Energy Conservation in the Tea Industry*

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The tea industry in India is examining the amount of energy required for tea processing. Usually in other industries, one needs something like 1 to 1.5 kWh/kg of produce (kWh is normally used as an electrical unit, but here refers to thermal units). In the tea industry, we use approximately (in traditional tray dryers) 3.0 kWh (thermal) per kg of made tea. In addition to thermal energy, 0.7 kWh of electrical energy is needed. Adding to this the lighting loads of the residences, services and factories, the electrical load is about 1 kWh/kg of tea. So, even though we are using 3 kWh thermal and 1 kWh electrical per kg of made tea, the tea industry has not considered the energy aspects seriously until now. Perhaps this is because the energy costs have been too small a fraction of the total costs. With oil and coal prices going up and the energy mix in the tea processing (for various reasons of public policy) changing from the traditional photosynthetic solar route of fuelwood to oil and coal, the energy costs are escalating, the reliability of fuel supply is eroding, and the tea industry is wondering what should be done. This is a good beginning.

INTEGRATED MANAGEMENT

It is now well known that the tea industry is particularly tight with money, and so one of the most effective things to start with is good housekeeping. From the point of view of integrated energy management, we not only have to consider additional local sources of energy – like solar, biogas, wind etc. – but must also see where the heat is being used, where the leaks can be plugged, and where efficiency can be improved. There is considerable scope for improvement here. Another special feature of tea processing, particularly with respect to ambient energy sources, such as solar energy, is the mismatch between production schedules and solar incidence. We have done some extrapolations, because in plantations we have only rainfall and temperature data and no sunshine or radiation data. Only sunshine data from the closest meteorological station and from the Research Institute in Cinchona have been used to estimate the radiation incidence, and the United Planters Association of South India (UPASI) average monthly product figures have been used. In conformity with the practice in the industry, where every input is computed per kg of tea, we will be valuing the solar contribution, also per unit area of solar collectors. The number of solar collectors to be installed, and the resources and investment that can be made available, subject to certain lower and upper limits, need to be decided by the management of tea estates.

DRYING PROCESS

Fig. 1 shows the standard drying curve of tea for the conventional tray dryer. It takes a

*Adapted, with permission, from an article first printed in The Planters' Chronicle, September 1982.

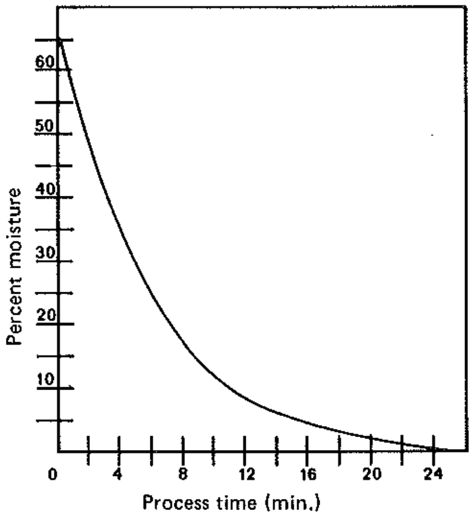

Fig. 1 Drying curve for tea

cycle of 24 to 26 minutes to get down from a moisture of 55-60% to 3% when the inlet hot air temperature is 88-93°C. In the latest technology of fluidised bed dryers, however, we have a hot air input of 125-126°C, and the drying cycle duration and air flows required are nearly 50% of those in the conventional tray dryer.

Fig. 2 shows the common arrangement of a six-level tray dryer. The flue pipes are the air pipes on the furnace side connected through a blower to the actual drying chamber, where the tea moves from the inlet at the higher level to the discharge at the lower level and dries in the process. Even though we are talking about energy, there are few reliable data on the exit conditions of the air, viz. dry bulb and wet bulb temperatures. We have tried to get some measurements, and there are some difficulties in measuring the wet bulb temperature because tea soils the wet bulb muslin. However, these measurements should be made. Secondly, there is very little information on the CO_2 percentage or the flue gas temperatures of the furnace from which combustion efficiency could be estimated. A tremendous amount of heat is wasted in these areas.

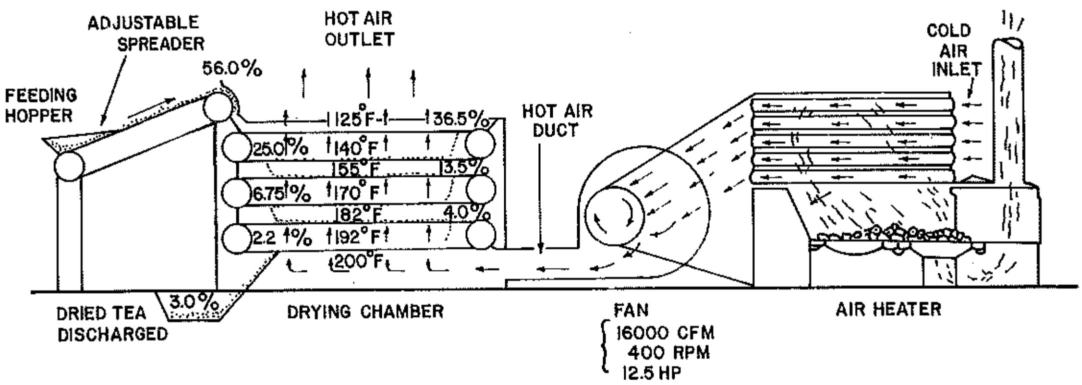

Fig. 2 Modern six tray dryer

HEAT BALANCES

The usual hourly output for a conventional tea dryer is 200 kg of dry tea, and its specified air flow with a three-fourths opening is 15,500 ft^3/min (439 m^3/min). For wood-fired systems, the fuel input is equivalent to 5,000 kcal, and as shown in Fig. 3, the heat transferred to the hot air entering the dryer is only 2,000 kcal. So from the combustion and the heat exchanger units alone 60% of the heat has been lost. Then again, in the next stage of the dryer nearly half of the heat is lost in the dryer exhaust. In the tea dryer, we lose another one third to fixtures, exit tea and insulation losses etc. The actual heat required for one kg of dry tea (we have not included made-tea here because people use different percentages for reconstitution in CTC* teas) is only 640 kcal/kg and thus the net dryer heat efficiency is as low as 13%. There is lot of wastage, and therefore considerable scope for improvement.

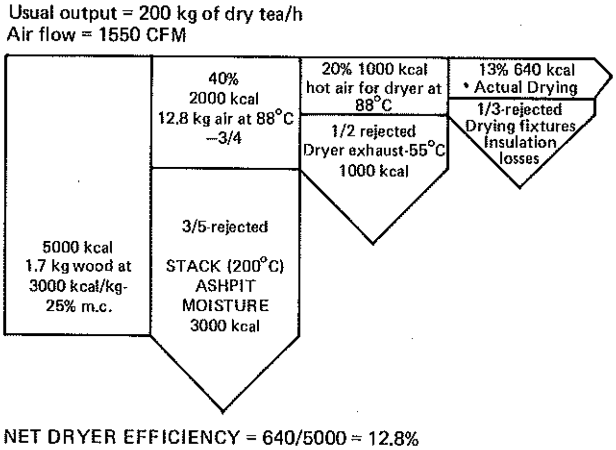

Fig. 3 Drying heat balances for tea (kg of dry tea): six level tray dryer

Fig. 4 shows the heat balance for one of the oil-fired fluidised bed dryers. Fluidised bed dryers to be coupled with existing conventional furnaces using leco, coal or firewood are also being made. For the oil-fired unit considered for heat balance here, the input is about 1,366 kcal, and the heat finally used is still about 600 kcal. In the tea dryer, we lose another one third to fixtures, exit tea and insulation losses etc. For the actual heat required for one kg of dry tea (made-tea is not included here) the net efficiency is 44%; and the amount of heat rejected in dryer exhaust is about one-fourth. Spot measurements indicated 60°C exit temperature, but this temperature may not be accurate. In the fluidised bed dryers using conventional fuels, exhaust temperatures are estimated to be approximately 80°C or more. Fluidised bed dryers are thus energy economic; but it is for the tea industry to decide whether the so-called high-fired teas from fluidised bed dryers have the right flavour and the right market.

*A style of black tea manufacture.

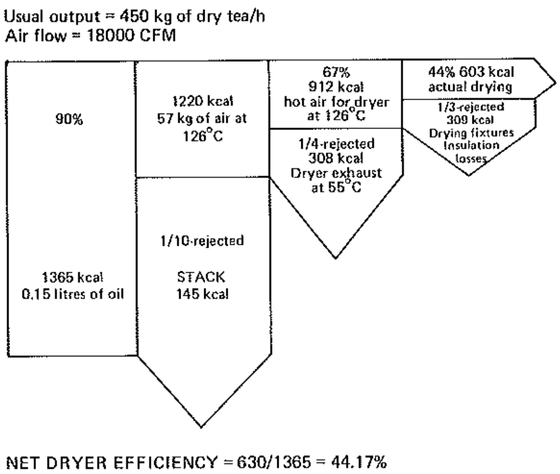

Fig. 4 Drying heat balances for tea (kg of dry tea): fluidised bed dryer

COMBUSTION EFFICIENCY

To turn now to a discussion of the combustion units. It should first be noted that if we have ideal conditions for combustion – conditions which in some way approximate to the boiler design – the combustion efficiency should be as high as 60-70%. But one cannot always achieve such ef-

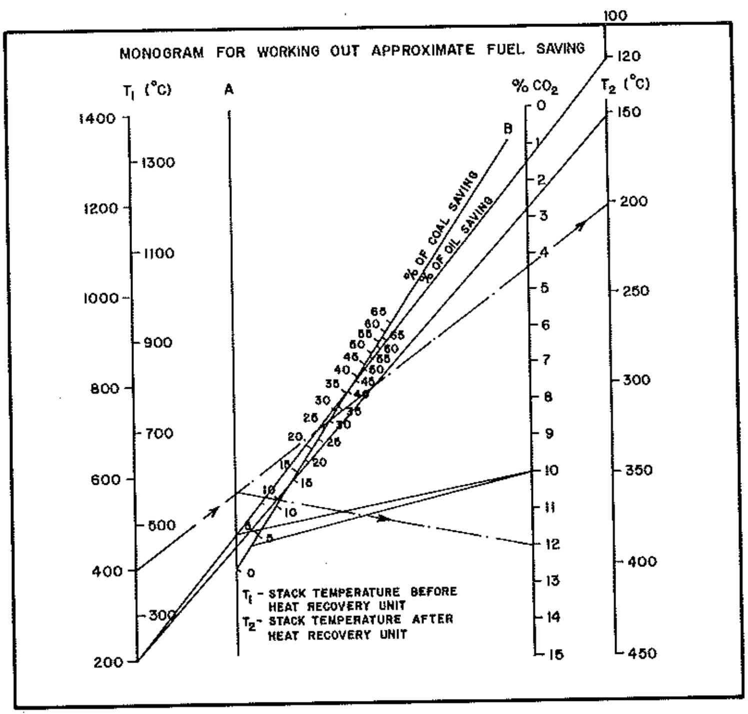

Fig. 5 Heat recovery unit

ficiency because the boilers need to be designed for closely monitored fuel specifications. 100% excess air and 10% CO_2 normally indicate very good combustion. As can be seen in Fig. 5, for heat recovery from flue gases, if flue temperatures are decreased from 200°C to 120°C, one can have 5-6% saving in addition to enhanced efficiency because of good combustion. However, in the furnaces normally used, it is questionable whether or not we in fact obtain 100% excess air and 10% CO_2. This is an area to investigate. In view of the additional investments needed for the heat recovery unit, one might reasonably question the use of 5-7% saving. But the problem is that until now, the energy costs in tea processing were roughly less than 10% of the total cost of production because of the labour intensive nature of the industry. However, this fraction will rise, and if one has to reduce energy costs, one will have to look at every fraction of a percent.

SOLAR COLLECTORS

As regards the use of solar energy, it is very important that instead of promoting the idea enthusiastically we should do some hard professional thinking. Fig. 6 shows sections of typical water and air heating collectors of the flat-plate type. A solar collector is a metallic black plate, insulated at the back and having a glass window at the front. The black metal plate in the air is at a slightly higher temperature, and if insulated at the bottom, it will have an even higher temperature. If we put a glass window at the top, the cold air will not touch the hot plate and consequently heat losses by convection will be prevented, and even higher temperatures can be obtained. Also, the glass window (the greenhouse effect) will prevent heat from being lost through radiation, and we can attain reasonably high temperatures. Now the question is how to utilise the heat which has been obtained, because there is no point in simply having the heat without making use of it. The heat can be transferred through a water system, in which case there are tubes through which the water flows; or it can be transferred through an air system using ducts through which air is made to flow by a blower/chimney. These tubes/ducts are thermally attached to the hot black plate.

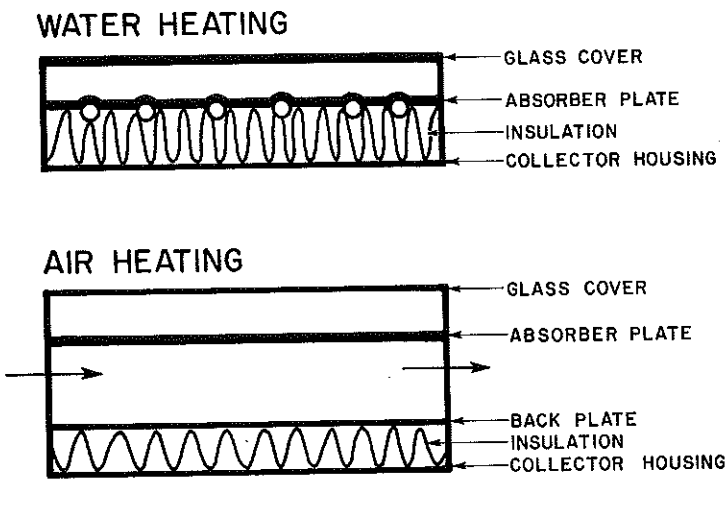

Fig. 6 Flat plate collectors for solar energy

SOLAR DRYING

Two of the most common solar drying systems, particularly for agricultural products, are shown in Fig. 7. These are forced convection systems using blowers, and in most cases these already exist because they are already used with fuel-fired furnaces. A considerable amount of work has been done on natural convection systems; but they are not really suitable, except on a cottage scale, for producing reliable quality agricultural products. One of the systems is the shelf-type chamber, which could for example be used for cardamom and arecanut. The other one, which is rather similar to a tea dryer is coupled to a fuel-fired furnace and uses heat generated by solar as a preheating system for the existing combustion source. For any crop requiring 100% reliability, subject to the exigencies of the Electricity Boards, the conventional fuel source is necessary and so is the availability of power. Further, the solar system may or may not have storage. Storage systems using hot water are usually very costly and are not relevant when an auxiliary fuel source is already present.

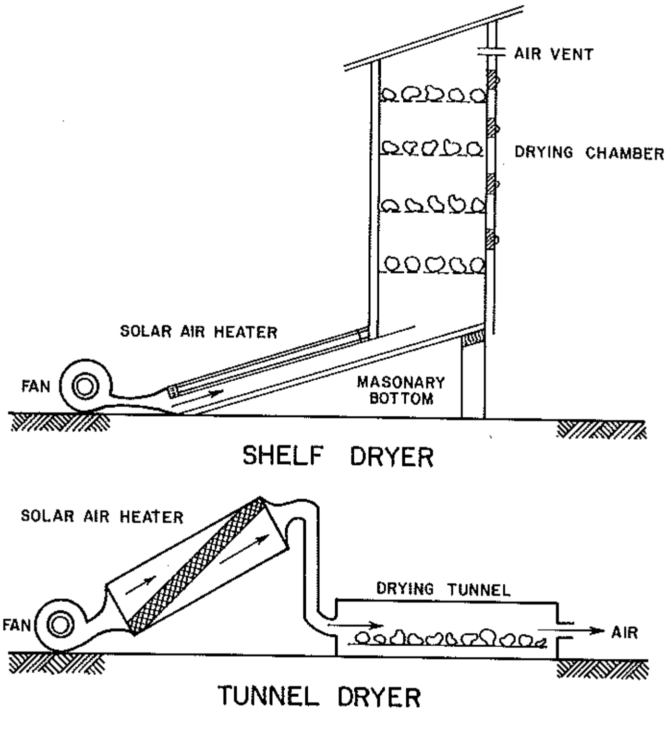

Fig. 7 Solar drying systems

DRYER EXHAUST

If the air to be recycled is at a lower temperature than the collector outlet design temperature (see Fig. 8), it is passed through the solar collector. On the other hand, if the recycled air is at

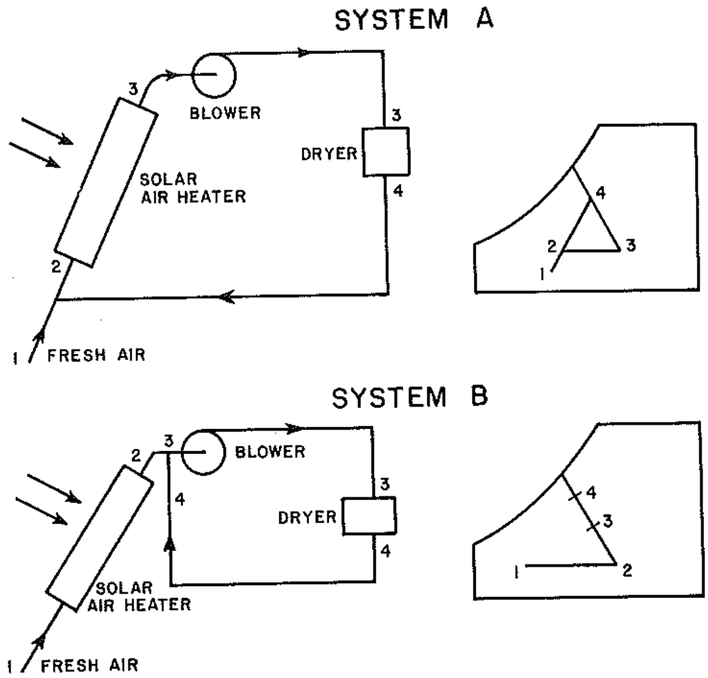

Fig. 8 Solar air recycling systems

a higher temperature than the temperature of the collector, we bypass the collector and take it directly to the furnace or a mixing chamber before the dryer. It is relatively important to consider not only the amount of the solar fraction that one wants to get from solar energy but also the temperature, i.e. the quality of heat we would like solar energy to provide. This is because the higher the temperature, the lower the efficiency of the collector and the higher the costs of unit solar heat.

PRODUCTION VS CLIMATE

Since the incidence of solar radiation and production schedules are highly location specific, we have considered only one of the tea estates. Using production profiles for Anamalais provided by UPASI, we have tried to correlate the data for production with the climatic data. Table 1 shows the production (month by month) and the average temperatures which all the estates record, together with the number of rainy days. But all the estates do not have sunshine hours. So, what we have done is as follows: taking sunshine hours from Cinchona and assuming that on the non-rainy days, the sunshine hours are everywhere (for Anamalais) the same, we have obtained the average sunshine hours on non-rainy days. For the rainy days (because rainfall depends on which side of the hill you are) we have developed correlations by which one relates the average sunshine hours to average rainfall. Thus we can calculate monthly average sunshine hours for any estate and then estimate the solar intensity and the solar incidence on the collector. Table 1 shows the mean

Table 1
Tea production and climatic data
(Anamalais – Panimed)

Month	Fraction of Annual Production (%)	Average Temperature (°C)	No. of Rainy days	Average Sunshine Hours	H (kWh/m^2 day)	H Coll (kWh/m^2 day)
January	8.0	19.8	0	7.8	5.87	4.97
February	4.0	20.3	2	9.0	6.83	5.52
March	6.3	22.3	15	8.2	6.68	5.00
April	15.0	22.7	13	7.7	6.56	4.57
May						
June						
July			MONSOONS			
August						
September						
October	12.00	21.7	20	4.0	4.83	2.66
November	7.00	20.8	10	4.7	4.73	2.75
December	9.5	20.0	1	6.5	5.28	4.47

values for each month – except for monsoons where solar drying has not been considered. In addition, there is also the cloudiness pattern governing the statistical distribution around the mean. Using the *Radiation Data Handbook, Solar Radiation over India,*[1] and the frequency pattern in terms of the mean value, we get the cloudiness pattern. This is very important in relation to recycling and the temperature which we want from solar collectors, as it determines the operating hours when the collector can give useful heat.[2]

FUEL COSTS

Table 2 shows the calculated fuel costs according to their respective sources. The efficiencies we have used here are calculated from the fuel to tea ratios, which UPASI has collected as representative values for various regions at the current level of practice. Using 1981 costs, figures and average calorific values (also supplied by UPASI), we get figures which may reasonably be considered to be valid. Looking at the costs at source, the fuelwood is hardly 4 paise (approximately US$0.004) per kWh and the solar energy is free. But when we consider rupees (1 rupee = approximately US$0.1) per kWh for hot air, the wood is 8 paise (approximately US$0.008) and the solar one is about 20 paise (approximately US$0.02). We have used a solar collector at 50°C because it is not only cheaper but also easier if we want to recycle the exhaust (it is also 55-60°C).[3] The broad conclusion is that although the solar energy is cheaper than oil and coal, it is still twice as costly as fuelwood. So if one can use fuelwood (we have to use some fuel anyhow), and depending upon how much land is available, one must use it efficiently, there is no contradiction to supplementing it with solar energy in its direct form. Leco shows a considerable advantage, but we think this needs to be confirmed by longer experience.

Table 2
Sourcewise fuel costs

FUEL	Efficiency	(Cost (Rs./kWh) At source	For hot air	Cost Rs./kg of made tea)
Fuelwood Rs. 130/tonne 3000 kcal/kg	44.5%	0.037	0.084	0.26
Furnace Oil Rs. 2.46/litre 9100 kcal/kg	52.2%	0.232	0.445	1.38
Ordinary fluidised (made tea is 50% of dry)	93.8	0.232	0.247	0.70
Coal Rs. 657/tonne 5500 kcal/kg	43.2%	0.103	0.235	0.74
Leco Rs. 984/tonne 6700 kcal/kg	70.1%	0.120	0.171	0.53
Biogas Rs. 1000/m^3, 5 m^3 plant at 12% for 10 years 4450 kcal/m^3	70.0%	0.158	0.226	0.70
Solar Anamalais single cover, Rs. 500/m^2 12% for 10 years	48.0% at 50°C	free	0.197	0.61

SOLAR FRACTION

Looking at the solar data sheet for tea drying (Table 3), one finds that one metre square of collector (at this particular location) gives 500 kWh per year. This is after the solar incidence has been matched with the tea production and processing schedules. This is done by assuming that at least 400 kg/h of tea is being dried and the process continues till 3 p.m. in peak months. In terms of fuel savings, the heat is equivalent to 90 litres of oil or 180 kg of coal, or 300 kg of fuelwood, for conventional tea dryers at the present level of their operational efficiency. The solar operating hours are of the order of 1,336 per year. This is because 90% of the sunshine hours occur in the 8 solar months when 72% of the production takes place. On the basis of the solar months, the use factor is 52.8%, and for the full year it is 38.5%. The solar energy fraction on the basis of sunny hours only is 15% and for full operation during the sun-up months it is 9%, and on a full-year basis, it is 6.5%. Pay-back periods would come to about 5-7 years without incentives or inflation

Table 3
Tea drying solar data sheet

* One m^2 of the T.E.R.I. solar air heater at 48% – 50°C – 40 kg/h m^2 gives 500 kWh/yr =>161 kg of made tea

  – or saves 90 litres of oil,
  or 180 kg of coal, or
  320 kg of fuelwood.

* For Anamalais (400 kg/h: 10^6 kg/yr), solar operating hours = 1,336/yr

  52.8% of sun-up months
  (Jan-May, Oct-Dec)
  = 38.5% for a full year (3,470)

* Solar energy contribution in sun-up months:[1]

for sunny hours	=	15%
for full operation	=	9%
for full year	=	6.5%

[1] If 1 m^2 of collector area is used per kg per hour of tea dried (maximum permitted = 3 m^2/kg/h) for tray dryers and half for fluidized bed dryers.

in full prices. All these figures are for a one metre square collector area being used per kg/h of dry tea, and the maximum area we can use is up to 3 m^2 per kg/h if no recycling of dryer exhaust is done for the drying itself. This is the case, if the dryer exhaust is used for withering whenever it is needed. If recycling is required for drying, one can start with a minimum collector area of 1 m^2/kg per hour of dry tea and match it with the fraction of recycling done. The advantage of recycling lies in the larger number of operating hours it contributes. But there are problems of fibre separation and combustion hazards, if direct recycling is done and extra investments are involved. If heat exchange equipment is used, these problems need much more detailed investigations.

CONCLUSIONS

The energy management aspects of processing in the tea industry resolve themselves into three major areas of attention, namely good housekeeping, energy recovery and employment of additional energy resources – as detailed below:

* **Good Housekeeping**
  - Use dry wood (minstack – 6 weeks)
  - Regulate dryer air flow
  - Clear air and flue tubes
  - Improve combustion efficiency
  - Plug heat leaks (lagging)
  - Maintain fans, motors, controls

* **Energy Recovery**
  - From flue gases
  - From dryer exhaust
  - Better drying efficiency – fluidised beds
* **Energy Resources**
  - Solar pre-heating
  - Co-generation – biomass fired 400 kW power station
  - Solar water heating for services
  - Biogas plants for lines

The relative costs and energy savings for each of these measures will obviously depend upon each estate. The evolution of a methodology for an optimum 'blend' would need much more monitoring, analysis and on-site trials – a challenging programme for years to come.

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