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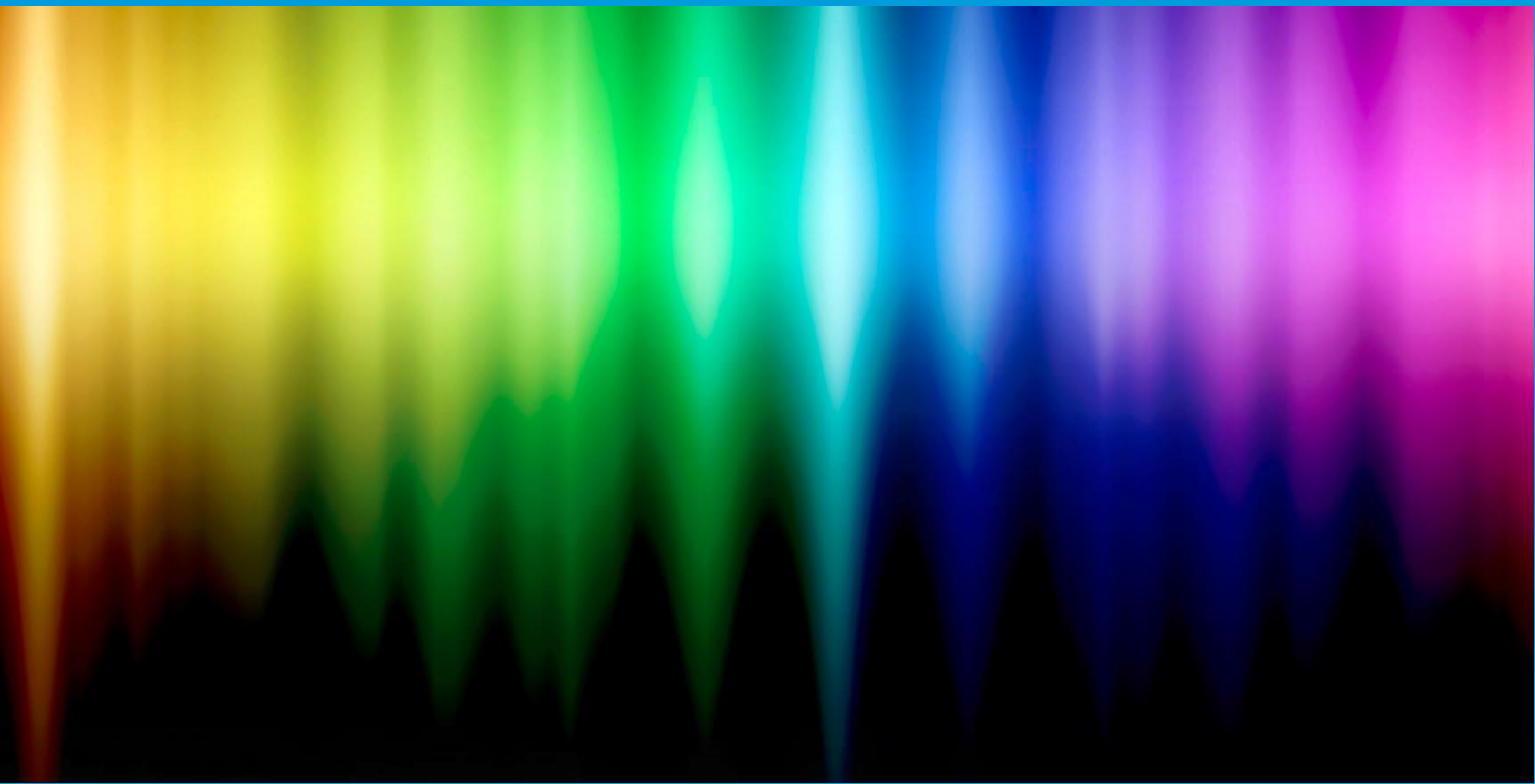


Mapping CST Technologies for Industrial Process Heating & Cooling

"Promoting Business Models for Increasing Penetration and Scaling up of Solar Energy""

April 2017

TABLE OF CONTENTS

List of Figures

List of Tables

1. Introduction

The United Nations Industrial Development Organization (UNIDO) in association with the Ministry of New and Renewable Energy (MNRE), Government of India (GoI) has started the implementation of the project titled “Promoting Business Models for Increasing Penetration and Scaling up of Solar Energy” in India. As per the TOR the following sectors were identified for incorporation of CST technologies.

S. No.	Sector	S. No.	Sector
1	Textiles (Weaving, Finishing)	8	Rubber
2	Pharmaceuticals	9	Chemical & Fertiliser
3	Tobacco	10	Petroleum Refineries
4	Breweries	11	Desalination
5	Pulp & paper	12	Ceramic tile & pottery
6.	Electroplating	13	Plaster of Paris, Steel re-rolling, Cement, Mining
7	Food processing (including Dairy & Sugar)	14	Other industries including tertiary using steam or cooling

This report is an extension of the process information booklet. The process information booklet showcased the key process information like process flow diagram, process description and heating & cooling requirements of 12 different sectors. Through secondary research and thorough consultation with relevant stakeholders (UNIDO officials, various technology providers, channel partners and industries/companies where the CST technologies have been successfully implemented) and analyzing the heat requirement of each sectorial process and mapping with the heat range of the available CST technologies, the following 12 different sectors were selected for further study:

- Food Processing Industry
- Textile Industry
- Breweries
- Pharmaceutical Industry
- Cement Industry
- Petroleum Refining
- Electroplating Industry
- Tobacco Industry
- Pulp and Paper Sector
- Desalination
- Rubber Industry

This report consists of the following studies.

- Identification and process mapping of concentrated solar thermal technologies which are suitable for addressing the heating and cooling requirement of the industries in the selected sectors.
- Cost of delivering the selected technology
- Development of successful case studies in India
- The major issues that are faced while integrating the concentrated solar thermal technology with that of the existing industrial processes.
- The challenges that are faced by the industries while integrating CST technologies operating these technologies.

2. Identification of Concentrated Solar Thermal (CST) Technologies for industrial processes

The main component of the solar system is the solar collector. The collector converts the solar radiation in to heat and the heat collected is captured in the working fluid (e.g. Water) which circulates into the system. Collectors which provide heat to medium temperature processes (80°C to 350°C) are different from the most commonly used collectors. For processes operating under medium temperature, special high performance collectors were developed by International Energy Agency's solar heating and cooling program. The exhibit below illustrates the characteristics of various solar thermal collectors that have been identified by MNRE (Ministry of New and Renewable Energy).

Table 1: Temperature characteristics of various CST

Collector type	Concentration	Indicative temperature range (°C)
Non Imaging Concentrator	No	Up to 120
Fixed Focus Elliptical Dish (Scheffler)	Yes	Up to 150
Fresnel Reflector based dish	Yes	Up to 350
Linear Fresnel Reflector (LFR)	Yes	Up to 250
Parabolic Trough Collector (PTC)	Yes	Up to 250
Paraboloid dish	Yes	Up to 350

Source: cshindia.in

This section of the report identifies the most suitable concentrated solar thermal technologies which are available for the respective processes of 12 different industrial sectors. It also portrays an overview of the cost of delivering such concentrated solar heating technologies and the area required for per unit generation of heat

2.1 Food Processing Industry

2.2 Introduction

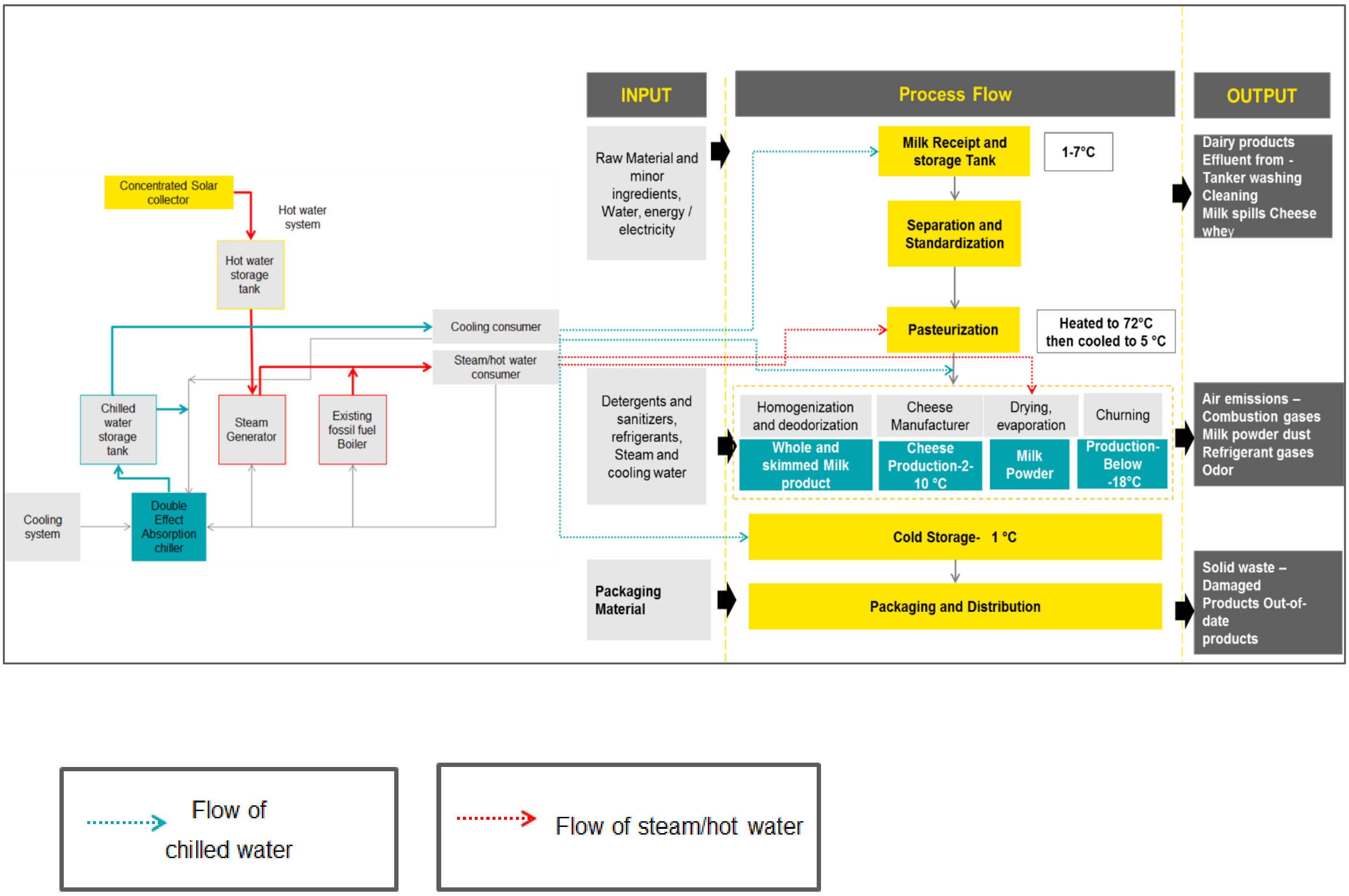
The food industry, which is currently valued at **USD 39.71 billion**, is expected to grow at a Compounded Annual Growth Rate (CAGR) of 11% to **USD 65.4 billion by 2018**. India ranks 12th in the World in exports of food and food products. Major industries constituting the sector are grain milling, sugar, edible oils, beverages, fruits & vegetables processing and dairy products. During FY11–16, India's exports of processed food and related products grew at a **CAGR of 11.74%,** reaching USD 16.2 billion. In FY17 India's exports stood at USD 1.3 billion.

India is the second largest food producer in the world after China. The Indian food processing industry accounts for 32% of the country's total food market, 14% of manufacturing GDP, 13% of India's exports and 6% of total industrial investment.

<u>Process in food processing industry in dairy unit</u>

The exhibit below illustrates the possible processes where CST technology integration is possible in diary processes.

Figure 1: Application of CST technology in diary industry



4.1. Process Description- Dairy Product Processing

#	Process Area		Description
1.	Collection and storage		• After collecting the milk from various sources, it is stored at less than 7 °C at the plant and is usually processed within 24 hours, but can be held for up to 72 hours (3 days) before processing
2.	Separation		• Centrifugal separation and clarification is generally followed for separating dirt particles, udder cells and bacteria
3.	pasteurization		• It reduces the activity of microbes rather than killing it
4.	Product manufacturing	Homogenization and deodorization for milk	• Homogenization prevents gravity separation of the fat in the product and to improve the s stability of mainly cultured products. • The homogenizer consists of a high-pressure pump and homogenizing valve driven by a powerful electric motor
		Cheese manufacturing	• The process includes culturing coagulation, draining, scalding and mold ripening.
		Drying for milk powder	• The pasteurized milk is dried using hot air
		Butter Production	• Butter is produced as batches in churns or continuously in a continuous butter-making machine. • Although churns are still used today, most of them have been replaced by continuous machines. • The churning step produces buttermilk, which represents a potential waste stream unless collected for sale.
		Ice cream	• Ice cream manufacture involves the handling of both dry and liquid raw materials including reception of milk, cream, sugar and other
5.	Cold Storage		• The products are stored before distribution
6.	Packing and Distribution		• Packaging protects the product from oxygen, light and bacterial contamination,

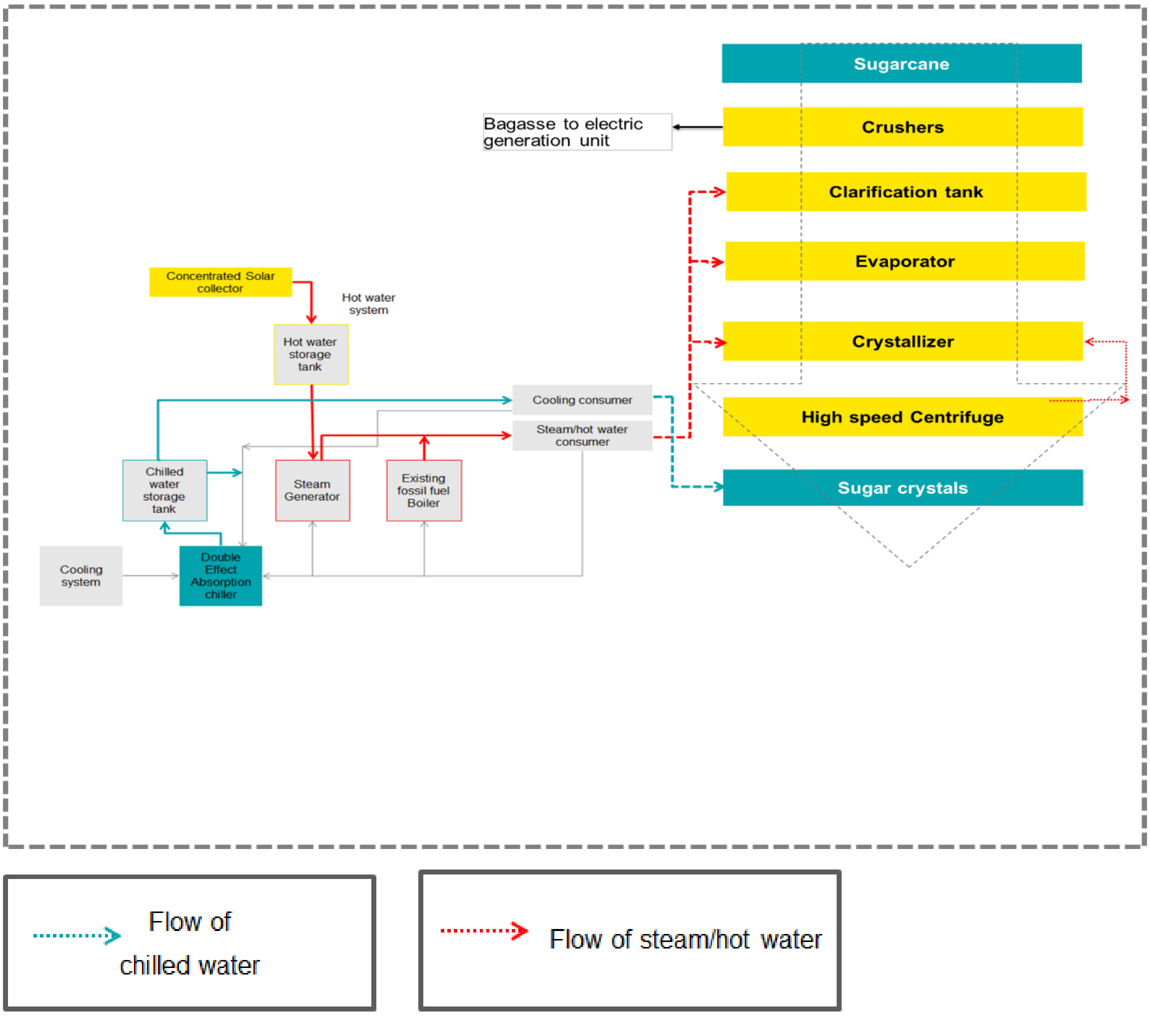
The exhibit below illustrates the possible processes where CST technology integration is possible in cattle, poultry and fish processing processes.

Sugarcane Industry

India is the largest consumer of sugar in the world with a consumption of 16 million tons per year having 633 sugar mills (approximately) in the country. The mills are mainly located in the states of Uttar Pradesh, Maharashtra, Karnataka, Gujarat, Tamil Nadu, Andhra Pradesh, Bihar, Punjab, and Orissa contributing to more than 85% of total sugar production in India.

The industry has an annual turnover of INR 500 million providing employment to 5 million people in the country

Figure 2: Application of CST technology in sugarcane industry

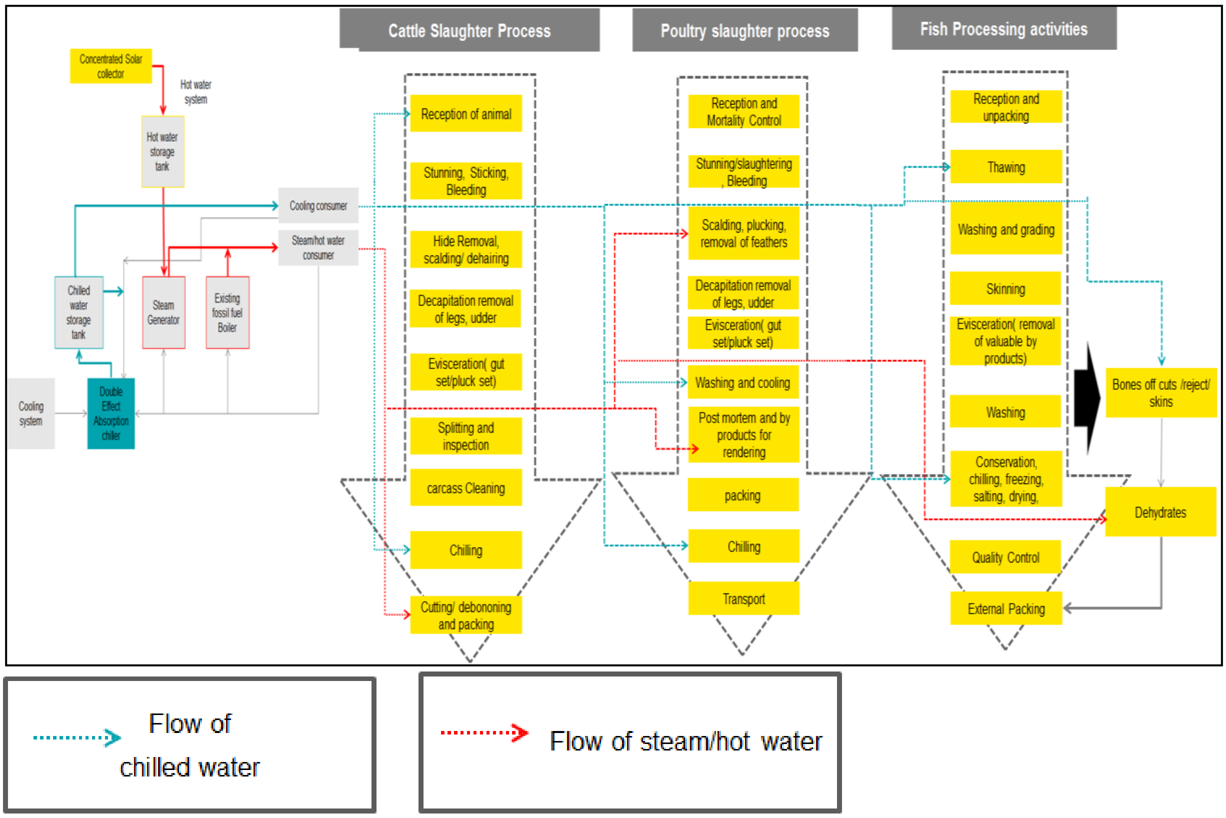


Process Description- Sugarcane Industry

No.	Process	Description
1.	Sugarcane crushing and juice extraction	The Sugarcanes are cut into pieces and crushed in a series of rollers to extract the juice, in the mill house. The milk of lime is then added to the juice and heated, when all the colloidal and suspended impurities are coagulated. During this treatment, much of the color is also removed.
2.	Clarification	The clarification (or defecation) process is designed to remove both soluble and insoluble impurities (such as sand, soil, and ground rock) that have not been removed by preliminary screening. The process employs lime and heat as the clarifying agents.
3.	Evaporation	For concentration of the clarified juice (containing 85% water), about two-thirds of the water is removed through vacuum evaporation. Generally, 4 vacuum-boiling cells or bodies are arranged in series so that each succeeding body has a higher vacuum (and therefore boils at a lower temperature). The vapor from the last cell goes to a condenser. The syrup leaves the last body continuously with about 65 percent solids and 35 percent water.

No.	Process	Description
4.	Crystallization	Crystallization takes place in a single-stage vacuum pan. The syrup is evaporated until saturated with sugar. When the saturation point has been exceeded, small grains of sugar are added to the pan which serve as nuclei for the formation of sugar crystals. Additional syrup is added to the strike and evaporated so that the original crystals that were formed are allowed to grow in size. Crystallization continues in the crystallizers as the massecuite (dense mixture of syrup and sugar crystals) is slowly stirred and cooled.
5.	Centrifuging	The high-speed centrifugal action is used to separate the massecuite into raw sugar crystals and molasses. The centrifugal machine has a cylindrical basket suspended on a spindle, with perforated sides lined with wire cloth. The basket revolves at speeds from 1,000 to 1,800 RPM. The raw sugar is retained in the centrifuge basket because the perforated lining retains the sugar crystals. The mother liquor, or molasses, passes through the lining (due to the centrifugal force exerted). The final molasses (blackstrap molasses) containing sucrose, reducing sugars, organic non-sugars, ash, and water, is sent to large storage tanks.
6.	Drying and packaging	Damp sugar crystals are dried by being tumbled through heated air in a granulator. The dry sugar crystals are then sorted by size through vibrating screens and placed into storage bins. Sugar is then sent to be packed in the familiar packaging we see in grocery stores, in bulk packaging, or in liquid form for industrial use.

Figure 3: Application of CST technology in cattle, poultry and fish processing industry.



Process Description- Cattle Poultry and fish Processing Industry

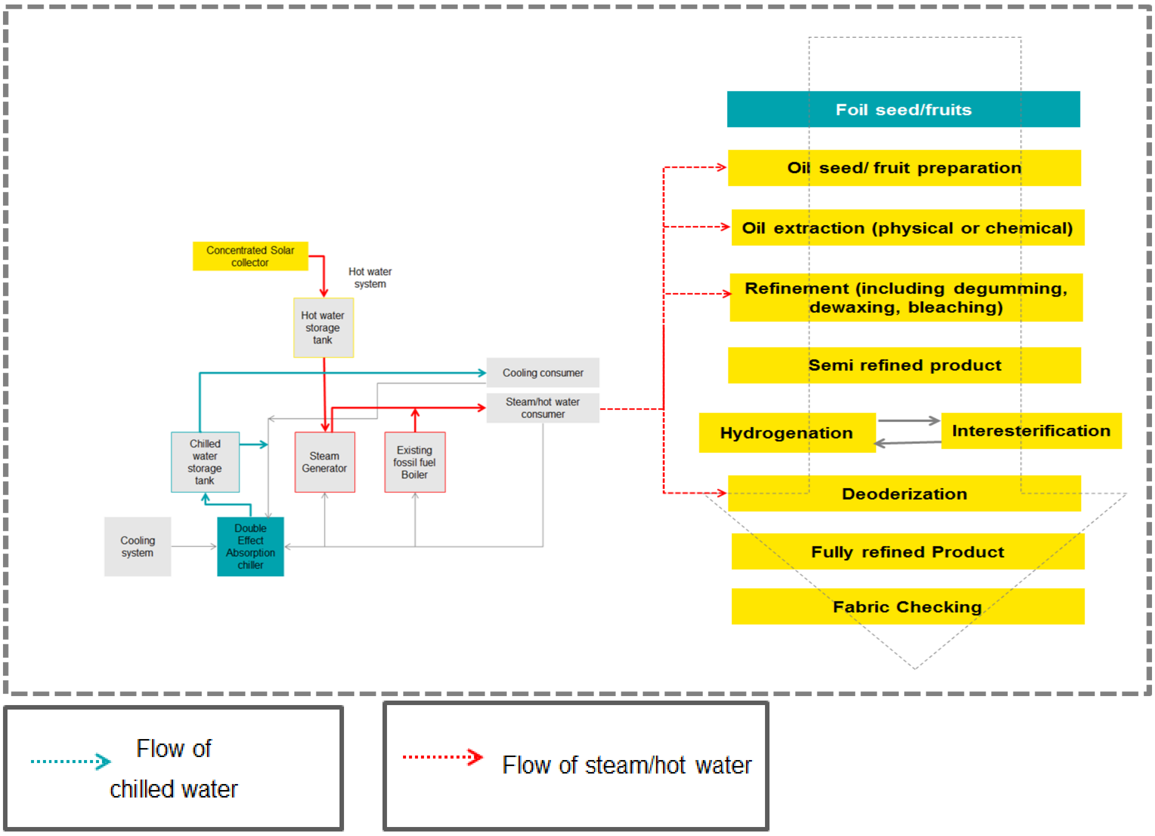
#	Process Area	Description

		Cattle	Poultry	Fish
1.	Reception of animal and fish	• Slaughter houses have separate arrangements for cows and pigs	.	• Raw materials are typically received at the fish processing facility from a commercial fishing vessel or fish farm
2.	Shackling and Stunning, Slaughtering and bleeding Fish are thawed	• Pigs are stunned with either CO_2 anesthetization or with electric stunning (a captive bolt pistol might alternatively be applied)	• The bird are cut with an extremely sharp knife and are bled at least for two minutes.	• Fresh raw fishes are graded and separated and frozen raw material has to • be thawed (e.g. under running water or with air at controlled • temperatures) , Usually temperature above 4 °C
3.	Scalding removal of leg and de capitation for meat skinning for fish	• For bovine the hides are removed manually • After bleeding of pig carcasses, they are immersed in the scalding tank (60°C) for about 3 to 6 minutes to facilitate the removal of the bristles and to loosen the toenails.	• After bleeding birds are scalded with water or steam at temperature greater 65°C and birds prepared for chilled distribution are scalded at 60 °C	• The processing phase begins with skinning and cutting where the edible parts are removed from waste products
4.	Evisceration	• Evisceration includes opening of the carcass at the belly and removing bladder, uterus, liver, and intestines. and liver kidney and heart undergo cleaning in separate departments	• The head and the leg are removed the head is used as animal by product and the legs are further processed, heated and treated for human consumption • Manual removal of internal organs takes place.	• Evisceration takes place at cutting table where head tail and inedible parts are removed any valuable by products like liver and roe are sent to separate process stream
5.	Carcass cleaning/ Filleting	• The carcass is split, cleaned, weighed and inspected and classified.	• The feather are plucked off with the help of a special machine	• After evisceration cleaned fish are cleaned and further cut and filleted
6.	Cutting/Deboning/ , salting drying	• To prevent retail cuts slaughter houses perform the following processing like. cutting, deboning, grinding, mixing with additives, pickling, • Smoking, cooking, and canning) to produce retail cuts.	• After rinsing the birds carcass are cooled quickly below 4 °C and are stored at coolers	• Preservation methods typically used in fish processing include • chilling and freezing**(0 °C to -18°C)**, canning, brining and salting, fermenting, drying, and smoking, which may be used in various combinations,

				such as fermentation with salting and drying
7.	Rendering/ dehydration	• Rendering is a heat treatment of animal by-products to eliminate the risk of spreading disease to animals and humans, and to produce usable products such as proteins and fat. Rendering includes evaporative processes that may generate a foul odor. from : 80 - 250 °C	• To reduce risk of spreading disease rendering is carried out The temperature varies from : 80 - 250 °C	• Primarily two by products: Fish meal and fish oil. • Raw material is cooked for 20 minutes at a temperature of around 90 °C. • Separation of oil from stick water. • Stick water is passed through several stages of evaporator • Then dried the inlet air temperature is maintained at 500 to 600°C to reduce moisture content ot less than 10 %.. High temperature is maintained to avoid formation of flue gas.

The exhibit below illustrates the processes where heat generated from CST technology can be applied in vegetable oil.

Figure 4: Application of CST technology in vegetable oil industry.



Process Description- Vegetable Oil

#	Process Area	Process Description
1.	Extraction	• Oil is extracted from beans, grains, seeds, nuts, and fruits. • The raw materials are received and weighed at the facility, cleaned to remove stalks, stones, and other matter, then weighed and stored before initial processing. • Oil extraction can be performed mechanically (e.g., by boiling fruits and pressing seeds and nuts) or in combination with a chemical extraction process using solvents (usually hexane). • Most large-scale commercial facilities use chemical extraction (with hexane) • The extraction is normally followed by skimming (boiled oils) or filtration (pressed fats), • Separation of the crude oil occurs from the solvent-oil mixture (miscella). • Hexane is removed from the oil through distillation, and from the flakes through steam vapor in a desolventizer and recovered for reuse after condensation and separation from water • Mechanical Extraction for olive 40° C
2.	Refining	The crude oil is refined to remove undesired impurities, such as gums, free fatty acids (FFA), traces of metals, coloring components, and volatile components The oil is refined either by chemical or physical process **Chemical Process** • Conventional chemical refining involves degumming (for the removal of phospholipids), neutralization (for the removal of FFA), bleaching (for decolorization) and deodorization • The mixture is then centrifuged for separation of Hydratable phospholipids • **During degumming, caustic soda is added to the oil, The oil is preheated to a temperature between 75°C and 110°C to saponify the FFA** • This process gives rise to two main outputs, namely semi refined oil and soap stock. • The soap stock is removed by precipitation, followed by sedimentation or centrifugation, and may be further processed into acid oils by splitting. • **The soap stock is heated to between 70°C and 100°C and reacts with sulfuric acid to reform the fatty acids.** • The neutralized oil is bleached to remove coloring matter and other minor constituents prior to deodorization. Spent bleaching earth is the main solid waste arising from this stage. Physical refining • Physical refining is a more simple process in which the crude oil is degummed and bleached, and then steam-stripped to remove FFA, odor, and VOCs all in one step. • A physical pretreatment can be used to achieve a low phospholipid content by degumming and using bleaching earth. • FFA can be stripped from the physically pretreated oil by using steam in a vacuum at temperatures of around 250°C • Previous neutralization stages are not necessary because the neutralization and deodorization are combined. • A scrubber is then used to condense the greater part of the fat from the vapors as a water-free product
3.	Hydrogenation	• In this process fresh oil is deaerated and dried in a buffer tank. • Hydrogenation is usually carried out by dispersing hydrogen gas in the oil in the presence of a finely divided catalyst (usually nickel), supported on diatomaceous earth.

#	Process Area	Process Description
		• The resultant hydrogenated fats are filtered to remove the hydrogenation catalyst, subjected to light earth bleach, and deodorized before they can be used for edible purposes. • After hardening, the oil is mixed with an aqueous solution to produce an emulsion. • The emulsified mixture is then pasteurized, cooled, and crystallized to obtain the final product
4.	Inter-esterification	• Inter-esterification involves the separation of triglycerides into fatty acids and glycerol, followed by recombination. • The reaction is carried out using phosphoric or citric acid with a catalyst, typically sodium methoxide.
5.	Deodorization	• The bleached oil is steam-distilled at low pressure to remove volatile impurities, including undesirable odors, flavors, and pigments. • Volatile components are removed from the feedstock using steam in a process that may last from 15 minutes to five hours. • The vapors from the deodorizer contain air, water vapor, fatty acids and other variables. • Before entering the vessel, the vapors passes through a scrubber and a scrubbing liquid is sprayed into the vapor stream. • Fatty acids and volatiles partly condense on the scrubbing droplets or alternatively on the packing material. • The deodorization process produces the fully refined, edible oils and fats

The exhibit below illustrated the heating and cooling requirement in the Food Processing sector.

Table 2: Heating and cooling requirement in food processing industry

Processes	Temperature (°C)
Collection and storage	1 to 7° °C
Pasteurization	Pasteurization using High temperature Short Time (HTST). The milk is heated **to 72 °C** then chilling to a temperature of less than 5°C. The storage maintains the milk temperature to 5°C. refrigerant is required
Cheese Manufacturing	2 to 10 °C
Ice cream	Below -18 °C
Cold storage	1°C
Milk Powder	deg C
Washing	
Poultry , meat and fish	
Fish are thawed	temperature above 4 °C
Cutting/Deboning/, salting drying	(0 °C to -18°C) fish
Rendering/ dehydration meat and poultry	80 - 250 °C
Manufacturing of fish oil and fish meal	90 °C.
Drying	500 to 600°C
Vegetable Oil	
Mechanical extraction of oil	40°C
Chemical refining - Degumming(oil is preheated)	75 to 110°C
Chemical refining - Soap stock heating	70 to 100°C
Physical refining	250°C
Overall sectorial temperature requirement	
Chilling / cold storage	<5°C
Cooking, extraction, mashing, baking	150 to 250 °C
Pasteurization / Blanching	<100^{0}C
Drying / Dehydration	70 to 150°C
Milk Powder preparation	180 to 300°C
Honey Processing	100 to 150 °C

Processes	Temperature (°C)
Sugarcane	
Sugarcane crushing and juice extraction	Standard temperature
Clarification	Standard temperature
Evaporation	
Crystallization	
Centrifuging	
Drying and packaging	Standard temperature

The table below illustrates the suitable concentrated solar thermal technology in food processing sector, their indicative temperature, cost of delivery and output.

Table 3: CST technologies suitable for food processing industry

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Relevant Processes
Linear Fresnel Reflector (LFR) Parabolic Trough Collector Paraboloid dish & NIC	Up to 250	18000	**Diary** ► ~~Collection and storage~~ ► Pasteurization ► Cheese Manufacturing ► Ice cream ► Milk Powder **Poultry , meat and fish** ► Fish are thawed ► Cutting/Deboning/, salting drying ► Rendering/ dehydration meat and poultry ► Manufacturing of fish oil and fish meal **Vegetable Oil** ► Mechanical extraction of oil ► Chemical refining - Degumming(oil is preheated) ► Chemical refining - Soap stock heating ► Physical refining

2.3 Textile Sector

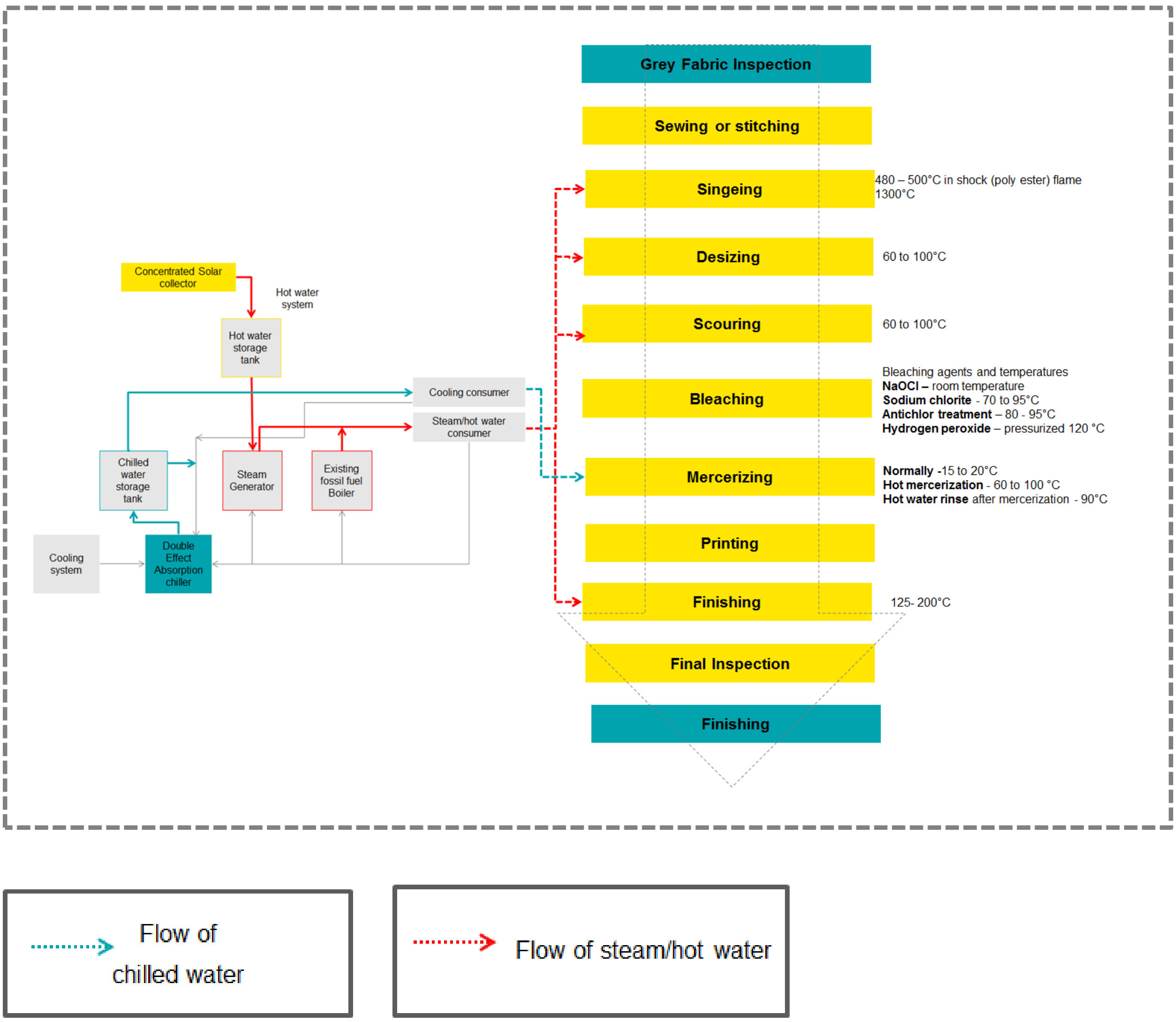
Currently in FY 2017-17 there is 9 million tons of fibre production in India which is expected to reach 10 million tons by 2017-18. **Current market size is** USD 108 billion and it is expected to reach USD 223 billion by 2021. The sector contributes 5% to India's GDP, and 14% to overall Index of Industrial Production .It has a potential to reach USD 500 billion, implying a sales rise to USD 315 billion from USD 68 billion. The industry (including dyed and printed) attracted Foreign Direct Investment (FDI) worth USD 1.85 billion during April 2000 to March 2016.

The Indian textile industry occupies the following position across the globe.

- Cotton – Second largest cotton and cellulosic fibers producing country in the world.
- Silk – India is the second largest producer of silk and contributes about 18% to the total world raw silk production.
- Wool –India has 3rd largest sheep population in the world, having 6.15 crores sheep, producing 45 million kg of raw wool, and accounting for 3.1% of total world wool production. India ranks 6th amongst clean wool producer countries and 9th amongst greasy wool producers.
- Man-Made Fibers- the fourth largest in synthetic fibers/ yarns globally.
- Jute – India is the largest producer and second largest exporter of the jute goods

The exhibit below illustrates the Concentrated Solar Heat Technology application in textile sector

Figure 5: CST technology integration in textile industry



Process Description: Combing yarn manufacturing[1].

Phase	Process Name	Process Description
1	Blow room	Following are the basic operation or objectives of blow room: • Opening • Cleaning • Mixing or blending • Micro dust removal • Extraction of impurities • Uniform feeding in machines such as carding machine. • Recycling the waste material • The output is lap or chute.
2	Carding	The second step in the yarn manufacturing process is the carding. The carding process is the heart of the yarn manufacturing process and comprises of the following activities • Removal of impurities, • Fibers are separated individually and are arranged into longitudinal direction or fiber alignment. • Fiber blending. • Removal of short fiber. • Formation of carded
3	Lap formation	After carding process the material is transferred to the draw frame in the form of sliver (rope).
4	Combing Section	• Combing section is used to get high quality yarn. The fiber comes in the form of lap. • The objective of the process is to remove the short length fibers and to retain the long length fibers. The sliver coming out of this process is smoother and longer. The sliver coming out is called combed sliver.
5	Roving Frame Section	• In the roving section the linear density of sliver is reduced and converted into roving (thin form of ropes). • In this step, a twister is inserted to make a yarn in the spinning mill. The output of this section is roving which will be further processed
6	Ring Spinning	The roving produced in the previous process is further drafted and the yarn is formed by elongating it for specific linear density and twisting it to create yarn strength and then winding it to a ring shaped bobbin. This section is divided into • **Drafting zone**: Increases the evenness and strength of the yarn • **Twisting zone:** In this zone the ring machine twists the yarn. The strength of the yarn depends upon the amount of twist the yarn makes. • **Winding zone:** Yarns are coiled around a plastic bobbin.
7.	Winding Process	• Winding involves transferring yarn from one type of package to another to facilitate subsequent processing. • Precision winders are used primarily for filament yarn and produce packages. • Drum winders are used mainly for spun yarns[2].

[1] Textile – Fibre to Fabric Processing P R Wadje
[2] IFC Environmental, Health and Safety Guidelines

Process Description of Fabric Manufacturing Process

Phase	Process Name	Process Description
1	Grey Yarn or Cones from weaving	• Yarns are received in cone forms. They are produced either by ring spinning or from open end spinning in single or double fold as required. For weaving, yarn used is categorized into: • Warp yarn- warping is required • Weft yarn- directly send for weaving[3]
2	Winding	• Winding involves transferring yarn from one type of package to another to facilitate subsequent processing. • Precision winders are used primarily for filament yarn and produce packages. • Drum winders are used mainly for spun yarns.
3	Warping	• The cones are put into creels and yarn from the cones is put together in sheet forms. • Direct warping: The sheets are wound on a barrel • Sectional warping: The sheets are wound around weaving beam. When yarn has different patches of coloration sectional warping is preferred.
4	Sizing	• Objective is to improve the strength and frictional resistance of the yarn. Chemicals are used to bind the threads • The sheets are formed by drawing yarn from several warp beams. • This process is important because during weaving, yarn has to undergo severe strain & stress as well as frictional operations
5	Drawing- in	• Weaving is interlacement to two sets wrap and weft threads in desired sequence • To weave the yarn is opened into two segments and the weft thread is inserted between the two sheets. This process is called shedding • The above process require warp yarn needs to be passed through heald eyes of the heald shafts, this operation is called as drawing-in
6	Beaming or Knotting	• Beaming is an activity during warp-making in which ends, withdrawn from a warping creel, are wound onto a beam to a length that is a multiple of the loom warp length

7.	Weaving	• Weaving is interlacement to two sets wrap and weft threads in desired sequence.
		• The weft thread is inserted between the wrap thefts with the help of different weaving machines
		• The different types of technologies available for weaving machines are briefly explained as below:
		  o Conventional Shuttle Weaving System by Ordinary Looms or Automatic Looms.
		  o Shuttle less Weaving System by Air jet / Water jet/Rapier/Projectile

Process Description of Wet Process

The wet process is divided into process coloration and finishing process. [4]

[3] Textile association of India
[4] Textile Manufacturing Process | Flowchart & Sequence _ Bijoy Rahman

Phase	Process Name	Process Description
1	**Singeing**	• Singeing is a process where the hairs or fabrics or fibers are removed. There are three techniques such as: o **Gas flame technique:** fabric gets smoother. o **Roller:** Fabric passes over the heated rotary copper cylinder. o **Heated Plate:** The fabric is kept over a heated plate.
2	**Desizing**	• It is used to remove materials sometimes done before weaving. Starches are often removed using enzymes by converting them to water soluble sugars.
3	**Scouring**	• Purifying step of looms using alkaline scouring agents like lime soda, caustic soda and soda ash. • Removal of impurities like waxes, proteins, machine oils, minerals, heavy metals, minerals, heavy metals and tars.
4	**Bleaching**	• Bleaching increases the whiteness of the textile. • Chlorine-based bleaches (sodium hypochlorite and sodium chlorite) or hydrogen peroxide are used for textile bleaching.
5	**Mercerizing**	• Mercerizing is the treatment of cotton yarn or fabric to increase its luster and affinity for dyes. • The fabric is treated with caustic soda solution and later with acids to neutralize
6	**Dyeing**	• It is the process of coloring fibers, yarns or fabrics with either natural or synthetic dyes. Dyeing requires temperatures in the range of 70 °C to 90 °C. • Dyeing involves 3 principal chemical processes retardation, migration and diffusion
7.	**Printing**	• Printing produces designs or motifs on the fabric by applying a colorant or other reagent, usually in a paste or ink. • There are several techniques which includes screen printing (in which a print paste is forced through a mesh, in contact with the substrate), sublimation printing (in which dyes that sublime readily are applied), and ink-jet printing.
8.	**Finishing**	• Manufacturing of garment s includes embroidery, garment assembly, home interiors, and other industrial uses of finished fabrics.

The exhibit below illustrates the heating and cooling requirement in the textile sector.

Table 4: Heating and cooling requirement in the textile sector:

Processes	Temperature(°C)
Singeing	480 – 500°C in shock (poly ester) flame 1300°C
De sizing	60 to 100°C
Scouring	60 to 100°C
Bleaching	Bleaching agents and temperatures **NaOCl –** room temperature **Sodium chlorite** - 70 to 95°C **Antichlor treatment** – 80 - 95°C **Hydrogen peroxide** – pressurized 120 °C
Mercerization	**Normally -**15 to 20°C **Hot mercerization** - 60 to 100 °C **Hot water rinse** after mercerization - 90°C
Combined desizing, scouring and bleaching	95°C
Combined scouring and bleaching	70°C
Drying	80 - 130°C
Finishing	125- 200°C

The table below illustrates the suitable concentrated solar thermal technology for the textile sector, their indicative temperature, cost of delivery and output.

Table 5: CST technologies applicable in textile sector

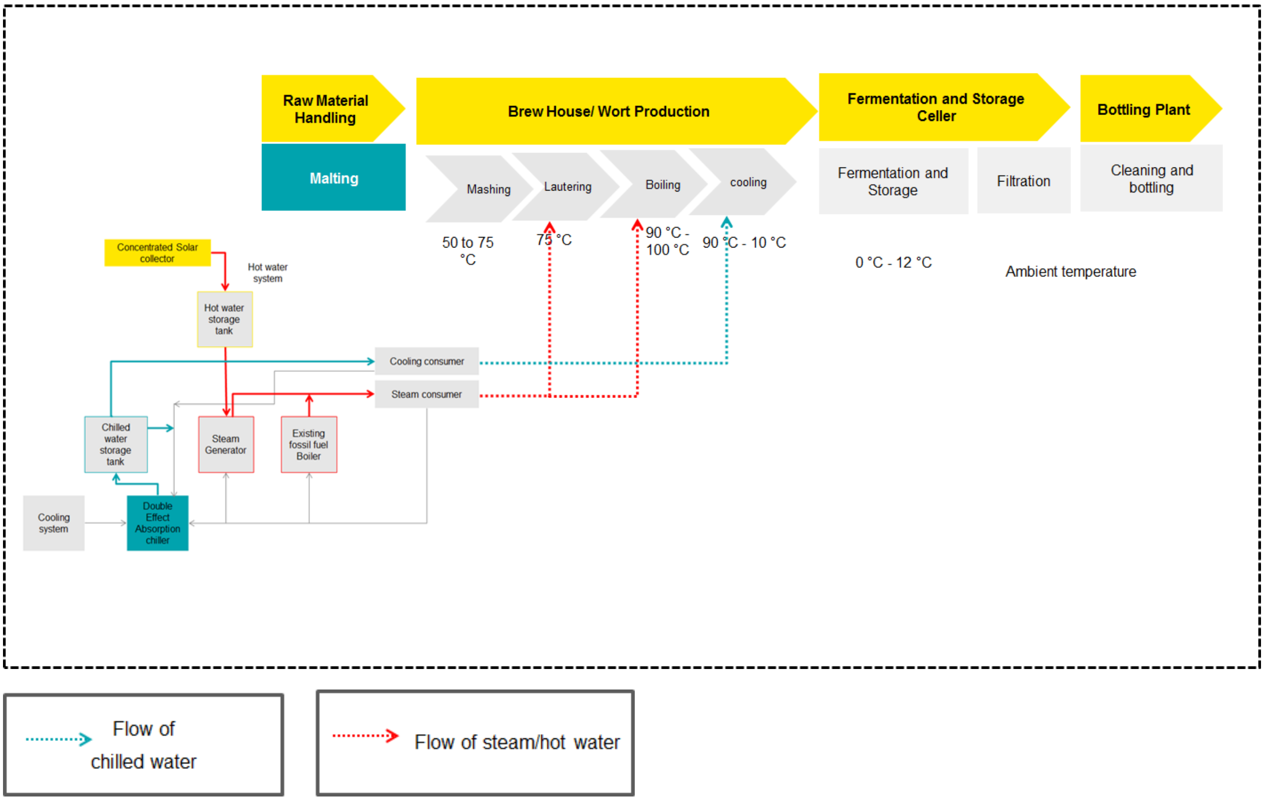
Applicable CST Technology(ies)	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Processes
Linear Fresnel Reflector (LFR)	Up to 250	18000	▶ Singeing ▶ De sizing ▶ Scouring ▶ Bleaching ▶ Mercerization ▶ Combined de-sizing, scouring and bleaching ▶ Combined scouring and bleaching ▶ Drying ▶ Finishing
Parabolic Trough Collector (PTC)	Up to 250	18000	
Paraboloid dish	Up to 350	20000	
Fresnel reflector based dish	Up to 350	20000	

2.4 Breweries

India is considered to be the third largest market for alcoholic beverages in the world. The country is the dominant producer of alcohol (65%) in South East Asian region. Alcohol use in India has registered a steady growth rate of 10 to 15% each year during the past decade.

The exhibit below illustrates the integration of concentrated solar thermal technology in breweries industry.

Figure 6: CST technology application in breweries



Process Description[5]

Phase	Process Name	Key Features
1.	Malting	Raw materials include cereal (barley malt, rice or maize), hops, water, and yeast. Malting convert starch into extractable sugar which are retrieved during mashing. Extracts from the hop are used as a preservative to add bitterness and yeast are further used for fermentation.
2.	Wort Production	• Once the cereals are cleaned and grinded the stage include mashing, lautering, worth boiling and cooling • **Milling:** ► Mixture of flour and husk are produced called grist ► Excessive dust should be produced to prevent spark and thereby preventing explosion • **Mashing:** After milling hot water is mixed with grist to for mash and is left alone. ► The objective is to extract high yield of fermentable extract.

[5] IFC Environmental, Health and Safety Guidelines

		▶ The extract is called wort. The major part of extraction takes place by means of the enzymatic breakdown of complex insoluble substances to simple water-soluble substances. • **Lautering:** Separation of the wort from the solid portion of the mash is called lautering. The filtrate is called the brewers grain. The wort is sold to the farmers for cattle fodder. • **Wort Boiling:** The wort is boiled for 1 to 1.5 hours. Heating and boiling of wort is extremely energy intensive. • **Wort Cooling:** ▶ Following boiling, the wort is cleaned, typically by passing it through a "whirlpool" which separates clean wort from residual solids known as trub. ▶ After clarification the wort is cooled by chilled water. Hot water arising from cooling can be used for the next batch of brewing
3.	Fermentation	• After cooling the wort is pumped into the fermentation vessel where yeast is added and fermentation starts • During fermentation, yeast converts sugar in wort to alcohol and Carbon-dioxide. The fermentation process is exothermic, and Temperatures are carefully controlled. • Carbon dioxide produced during fermentation may be collected for use in various brewery processes.
4.	Bottling Plant	• **Bottle Washing and Control:** Bottle washer where all internal and external impurities are removed. Bottle washer operations typically include soaking and washing, high temperature sterilization, and rinsing. • **Bottle Filling:** The bottles are transported by conveyor belts from the bottle washer to the filling machine. They are filled under pressure according to the quantity of dissolved carbon dioxide in the beer. An important process is to prevent oxygen to come into contact. Bottles are sealed immediately after filling. • **Pasteurization:** ▶ Beer is usually pasteurized to kill any remaining live yeasts or other microorganisms and prolong the shelf life. ▶ Two alternative methods are used for pasteurization: ○ **Tunnel pasteurization,** during which the beer is pasteurized in bottles or cans (i.e. the beer and container are pasteurized as a closed, assembled unit); ○ **Flash pasteurization,** which employs a heat exchanger in which the beer is pasteurized before it is filled into kegs.

The exhibit below illustrated the heating and cooling requirement in the breweries sector

Table 6: Heating and cooling requirement in the beverage sector

Processes	Temperature(°C)
Mashing	50°C to 75°C
Lautering	75°C
Boiling	90°C to 100°C
Cooling	100°C to 9°C
Sterilization	80 to 100 °C

The table below illustrates the suitable concentrated solar thermal technology for the breweries sector, their indicative temperature, cost of delivery and output.

Table 7: CST technologies applicable in breweries

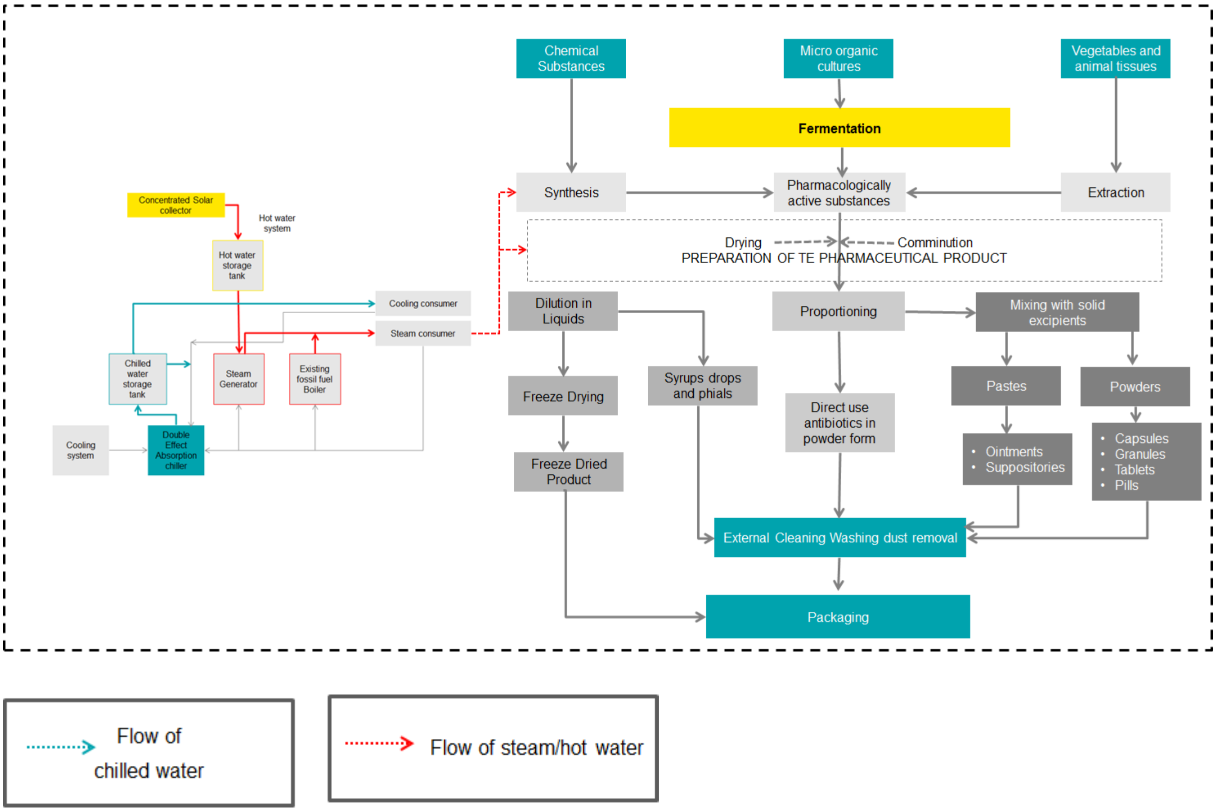
<table>
<tr><th>Suitable concentrated solar technologies</th><th>Indicative temperature of the technology (°C)</th><th>Cost of technology (INR/m^2)</th><th>Relevant processes</th></tr>
<tr><td>Non Imaging Concentrator</td><td>Up to 120</td><td>16000</td><td rowspan="2">• Mashing
• Lautering
• Boiling
• Cooling
• Sterilization</td></tr>
<tr><td>Fixed Focus Elliptical Dish (Scheffler)</td><td>Up to 150</td><td>18000</td></tr>
</table>

2.5 Pharmaceutical industry

The Indian pharmaceuticals market is the third largest in terms of volume and thirteen largest in terms of value, as per a report by equity master. Currently, the pharmaceutical industry stands at USD 20 billion. The Indian pharmaceuticals market increased at a CAGR of 12.79 per cent in 2015 from US$ 6 billion in 2005, and is expected to expand at a CAGR of 15.92 per cent to US$ 55 billion by 2020.Main clusters are found in Baddi in Himachal Pradesh, Delhi, Ahmedabad in Gujarat, Mumbai, Thane, Belapur in Maharashtra and Hyderabad in Andhra Pradesh.

The exhibit below illustrates an overview of the integration of concentrated solar technology in pharmaceutical industry

Figure 7: CST technology application in pharmaceutical industry



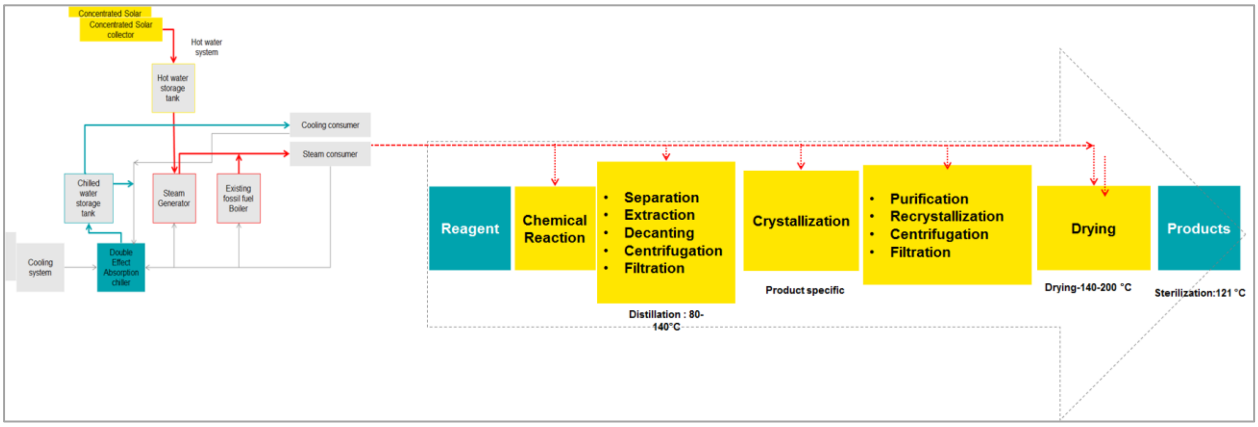
Process Description[6]

Phase	Process Name		Process Description
1	Research and Development		• Pre-clinical R&D: The compound are tested on animals. • Clinical RD,: Conducted in 3 phases , 1st phase determining safety oh humans, 2nd phase determining effectiveness of the drug on human and 3rd phase confirming the safety and human • Review of new drug application. • Post marketing surveillance: Monitoring the ongoing safety.
2		Chemical Synthesis	• Reaction: Raw materials are fed into a reactor vessel, where reactions such as alkylations, hydrogenations, or brominations are performed under controlled temperature and pressure

[6] ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY- Energy Efficiency Improvement and Cost Saving Opportunities for the Pharmaceutical Industry

			• Separation: The main types of separation processes are extraction, decanting, centrifugation, filtration, and crystallization • Crystallization: Formation of solid crystals from super saturated solution. The most common forms are cooling, solvent evaporation and chemical reaction • Purification: recrystallization, washing with solvents and filtration are some of the techniques • Drying: Drying is done by evaporating solvents from solids. Solvents are then condensed for reuse or disposal.
	Conversion of Natural Substances	Product Extraction	• Precipitation, purification, and solvent extraction methods are used to recover active ingredients from plants and tissues or to remove fats and oils from desired products.
		Fermentation	• Seed Separation: A medium containing microorganisms (Inoculum) are prepared in small batches. • Fermentation: The Inoculum is introduced to the fermenter, which is continuously agitated, aerated, and controlled for pH, temperature, and dissolved oxygen levels to optimize the fermentation it lasts from hours to weeks. • On completion of fermentation the desired by products are extracted by solvent extraction, precipitation or ion exchange process. • Sometimes heating or ultrasound might be required to break the cell wall of the microorganism
3	Formulation of Final Product		Conversion to useable forms: Common forms of pharmaceutical products include tablets, capsules, liquids, creams and ointments, aerosols, patches, and injectable dosages. • **Tablets**: They are produced by compression of powders • **Capsules are coated by gelatin**. First the gelatin mold is created to form the outer shell of the capsule. • **Ointments** are made by blending active ingredients with derivative or wax base. It is then cooled, rolled out, poured into tubes and packaged • **Liquid pharmaceutical formulations**, the active ingredients are weighed and dissolved into a liquid base. .Preservatives are added to prevent bacterial growth. • **Creams are semi solid emulsions** of oil in water and water in oil each phase is heated and then mixed together to form final product.

The exhibit below illustrates a simplified process of the pharmaceutical sector



Flow of chilled water

Flow of steam/hot water

The exhibit below illustrated the heating and cooling requirement in the breweries sector

Table 8: Heating and cooling requirement in the pharmaceutical sector

Processes	Temperatures (°C)
Distillation	80 to 140°C
Evaporation	160 to 250°C
Drying	140 to 200°C
Crystallization	Product specific
Sterilization	121°C, 2 bar
Granulation for drying	60 to 70°C[7]

The table below illustrates the suitable concentrated solar thermal technology for the pharmaceuticals sector, their indicative temperature, cost of delivery and output**.**

Table 9: CST technologies applicable in pharmaceutical sector

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Processes
Linear Fresnel Reflector (LFR)	Up to 250	18000	► Distillation ► Evaporation ► Drying ► Crystallization ► Sterilization ► Granulation for drying Finishing
Parabolic Trough Collector (PTC)	Up to 250	18000	
Paraboloid dish	Up to 350	20000	
Fresnel reflector based dish	Up to 350	20000	

[7] Clique solar – study on solar potential in pharmaceutical sector

2.6 Cement sector

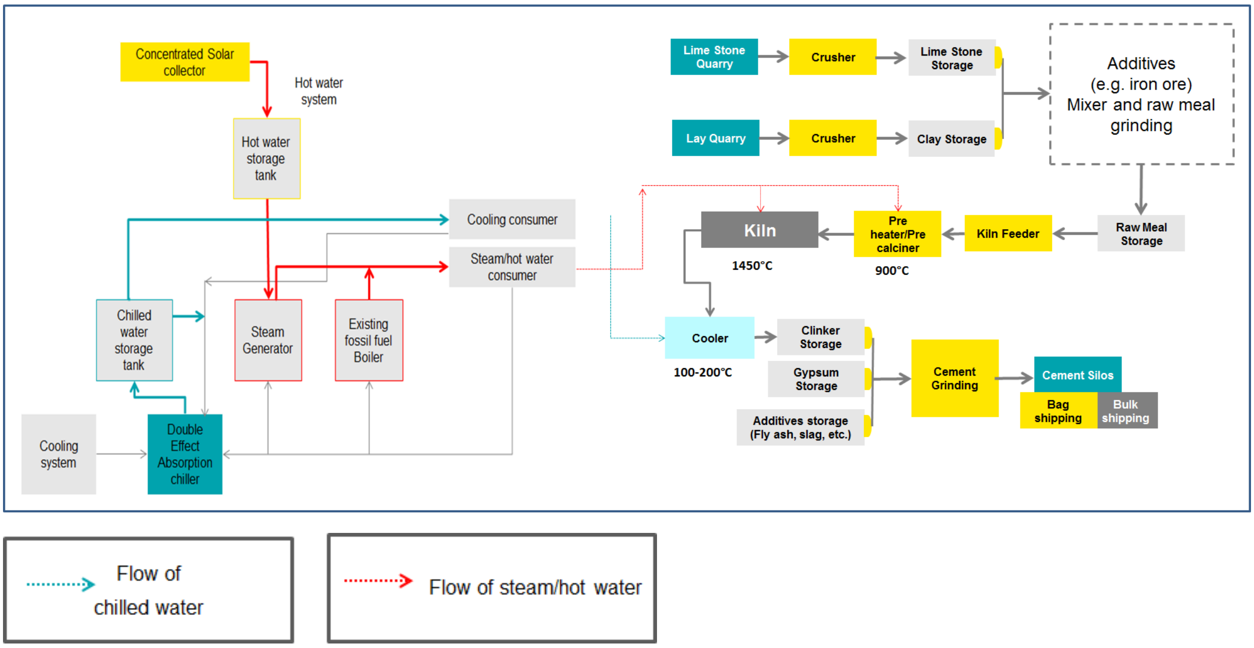
India is the second largest producer of cement in the world. The India cement industry provides employment to more than million people directly or indirectly. Ever since, it was deregulated in 1982, the Indian cement industry has attracted huge investments, both from Indian as well as foreign investors.

India's cement demand is expected to reach 550-600 million tons per annum (MTPA) by 2025. The housing sector is the major demand driver which accounts to 67 % and is followed by infrastructure, commercial development and industrial constructions. To meet the growing demand the expected capacity in 2017 is to add 56 million tons (MT). The current capacity is 366 MT and is expected to rise to 395 MT in 2016 and 421 MT in 2017.

The Indian cement industry is dominated by 20 cement companies which accounts for almost 70 per cent of the total cement production of the country. A total of 188 large cement plants together account for 97 per cent of the total installed capacity in the country, with 365 small plants account for the rest. Of these large cement plants, 77 are located in the states of Andhra Pradesh, Rajasthan and Tamil Nadu.

The illustrative below illustrated the Concentrated Solar Process Heat integration with the existing heating system in cement system

Figure 8: CST technology integration in cement industry



Process Description[8]:

Phase	Process Name	Process Description
1	Mining	• Mining is the first step for cement plant. • The raw materials are limestone (calcium carbonate, $CaCO_3$), clay (aluminum silicates), sand (silica oxide), and iron. • Hence all the cement plants are located near the quarry. So that the transportation cost is reduced. • There are also various other raw materials used for cement manufacturing. Some of them are shale, fly ash, mill scale and bauxite. These raw materials are directly brought from other sources because of small requirements

[8] IFC Environmental, Health and Safety Guidelines

Phase	Process Name	Process Description
2	Crushing	• Usually in a cement plant 80% limestone and 20 % clay is used to prepare the mix. • They are then grinded with the help of wheel type rollers and rotating table. • The fineness of the raw material is one of the most important factors for uniform burning.
3	Preheating	• After final grinding, the material is sent to the pre-heating chamber which of series of vertical cyclone from where the raw material passes before entering the kiln. • **Pre-heating chamber utilizes the emitting hot gases from kiln.** • Pre-heating of the material saves the energy and make plant environmental friendly.
4	Kiln	• It is the heart of the cement plant. • It is basically a huge rotating heating system. A temperature of 1450°C is maintained. • The mixture gets decarbonizes and forms a slurry. • On reaching the bottom the material is clinker shaped (clinkerization). The temperature of the flame and produced gases is close to 2000 °C
5	Cooling and Final grinding	• **Cooling** After passing out from the kiln, clinkers are cooled by mean of forced air to 100 °C to 200 °C. The heat released from the Clinker is reused by recirculating it back to the kiln. This saves energy • **Final Grinding** There is a steel ball that is used to grind the clinkers into powders
6	Packing	• Material is directly conveyed to the silos from the grinding mills. • The cement is packed in the bags only for those customers whom need is very small. • The remaining cement is shipped in bulk quantities by mean of trucks, rails or ships

The exhibit below illustrated the heating and cooling requirement in the cement sector

Table 10: Heating and cooling requirement in cement sector

Processes	Description	Temperature (°C)
Preheating	Preheating chamber uses the hot gases from the kiln. In this stage the calcium carbonate decomposes into calcium oxide and carbon dioxide(calcination) at around 900°C	900°C
Kiln	In the Kiln, the calcium oxide reacts with silica, alumina and iron oxide this process is called **clinkerization**. Where clinkers are produced.	Temperature at which the reaction takes place 1450°C Temperature of the flame and gases: 2000°C
Cooling Phase	The hot clinker produced in the above step enters the cooler and is cooled as quickly as possible.	1450°C to 100 – 200 °C

The table below illustrates the suitable concentrated solar thermal technology for the cement sector, their indicative temperature, cost of delivery and output.

Table 11: CST technologies applicable in cement sector

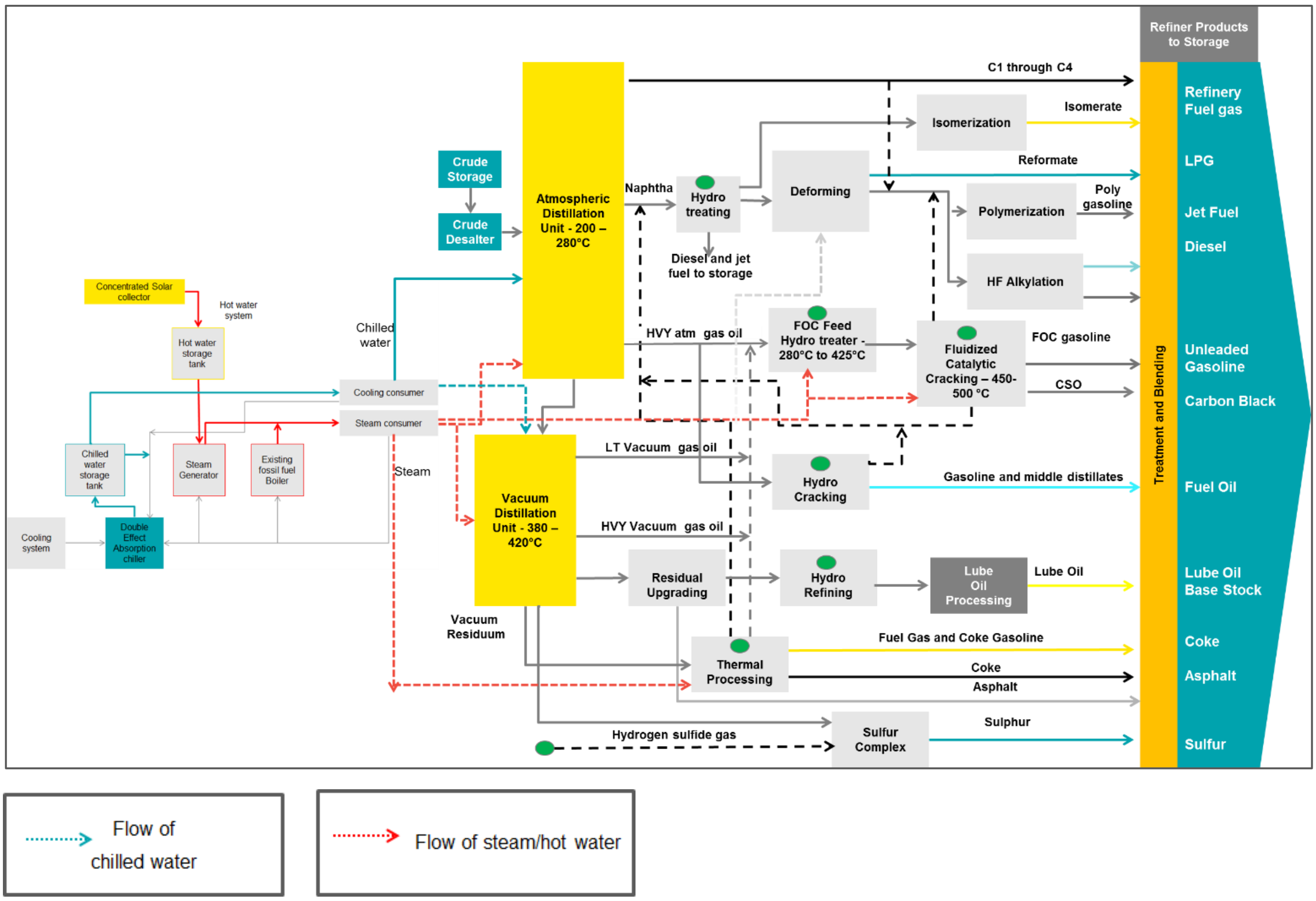
Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Process
Paraboloid Dish	Up to 350	20000	Preheating / pre calciner
Fresnel Reflector based Dish	Up to 350	20000	

2.7 Petroleum refining

Oil and gas industry ranks among the 6 core industries and India is the 4th largest consumer of crude oil and petroleum products in the world. India has India has 215.066 MMTPA of refining capacity, making it the second largest refiner in Asia after China[9]. Private joint venture companies own about 44% of total capacity. Major refineries are located in Bihar, Gujarat, Maharashtra, Tamil Nadu, West Bengal, Karnataka, Andhra Pradesh, Assam, Haryana and Kerala[10].

The exhibit below illustrates the integration of concentrated solar thermal technology in breweries industry.

Figure 9: Integration of existing CST technology with petroleum industry



[9] Make in India
[10] Map of India refineries in India

Process Description:

Phase	Process Name	Key Features
1.	Crude distillation Unit	• It comprises of 1. Atmospheric distillation unit 2. Side strippers 3. Heat exchanger network 4. Feed desalter 5. Furnace • The products coming out are gas & naphtha, kerosene, light gas oil, heavy gas oil and atmospheric residue. The temperature at the entrance of the furnace where the crude enters is 200 – 280°C. It is then further heated to about 330 – 370°C inside the furnace. The pressure maintained is about 1 bar
2.	Vacuum distillation unit (VDU)	• Since a low pressure is maintained at the previous process, the atmospheric residue do not decomposes and produces LVGO. • HVGO which are eventually subjected to cracking to produce even more lighter product • Atmospheric residue passes through the vacuum distillation unit and strippers to produce desire products. • **The pressure maintained is about 25 – 40 mm Hg.**
3.	Thermal Cracker	• Thermal cracking is a chemical cracking process which is followed by separation of constituents using physical principles like boiling point difference. • To produce coke, delayed coking is used instead of thermal cracking • **Operating Conditions: The temperature should be kept at around 450 – 500°C for the larger hydrocarbons to become unstable and break spontaneously. A 2-3 bar pressure must be maintained.**
4.	Hydro treaters	• Most of the crude are rich in sulfur content so the products coming out of ADU and VDU are rich in sulfur • Hydrogen is used for sulfur removal so that the sulfur is removed as hydrogen sulfide • The hydrogen that is used is obtained from the reformer unit where the naphtha is treated to form high octane number product. • **Operating Conditions: For Naphtha feed, the temperature may be kept at around 280-425°C and the pressure be maintained at 200 – 800 psig.**
5.	Fluidized Catalytic Cracker	• Most important step because a lower value heavy product is treated to produce a higher value lighter product • Desulfurized HVGO is transformed into lighter products like unsaturated light ends, light cracked naphtha, heavy cracked naphtha, cycle oil and slurry • **The temperature should be maintained at 34°C with pressure ranging from 75 kPa to 180 kPa. Moreover, the process is to be carried out in a relatively wet environment.**
6.	Separators	• The separator separates various gas fraction. For example C4 separator separates the desulfurized naphtha from all saturated light ends greater than or equal to C4s • C3 separator separates iso butane and n butanes from the gas fraction • C2 separator separates the saturated C3 fractions that are used for fuel gas production
7.	Naphtha slitter	• This unit have distillation columns which separates the heavy naphtha and the light naphtha • **Operating Conditions: The pressure is to be maintained between 1 kg/cm2 to 4.5 kg/cm2. The operating temperature range should be 167 – 250°C**

Phase	Process Name	Key Features
8.	Reformer	• Heavy naphtha do not have high octane number • A reforming unit is used to increase the octane number of the naphtha. It also produces light end products and reformed hydrogen. • **The initial liquid feed should be pumped at a reaction pressure of 5 – 45 atm, and the preheated feed mixture should be heated to a reaction temperature of 495 – 520°C.**
9.	Alkylation and isomerization	• The unsaturated light ends generated from the FCC process are stabilized by alkylation process using isobutene generated from the C4 separator. • The product has higher octane number than the feed stream and the isomerization unit helps in generating the required amount of iso-butane
10.	Gas treatment	• The product coming out of C2 separator contains hydrogen sulfide and useless gases. • The treatment unit converts hydrogen sulfide to sulfur and the gas to useful fuel gas which van be further used for furnace gases with furnace oil in the CDU • **Operating Conditions: Gas treaters may operate at temperatures ranging from 150 psig (low pressure units) to 3000 psig (high pressure units).**
11.	Blending Pools	To achieve desired product blending is carried out. There are 4 blending pools • LPG blending pool gives C3 LPG and C4LPG, • Gasoline pool is one of the most important blending pools .In this process the material is blended with appropriate amount of n-butane, reformate, light naphtha, alkylate and light cracked naphtha to produce premium and gasoline product. • The gasoil pool produces automotive diesel and heating oil from kerosene (from CDU), LGO, LVGO and slurry • In the fuel oil pool haring diesel, heavy fuel oil and bunker oil are produced from LVGO, slurry and cracked residue.
12.	Stream Splitter	To split different stream like kerosene splitter splits the kerosene that will be used for manufacturing kerosene product and the gasoil pool

The exhibit below illustrated the heating and cooling requirement in the petroleum refining sector

Table 12: Heating and cooling requirement in the petroleum sector

Processes	Temperature(°C)
Crude distillation Unit	200 – 280°C
Vacuum distillation unit (VDU)	The temperature is kept at around 380 – 420°C.
Thermal Cracker	450°C to 500°C
Hydro treater	280°C to 425°C
Naphtha Splitter	160 - 270°C
Reformer	499 - 520°C
Gas treatment	Gas treatment may operate at temperatures ranging from 150 psig (low pressure units) to 3000 psig (high pressure units).

The table below illustrates the suitable concentrated solar thermal technology for the petroleum refining sector, their indicative temperature, cost of delivery and output**.**

Table 13: CST technologies suitable for petroleum refining sector

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Processes
Linear Fresnel Reflector (LFR)	Up to 250	18000	► Crude distillation Unit ► Naphtha Splitter ► Reformer ► Gas treatment
Parabolic Trough Collector (PTC)	Up to 250	18000	
Paraboloid dish	Up to 350	20000	
Fresnel reflector based dish	Up to 350	20000	

2.8 Electroplating industry

The electroplating industry is divided into two categories

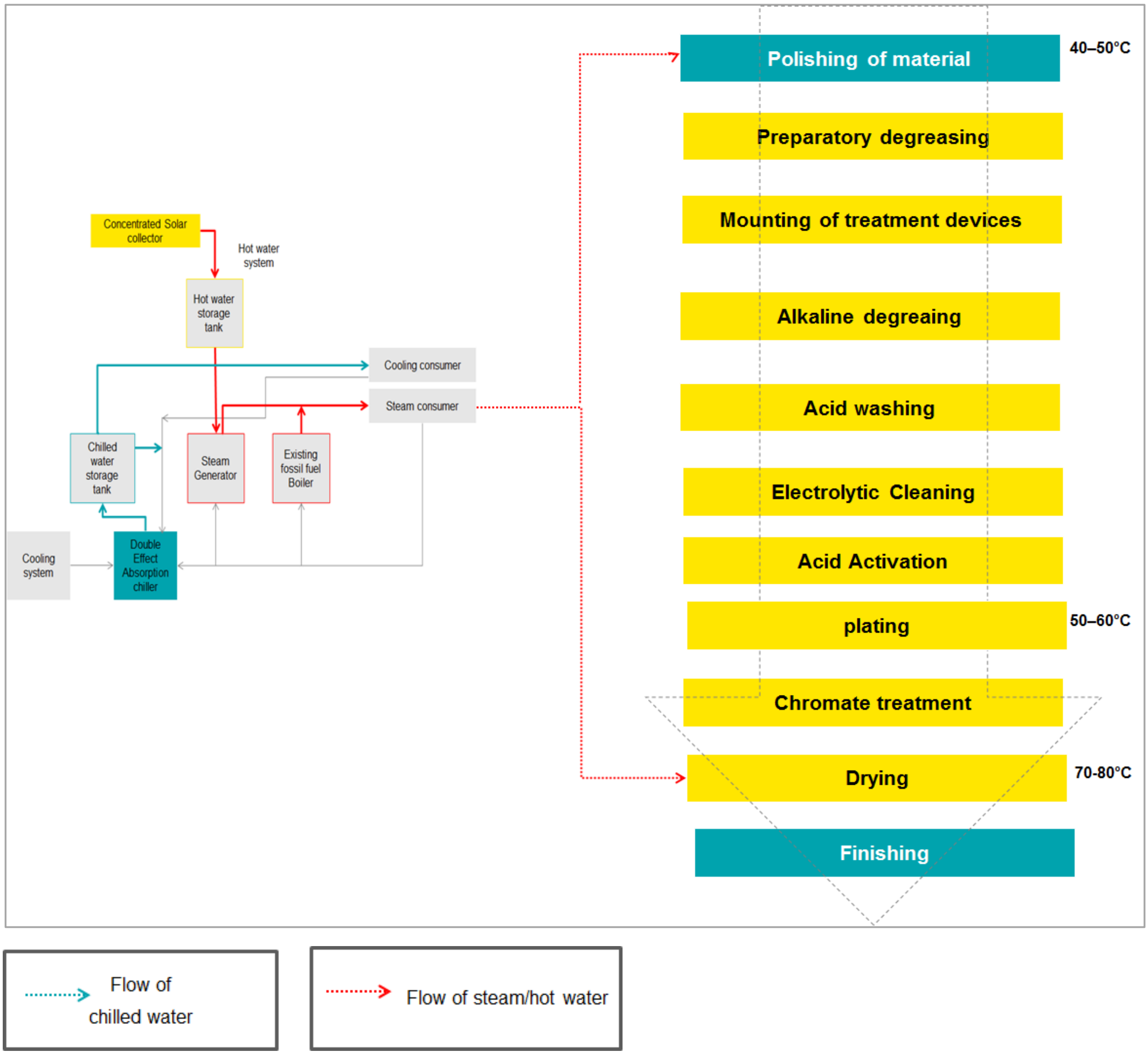
- Manufacturers who carry out electroplating as a part of finishing their product
- Units that carries out various types of electroplating

The industry employs 130,000 people in approximately 12,000 organized units and the average annual growth rate of the industry is around 16.66%

The major areas where electroplating industries can be found are Hyderabad, Delhi, Mumbai, Pune, Nasik, Ludhiana, Chennai, Madurai, Bangalore, Faridabad, and Ahmedabad.

The exhibit below illustrates the integration of Concentrated Solar Thermal technology in electroplating process.

Figure 10: CST technology application in electroplating industry



Process Description[11]

All plating process follows 6 steps which are Pre-processing, cleaning, plating, post plating treatment and post processes. The processes are described below.

Phase	Process Name	Key Features
1.	Pre processing	• Polishing, buffing, burnishing, etc. • Stripping off the plating or paint if the parts have been previously finished • Pre-process cleaning if the parts have heavy grease or buffing compound • Mounting of the parts on plating racks, wiring on to hooks or loading the small parts into plating barrels
2.	Cleaning	• Cleaners operate at a temperature range of 50 to 70 and are alkaline based. • The metals are soaked in the cleaner and electro cleaning is used • It is then followed by water rinse
3.	Activation	• It includes soaking the metal parts in acid or some acidic solution. In some processes electric current is also passed through the solution. This step also ends by rinsing with water.
4.	Plating	• Electroplating is also known as electro-chemical plating, is an electrolytic process. • In this process metal ions in an electrolyte solution are deposited onto a cathode. • Anode is generally made of metal being plated so it serves as source of coating metal. • Work piece where coating is to be applied is made the cathode. • Direct current from an external power source is passed through electrolyte solution. The electrolyte is an aqueous solution of acids, bases or salts. • Electrolyte conducts electric current by the movement of plate metal ions in solution.
5.	Post Plating Treatment	• Post-plating treatment can include chromate application over zinc plating, oxidation for the antique process, dyeing, dip lacquers • Parts are usually dried using a hot rinse followed by spinning or oven drying.
6.	Post Process	• Post-process treatments can include removing parts from plating racks and ten carrying out inspections, testing • Packing , buffing, grinding, spray lacquers or painting, baking, etc.

The table below illustrated the heating and cooling requirement in the electro plating sector

Table 14: Heating and cooling requirement in the electroplating sector

Processes	Temperature(°C)
Cleaning and washing	40–50°C
plating	50–60°C
Post plating / drying	70–80°C

The table below illustrates the suitable concentrated solar thermal technology in electroplating sector, their indicative temperature, cost of delivery and output.

[11] Identification of Industrial Sectors Promising for Commercialization of Solar Energy Commercialization of Solar Energy in Urban and Industrial Areas – ComSolar

Table 15: CST technologies suitable for electroplating sector

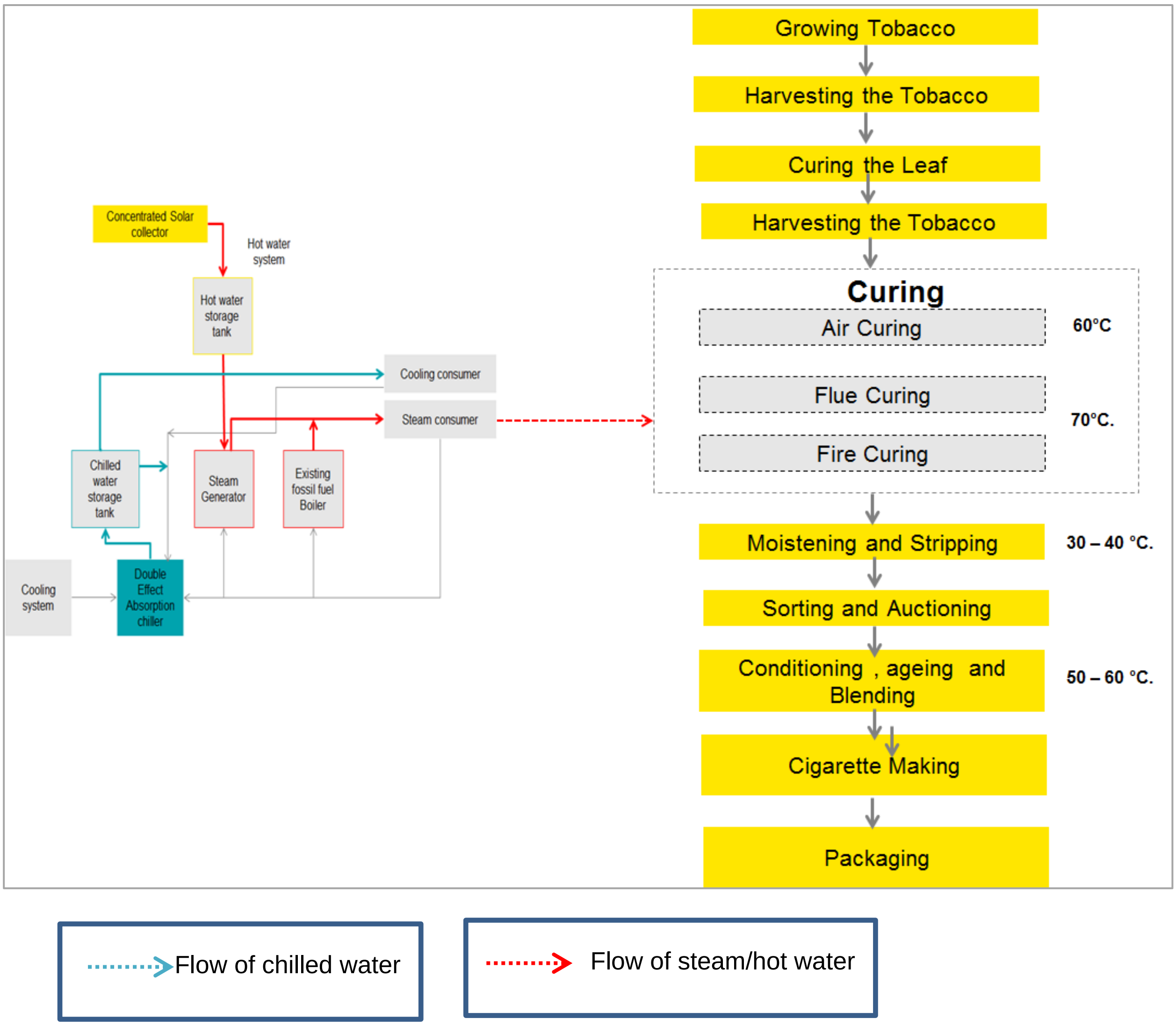
Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m²)	Processes
Non Imaging Concentrator	Up to 120	16000	▶ Cleaning and washing ▶ plating ▶ Post plating / drying
Fixed Focus Elliptical Dish (Scheffler)	Up to 150	18000	

2.9. Tobacco Industry

India ranks third among the tobacco production after Brazil and US. India exports tobacco to about 100 countries and has exported about 246 million Kgs of tobacco and tobacco products in the year 2014 -2015. Exports of Indian tobacco and tobacco products have grown at a CAGR of 9% to USD 918.9 million in 2014–15 from USD 502.2 million in 2007–08. The major Tobacco growing areas are Andhra Pradesh, Karnataka, Gujarat, Tamil Nadu, West Bengal, Assam, Bihar and Uttar Pradesh.

The exhibit below illustrates an overview of the concentrated solar heating technology in tobacco industry

Figure 11: CST technology application in tobacco industry



Process Description: Primary Process

Phase	Process Name		Key Features
1.	Growing of Tobacco		• Tobacco is initially grown in outdoor frames called seed beg • In warmer region it is covered with mulch or cotton top sheet and in cooler regions with plastic or glass. • After 10 week when the seedlings are almost 10 inches tall they are transplanted to the fields. • As the plant grow the heads are often broken off by hand so the leaves grow fuller. • The plant stays in the field 90 to 120 days.
2.	Harvesting of tobacco		• Tobacco are harvested by two methods: • Priming – the leaves are gathered and brought to a curing barn as they ripen. • Stalk cutting method the entire plant is cut and the plants are allowed to wilt before taken to curing barn.
3.	Curing	Air Curing	• Air curing uses natural weather condition to dry tobacco • Ventilators that can be opened and closed to control temperature and humidity. .Artificial heat is used during cold temperature and humid conditions.
		Flue Curing	• In flue curing artificial heating is done through air flowing from metal pipes attached to furnaces. • This method is problematic because smoke can come in direct contact with air. It takes around 4 to 6 days
		Fire curing	• Wood is burned. • The smoke generated from it comes in direct contact with the leaves thereby producing a smoky aroma. This process commences after the leaves arer dried naturally for 3 to 5 days and and they are fire dried for 3 to 40 days.
4.	Moistening and stripping		• Cured tobacco leaves are conditioned in moistening chamber. This prevents the leaves from being brittle. • Then they are passed through strippers where they are sprayed with additional moisture so that they do not crack or break.
5.	Sorting and auctioning		• The leaves are divided and graded on the basis of size cooler and quality. • They are put in bundles and taken to the ware house where they are graded again and auctioned to the manufacture.
6.	Conditioning, aging and blending		• After the cigarette manufacturer purchases it they treat and age the tobacco to enhance its flavor. • The manufacturer dries the leaves and then add uniform amount of moisture. • Pack them into barrels and age for 3 years • After it is aged the tobacco leaves are again moistened and the stalks and other wastes are removes. • Leaves of different tobacco are mixed and a particular flavor is created.
7.	Making of the cigarettes		• After blending the tobacco leaves are pressed intocakes and mechanically shredded • Additional flavors are added • The final shredded tobacco are dispersed over a continuous roll of paper • A machine rolls the paper around the tobacco and cuts it to a desired length • A device then grabs the cigarette and attach a filter to one end • Modern cigarette machine can produce 25 to 30 cigarettes a second
8.	Packaging		20s or 10 s pack. The hard and soft packs are mechanically sealed

Process Description: Reconstituted Tobacco Manufacturing

This process utilizes the waste tobacco generated from the cigarette manufacturing units. The process is involves the following steps.

- Raw material storage: receipt and storage of the raw materials;
- Extraction phase: extraction of the water-soluble materials;
- Evaporation phase: removal of water from the soluble material to concentrate the tobacco extract;
- Refining stage: changing the properties of the cellulose material for optimum sheet forming;
- Sheet formation: formation of the cellulose material into a sheet;
- Reapplication of concentrated tobacco extract: application of the concentrated tobacco extract onto the sheet; and
- Final drying stage: drying and cutting of the tobacco sheet to its final product specifications.

The exhibit below illustrated the heating and cooling requirement in the Tobacco sector

Table 16: Heating and cooling requirement in the Tobacco sector

Processes	Temperature(°C)
Leaf Drying	40°C
Stem Drying	70°C.
Re-drying	100°C
Favorable travel temperature	20°C
Softening	50°C - 60°C
Stemming and stripping	30 - 40 °C

The table below illustrates the suitable concentrated solar thermal technology in tobacco sector, their indicative temperature, cost of delivery and output**.**

Table 17: CST technology suitable for tobacco industry

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Processes
Non Imaging Concentrator	Up to 120	16000	► Leaf Drying ► Stem Drying ► Re-drying ► Favorable travel temperature ► Softening ► Stemming and stripping
Fixed Focus Elliptical Dish (Scheffler)	Up to 150	18000	

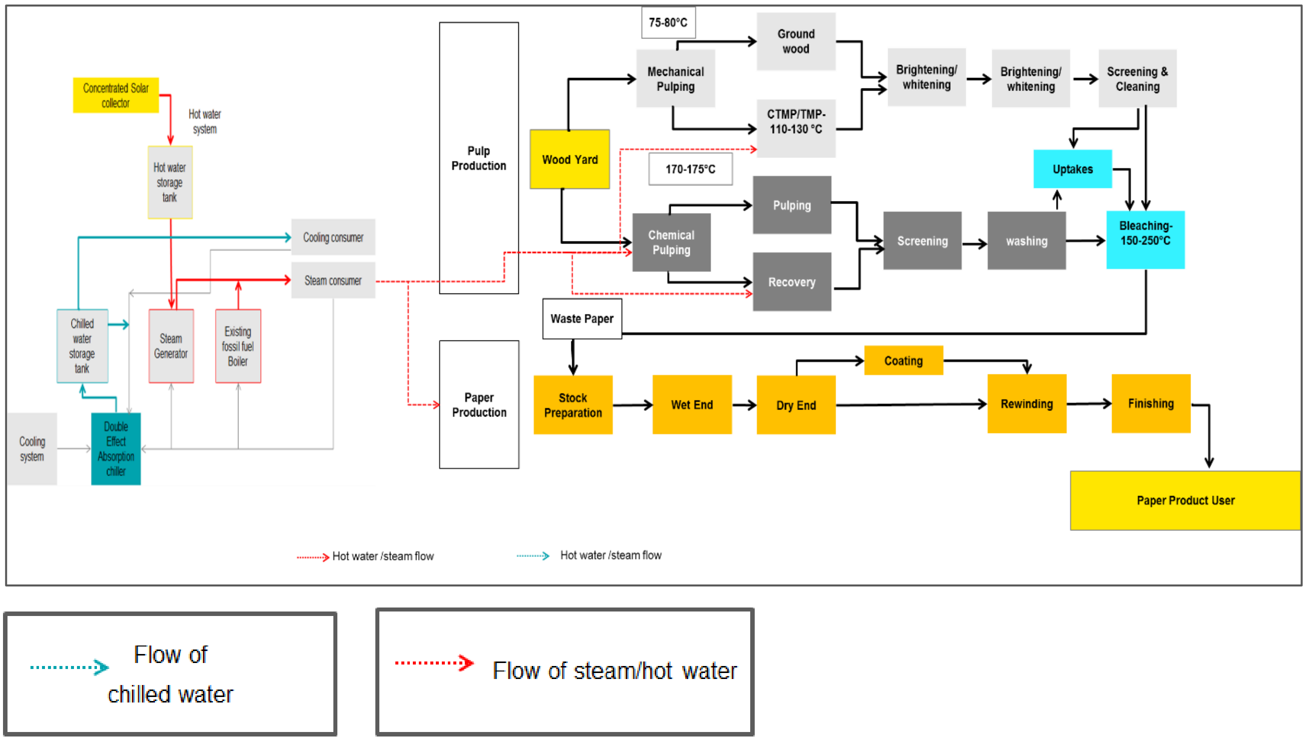
2.9 Pulp and Paper Sector

The pulp and paper sector is one of the most energy-intensive sectors within the Indian economy. The paper industry in India accounts for about 1.6% of the world's production of paper and paperboard.

There are about 515 units engaged in the manufacture of paper, paperboards and newsprint in India. The clusters are found in Titagarh, West Bengal, Pune, Ballarshah, Maharashtra, Kaghaznagar, Kamalapuram, Sarapaka, Vikarabad, Kakinada, Rajahmudry, Andhra Pradesh, Jaykapuram, Gaganpur, Orissa, Kagithapuram, TamilNadu, Yamunanagar, Bahadurgarh, Haryana, Saharanpur, Uttar Pradesh, Dandel, and Goa

The exhibit below illustrates an overview of the concentrated solar heating technology in Pulp and Paper industry

Figure 12: An overview of CST technology application in paper industry



Process Description[12]:

Phase	Process Name	Key Features
1.	Raw Material Preparation	• Wood arrives in mills in various in variety of forms including wood logs, chips, and sawdust. • The logs are cut to manageable size and then debarked. • Acceptable lumber wood are removed from this stage. • Residual or waste wood from lumber processing is returned to the chipping process • Bark from the lumber is removed mechanically in order to prevent contamination • Most of the pulping process required uniform size chipped wood • Screening takes place where the too large and small chips are removed. Large chips goes for re-cutting and small chips are used for other purposed and enters the rejected bark stream.

[12] Environmental, Health, and Safety Guidelines, pulp and paper mills, IFC

Phase	Process Name	Key Features
		• Non wood fibers are handled in a manner that will minimize degradation and maximize pulp yield.
2.	Pulping	• Pulping is a process where cellulose that acts as a natural binder are broken down into specific fibers known as pulp. • They are categorized into chemical and mechanical pulping process **Chemical Pulping:** Primarily relies on chemical reactants and heat and to soften and dissolve lignin in wood chips and refine them further using Mechanical process. • Principal chemical pulping processes include the alkaline sulfate or Kraft pulping process, acid sulfite, and semi-chemical pulping.
		Kraft Pulping • Kraft pulping represents approximately 80% of current pulp production worldwide and virtually all new construction. • The wood chips are broken down into lignin and hemicellulose • This process requires mixing of the chips in a digester with white liquor and an aqueous solution of sodium sulfide and sodium hydroxide. • Once the process is completed the liquor is separated from the stock. The pulp is called the brown stock • The brown stock is treated with oxygen and sodium hydroxide to remove certain residual lignin. This process is called oxygen delignification. • The brown stock is then bleached, to achieve desired brightness, strength, and purity of the final pulp product. • Recovery of feed stock: o Black liquor is recovered by evaporation of water and then burned in a recovery furnace, which destroys the organic constituents and generates heat used to make steam for other facility uses. o Green liquor is a mixture of sodium carbonate and sodium sulfide which is formed at the bottom of the recovery boiler. o In Causticizer calcium oxide is added to the green liquor and it is converted to white liquor which is used as a feed in the digester. **Sulfite Pulping Process** • The main constituents are aqueous sulfur dioxide and a base. The base varies and affects the process conditions, chemical and energy recovery, water use, and properties of the pulp. • Both calcium and magnesium sulfite process is considered environmentally unacceptable. • Sodium and ammonium base are considered expensive • Although calcium base is considered inexpensive but the materials cannot be recovered. • Another limitation is that the energy consumption is much higher compared to Krafts process. **Semi chemical Pulping:**

Phase	Process Name	Key Features
		• In semi-chemical pulping, wood chips are partially digested to weaken the bonds between fibers, and then the chips are then mechanically treated in a refiner, which uses mechanical action to separate the fibers. • The most common semi-chemical pulping process is the neutral sulfite semi-chemical (NSSC) process • Since liquors contain lower concentrations of organic substances than those from Kraft and sulfite processes, chemical recovery is more costly.
		Mechanical Pulping Mechanical pulping involves pretreatment of wood with steam heat and/or weak chemical solution but primarily relies on mechanical equipment to reduce wood into fibrous material by abrasive refining or grinding. The two categories are • Thermo-mechanical Pulping(TMP) • Chemi -Thermomechanical Pulping(CTMP) Mechanical pulping gives high yields, but the mechanical disintegration requires high amounts of electric energy in the refining processes. Thermo-mechanical Pulping(TMP) • Wood chips are usually washed before thermo- mechanical pulping to remove stones, sand, scrap metal or other hard debris. • Steam is used to preheat the chips • Then they are refined either in a single stage at an elevated temperature and pressure or two-stage refining system • Better fiber fragmentation and formation of fine material • TMP pulp is most often used for newsprint. • The high amount of electrical energy used in refining is converted into heat as steam **Chemi -Thermomechanical Pulping(CTMP)** • The CTMP process is a combination of TMP process with chemical treatment of the wood chips. • Washed and screened wood chips are immersed in an alkaline chemical solution of Sodium sulphite (Na_2SO_3) and alkaline peroxide for hardwoods. • Yields is lower than TMP
3.	**Deinking**	• Deinking processes are used to remove ink to make the pulp brighter and cleaner. • Recycled fiber with deinking is used in newsprint, magazine paper and tissue. • Some products like corrugated board, carton board, and some tissue might not require high brightness • Deinking process may result to lower yield
4.	**Bleaching**	• Bleaching increase the pulp's brightness. Bleached pulps create papers that are whiter, brighter, softer, and more absorbent than unbleached pulps • Type of product and pulping process affect the quality of bleaching.

Phase	Process Name	Key Features
5.	**Papermaking**	• After pulping (and bleaching, if applicable), the finished pulp is processed into the stock used for paper manufacture. . • Processing of pulp in integrated mills includes pulp blending dispersion in water, beating and refining to add density and strength, and addition of any necessary wet additives. • The processed pulp is converted into a paper product via a paper production machine, • Water is removed by gravity, vacuum chambers, and vacuum rolls. • The continuous sheet is then pressed between a series of cylinders to remove more water and compress the fibers. • After pressing, the sheet enters a drying section, where the paper fibers begin to bond together as steam heated cylinders compress the sheets. • In the calendar process, the sheet is pressed between heavy rolls to reduce paper thickness and produce a smooth surface. • Coatings can be applied to the paper at this point to improve gloss, color, printing detail, and brilliance. • The paper product is the spooled for storage.
6.	**Recovery of white liquor**	Ancillary units have 4 broad stages • Evaporation • Combustion of the black liquor in the recovery boiler • Causticizing • Conversion of CaCO3 to CaO

The exhibit below illustrated the heating and cooling requirement in the Pulp and paper sector[13].

Table 18: Heating and cooling requirement in pulp and paper industry

Processes		Temperature(°C)
Kraft Pulping(cooking temperature)		170 to 175°C
pulping of rice straw, wheat straw, grasses jute sticks(Cooking temp)		135-140 C.
Refining mechanical pulping CTMP(hard wood -chemical soak)		75-80°C
Refining(thermo-mechanical pulping)	steam	110 to 120°C
	refining	100 to 130°C
Recovery of Black liquor[14]		
Conversion of calcium carbonate to calcium oxide		1000 to 1200°C
Black liquor evaporation[15]		150 to 250°C
Causticizing		100°C

The table below illustrates the suitable concentrated solar thermal technology in tobacco sector, their indicative temperature, cost of delivery and output.

Table 19: CST technologies suitable for tobacco industry

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Processes

[13] Allan M. Springer, Industrial Environmental control: Pulp and paper industry(Ney York,NY John Wiley sons, 19SS), p. 147
[14] http://nzic.org.nz/ChemProcesses/forestry/4C.pdf
[15] Identification of Industrial Sectors Promising for Commercialization of Solar Energy Commercialization of Solar Energy in Urban and Industrial Areas – ComSolar

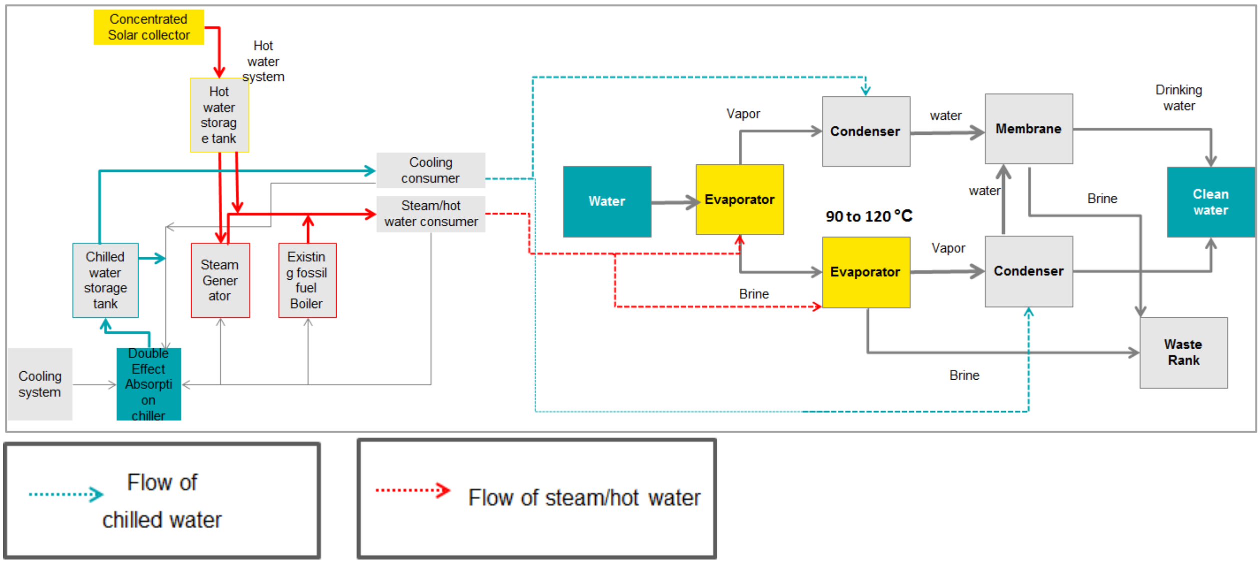
Linear Fresnel Reflector (LFR)	Up to 250	18000	► Kraft Pulping(cooking temperature) ► pulping of rice straw, wheat straw, grasses jute sticks(Cooking temp) ► Refining mechanical pulping CTMP(hard wood -chemical soak) ► Refining(thermo-mechanical pulping) ► Black liquor evaporation ► Causticizing
Parabolic Trough Collector (PTC)	Up to 250	18000	
Paraboloid dish	Up to 350	20000	
Fresnel reflector based dish	Up to 350	20000	

2.10 Desalination Industry

The desalination industry in India is currently estimated to be USD 660 million. It is estimated that the desalination business might grow to USD 1.6 billion within a span of 5 years[16]. Desalination plants are found in Chennai, Bangalore, Coimbatore, Mumbai, Salem, Pune, Goa.

The exhibit below illustrates the possible processes where heat generated from CST can be applied in desalination industry

Figure 13: Application of CST technology in desalination industry.



Process Description:

Type	Processes in use	Key Features
Thermal Process		
1.	Multi Stage Flash Distillation Process	The seawater passes through the heating stages and is heated further in the heat recovery sections of each subsequent stage. The feed water is further heated in the brine heater using externally supplied steam. This raises the feed water to its highest temperature, It is then passed through various stages where flashing takes place. The vapor pressure in each of these stages is controlled so that the heated brine enters each chamber at the proper temperature and pressure (each lower than the preceding stage) to cause instantaneous and violent boiling/evaporation. The freshwater is formed by condensation of the water vapor, which is collected at each stage and passed on from stage to stage in parallel with the brine. At each stage, the product water is also flash-boiled so that it be cooled and the surplus heat recovered for preheating the feed water.

[16] www.bloomberg.com

2.	Multi Effect Distillation	• Saline water passes through the tubes in the form of thin film. This causes in faster rate of evaporation • In multiple-effect units steam is condensed on one side of a tube wall while saline water is evaporated on the other side (The energy used for evaporation is the heat of condensation of the steam. • Usually there is a series of condensation-evaporation processes taking place
Membrane Process		
3.	Reverse Osmosis	• Reverse osmosis system consists of four major components/processes: (1) pretreatment, (2) pressurization, (3) membrane separation, and (4) post-treatment stabilization • **Pretreatment:** The feed water is pretreated to be compatible with the membranes • The process includes removal of suspended solids, adjusting the pH, and adding a threshold inhibitor to control scaling caused by constituents such as calcium sulfate. • **Pressurization:** The pump raises the pressure of the pretreated feed water to an operating pressure which is appropriate for the membrane and the salinity of the feed water • **Separation:** The permeable membranes inhibit the passage of dissolved salts while permitting only water to pass through. • After the water is passed through the membrane two streams are formed in a freshwater product stream and a concentrated brine reject stream • **Stabilization**: degasification before being transferred to the distribution system for use as drinking water, the water coming out of the RO unit undergoes pH adjustment and degasification.
4.	Electro dialysis reversal	• Electrochemical separation process that removes ions and other charged species from water and other fluids. • EDR produces two effluent streams: a low salinity product water and a high salinity concentrate.
5.	Membrane distillation (MD)	• Membrane Distillation (MD) is a thermally-driven separation process, in which only vapour molecules transfer through a microporous hydrophobic membrane • The driving force for desalination is the vapor pressure of water across the membrane, rather than total pressure • The membrane only allows vapor to pass through it
6.	Electro dialysis	Electro dialysis depends on the following general principles: • Most salts dissolved in water are ionic, being positively (cationic) or negatively (anionic) charged. • These ions are attracted to electrodes with an opposite electric charge. • An electro dialysis unit is made up of the following basic components : o Pre-treatment o Membrane Stack o Low-Pressure Circulation pump o DC power supply (rectifier) o Post-treatment

The exhibit below illustrated the heating and cooling requirement in the Desalination Industry.

Table 20: Heating and cooling requirement in desalination industry

Processes	Temperature(°C)
Multi stage Flash Distillation	90 to 120 °C
Multi Effect Distillation	Boiling point of sea water

The table below illustrates the suitable concentrated solar thermal technology in desalination sector and their respective indicative temperature, cost of delivery and output.

Table 21: CST technologies suitable for desalination industry

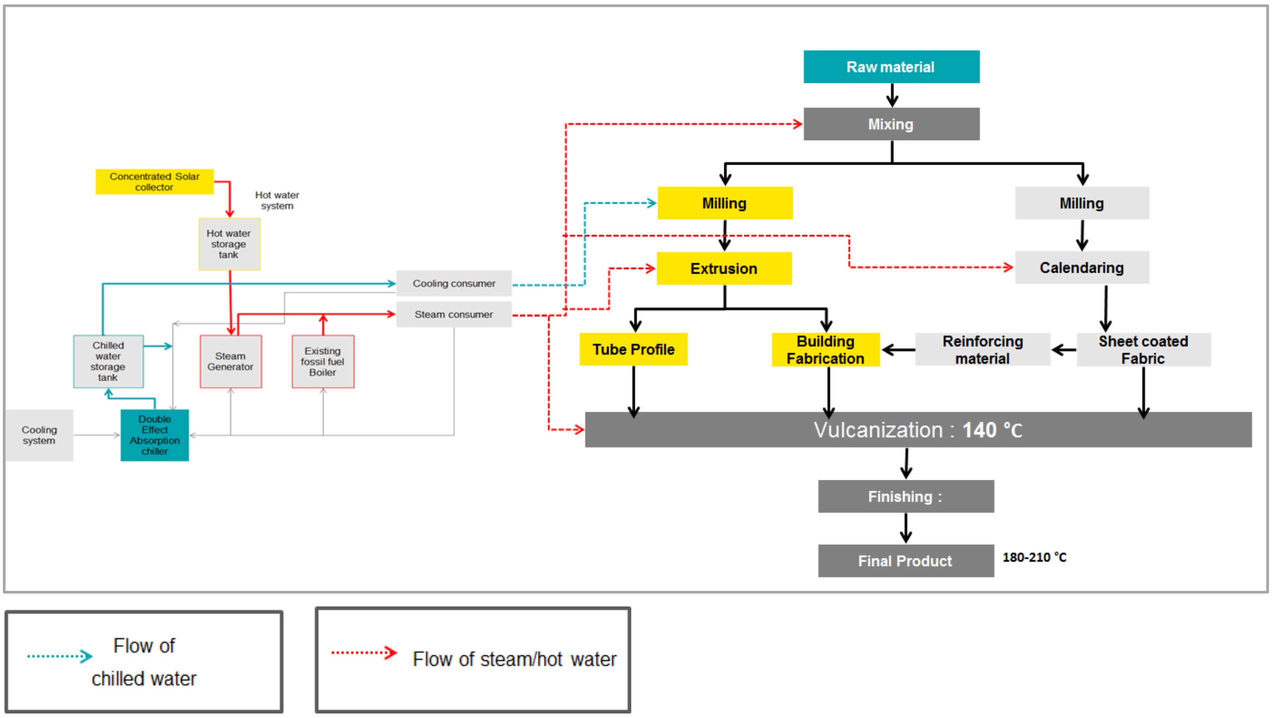
<table>
<tr><th>Suitable concentrated solar technologies</th><th>Indicative temperature of the technology (°C)</th><th>Cost of technology (INR/m^2)</th><th>Relevant processes</th></tr>
<tr><td>Non Imaging Concentrator</td><td>Up to 120</td><td>16000</td><td rowspan="2">► Multi stage Flash Distillation
► Multi Effect Distillation</td></tr>
<tr><td>Fixed Focus Elliptical Dish (Scheffler)</td><td>Up to 150</td><td>18000</td></tr>
</table>

2.11 Rubber industry

India is the world's largest producer and the third largest consumer of natural rubber. The Indian rubber sector comprises of 30 large scale, 300 medium scale and around 5600 small scale and tiny sector units. Today Indian Rubber Industry consists of turnover of INR 12000 crores. The major rubber producing areas are Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Punjab, Maharashtra, Goa, North Eastern states and Andaman & Nicobar Island.

The exhibit below illustrates the integration of CST in general rubber manufacturing processes

Figure 14: Application of CST technology in rubber industry

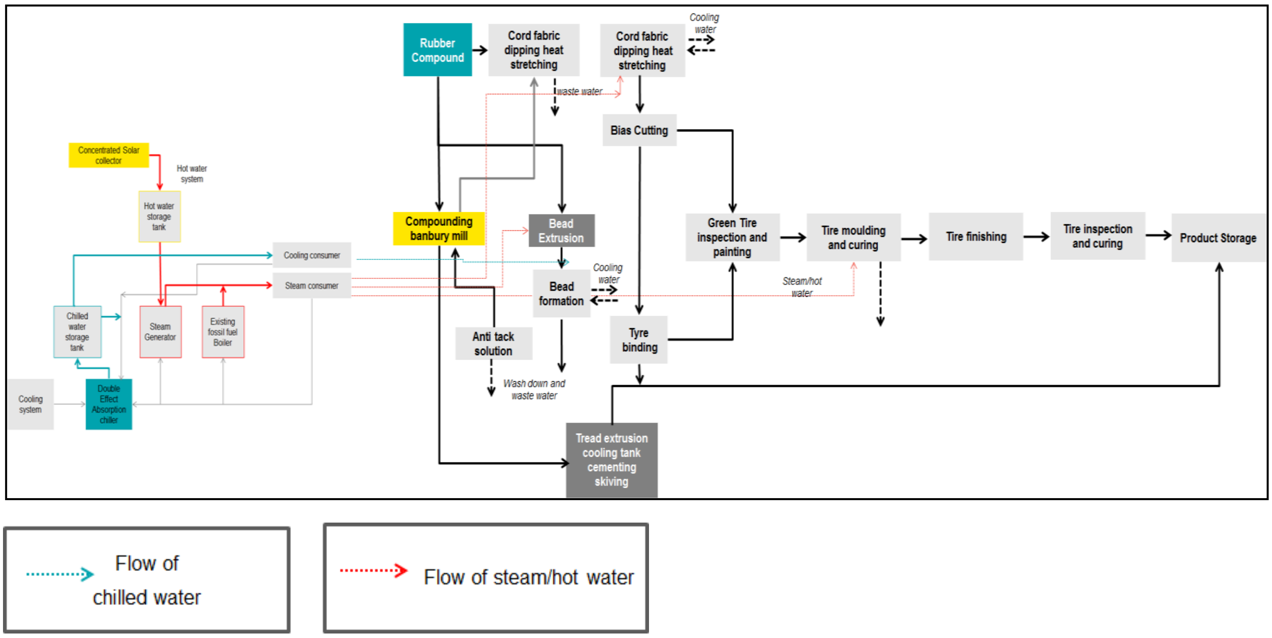


There are several rubber products. Each product has a distinctive process of manufacturing.. Highlighted below are some of the rubber products and their process of preparation.

Tyre Manufacturing:

The exhibit below illustrates the possible processes in tyre manufacturing industry where heat generated from CST technology can be applied.

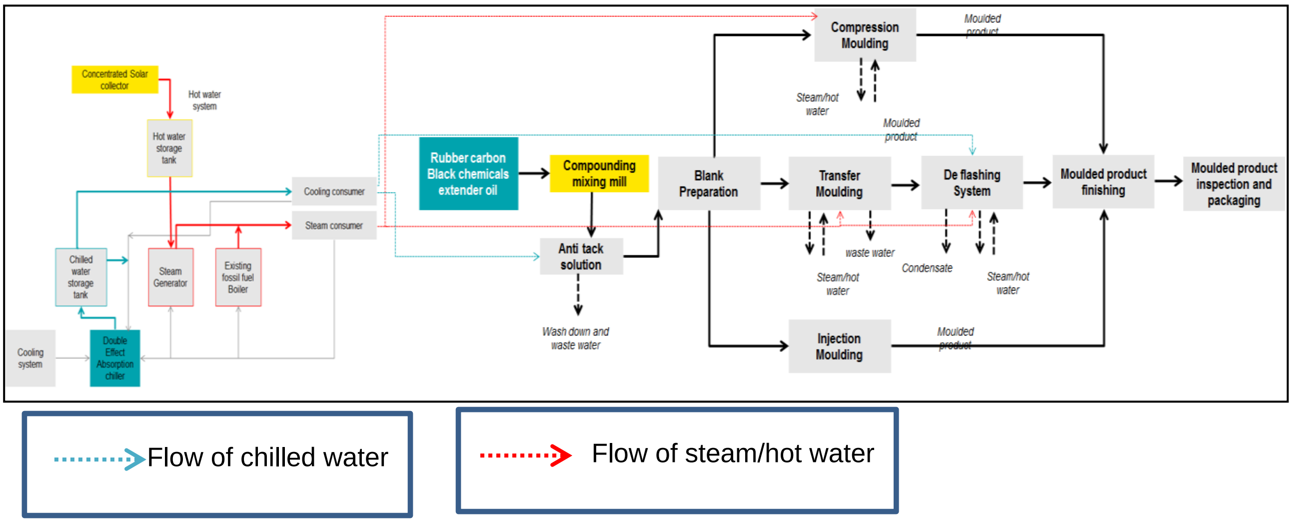
Figure 15: Application of heat generated from CST technologies in tyre manufacturing



Tube Manufacturing

The exhibit below illustrates the possible processes in molded item manufacturing industry where CST technology can be applied

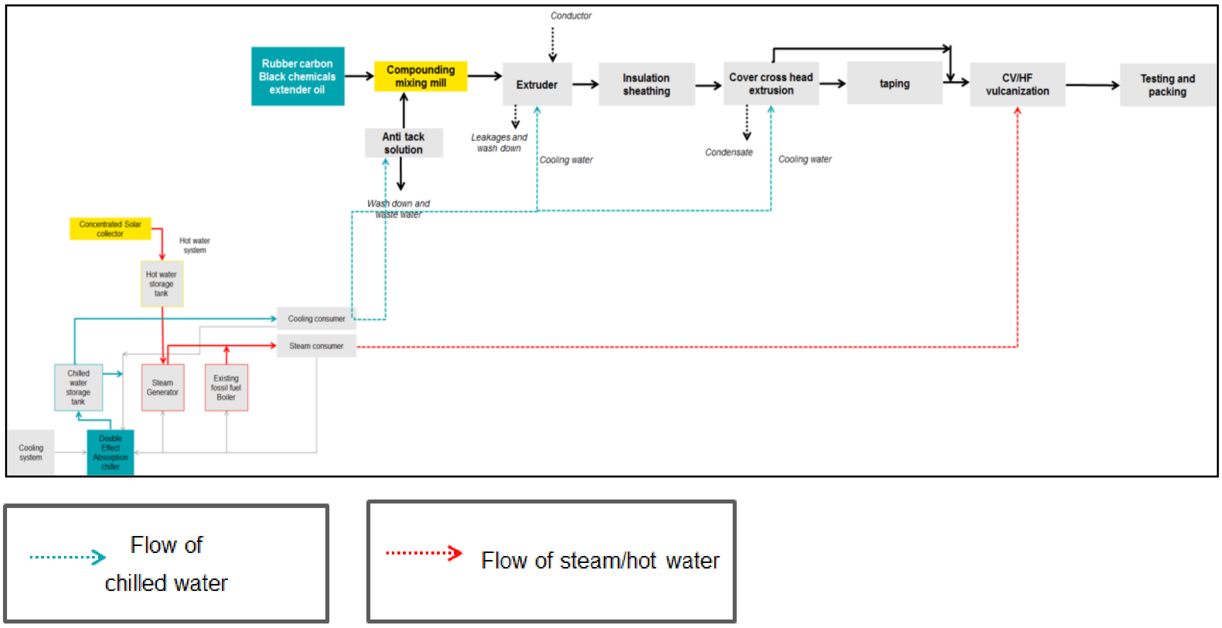
Figure 16: Application of heat generated from CST technologies in molded item manufacturing



Extruded item manufacturing

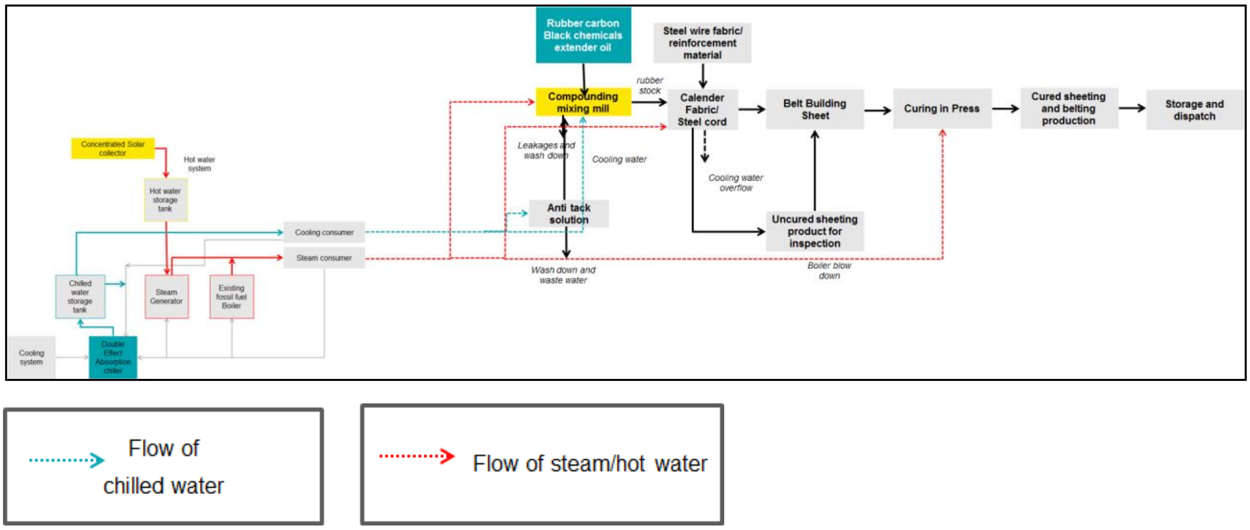
The exhibit below illustrates the possible processes in extruded item manufacturing industry where CST technology can be applied.

Figure 17: Application of heat generated from CST technologies in extruded item manufacturing



Calendared item manufacturing

The exhibit below illustrates the possible processes in calendared item manufacturing industry where CST technology can be applied



Process Description[17]:

Rubber product production methods are extremely diverse some of the common methods are

Phase	Process Name	Key Features

[17] Comprehensive Industry Documents Series: Development Of Standards For Rubber Products Manufacturing Industry, CPCB, MoEFF

1.	Mixing	• The rubber product manufacturing process begins with the production of a rubber mix • The mix comprises of raw and / or synthetic rubber, carbon black (the primary filler used in making a rubber mixture), oils and miscellaneous chemicals. • The mix varies depending on the product to be produced • Banbury mixture is used to mix the ingredients
2.	Milling	The mixed rubber is sent to the mill to form long strip or sheets The anti-tack solution prevents the rubber sheets to stick with each other while cooling. Cool water or air is used for cooling
	Extruder	• The rubber is heated again and sent to the extruder. • Extruders transform the rubber into various shapes or profiles by forcing it through dies *via* a rotating screw. • Extruding leads to further heating of rubber. • The rubber is then cooled using water bath or spray conveyor
7.	**Calendaring**	• Calendars receive hot strips of rubber from mills and squeeze them into reinforcing fibers or cloth-like fiber materials, • Calendars are also used to produce non reinforced thickness-controlled sheets of rubber.
8.	**Building and Fabrication**	• Extruded and calendared rubber components are with wire, polyester and other reinforcing materials to produce various rubber products. • Adhesives, called cements, are sometimes used to enhance the bonding of the various product and layers. • This fabrication, reinforcing, pre-curing and bonding process is referred to as building.
9.	**Vulcanization**	• Vulcanization or curing involves heated compression moulds, steam heated pressure vessels (autoclaves), hot air and microwave ovens or various molten and fluidized bed units. • During the curing process the polymer chains in the rubber matrix cross-link to form a final product of durable elastic, thermo set rubber.
10.	**Finishing**	• Finishing operations may include grinding, printing, washing, wiping and buffing.

Phase	Process Name	Key Features
1	**Tyre manufacturing**	• Mixing involves weighing and combining various ingredients (natural and synthetic rubbers, oil, carbon black, zinc oxide, sulphur and other chemicals) to create a homogeneous rubber compound that is discharged to a drop mill. • Milling • Extruding • Processing fabrics and coating them with rubber are in calendaring operation • Processing bead-wires and coating them with rubber is an extruding process • The components goes through air or water cooling before tyre building • Cementing and marking process are used at various stages throughout tyre building process. Cements are adhesives that hold together the component • Assembling all of the components (bead-wires, coated fabrics, treads etc.) on a tyre building collapsible cylinder, shaped like a wide drum.

<table>
<tr><td></td><td></td><td>

Uncured tyre is manufactured.
Vulcanization and curing of the tyre
Grinding and removal of excess rubber
Finishing the product involves trimming, buffing, balancing and quality control inspection.

</td></tr>
<tr><td></td><td>Tube Manufacturing moulding product/</td><td>
<u>Category A</u>

The process by which the tube is formed is similar to the extrusion of the tread in the tyre industry. The different steps involved are:

Preparation or compounding of the raw materials.
The extrusion of these compounded materials to form a tube.
The building, moulding and curing to form the final product.

<u>Molded Product Manufacturing (Category B)</u>

Compounding is carried out in Bunbary mixer/kneader depending on scale of operation
Forming is carried out where a required shape is provided. This process takes place in a warm up mill
The rubber is cooled and dipped in antilock agent
Cutting and slicing takes place
Rubber articles are produced by moulding.
There are three methods of moulding compression moulding, transfer moulding, injection moulding
After moulding the overflow of rubber or flash are removed by hand or grinding wheel or press dies or chilling with dry ice and tumbling hot blasting

Extruded/Calendared Product Manufacturing Process (Category C)

Compounding of basic ingredients similar to molding items
Sheeting of rubber on a sheeting mill
Contact cooling and anti-tacking of rubber sheet
Extruding the rubber sheet as final desired sheet. In cases where the dimensions of the extruded rubber sheet are critical, the extruded rubber is calendared to the desired thickness.
Contact cooling and antitacking of extruded/calendared sheets for further storage/processing
Belting is manufactured by extruding the rubber onto the wire reinforcement in the extruder or calendaring the rubber sheeting onto reinforcement fabric.
Extruders and calendars require cooling water. Oil and grease can leak from the machinery.
Curing of belting or extruded and calendared sheeting press curing technique.

</td></tr>
<tr><td></td><td>Latex based dipped item manufacturing</td><td>
Fabricated Product Manufacturing Process (Category D)

Latex Based Dipped Goods Manufacturing Process:
2 types of dip (1) straight dip and (2) coagulant dip

Coagulant dip: The forms are dried in open and dipped in coagulant solution which is an organic water base and coagulant solution.
</td></tr>
</table>

		Latex dip: After coating with coagulant it is dipped in latex. Compounding of the ingredient with rubber latex id done prior to the operation. **Preliminary Drying:** **Washing and Drying:** The latex is dried in hot water tank and sent through the oven for further drying. **Curing:** The rubber goods are cured in an oven at approx. 90°C **Cooling and Form Stripping:** The latex are cooled and the forms are stripped using lubricating agent **Packaging, sterilizing with chlorine dip tanks and form washing**
11.	**Latex based foam items**	• There are two processes for manufacturing of latx foa, • **Dunlop process** o Mechanically whipping the latex to a froth o Setting the frothed mass with a coagulant or gelling agent o Vulcanizing the rubber so that the foam is permanent. o When the curing cycle is completed, the product is removed from the mold and washed with water • **Talalay Process** o The froth is produced by chemicals rather
12.	**Reclaining Rubber**	• **Debeading :** Beads in scrap tyre are removed manually • **Size reduction:** Debeaded scrap tyre is reduced by mechanical chopping or cracking on a very heavy cracker mill to a suitable size devulcanization • **Devulcanization:** cross linking of the rubber are broken down by depolymerization There are 3 types of depolymerization process o **Wet digester process:** The digester process consists of placing the ground scrap, water and reclaimed agents into a steam-jacketed agitator-equipped autoclave (digester). The batch is then cooked for 5-24 hours at 180-210° C o **Pan Process:** The finely ground scrap which is usually free from fiber is blended with the correct amount of reclaiming agents and placed in a single shell pressure vessel (autoclave) into which live steam is passed. Depolymerization is carried out at about 185° C for 2- 18 hours. o **Mechanical Reclaiming Process:** The fine ground, fabric free rubber scrap is fed continuously into a high temperature, high shear machine. The discharged reclaimed rubber needs no drying and is ready for further processing. • **Final processing :** The final stage of the reclaiming operations involves straining to remove foreign matter before going to refining and sheeting mill

The exhibit below illustrated the heating and cooling requirement in the rubber Industry.

Table 22: Heating and cooling requirement in rubber industry

Processes	Temperature(°C)
Mixing products: • Tire Inner Liner (BrIIR/NR) • Tire Ply Coat (Natural Rubber / Synthetic Rubber) • Tire Belt Coat (Natural Rubber) • Tire Base / Sidewall (Natural Rubber / Polybutadiene Rubber) • Tire Apex (Natural Rubber) • Tire Tread (Styrene Butadiene Rubber / Polybutadiene Rubber) • Tire Bladder • EPDM 2 (Peroxide Cure) • EPDM 3 (Non-black EPDM Sulfur Cure)	Single pass: 165°C Double pass: 115 °C to 120 °C

• Emulsion SBR (SBR 1502)		
Vulcanization(tyre manufacturing		140°C
Curing(latex based dipped item)		90°C
Injection moulding[18]		165 to 200 °C
Compression moulding		150 to 170 °C
Devulcanization	Wet digester process	180-210°C
	Pan process	185° C
	Mechanical reclaiming project	>100°C

The table below illustrates the suitable concentrated solar thermal technology in rubber sector, their indicative temperature, cost of delivery and output.

Table 23: CST technologies suitable for rubber industry

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Relevant Processes
Linear Fresnel Reflector (LFR)	Up to 250	18000	► Vulcanization (tyre manufacturing ► Curing(latex based dipped item) ► Injection moulding ► Compression moulding ► Devulcanization
Parabolic Trough Collector (PTC)	Up to 250	18000	
Paraboloid dish	Up to 350	20000	
Fresnel reflector based dish	Up to 350	20000	

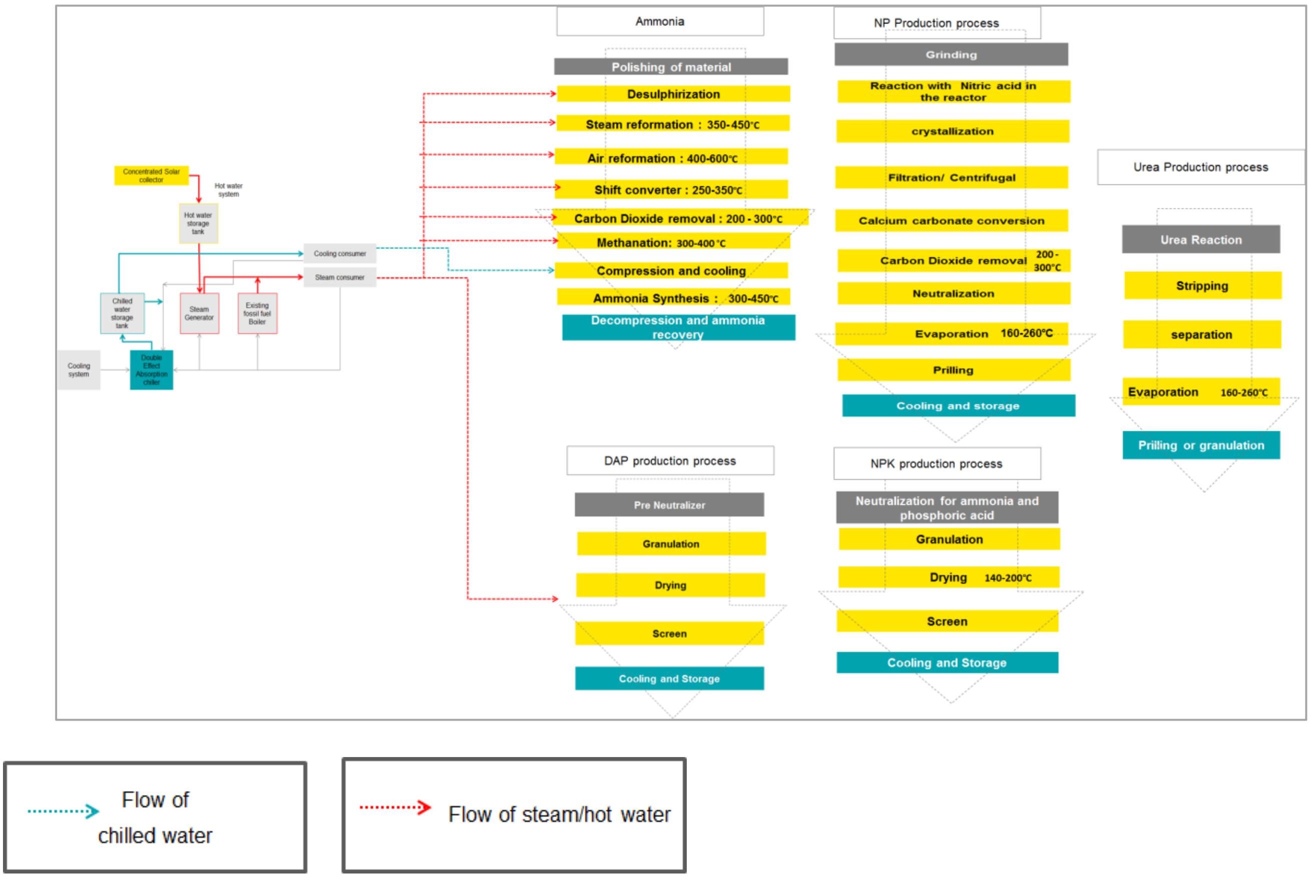
[18] Vip Polmer website

2.12 Fertilizer Sector

India is ranked third in production of fertilizers. India is the second biggest consumer of fertilizer in the world next only to China. There are 57 large sized and 64 medium and small sized chemical fertilizer production units in India. These plants produce around 121 MT of fertilizers per year. Fertilizer industry clusters are found in Maharashtra, Orissa, Tamil Nadu, Kerala, Andhra Pradesh, Rajasthan, Madhya Pradesh, Haryana and Punjab.

The exhibit below illustrated the heating and cooling requirement in the fertilizer Industry.

Figure 18: Application of heat generated from CST technologies in fertilizer sector



Process Description: General Process

Phase	Process Name	Key Features
1.	Granulation and drying	• **The drying section is Categorized into drying part, granulation part, screening, crushing, cooling and coating** • The granulation can be performed by different equipment such as drums. • The fertilizer may be cooled in a cooling drum or in a fluidized bed cooler. • The coating can be a combination consisting of a treatment with an organic agent and an inorganic powder. • Concentrated ammonium nitrate solution may be added directly into the granulator and ammoniation rates in the pipe reactor vary according to the product. • The granules obtained are dried in a drying section using a heated air stream.
2.	Screening, crushing, cooling and coating	• The dry granules are screened into **three fractions**. • The over-size is removed and returned via the crusher to the granulator, together with the fines.

Phase	Process Name	Key Features
		• The product-sized fraction is removed with the possibility of returning part of this fraction to the granulator to stabilize the recycle loop. • Finally the on-spec fraction is cooled in classical cooling equipment such as a fluidized bed cooler or a cooling drum. • The cooled product is fed into a coating drum where a surface coating is applied to prevent caking.
3.	Gas scrubbing and dust removal	• Gases from the granulator and the dryer are scrubbed in scrubbers with recirculating ammonium phosphate. • Make-up phosphoric or sulphuric acid can be added for pH control if necessary. • The scrubber liquor which is being recycled is fed to the pipe reactor in the granulator. • The air coming from the cooling equipment is generally recycled as secondary air to the dryer after de-dusting.
4.	Drum Granulation with Ammonization	• This process consists of a classical granulation loop using mainly solid raw materials. • Ammonium nitrate solution and/or steam is/are fed into the granulator. • The process is very flexible, and is able to produce a broad spectrum of grades including products with low nitrogen content.

Table 24: Heating and cooling requirement in fertilizer industry

Processes	Temperature(°C)
Primary Reforming	350-450°C
Secondary Reforming	400 – 600 °C
Ammonia Synthesis	300 – 450 °C
Shift converter (high)	350 – 450 °C
Shift converter (low)	200 – 250 °C
CO2 Removal	200 – 300 °C
Methanation	300 – 400 °C
Evaporation	160 - 250°C
Drying	140 - 200°C
Steam stripping	180 - 300°C

The table below illustrates the suitable concentrated solar thermal technology in rubber sector, their indicative temperature, cost of delivery and output.

Table 25: CST technologies suitable for rubber industry

Suitable concentrated solar technologies	Indicative temperature of the technology (°C)	Cost of technology (INR/m^2)	Relevant Processes
Linear Fresnel Reflector (LFR)	Up to 250	18000	➤ Shift converter (low) ➤ CO2 Removal ➤ Methanation ➤ Evaporation ➤ Drying ➤ Steam stripping
Parabolic Trough Collector (PTC)	Up to 250	18000	
Paraboloid dish	Up to 350	20000	
Fresnel reflector based dish	Up to 350	20000	

3. Case Studies of successful Concentrated Solar Thermal Technology (CST) installations in India[19]

- Salem Dairy/Mahananda dairy (ARUN)
- Unique Bio tech (Paraboloid)/Siddhartha surgical(PTC)
- ~~Almond House(PTC)~~
- Mother dairy(PTC)
- ITC Bangalore/Pune (NIC)
- Mahindra & Mahindra (Nagpur)
- Honeywell (PTC)
- For laundry application (commissioned at Goa/Aurangabad, ATE manufacturer

CASE STUDY 1: Using non imaging concentrator for boiler feed water pre-heating in ITC Tobacco factory

Table 26: Snapshot of the project details

Location	*Meenakunte Village, Jallahobli, Bengaluru*
Application	*Preheating water*
Type	*Scheffler dishes*
Delivery	95˚C
Capacity	*1.1 kWth per dish*
Total area of system	*700.4 m^2*
Dish number	*200 dishes*
Aperture area	*3.4m^2*
Industry	*Tobacco*
Type and quantity of fuel saved	*38000 liters of HSD saved per year*
Cost of installation	*INR 124 lakhs*

Processes where steam or hot water generated can be used in diary industry
• *Preheat water before sending it to boiler* • *The steam produced in the boiler is used in conditioning, flavoring and drying of the tobacco*

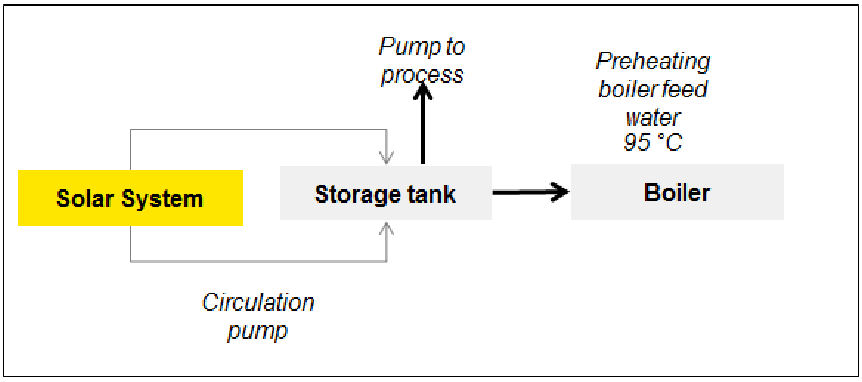
[19] Source: cshindia.in; http://mnre.gov.in; www.itpower.co.in

Key highlights:

- The non-imaging collector is installed in the ITC tobacco division in Meenakunthe village, north Bengaluru. The facility has a production capacity of 170 million cigarettes a day and it produces around 27 domestic brands and around 57 export brands.
- The facility has been awarded several times because of their environment friendly state of the art production facilities.
- The solar system installed in this facility has 200 modules. Each module has a collector area of 3.4m^2. The non-imaging collector preheats the water to 95˚C. The biggest advantage of these collectors is that they can produce heat to 120 ˚C and is integrated with a secondary reflector which captures maximum solar radiation irrespective of the seasonal variations. Moreover these concentrators can also work in diffused radiation unlike other collectors.
- 35000 liters of hot water is provided to the system for 7 hours daily.
- The water is preheated by these concentrators and is then sent to the boiler for generation of steam. This steam is used for curing, flavoring, and flash drying of the tobacco.
- This installation has helped ITC to save fuel cost of around INR 2.5 lakh per month

The exhibit below illustrates the flow of operation in ITC Tobacco factory

Figure 19: Process heat flow in ITC industry



CASE STUDY 2: Solar Steam for Process Heat by using Scheffler Dishes at M/s. Hindusthan Vidyut Products Ltd[20],

Table 27: Snapshot of the project details

Location	*Chandigarh, Haryana*
Application	*Steam for process heat*
Type	*Scheffler dishes*
Delivery	*Up to 10 bar and 85˚C*
Capacity	*6 kWth per dish*
Total area of system	*320m^2*
Dish number	*20 dishes*
Collector area	*16m^2*
Industry	*Food processing*
Type and quantity of fuel saved	*270 liters of diesel saved per day*
Cost of installation	*INR 55.08 lakhs*
Processes where steam or hot water generated can be used in food processing industry	
Vulcanizing cables	

Key highlights:

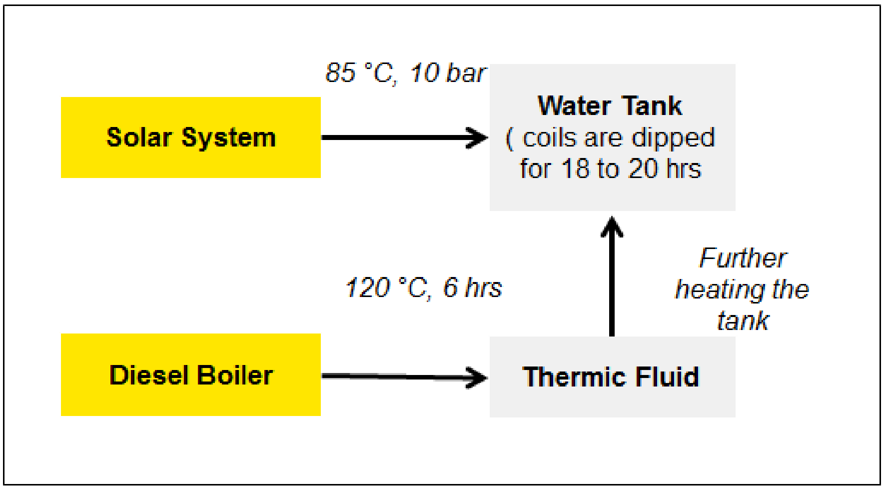
- M/s. Hindusthan Vidyut Products Ltd pioneers in the manufacturing of overhead conductors, underground cables & electro – porcelain high tension insulators.
- In 2012 the establishment has implemented 320m^2 of concentrated solar collector for heating their processes. The system is integrated with 20 Scheffler based solar concentrators and a diesel boiler which is used 24 hours a day to satisfy the heating requirement of the facility.
- The primary operation of the system is to provide heat for vulcanization of the cables. The cables are dipped in a heated water tank for 18 to 24 hours. The temperature and pressure of the tank is monitored at regular intervals and is maintained at a temperature and pressure of 85°C and 10 bar respectively.
- The boiler is used to heat the thermic fluid at a temperature of 125°C for 6 hours. This fluid is further circulated to the heating tank to raise the temperature of the water

[20] www.cshindia.in

• According to an audit report carried out in in 2013, the system is completely operational and is operated for 300 days in a year. Moreover, the system saves around 81000 liters of fuel per year.

The exhibit below illustrates the flow of operation in M/s. Hindusthan Vidyut Products Ltd,

Figure 20: CST process flow in Hindusthan Vidyut Products Ltd.



CASE STUDY 3: Solar installation in Chitale Dairy

Table 28: Snapshot of the project details

Location	*Sangli, Maharashtra*
Application	*Steam generation for Milk processing*
Type	*Fresnel Paraboloid solar concentrator*
Delivery	*Up to 4.5 Kg/cm^2 and 150˚C*
Capacity	*80-100 kWth per dish*
Total area of system	*320m^2*
Dish number	*2 dishes*
Aperture area	*160m^2*
Industry	*Food processing*
Type and quantity of fuel saved	*40,080 liters per year of furnace oil saved*
Cost of installation	*INR 71.98 lakhs*

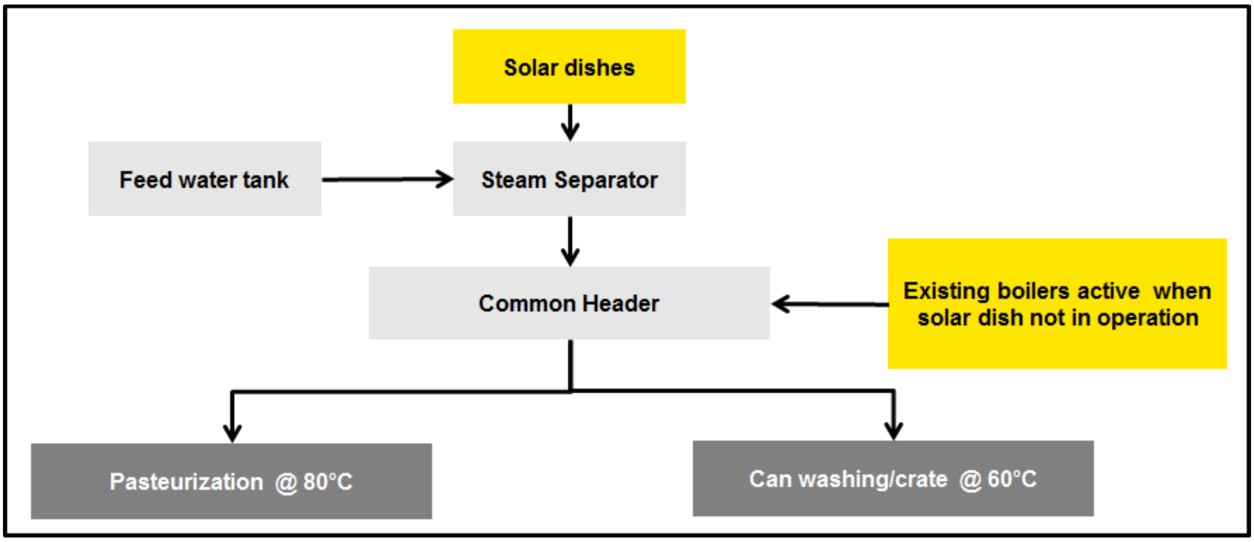
Processes where steam or hot water generated can be used in diary industry
• *Pasteurization* • *Milk Powder* • *Can Washing* • *Cleaning in Place* • *Crate washing* • *Sterilization*

<u>*Key highlights:*</u>

- Chitale diary has set an example by pioneering the successful use of solar technology to satisfy their thermal requirements. Fresnel Paraboloid solar concentrators were installed to cater the thermal needs of the diary.
- A steam separator is incorporated with the solar steam generation system. The steam separator acts as a steam separator as well as a buffer water storage tank.
- The day begins with collection of water from the steam separator. The water circulates through the reservoir coil.
- The water is then converted to wet steam and this wet steam is transferred to the steam separator.
- The dry steam is generated from the top of the stream separator at a controlled pressure and temperature (5 bar, 152°C).
- The dry steam generated from the system is collected in the common header for milk processing & other application.

The exhibit below illustrates the flow of operation in Chitale diary

Figure 21: CST process flow in ITC industry



CASE STUDY 4: Solar installation in Mahananda Dairy

Table 29: Snapshot of the project details

Location	*Latur, Maharashtra*
Application	*Pressurized Hot water for Milk processing*
Type	*Fresnel Paraboloid solar concentrator*
Delivery	*2 Kg/cm^2 and 120˚C*
Capacity	*80-100 kWth per dish*
Total area of system	*160m^2*
Dish number	*1 dish*
Aperture area	*160m^2*
Industry	*Food processing*
Type and quantity of fuel saved	*27000 liter/year of furnace oil saved*
Cost of installation	*INR 52 lakhs*
Processes where steam or hot water generated can be used in diary industry	
• *Pasteurization* • *Milk Powder* • *Can Washing* • *Cleaning in Place* • *Crate washing* • *Sterilization*	

Key Highlights

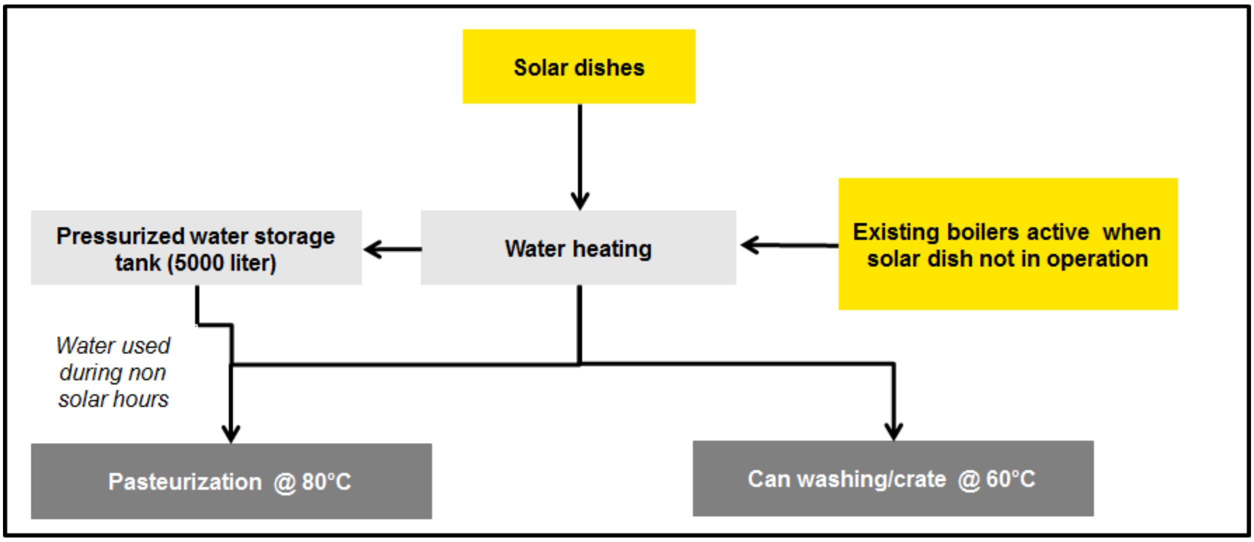
A single dish Fresnel Paraboloid solar concentrator was installed to generate hot water for milk pasteurization. Since there was a distinct mismatch between the plant operation and the availability of sun, a storage tank with a capacity of 5000 liters were installed. Pressurized water was selected as a medium of heat transfer and storage, the water stored in the tank was used as a heat source during non- solar hour operation.

Some of the advantages for using water as a heat storage and transfer medium are listed below.

- High specific heat
- No fire hazards
- No possibility of accelerated oxidization overnight (as in case of tarring of thermic oil)
- Compatibility with food products and low operational cost.

The exhibit below illustrates the flow of operation in Mahanand diary

Figure 22: CST process flow in Mahanand diary



CASE STUDY 5: Solar installation in Gajraj dry cleaners

Table 30: Snapshot of the project details

Location	*Ahmednagar, Maharashtra*
Application	*dry cleaning*
Type	*Scheffler Dishes*
Delivery	*Up to 18 bar and 180˚C*
Capacity	*80-100 kWth per dish*
Total area of system	*240m²*
Dish number	*15 dishes*
Aperture area	*16m²*
Industry	*Dry cleaning (Textile)*
Type and quantity of fuel saved	*HSD saved 30 liters per day*
Cost of installation	*INR 23 Lakh*

Processes where steam or hot water generated can be used in dry cleaning
The system is operated for steam. It is integrated with the existing boiler

Key Highlights

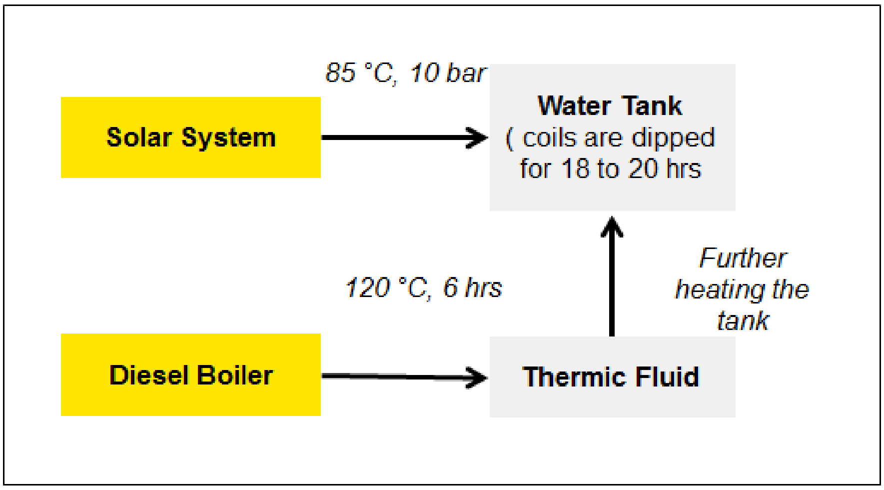
The system was commissioned during March 2006 by Supreme Rays Solar System. Prior to the implementation of the solar system the establishment was using HSD for its end use and consumption. The system is integrated with its existing process. The project is set up at a cost of INR 23 Lakh with and has grant availability from MNRE of the order of INR 8.5 Lakh.

Some of the advantages for using water as a heat storage and transfer medium are listed below.

- High specific heat
- No fire hazards
- No possibility of accelerated oxidization overnight (as in case of tarring of thermic oil)
- Compatibility with food products and low operational cost.

The exhibit below illustrates the flow of operation in Gajraj cleaners

Figure 22: Process heat flow in Gajraj cleaners



4. Barriers and challenges while installing and operating Concentrated Solar Heating Technologies (CST)

This section looks into the typical challenges that are encountered while installing Concentrated Solar Thermal Technologies. Through thorough stakeholder discussion with both technological provider and successful beneficiaries of CST technologies, we have listed below some of the major challenges that are encountered during Concentrated Solar Thermal technology installation and operation.

1. **Availability of Area of installation**: Since CST technology requires large areas for installation, availability of area for installation and operation is a major challenge. Usually Concentrated Solar thermal concentrators are installed on roof or on ground which are close to the point of heat application.
2. **Structurally sound platform or base for CST installation:** It is recommended to install CSTs on ground or on reinforced cement concrete roof tops. Several industries use tin shed or asbestos to cover their roof. Installing CSTs on these tin shed or asbestos roof is not recommended for the following reasons.
    - Tin shed or asbestos roofs are 12 m high, hence periodic cleaning and maintenance becomes a challenge because of safety issues.
    - CSTs have extensive piping design to carry thermic fluid or water. If there is a leakage, repairing the damaged section of the CST becomes a cumbersome task.

    If the CST is installed on a structurally firm base like RCC roof or on the ground then the above issues and challenges does not exist.

3. **Optimized structural design to achieve high efficiency:** Heat generated from concentrated solar technologies is prone to losses. If the device is not erected in an efficient manner the system may incur heat losses greater than 70%. To minimize such losses the designing and placement of the concentrator is of vital importance. Special care must be taken to create a sharp focus. Depending on the design and the type of collector and concentrator the concentration ratio varies from 10 to 100. A well designed CST system will have an efficiency of 40% to 45%.

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4. **Integration of solar heat into an industrial process:** Due to the varied and unreliable nature of heat generated from CST, it is recommended that the CST technology should be integrated with the existing boilers or heat generation system. Listed below are some of the major challenges faced by standalone CST system
    - CST does not work on non-sunny days
    - To achieve the required process temperature, CST takes considerable amount of time. It becomes extremely difficult to install CST for a continuous process
    - The CST systems that are to be integrated with the existing boiler system installed in the industry come under different specifications standards, hence, industry owners are reluctant to have any integration after the boiler

    Hence, integration with the conventional heat supply system will ensure continuous transfer of heat into the relevant processes. Listed below are some of the vital engineering issues that the implementing agencies and the beneficiary industry should address while coupling CST technology with that of the existing boiler system.

    - The distance between solar field and the point of heat application should be as close as possible. It is observed that as the distance increases there is an increase in pressure and temperature losses.
    - One of the major challenge that encountered by the implementation team is balancing the heat generated from CST with that of the existing boiler. Due to diurnal, seasonal and spatial variations of solar profile of a region the heat generated from CST fluctuates. Based on the heat generation profile and available investments the implementation agency and the beneficiary industry has to decide on the following technical factors

- Integrating CST technologies with the existing system to preheat water or other fluids which will be further used for steam generation or for process heat
- Integrating CST technologies with the existing system to generate steam
- Coupling CST technologies directly to an individual process.
- Requirement of a solar storage system like heat drums
- Type of fuel that should be used for boilers alongside CST technologies.

On consultation with the technology providers it was found out that the cost of fuel and the gross calorific value of the respective fuels play a pivotal role in determining the payback period of CST coupled boiler technology. The below table illustrates the payback period of CST- boiler integrated technology

Table 31: Payback periods for various CST - boiler technologies[21]

Type of boiler	Payback period
Coal fired boiler + CST	8 years
Furnace oil boiler	4 to 5 years
HSD	3 years
LPG	2.5 years

Indigenous development of reflectors / reflective films may be a long term goal and the MNRE may consider means of going about it

- The key components of the system, the reflective film or reflective metal surfaces are not made in India. Indigenous development of reflectors may be a long term goal. The collaboration with the international companies may reduce the learning curve and help in diffusion of this technology in industrial sector for high-term applications.

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[21] Stakeholder discussion with Thermax limited, Taylormade Solar Solutions Pvt. Ltd., Megawatt Solutions Pvt. Ltd

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