

## THERMAL ENERGY DEMANDS OF THE TEA INDUSTRY AND THE ROLE OF FUELWOOD TREES IN A SELF SUSTAINING ENVIRONMENT

W. C. A. de Silva<sup>1</sup>

*(Tea Research Institute of Sri Lanka, Talawakele, Sri Lanka)*

The tea industry is the largest industrial consumer of fuelwood. To buffer escalating costs of fuelwood as well as to minimize soil degradation, establishment of environment friendly self sustaining wood energy systems is suggested. Taking into consideration thermal energy demands in tea processing as well as demands for fuelwood by the estate domestic sector, empirical formulae are presented for purposes of planning out wood energy plantation at estate/factory level.

Means already available or likely to be available in the future for improved/reduced wood energy utilization by the tea industry are described.

### INTRODUCTION

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.

As at now, the tea industry which is the largest industrial consumer of fuelwood is heavily dependent on fuelwood supplies from rubber plantations, and to a lesser extent on forests and other non-forest wood lots at individual estate level. Rubberwood is now gaining in popularity as timber and lesser and lesser will be available in the future for use as fuelwood and that too at escalating costs as shown below in Table 1. In this scenario, in the foreseeable future the tea industry may be forced to meet its energy demand by either imported oil or by turning towards forests (natural or man-made) for fuelwood requirements. Both these options might create environmental degradation. To meet this situation, in the short term it is essential to develop self sustaining environment friendly wood energy systems at subregional/individual estate level and to adopt improved wood energy utilization through better technologies of conversion. In the long term, replacement of wood energy, at least partially, with non traditional forms of energy needs to be considered.

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**TABLE 1 – Prices paid for fuelwood delivered to St. Joachim factory during the period 1975 to 1994**

<i>Year</i>	<i>Price (Rs/cub. yd)</i>
1975 – 1980	38/-
1981 – 1985	96/-
1986 – 1990	152/85
1991	196/-
1992	196/-
1993	254/25
1994	315/-

### **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 fuel (Haskoning, 1989).

### **Wood fuel/thermal energy demand**

In the tea industry fuelwood is required

- a) for generation of hot air for withering
- b) for generation of hot air for drying.
- c) to meet the demand from Estate household sector.

The moisture content of harvested tea leaf is in the range of 70–80% (wet basis) and in withering operations moisture content is reduced to a level that lends itself to the unit operations of rolling and roll breaking. At this stage the accepted level of moisture depends on the method of manufacture adopted being  $54 \pm 1.5\%$  (wet basis) for high/mid-grown teas having liquoring characteristics;  $59 \pm 2\%$  (wet basis) for low grows manufactured for leaf style to suit markets in the Middle East; and  $70 \pm 2\%$  (wet basis) for CTC teas to suit markets requiring small leaf grades having thick coloury liquors.

Rolled leaf after the process of fermentation (essentially enzymic oxidation/polymerization of tea polyphenols) is subjected to the unit operation of drying. In this operation the moisture content is reduced to 3% in either Endless Chain Tray Driers or Fluidized Bed Driers supplied with hot air from either Air Heaters or Steam Boiler/Radiator Systems.

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 needed for generation of hot air in withering and drying. The reason was obvious—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 about 15% of total production), use of fuelwood for the generation of thermal energy is the common practice.

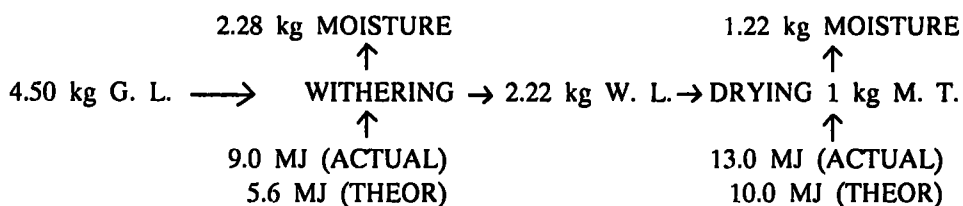
Considering the recommended operating parameters during withering and drying operations, thermal energy requirements calculated theoretically together with actual thermal energy usage observed in high/mid and low-country factories by analysis of historical data supported by data from energy audits (de Silva, 1993) are presented in Table 2.

TABLE 2 – Thermal energy consumption in tea processing unit operation wise (MJ/kgMT)

	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 Fig. 1.

#### UP/MID-COUNTRY



#### LOW-COUNTRY

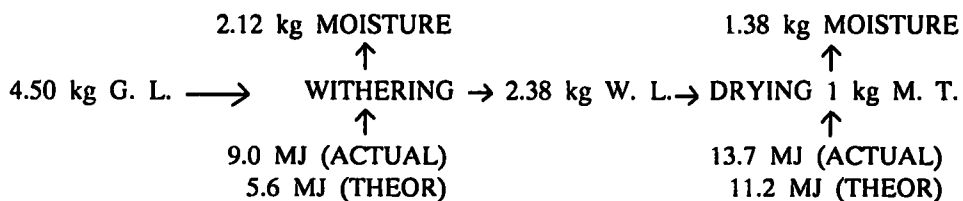


Fig. 1 – Thermal energy and mass flow for typical up-country and low-country factories (theoretical and actual basis)

From the above the total average thermal energy usage in tea processing (withering and drying) could be taken as 22.4 MJ per kg of made tea. As already stated most tea factories depend on fuelwood for thermal energy requirements. The moisture content of fuelwood used varies from 25 to 45% and depending on this, fuelwood demand for tea processing varies from 1.8 to 2.2 kg fuelwood/kg made tea at fuelwood moisture contents of 25 to 35% respectively.

A statistically designed study of household fuel consumption conducted in 1983 has shown that the per capita consumption of biomass fuel for household cooking was 496 kg yr<sup>-1</sup> for the island as a whole and 526 kg yr<sup>-1</sup> for the rural sector, which used biomass fuel exclusively (Wijesinghe, 1984). The recently conducted Forestry Master Plan revision studies (unpublished data) have shown that in the estate sector the per capita fuelwood consumption varies from 606 kg yr<sup>-1</sup> in the Badulla district to 770 kg yr<sup>-1</sup> in the Nuwara Eliya district.

Up to the present time the estate domestic requirement of fuelwood has been largely met by the removal of prunings and to a lesser extent from shade trees and other outside sources. It is interesting to note that on a 4 – year pruning cycle the average fuelwood yield from prunings is 13.1 m<sup>3</sup>ha<sup>-1</sup> (Nanayakkara, 1986) which is consistent with TRI findings for seedling tea. Prunings, if used as fuelwood, are sufficient to sustain the household fuelwood requirements of a labour force (including children and dependents) of 2.7 to 3.4 per hectare based on a per capita consumption of 606 to 770 kg yr<sup>-1</sup> at a fuelwood moisture content of 20%. However, removal of prunings causes environmental soil degradation and to maintain a sustainable tea growing environment, tea prunings should be kept in the fields for mulch while domestic requirement of fuelwood by labour should be met from other sources.

Self sustaining wood energy systems should be planned, based on the aforementioned estimates for fuelwood consumption by the industrial and household arms of the tea industry. The proportion of land that should be set apart for this purpose must take into account the productivity of the estate (yield/hectare), specific fuelwood consumption in processing (kg kg<sup>-1</sup> MT), mean annual increment of fuelwood species (m<sup>3</sup> ha<sup>-1</sup> an<sup>-1</sup>) selected for planting and its years of rotation, as well as the estate household population density (persons/hectare). Additional areas under fuelwood would be necessary for factories dealing with outside leaf. At the same time the energy policy of an Estate/Factory must be integrated with the overall development objectives.

### **Self sustaining wood energy systems**

If the demand is to be met at estate level the land area that should be set apart for fuelwood in tea processing and for the estate household sector, could be estimated

by the following formula:

$$A_f = \frac{8(PF + 770p)}{(Ms) \cdot 10^4} \cdot A_t \quad ; \quad A_t \neq 0$$

[Nomenclature used is given in Appendix]

This formula was derived taking into consideration all the influencing factors already enumerated.

### Application of formula to develop self sustaining wood energy systems

#### 1) Case of plantations

For an estate of 400 ha yielding 1,500 kg yr<sup>-1</sup> the land area required (subdivided into equal lots depending on rotation years) under say *Eucalyptus grandis* with a Mean Annual Increment of 42.5 m<sup>3</sup> ha<sup>-1</sup> an<sup>-1</sup> on a 10 year rotation, depending on varying conditions, are as follows :

- a) Catering to the needs of processing estate leaf only.

At specific fuelwood consumption of

- i) 2 kg kg<sup>-1</sup> MT

$$A_f = 0.113 A_t \text{ (i.e. 11.3\% of tea area)}$$

- ii) 1.5 kg kg<sup>-1</sup> MT

$$A_f = 0.085 A_t \text{ (i.e. 8.5\% of tea area)}$$

- b) Catering to the needs of processing estate leaf (requiring 2 kg kg<sup>-1</sup> MT) and estate household sector (assuming a population density of 4 persons per hectare of tea in bearing).

$$A_f = 0.229 A_t \text{ (i.e. 22.9\% of tea area)}$$

- c) Catering to the needs of

- |   |   |
|---|---|
| i) processing estate leaf (600,000 kg MT)   | } fuelwood usage<br>at 2 kg kg <sup>-1</sup> MT |
| ii) processing outside leaf (120,000 kg MT) |   |

- iii) Estate household sector (population density of 4 persons/hectare of tea)

$$A_f = 0.251 A_t \text{ (i.e. 25.1\% of tea area)}$$

## 2) Case of bought leaf factories

Consider the case of a bought leaf factory depending on village labour for production. In this situation the formula giving the land area required to maintain a sustainable supply of fuelwood reduces to

$$A_f = \frac{8 KF}{(Ms) \cdot 10^1} ; \quad A_t = 0$$

Thus for a bought leaf factory, for example, producing 750,000 kg MT annum<sup>-1</sup> at a fuelwood consumption rate of 2 kg kg<sup>-1</sup> MT, the area required under *Eucalyptus grandis* (with MAI OF 42.5 m<sup>3</sup> ha<sup>-1</sup> an<sup>-1</sup>) to maintain a sustainable supply of fuelwood is about 56 ha.

### Improved wood energy utilization

The present wood combustion systems used in the tea industry though simple are quite wasteful and this is further aggravated by the use of fuelwood with high moisture contents. Saving energy is as good as creating/growing it. Thus, there is a need for improvement of wood energy utilization through better technologies of conversion. Even though air drying of fuelwood from about 50% (wet basis for fresh wood) to about 20% moisture (wet basis) has been advocated, this is hardly adhered to by the Industry for various reasons. The moisture content of fuelwood as used by the tea industry varies from 25% to 45%. A saving of 8.4% in fuelwood could be achieved by the use of fuelwood dried to 20% moisture when compared with the use of fuelwood at 45% moisture. Savings could be further enhanced to about 10% if furnace flue gases are used to reduce the moisture level to 10%.

At the same time, even though the use of split firewood (45cm or 18" by 20 cm or 8" girth) has been advocated, very many factories continue to feed logs to furnaces. The use of cut fuelwood in optimum size pieces will help to reduce fuelwood consumption by at least a further 10 – 15%.

Thus it is seen that splitting and drying is a critical fuelwood conservation measure. If this practice is adopted immediate total saving of about 22% is within the reach of the tea industry.

It must also be conceded that the present wood combustion systems used in the tea industry though simple are quite wasteful. Improvements in air heater efficiencies could be achieved by using economizer or additional heat exchanger to utilize residual heat in flue gases from existing air heaters. However ultimately the present low efficient wood fired air heaters need to be replaced with better designed heaters having efficiencies of the order of 75%. Such air heaters obtained under a programme funded by the Netherlands Government were field tested in two factories (Haskoning, 1990). Even though these furnaces were conceptually sound they were mechanically defective,

resulting in constant furnace failures under operating conditions in our factories. From the experience gained, a local engineering firm has now designed and commissioned an air heater giving a minimum efficiency of 75%. Country-wide application of such air heaters will lead to fuelwood saving of at least 50%.

Improved wood energy utilization could also be brought about by wood gasification. Field testing of two gasifier systems are in progress at the low-country station of the Tea Research Institute. Performance data indicate that fuel savings of the order of 30–50% could be achieved once technical problems associated with wood gasification are overcome.

### **Non-traditional energy resources**

Peering into the future, the use of solar energy in Sri Lanka is particularly attractive as number of day light hours per year exceeds 4,000 with intense direct sunlight exceeding 1,800 h year<sup>-1</sup> in most tea growing districts. Use of solar collectors to obtain the full energy requirements of drying/withering will be cost prohibitive. However, use of low cost flat plate collectors using as far as possible locally available materials for pre-heating air (without storage) needed in drying operations during day hours needs investigating. This will be carried out in a project sponsored by SAREC with the University of Peradeniya and Royal Institute of Technology, Stockholm collaborating with the TRI. A solar fraction of 30% of energy requirements in drying is aimed at.

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## Appendix

### NOMENCLATURE

- Af = Area under fuelwood (hectares)
- At = Area under tea (hectares)
- F = Specific fuelwood consumption in tea processing, reckoned at 20% M.C. for fuelwood ( $\text{kg}^{-1}$  MT)
- K = Production of outside (bought) leaf ( $\text{kg MT an}^{-1}$ )
- M = Mean Annual growth increment (MAI) of species selected for fuelwood ( $\text{m}^3 \text{ha}^{-1} \text{an}^{-1}$ )
- P = Factory Production/hectare of tea in bearing ( $\text{kg MT ha}^{-1}$ ) defined by  $(Y+K/At)$
- P = Population density of household sector (persons/ha)
- r = Rotation years of fuelwood species
- s = Specific gravity of fuelwood species (dimensionless)
- Y = Yield Productivity of Estate ( $\text{kg MT ha}^{-1} \text{an}^{-1}$ )

### NON STANDARD ABBREVIATIONS USED

- GL - Green Leaf
- MT - Made Tea
- WL - Withered Leaf
- MC - Moisture Content