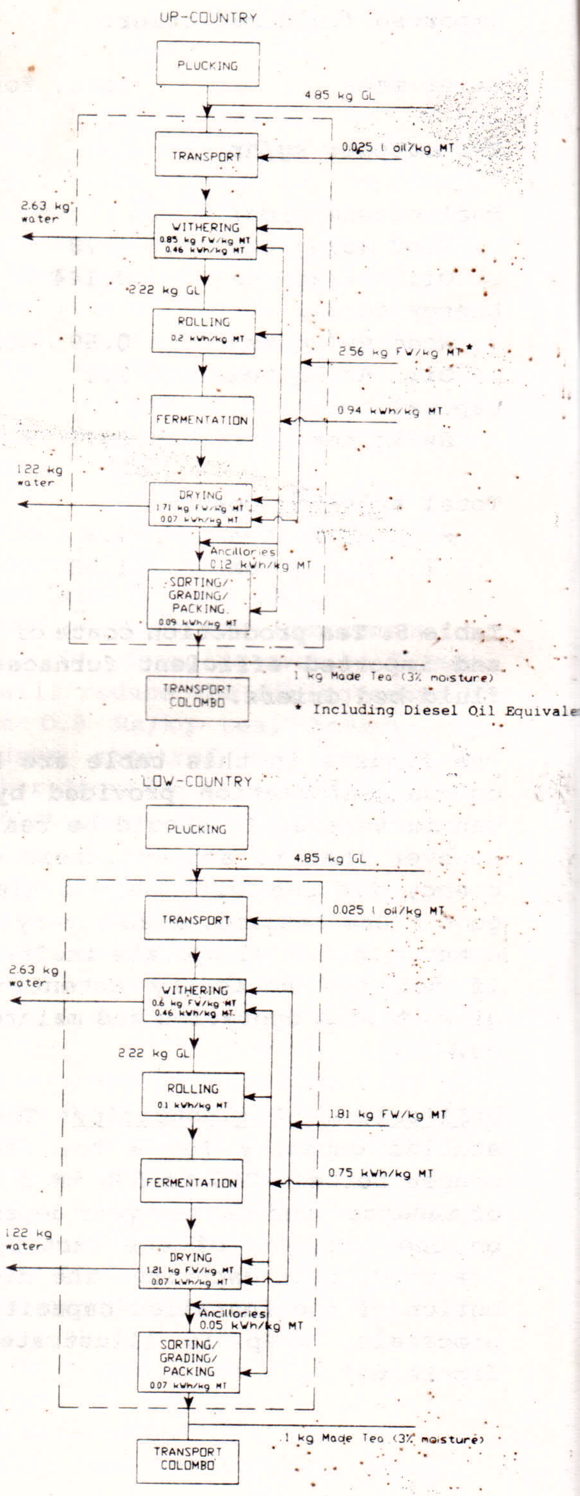

Fig.9. Energy flow diagrams.

DOMESTIC ENERGY CONSUMPTION

Electricity: In general the staff bungalows, creches, hospitals, maternity wards and temples are connected to the electricity supply scheme of the factory and billed at the industrial rate. At a few estates the domestic electricity consumption was measured which appeared to be a considerable part of the total consumption (15 to 20%).

A sample reading of the daily consumption pattern at one estate is illustrated in figure 10, resulting in a consumption of 0.08 kWh/kg tea, equivalent to about 0.16 Rs/kg tea. A separate domestic metering system will reduce the costs and also a controlled use of the electricity will lead to awareness of the staff in saving electricity.

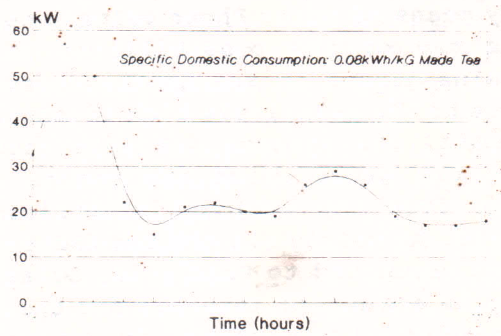

Fig.10. Domestic electricity consumption at a mid country estate.

Firewood: The per capita consumption of firewood of the estate workers was found to be higher than other country wide surveys have estimated. Besides for cooking, large amounts of firewood are used for warming up water for bathing. Converted in kg firewood per kg produced tea of the factory, the domestic consumption in the Up Country amounted up to 22 kg/kg tea and in the Mid Country upto 8 kg/kg tea, from which about 70% was used for hot water production.

Firewood Source: Tea prunings are the main source of firewood for domestic use, however as pruning is done at a 4 to 5 year cycle and produces about 2200 kg/ha/year, the annual production of an average 500 ha estate is about 1 million kg per year. An estate with about 3000 people will require about 7 million kg firewood per year. The introduction of efficient cooking and hot water stoves is a very necessary item. The specific problems however with the applicable type, size and use of the woodstoves are constraining factors in the implementation.

Kerosene: Also the kerosene consumption for domestic lighting is high when converted to the use per kg tea produced; about 0.1 l/kg tea. Nearly all lighting armatures are very simple bottle lamps, producing more smoke and heat than light. Apart from the low illuminating efficiency of the bottle lamp, it is a potential fire and health hazard, especially for young children. The smoke and soot will lead to respiratory diseases.

ALTERNATIVE ENERGY SOURCES

Sri Lanka has quite a high potential of alternative energy sources, however for the tea industry, the application of these sources proves to be limited due to several reasons.

Biomass: Several sources of biomass are available in relatively large quantities, however the costs involved with processing the biomass into an acceptable form for transport and fuel conversion are constraining factors for large scale application. Especially in these areas of the tea districts where substitution of firewood and oil are most required (Up Country).

Ricehusk: The annual production on rice husk of the whole country amounts to roughly 470,000 tons. The main rice husk producing areas (Polonnaruwa and Ampara) are relatively far away from the tea producing districts.

The annual rice husk production in the tea producing areas is estimated as follows:

- Ratnapura: 15,000 tons
- Kandy: 17,000 tons
- N' Eliya: 5,000 tons
- Badulla: 24,000 tons

To reduce the volume a type of densification of the rice husk will be necessary. The IBEC project (5) concludes that the break-even distance to transport rice husk between the rice mill and the tea estate amounts to 77 km, assuming a firewood price of 650 Rs/ton. Replacement of diesel oil results in a break-even distance of 440 km. These figures show that replacement of firewood and oil by rice husk is of interest. It is advised to investigate this possibility more in detail for the Badulla area. The viability of the introduction of rice husk will mainly depend on thr efficiency of the collecting system, as the rice husk production centres are relatively small rice mills.

<u>Coirdust</u>: The stock of this waste product of the coconut coir fibre process is estimated at 5 million tons and the annual production amounts to approximately 140,000 tons (20% m.c.). The stock and production centres are concentrated in the coconut triangle Colombo - Kurunegala - Puttalam. The costs to convert the coir dust into an acceptable fuel and the transport costs to deliver the fuel at the estates are higher than for rice husk. The main problem in the conversion technique is the necessity to dry the wet coir dust (80% m.c.) before pressing or briquetting can take place. The IBEC project (5) mentions a break-even distance for a low density briquette of 45 km for fire wood and 403 km for diesel oil.

<u>Mini hydro</u>: With the increasing electricity price the interest to rehabilitate neglected mini hydro schemes raised during the last 15 years. Under several programmes quite a number of units were recommissioned. It has proved that only rehabilitation of units with a rather good existing infrastructure and therefore low capital costs leads to competitive electricity prices. An agreement with the Ceylon Electricity Board on delivery of excess electricity into the main grid will increase the plant capacity factor and decrease the generating costs. In case no grid delivery is allowed, an interesting option for some specific sites with a high hydro potential, is the possibility to buffer the excess electricity in a hot water system. The stored energy can be used for the thermal energy requirement of the factory. A sample study was made for the Carolina estate (3).

<u>Solar energy</u>: Electricity generation by means of Solar Photo voltaic cells is one of the possibilities which gains ground in Sri Lanka. However, due to the relatively high investment costs, the systems are only viable in the areas which are remote and far from the national electricitry grid. As nearly all the tea factories are connected to this grid, Solar PV cells are not of interest for the tea manufacturing process. Even in case the initial costs decrease, the low voltage level (12 - 24 volts) of Solar PV is a constraining factor for motive power. A possible application could be for domestic use (lighting, radio and television) at remote line house concentrations at the estates.

<u>Hot air generation</u>: Another application of solar energy could be the production of hot air for the manufacturing process. Especially the withering process could make use of preheated air by solar radiation. However, the time when the energy is mostly needed (during wet weather and at night) does not coincide with the availability of the energy. This requires an energy buffer in the form of a hot water system, rock tanks or phase change material. A case study

(3) indicates that at the prevailing firewood prices these applications are not viable yet.

Hot water generation: Hot water production by means of solar collectors for the Up Country district has been investigated through a project under the Energy Programme. Maternity wards and creches were identified as target groups for providing solar water systems. Based on a local design the costs for several systems with a panel size of 1.8 x 1.2 m, were analysed which resulted in the following prices:

- 1 panel/100 litres: Rs 18,000.
- 2 panel/200 litres: Rs 34,000.
- 3 panel/455 litres: Rs 49,000.

From the installed systems it was proved that even in the very wet district of Hatton, an average temperature increase of 25 C could be achieved. However the capital costs of the solar heating systems are still to high to compete with electricity (geysers) or with firewood (drum type water heaters). Very simple systems, manufactured from i.e. black painted oil drums, should be developed at rather low costs for the estate labour.

Wind energy: Due to the constant monsoon winds certain areas in Sri Lanka may have a potential to generate electricity with wind turbines. These areas are located mainly along the coast in the South (Hambantota area) and in the North of the country. High wind speeds are also reported in the Up Country at certain gaps (Ambewela). However, these Up Country winds are blowing only during a relatively short time of the season. The locations of most of the estates (between hills) are not the most viable places to install wind turbines. In fact with the present capital costs of windmills it is not viable to replace the electricity delivered by the national grid, even in areas with a high wind potential. A project under the Energy Programme is now underway to measure the wind and solar potential in the southern district of Sri Lanka. With the results of this study a more definite conclusion can be drawn, however it is very unlikely that wind energy will play a major role for electricity supply for the tea estates.

CONCLUSIONS AND RECOMMENDATIONS

From the surveys and additional work carried out since 1986 the following conclusions can be made:

a. The cost of tea production is mainly influenced by:
   - labour costs;
   - field maintenance costs;
   - overhead costs.

b. The energy consumption of the process is relatively high:
   - thermal requirement upto 2.5 kg wood/kg Made Tea;
   - electrical requirement upto 0.94 kWh/kg Made Tea.

c. Main savings can be achieved by better house keeping:
   - dry storage of firewood;
   - improved maintenance procedures;
   - monitoring of energy consumption pattern;
   - operate the driers and troughs at the rated conditions.

d. Additional savings can be achieved by relatively small investments:
   - optimal lay-out of withering fan-motor-trough system;
   - introduction of selective switching of factory lighting and introduction of more efficient lighting armatures;
   - improve draft control of furnaces/air heaters;
   - install measurement equipment (thermocouples) and monitor the performance of the equipment regularly.

e. More savings can be achieved by larger investments:
   - up date factory design and manufacturing systems;
   - introduction of firewood or other biomass on these estates which are firing diesel oil;
   - changing over to furnace oil instead of diesel oil is cost effective but also creates a sulphur dioxide, emission problem;
   - establishment of fuelwood plantations on the estates;
   - introduction of more efficient furnaces and driers.

f. Introduction of alternative energy sources for the tea process has a limited scope at the moment, which is caused by the prevailing prices of fuelwood and electricity:
   - rice husk - some scope in the Badulla area, pending the success of a reliable briquetting plant;
   - solar energy - no scope for the tea manufacturing process;
   - wind energy - no scope;
   - mini hydro - a realistic scope but viability depends on site conditions and possibility to deliver excess electricity into the national grid.

g. Introduction of more efficient and sophisticated tea driers from abroad leads to lower initial production costs but the higher capital costs increase the total cost of production considerably.

h. The domestic energy consumption of the estate labour is high. Due attention should be given to this item and introduction of efficient woodstoves for cooking and water heating should be encouraged. Simple solar water heating systems should be developed.

i. As a result of energy conservation activities the following cost savings should be achieved.

Per estate the savings may vary, pending the condition of the equipment, type of fuel used and management qualifications:

- Storage of dry fire wood: 0.1 Rs/kg MT
- Improved withering systems: 0.4 Rs/kg MT
- Improved air heater systems: 0.1 to 0.65 Rs/kg MT
- Improved utilization of electricity:
  Time of day metering; 0.2 to 0.4 Rs/kg MT
  More efficient and selective lighting systems; 0.02 Rs/kg MT

The overall target could be a saving of 25 to 50% of the energy bill, the lower figure to be achieved by good housekeeping and energy management, the maximum saving to be achieved by additional introduction of more efficient design technologies.

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SLEMA NEWS AND FUTURE EVENTS

* A Workshop on Cogeneration Systems is being organised by SLEMA, jointly with the Ministry of Power and Energy. The date has been fixed for the 31st May, 1990. The program is intended to improve the awareness of Sri Lankan industrialists about the prospects of cogeneration. The day's programme will be conducted in 2 sessions, one for Senior Executives in Industry and the other for Engineers and plant designers.
  The number of participants will be limited to 50 in the technical sessions. A very limited number of nominations will be reserved for SLEMA members. Members interested in participating in the above Workshop should immediately inform the Joint Secretaries.
* The Annual Sessions of SLEMA are to be held on 31st July, 1990. The theme of the sessions will be "Energy and Environment" where a number of research papers will be presented.
  The Annual General Meeting will be held in the evening of the same day, followed by the Annual Dinner. The CPC Award and the Mohan Munasinghe Award will be presented at the Annual Dinner.
* Members are reminded that the entries to the CPC Award and the Mohan Munasinghe Award for this year close on 31st May 1990.
* Subscription renewal notices for 1990 have been mailed to all members. Please ensure that all your arrears are settled promptly to ensure your continued participation in SLEMA events and to continue to receive the SLEMA JOURNAL and SLEMA NEWS.