ECONOMIC ASPECTS OF SOLAR AIR PRE-HEATING IN SOUTH INDIAN TEA FACTORIES

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ABSTRACT

Tea processing is an energy intensive operation requiring both thermal and electrical energy. Hot air at a temperature of 100-130° C for tea drying and also for withering is obtained by burning coal or firewood. Roof integrated solar air heating system being used in tea factories of south India as partial energy delivery '*ped*' system during the last four years is an environmentally sound option. This paper aims to present the economical analysis of one such system of 212 m^2 collector area which has been in operation for a period of 2.75 years. This system has reduced specific fuel consumption for tea production from 0.932 to 0.71 kg / kg dmt (drier mouth tea) or approximately 25% fuel savings. The economic analysis by finding annual investment cost and return cost with the inclusion of concessions offered by the government shows a pay back period of less than 2 years and less than 4 years for profit making and non-profit making companies respectively and thus establishing the economic viability of this method.

01. INTRODUCTION

India produces around 29% of world's tea production (2589 Mkg in 1993) through its 1267 tea factories situated in north and south India (Ramadurai 1994). South India from its 308 tea factories produces annually 178 Mkg of tea in 1993 and occupies an important place in the world tea map. Tea processing is highly energy intensive. Tea industry spent 700 Mkg of coal or its equivalent in India in 1990 (Ramakrishna et al 1993). CTC and Orthodox are the two different processing methods being adopted in South India.

Thermal energy obtained from coal or fuel wood is needed for the withering and drying of green tea leaves from 75 ± 5% moisture content(m.c) wet basis(w.b) to 2.5 ± 0.5% m.c.w.b. Withering is the process in which harvested green leaves are spread with a bed thickness of around 0.25m over wire mesh in a specially made wooden trough where a cross flow of ambient air during favourable weather condition or heated air not exceeding 32^0C maintained by axial electric fan with a flow rate of 0.175 ± 0.075m^3/s per m^2 is achieved. A bank of hot air (temperature range of 100 to 130°C) producing heater/furnace fed by solid fuel using cast iron tubes as heat-exchanger coupled to a drier in which hot air is blown at the rate of 40-120m^3 / kg for moisture removal (Desilva 1993) is used for tea drying. The conventional tray type or fluid bed type dryers are used in south Indian tea factories.

Solar thermal energy application in tea industry is a sound option as an alternative to the depleting and polluting conventional fuels.

The temperature range required in tea processing is higher than the generally obtained range of solar flat plate collector. Hence solar air preheater as partial energy delivery '*ped*' unit rather than full energy delivery units '*fed*' is preferable. Nine such ped units of collector area around 2700 m^2 have been installed between the period 1991-95 in south Indian tea factories.(Table 1)

This paper describes one such installed unit of collector area 212 m^2 including its fabrication, fuel saving performance for a period of 2.75 years and economical assessment using pay back period method.

02. SITE DETAILS

The factory is located at a latitude 11°N, longitude 77°E and altitude 1950 MASL near a town Coonoor in Nilgiris district of Tamilnadu state in India. The factory produces around 0.3 million kg of orthodox tea per annum. During 1990 the factory produced 0.275 million kg of tea using 239,000 kg of coal. The factory has two banks of heater and drier, the first bank a small Sirroco make air heater (fed by coal or fuelwood) coupled with a conventional tray type drier of output 120 kg dmt/h (dmt = drier mouth tea) and the second a large Sirroco make air heater (fed by coal or fuelwood) coupled with a fluid bed drier of output 200 kg dmt/h. The precipitation at the site is 1500100 mm and 110 ± 10 wet days per year. The main factory has two inverted v shaped corrugated galvanised iron roof of 28.75m length along the apex which lies along east and west direction. A wooden false ceiling is fixed below the two inverted V shaped roof.

03. SOLAR AIR HEATER

The solar air heater is used to pre-heat the air which is further heated by the conventional furnace before blown into the drier. The flat plate collector is formed by converting the one side of the south facing galvanised iron roof of 20° tilt angle, length 28.75 m and breadth 7.37 m. The total 212 m^2 area of the collector is segregated into 4 equal units each of area 53 m^2 by using double metal sheet partition.

The roof after scratching is painted with commercial heat resistant dull black paint. Tempered glass of 4 mm thickness is used to form collector transparent cover using aluminium sections and frames for support. A vertical space of 150-165 mm is formed between the cover and roof in order to provide a mass flow rate of 0.0024 - 0.0026 kg/s per m^2 (Beckmann et al 1977).Using 3 metal partitions, air blown over the absorber is made to undergo 4 passes (Fig. 1a). All the sides of the collector are enclosed by double metal sheet with 40 mm thick mineral wool insulation. Lower side of the roof is insulated by 50 mm thick mineral wool slab and 25 mm thick polystyrene sheet.

Four separate curved metal ducts connect the attic formed by wooden false-ceiling and solar inlet as shown in figure 1b. The temperature in the attic is higher than the ambient during sunny days. The hot air outlets of 4 collectors are connected to a 7.5 kW centrifugal blower through metal duct insulated with 50 mm thick mineral wool slab. The blower outlet is connected to the ambient air inlets of the two conventional heaters through a duct network. Using two dampers it is possible to provide solar heated air to one of the heaters since the factory uses any one of the heater-drier banks at a time. Provision is also made to use the hot air directly for withering of tea leaves during the non-operating period of the drier. The mass flow rate through the collector is maintained at 5 to 5.5 kg/s with sufficient pressure drop. Apart from the 212 m^2 glass collector, arrangements are made to collect the heat from the other roof metal sheet (i-e) 212 m^2 South facing and 424 m^2 North facing bare-plate collector.(Fig.1b)

Thus the solar inlet air is preheated in the attic taking advantage of solar insolation falling on the bareplate collector.

04. RESULTS AND DISCUSSION

The solar air heater, after its installation in April 1992, has been in continuous operation. The harvested green leaves, arriving generally in the noon or evening to the factory, pass through the withering process for one full night. Rolling of withered leaves followed by fermentation, consuming around two hours period, start from the next day early morning six. Then the drying process starts around eight in the morning. As the withered leaves are continuously processed, the drying process continues till the evening during the peak leaf harvest season or till 13:00 - 14:00 hours in lean leaf harvest period.

During sunshine days the solar air heater is used from around 9 in the morning. When the drier is not operating during sunshine period, the solar heated air is used for withering. The factory reports that the quality and output of drier is not affected by the introduction of solar preheated air. It also reports that the quality of withered leaves using solar hot air is better than conventional withering which is generally done by hot drier exhaust air.

Due to the paucity of sophisticated instruments and technical manpower, the unit is mainly monitored daily on the basis of fuel savings. Details like total tea processed, fuel used, total hours of solar heating used, solar inlet and outlet temperatures, ambient temperature and fuel saved by solar heating are recorded everyday and then consolidated to monthly values. Records of this monthly figures from April 1992 to December 1994 are presented in Table 2, Table 3 and Table 4. The fuel consumption comparison with and without solar heating is shown in Table 5.

04.1 FUEL SAVINGS

The solar heating during the period April 1992 to December 1994 (2.75y) in combination with the conventional heaters to produce 0.98 million kg dmt have reduced the fuel consumption by 199,000 kg of coal of monetary value Rs. 498,275 (= US$ 14655).

During the first year of operation covering April 1992 to March 1993, the solar heating is used on 283 days or 1545 hours(h) (1063 h for drying and 482 h for withering).

The hours of solar heating used during the periods April 1993 to March 1994 and April 1994 to Dec. 1994 are 1455 (1094.5 h for drying and 360.5 h for withering) and 1073 (857 h for drying and 216 h for withering) respectively. The average hours of solar heating used for the above three periods are 5.5 h/day 5.05 h/day and 4.85 h/day respectively. The yearly performance of the solar unit is very much dependent on the weather conditions. The first period (April 1992 - March 1993) is very ideal with a slight drought condition in most months except October '92, a period of overcast sky, and November '92 which received a heavy rainfall of 648 mm. During the second period of consideration (April 1993 to March 1994), the site received a higher rainfall with many overcast days leading to reduced fuel savings. The variations of solar fraction on the factory's thermal requirement are shown in fig 2.

The annual average specific fuel consumption, (i-e) the average kg of coal required to process 1 kg dmt, comparing the period before the solar heating introduced, has been reduced from 0.93 to 0.65 (April '92 - March '93), 0.78

(April 93- March 94) and 0.7 (April '94 - December '94). The percentage of fuel savings, obtained from the ratio of fuel saved to the total fuel used, for the above three periods are 36.4%, 25.3% and 25% respectively due to the solar pre heating unit.

04.2 ECONOMIC ASSESSMENT

The value of a solar process ultimately must be assessed in economic terms (Duffie & Beckmann, 1980). The economics of this particular system is analysed using a simple payback method. This involves to find the annual investment costs and return costs starting from zero time. The payback period is defined as the period required for the return cost to exceed the investment cost.

The investment cost, in the first year is the sum of the unit's cost, interest on capital and annual recurring cost which is the total of parasitic energy cost, maintenance cost of the unit, insurance etc. The return cost in the first year is the total of any tax savings, government capital subsidy if available and fuel savings. The excess of investment over the return is brought forward (B.F) to the second year as investment and added with interest and recurring cost. The return in the second year is only the fuel savings cost. An escalation rate is applied to the recurring cost (parasitic energy cost and maintenance cost) and also the fuel savings cost. From the analysis of the factory's past cost for fuel and electricity, a 10% escalation rate to the parasitic energy and the maintenance cost and a 8% to the fuel cost are added.

Government of India, offers, at present (1994 - 95 financial year), for solar air heating system the following incentives:

1. A 100% depreciation on the cost of the unit in the first year itself it means for a profit making tea company if it invests say a 100 units of money for a solar air heating system and it has a tax liability on its profit say 200 units then it has to pay the tax only on 200 - (0.40 * 100) = 160 units. Hence a profit making tea company gets 40% of the capital investment on solar heating as tax concession. A non profit making company does not have this concession but the depreciation could be carried forward to be set off against future profit.

2. Around 30% of the system's capital cost of Rs. 800 (US$ 24) per m^2 of the collector is paid by the Government as capital subsidy. Both profit making and non-profit making companies are eligible.
3. Indian Renewable Energy Development Agency (IREDA), a Government undertaking provides a soft loan for 75% system cost at an interest rate of 8.3% for a profit making company.

04.3 Pay Back Analysis

A pay back analysis has been done for two situations namely a profit making company and a non-profit making company. This analysis has been done by finding annual investment cost which is the sum of capital cost, interest cost and recurring cost including parasitic energy cost and maintenance cost. The return cost is determined by finding the sum of tax saving, fuel savings and governmental subsidies. The pay back period is determined when the investment cost equates the returns. For the interest on the capital cost the prevailing bank interest of 16% has been considered. The adding of 100% depreciation to the returns cost is eligible only for the profit making company. This analysis shows that the pay back period for the profit making company is less than 2 years while for a non-profit making company it is less than 4 years as shown in Pay Back Flowcharts I and II.

05. CONCLUSIONS

Thus the installation, monitoring, fuel savings and economic assessment of a 212 m^2 area solar air heating '*ped*' system for pre heating the air of tea processing in South India are briefly reviewed. This study indicates the following:

1. In south Indian tea factories using solar energy it is possible to save annually an average of 25% fossil used in tea factories. Since 40% of tea factories in South India are using fuelwood, this reduction in fuel consumption will reduce the pressure being faced by natural forests.
2. Using economic analysis, it is found that the payback period for the considered system is less than two years due to Governmental concessions for renewable energy application in Indian Industries. It is also found that the payback period for a non-profit making company is

3 years and 4 months, using 16% commercial bank interest on capital costs, 10% escalation rate on parasitic energy and maintenance cost and 8% escalation rate on fuel cost.

3. The solar air preheating *'ped'* system for tea processing has been proven as an economically viable option.
4. The annual fuel consumption around 454 million kg of coal (Lignite) or its equivalent for tea processing in India could be reduced by 25% by using 0.6 million m^2 solar collector.

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TABLE - 1

DETAILS OF '*ped*' UNITS INSTALLED IN SOUTH INDIA

SL.NO.	LOCATION OF THE '*ped*' UNITS	COLLECTOR AREA m^2
1	Manjolai Tea Factory Tirunelveli, Tamilnadu(TN)	130
2	Golden Hills Tea Factory Near Coonoor, TN	112
3	UPASI Demonstration Tea Factory Coonoor, TN	100
4	Kavukal Tea Factory Kothagiri, TN	220
5	Kilkothagiri Tea Factory, Kilkothagiri, TN	250
6	Parkside Tea Factory Near Coonoor, TN	320
7	Pandiar Tea Factory Near Gudalur, TN	320
8	Guernesy Tea Factory, Brookland, Coonoor, TN	390
9	Glendale Tea Factory Coonoor, TN	585

TABLE - 2

SOLAR AIR HEATER'S OPERATION AND FUEL SAVING DETAILS FOR THE PERIOD FROM APRIL 1992 TO MARCH 1993

Month	Tea processed kg	Coal used kg	No. of days solar used	No. of wet days	Rainfall mm	Hrs. solar used for drying	Hrs. solar used for withering	Total solar hours used	Total fuel saved by solar heat kg	Total savings in cost Rs.
April	15,273	8,949	21	3	39	85	54	139	6,832	484
May	24,205	11,993	23	10	74	124	50	174	8,536	605
June	48,581	29,074	20	13	115	107	40	147	7,224	512
July	33,052	19,050	22	18	70	75	7	82	6,225	441
August	21,537	11,290	27	13	75	71	43	114	5,810	427
Sept	24,041	16,697	28	11	91	103	51	154	4,868	345
Oct	21,039	16,931	23	12	142	96	28	124	1,300	92
Nov	31,482	25,883	16	19	648	71	12	83	5,166	366
Dec	30,942	23,741	21	6	30	90	33	123	5,765	407
Jan	14,887	10,635	28	0	68	74.5	42	116.5	4,103	290
Feb	11,076	6,346	24	1	0	65	61	126	3,619	257
Mar	26,547	15,195	30	2	2	102	61	163	11,767	699
Total	3,02,662	1,95,784	283	108	1,345	1,063.50	482	1,545.50	71,215	4,925

TABLE - 3

SOLAR AIR HEATER'S OPERATION AND FUEL SAVING DETAILS FOR THE PERIOD FROM APRIL 1993 TO MARCH 1994

Month	Tea processed kg	Coal used kg	No. of days solar used	No. of wet days	Rainfall mm	Hrs. solar used for drying	Hrs. solar used for withering	Total solar hours used	Total fuel saved by solar heat (kg)	Total savings in cost Rs.
April	41,855	24,670	30	5	20	128	108	236	12,894	929
May	21,192	13,395	29	9	91	95	71	166	8,300	598
June	34,896	25,940	22	8	69	84	16	100	5,500	396
July	38,912	29,905	24	15	62	87	28	115	6,325	456
August	15,760	12,830	25	10	73	59	48	107	5,885	424
Sept.	17,495	16,810	15	14	84	35	3	38	2,090	151
Oct.	46,972	47,790	25	20	473	94	0	94	5,170	373
Nov.	40,625	28,065	14	16	677	62	0	94	3,100	223

Dec.	22,565	20,090	22	10	412	71	16	87	4,785	345
Jan.	29,534	27,170	28	5	22	100	33	133	6,650	479
Feb.	36,819	30,760	23	5	35	121	5	126	6,300	487
Mar.	29,896	17,320	31	2	25	158.5	32.5	191	7,640	616
Total	3,76,521	2,94,745	288	199	1,773	1,094.5	360.5	1,455	74,639	5,477

TABLE - 4

SOLAR AIR HEATER'S OPERATION AND FUEL SAVING DETAILS FOR THE PERIOD FROM APRIL 1994 TO DECEMBER 1994

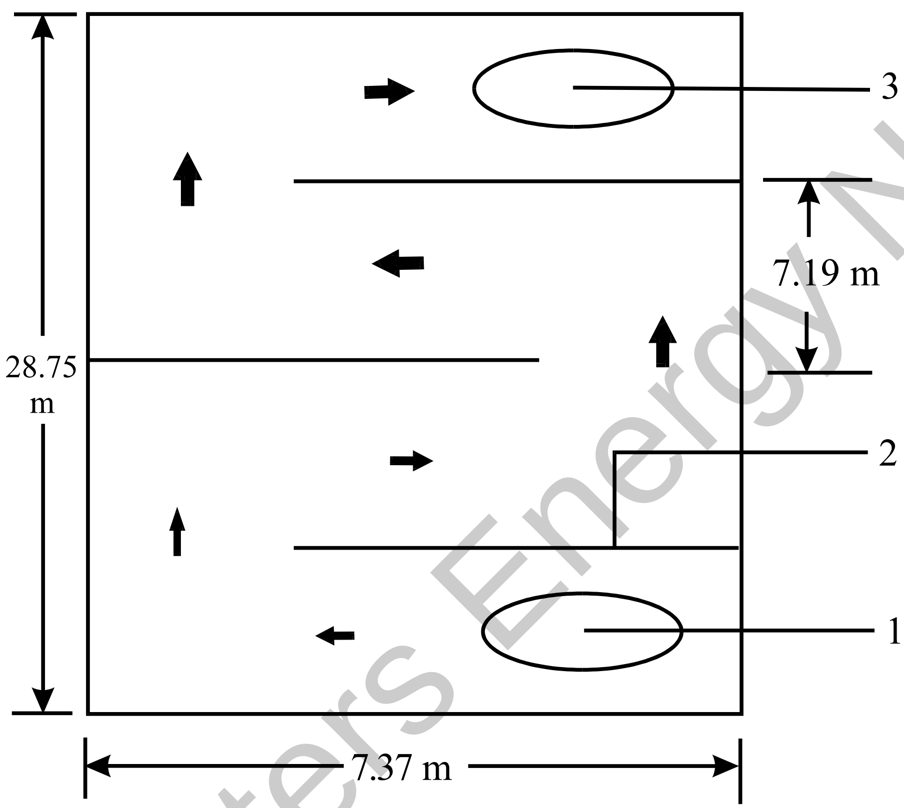
Month	Tea processed kg	Coal used kg	No. of days solar used	No. of wet days	Rainfall mm	Hrs. solar used for drying	Hrs. solar used for withering	Total solar hours used	Total fuel saved by solar heat (kg)	Total savings in cost Rs.
April	40,349	28,045	30	15	216	142	41	183	9,150	737
May	71,428	40,830	31	9	45	177	15	192	10,510	847
June	31,320	18,345	27	12	36	82	36	118	6,459	521
July	12,824	9,135	16	14	117	30	8	38	2,105	170
August	22,440	21,195	23	6	39	60	17	77	2,429	196
Sept	27,316	24,455	25	7	97	81	12	93	2,861	231
Oct	22,216	14,220	20	23	310	84	26	110	4,924	397
Nov	39,291	32,105	22	15	313	95	14	109	5,967	481
Dec	36,105	2,165	27	5	31	106	47	153	8,376	675
Total	3,03,289	2,12,495	221	106	1,204	857	216	1,073	52,781	4,254

TABLE - 5

FUEL CONSUMPTION COMPARISON WITH AND WITHOUT SOLAR HEATING

Period	Total Months	Total DMT kg	Total Fuel kg	Total Rainfall mm	Total solar heating Hrs	Total solar heating days	Avg. solar heating h/day	Sp. fuel cons. kg/kg dmt	Sp. fuel cost Rs/kg dmt	Fuel saved %	Avg. fuel pr. US$/kg
Apr 1991 - Dec1991	9	2,80,391	2,52,240	1084	Nil	Nil	Nil	0.93	2.01	Nil	0.064
Apr 1992 – Mar 993	12	3,02,662	1,95,784	1,354	1,546	283	5.5	0.65	1.52	36.4	0.069
Apr1993 – Mar 994	12	3,76,521	2,94,745	1,773	1,455	288	5.0	0.78	1.95	25.3	0.074
Apr 1994 – Dec1994	9	3,03,289	212495	1,204	1,073	221	4.85	0.70	1.92	25.0	0.081

Fig 1(a) Air flow over the Absorber

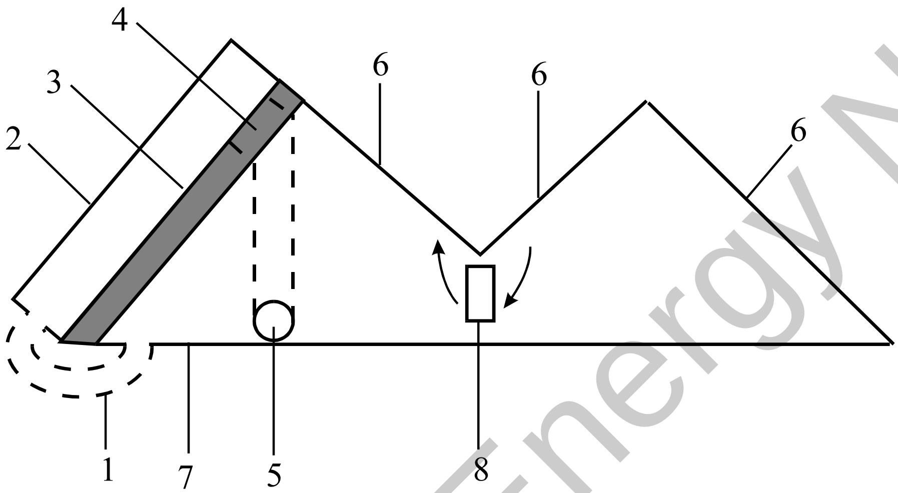


1 - Inlet from Attic

2 - Metal Partition

3 - Air Outlet to the duct

Fig. 1(b) - SCHEMATIC REPRESENTATION OF REGULAR AND BARE PLATE COLLECTORS ON GI ROOF OF TEA PROCESSING UNIT AT GOLDEN HILLS TEA ESTATE



1. Solar inlet from attic - GI duct

2. Regular 212 m^2 Solar Collector

3. Black painted GI roof - absorber

4. Insulation

5. Solar hot air outlet to furnace

6. Bare plate Collectors with black painted GI roof

7. Attic formed by wooden planks

8. Axial Fan to move hot air

Figure 2 - Variations of Solar Fraction on factory's thermal requirement