



Solar Thermal Solutions for Tea Processing Sector



1. Industry Overview

Tea processing is a thermally intensive operation. Withering and final drying remove substantial quantities of moisture from freshly harvested leaves, while hot air is also required for other controlled processing duties. In tea factories, thermal energy represents the dominant share of total process energy, with drying and withering accounting for a large proportion of the thermal requirement.

Solar Heat for Industrial Processes (SHIP) can be integrated particularly effectively as solar-air preheating upstream of conventional furnaces, as direct solar hot air for selected low-temperature duties, or through hot-water, boiler-feedwater and steam systems. A South Indian field study demonstrated a 212 m² roof-integrated solar-air preheater operating with a conventional furnace and reported approximately 25% fuel savings.

2. Typical Thermal Applications

Table 1: Tea processing applications, indicative temperature range and typical heat medium

Tea processing application	Indicative temperature	Typical heat medium
Withering	Ambient to 32°C	Air
Withering-air preheating	30 - 50°C	Hot air
Final tea drying	100 - 130°C	Hot air
Dryer air preheating	40 - 80°C+	Hot air
Boiler feedwater preheating	50 - 120°C	Hot water / suitable HTF
Process hot water / cleaning	50 - 90°C	Hot water
Steam / hot-water utility systems	120 - 180°C	Steam / hot water

3. Solar Thermal Technology Options

The appropriate technology should be selected based on required process temperature, heat-load profile, available area, solar resource and integration point.

Table 2: Solar thermal technology options, indicative applications and temperature range

Solar thermal technology		Indicative application	Temperature range
Non-concentrating solar thermal	Flat Plate Collector (FPC)	Withering and dryer-air preheating	30 - 80°C+
	Evacuated Tube Collector (ETC)	Low-temperature hot water and utility preheating	30 - 80°C
Non-imaging concentrating	CPC/evacuated-tube CPC/xCPC	Hot water and medium-temperature preheating	40 - 100°C
Concentrating Solar Thermal	Scheffler / parabolic dish	Low/medium-temperature process heat	60 - 120°C
	Parabolic Trough Collector (PTC)	Solar steam and higher-temperature process heat	100 - 250°C
	Linear Fresnel Reflector (LFR)	Medium-temperature process heat and steam	100 - 250°C
	Higher-temperature CST systems	Steam and medium-temperature process heat	100-250°C

Thermal storage can improve the utilisation of solar heat where the solar resource and process demand do not coincide. For tea processing applications below 100°C, hot-water storage can be a relatively simple option.

Potential storage options include:

- Hot-water tank: Low-temperature processes
- Pressurised water: Processes above 100°C
- Thermal-oil storage: Medium-temperature applications
- Phase-change materials: Specific temperature ranges
- Molten salt: Higher-temperature applications

4. How Solar Heat Can Be Integrated

A key principle in industrial solar thermal design is to identify the most technically and economically suitable integration point rather than simply connecting the solar field to the main boiler. IEA SHC specifically highlights process integration and selection of the appropriate integration concept as a critical part of SHIP project design.

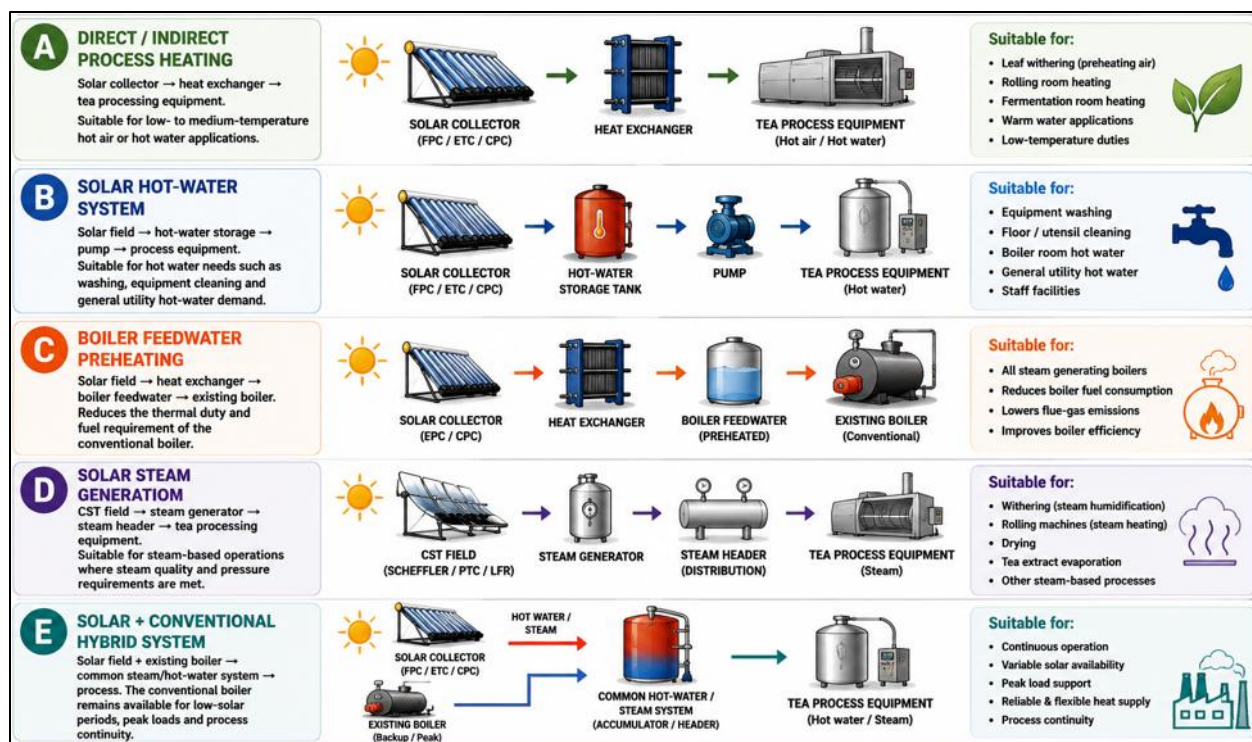


Figure 1: Illustration of solar heat integration to tea processing units

5. Key Benefits for Dairy Processing MSMEs

The solar contribution should be determined from the actual hourly thermal load rather than from a generic percentage. For tea factories, a solar-air preheating system can often be sized to provide a useful fraction of the dryer-furnace air-heating duty while retaining the existing furnace for temperature lift and backup. As a preliminary screening range, approximately 20 - 40% solar contribution to a suitable thermal load may be considered for a hybrid system, with higher fractions possible for well-matched low-temperature or daytime loads.

Economic assessment should include annual useful solar heat, fuel displaced, annual fuel-cost savings, CAPEX, O&M, LCOH, NPV, IRR, payback and the value of maintaining the existing furnace as backup. Published South Indian evidence reported a 2 to 4 years payback for a 212 m² roof-integrated solar-air preheater, depending on the financial status of the company and available government concessions.

Table below presents key benefits for tea processing MSMEs.

Table 3: Key benefits for textile sector MSMEs

 ENERGY	- Reduces coal, firewood, furnace oil, diesel or gas use in tea drying; - Reduces conventional furnace duty; - Provides renewable daytime process heat.	
 ECONOMIC	- Reduces exposure to fuel-price fluctuations; - Can reduce long-term drying-energy costs; - Can lower the specific fuel consumption per kg of made tea.	
 ENVIRONMENTAL	- Reduces fossil-fuel and biomass consumption and associated GHG emissions; - Can reduce local air-pollutant emissions where combustion is displaced.	
 OPERATIONAL	- Can be integrated upstream of existing furnaces and dryers; - Hybrid operation retains conventional heating for cloudy periods and peak loads; - Roof-integrated systems can use existing factory roof area.	
 PRODUCT QUALITY	Controlled preheating can maintain stable dryer inlet conditions while the conventional furnace provides the final temperature lift required for the drying process.	

6. Indian Case Example

A well-documented industrial demonstration is the roof-integrated solar-air preheating system studied by Palaniappan and Subramanian in a South Indian tea factory near Coonoor in the Nilgiris. The factory produced approximately 0.3 million kg of orthodox tea per year and used coal for its thermal process. The solar-air heater preheated combustion/drying air before the conventional furnace. This project reported approximately 25% fuel savings and reduction of specific fuel consumption from 0.932 to 0.71 kg/kg dmt (drier mouth tea or made tea).

Parameter	Reported project information
Project	Solar-air preheating system at Coonoor in the Nilgiris
Location	Near Coonoor, Nilgiris, Tamil Nadu
Installation / operation	Installed April 1992; monitored for about 33 months
Tea production	0.3 million kg/year
Baseline coal consumption	239,000 kg reported for 1990
Solar collector area	212 m ²
Collector type	Roof-integrated flat-plate solar-air heater
Process integration	Solar-preheated air supplied to conventional furnace/dryer
Fuel saving	25% reduction in specific fuel consumption
Specific fuel consumption	0.932 kg/kg dmt to 0.71 kg/kg dmt
Estimated fuel saving	59.8 tonnes coal/year if the 25% saving is applied to 239 t/year

Parameter	Reported project information
Reported economic payback	2 - 4 years depending on company status and concessions
CO₂ emission avoided	145 tCO ₂ e/year (considering emission factor 94.6 kg CO ₂ /GJ and net calorific value of 25.6 MJ/kg for coal)

7. Sources and References

- 1) Palaniappan, C. & Subramanian, S.V. (1998), 'Economics of solar air pre-heating in south Indian tea factories: a case study', Solar Energy 63(1), 31–37.
- 2) Confederation of Indian Industry, Green Power case study: 'Solar Air Heating System for Tea Drying' — 1996 Indian tea-factory installation.
- 3) Sharma, A. & Dutta, P.P. (2022), energy/exergy/economic assessment of a solar-air-heater-assisted tea withering trough.
- 4) Review of drying technology in the tea sector — thermal energy requirements and renewable-energy-assisted drying options.
- 5) IEA SHC Task 49 / Task 64 resources on Solar Heat for Industrial Processes (SHIP).