UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

CST Manufacturing Landscape in India

MNRE-GEF-UNIDO

"Promoting business models for increasing penetration and scaling up of solar energy"

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Executive Summary

India is endowed with good solar insolation receiving almost 300 sunny days in a year on average across the country. The calculated solar energy incidence on India's land area is about 5000 trillion kilo-watt hours per year[1] and there is lot of untapped potential of solar energy in India. National Institute of Solar Energy (NISE), an autonomous institute under Ministry of New & Renewable Energy, Government of India has estimated the total solar potential of India at a little less than 750 GW[2]. The daily average solar energy incident over India varies from 4 – 7 kWh/m2 with 1,500 – 2,000 sunshine hours per year (depending on the location). Western part of India has maximum radiation and this level decreases gradually as we progress from the west towards the east.

India is seen as a favourable market globally for the growth of Concentrating Solar Thermal (CST) technologies, primarily because of the high irradiance, the existence of local manufacturers and inclination amongst industry to replace polluting and expensive fuel. CST applications in India find diverse usage with systems being used for cooking purposes, as well as in Industries for process heat requirement (for example in automotive industries, textile industries, food industries, etc) as well as for catering to cooling needs. This technology not only presents an opportunity for decarbonization the highly emission intensive industrial heating process but also generates savings for the end user by off-setting/replacing the reoccurring expense of fuel purchase for heating. Inspite of the potential, the country has its own barriers to growth of CSTs, such as the non-existence of solar grade reflector manufacturers.

The supply chain of a solar concentrator conversion technology involve the integration of various components required for converting the solar radiation to thermal energy using a collector system (mirrors, reflectors, etc.), thermal energy conversion systems (boilers, heat exchangers), heat transfer mediums and system control equipment. The thermal energy generated through collectors can also be stored in storage devices for subsequent usage. The key sub-components required for CSTs are generally manufactured by specialized manufacturers and then assembled by various technology integrators based on the application. Some components such as tracker mechanisms have benefited by adopting technologies from the solar PV.

Increased efforts towards renewables have enabled manufacturers, integrators and installers of concentrating solar thermal technology to establish supply chains for critical components such as the reflectors and mirrors where other available existing technologies like boilers and steam turbines can be in most cases procured domestically.

In order to develop the domestic capabilities required to manufacture low cost and effective CST systems, we must first identify in detail the various components that constitute a CST system. The key components required in a solar thermal energy system can be classified broadly into the following four categories:

Solar Field Components

- Solar Collectors
- Mirrors and Reflectors
- Solar concentrators
- Evacuated and non evacuated Receiver tubes
- Absorber Coatings

Thermal Conversion and Storage Components

- Heat exchangers/receivers
- Heat transfer fluid pumps
- Thermal Energy storage/transfer mediums (air, water oil, etc.)
- Thermal storage resorviors

System Control Equipment

- Electronics control and sensors for temperature, pressure
- Pumping System
- Solar Tracker mechanism (stepper motors and drive modules)

Foundation and Support Structures

- Pylons
- Civil foundations for base structure
- Collector frame and support structures
- Piping structures for fluid flow

[1] https://www.seci.co.in/upload/static/files/mission_document_JNNSM(1).pdf
[2] https://niti.gov.in/sites/default/files/energy/175-GW-Renewable-Energy.pdf

The solar field components are deployed to reflect/concentrate the sunlight, the receiver components to absorb and transfer the heat to a transfer medium and the tracking mechanisms and support structures to mount and operate the system at the desired efficiency.

The final application of the system has a bearing on the design of the components that the overall system will require. While the industry has capabilities to domestically cater to the structural, civil, and mechanical requirements of these systems, some of the other critical components, such as mirrors, receiver tubes, heat transfer fluid (HTF), thermal energy storage technologies are currently imported. These imported components increase the capital cost of the overall system. Further cost reductions could be achieved in the future through local manufacturing of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures.

The fixed costs of CSTs are varied based on the temperature requirements, size of the system, component availability (eg: collector type) and other factors like piping, structural constraints, etc. The cost of the solar thermal systems has come down significantly in recent years, especially in the developed markets of Spain, North America, Germany, and China. This decrease may be attributed to the technological prowess (improved collector designs, improved materials, etc.), increased awareness and larger pool of manufactures and project developers, ultimately making the market more competitive. Economies of scale kick in when manufacturers who are market leaders in certain components of CST technologies (reflectors, receivers) can produce at lower cost.

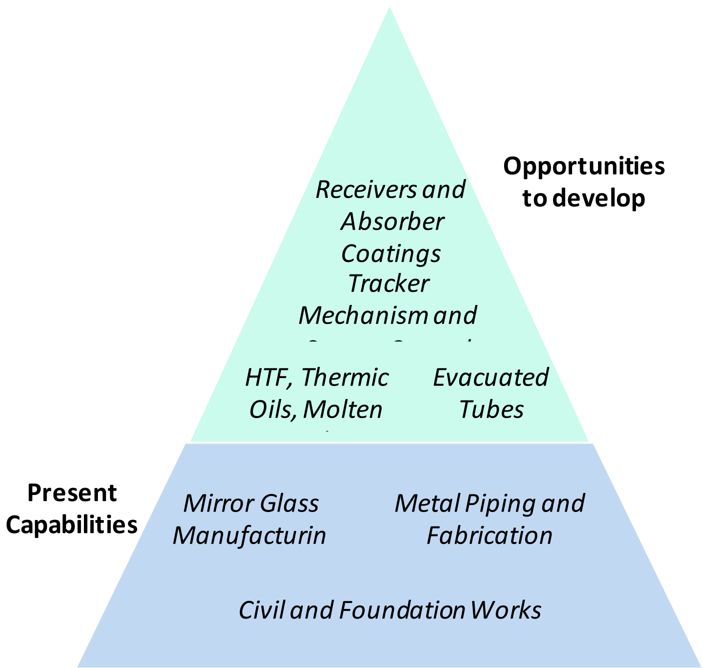
The lack of domestic manufacturing for several components can be attributed to the technological complexity of these components as well as the low market volumes for them, which reduces the investor interest in such manufacturing projects. India already has strong domestic manufacturing expertise in some of the adjacent areas required for CST component manufacturing, however a lack of market volumes and limited capacity deployment translating into low revenue generation has deterred domestic manufacturing from building the capabilities required for CST component manufacturing.

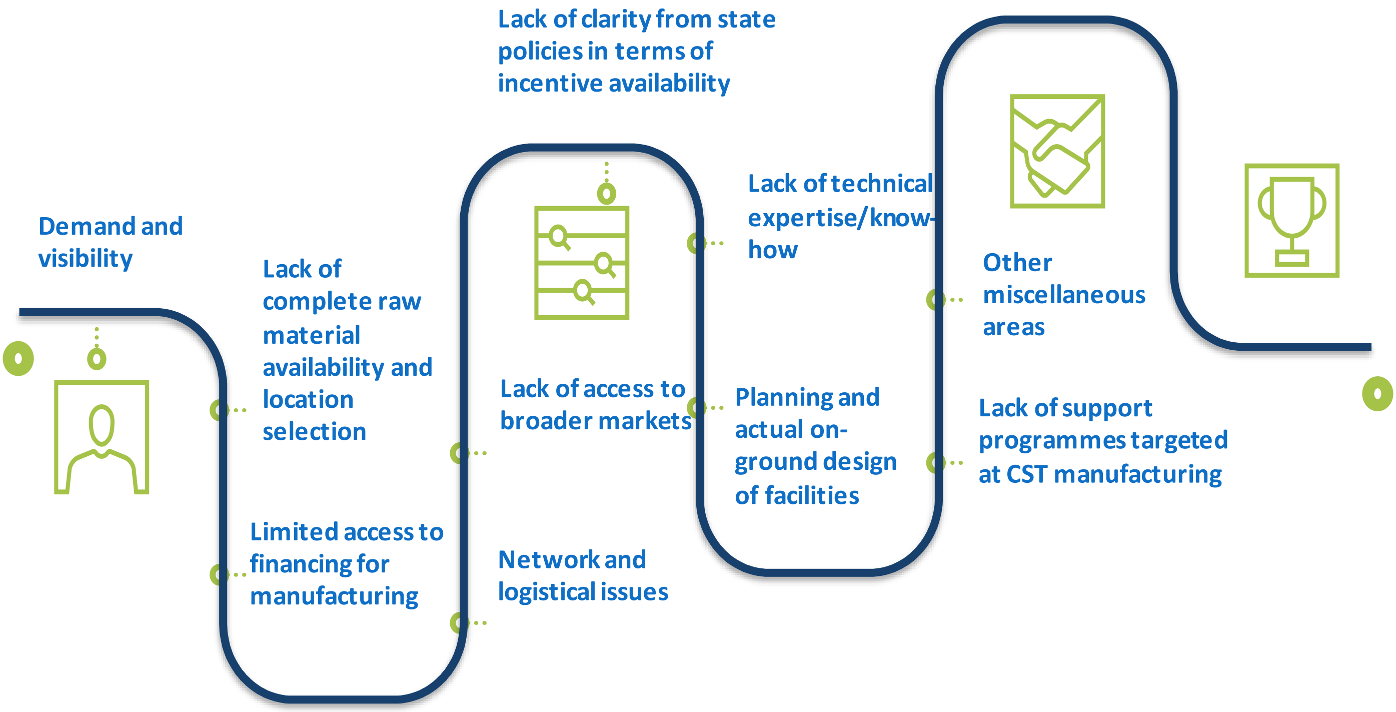
Considering India's increasing energy consumption over the years, the intervention of CST technologies into the overall energy mix presents a perfect opportunity for India to reduce its reliance on conventional resources, especially in the industrial, commercial and institutional sectors. The government has also been supportive of CSTs and has endeavoured to provide conducive policy and regulatory framework for the adoption of CSTs in India.

In order to promote the manufacturing of CST components in the country, India must first utilize the already existing manufacturing expertise that it has in many industries. For instance, the glass and mirror industry, metal fabrication, oil and chemical industry have adjacency with certain CST components that can be manufactured without developing the entire supply chain from scratch. India also needs to work towards developing the capabilities in the manufacturing of thermic oils and HTFs, absorber and reflective coatings as well as receiver/absorber tubes to maximize the domestic value capture of CST systems to be deployed in the country.

Assessing key areas of intervention to boost CST manufacturing

Building upon the CST domestic manufacturing as-is assessment, there are numerous roadblocks when it comes to realizing 100% indigenous manufacturing in India. There are certain components for which manufacturing is done by only a couple of players (such as solar grade mirrors) which clearly points to the lack of market players in the supply chain itself. Hence, the manufacturing of CST needs to be incentivized at the very basic level i.e. 'component level' to garner interest from the industry to participate and focus on localization of supply chain elements to reduce overall imports. In this regard, some of these potent areas of intervention have been analysed below.





Key Recommendations to boost domest manufacturing of CST Components

➢ **Issuance of amendment to existing policy framework**

The current policy framework at the state and central level does offer some incentives to number of ancillary industries for CST, though not directly. Policymakers should work towards creating incentives for the manufacturing of CST components while boosting domestic deployment and reducing cost of CST systems.

➢ **Awareness, manpower training and planning for manufacturing setup**

Manpower training and acquaintance CST manufacturing facility forms the bedrock for upscaling domestic manufacturing in India. Since, there is no historical evidences of proven success w.r.t. an integrated CST manufacturing facility, there is an obvious lack of technical-knowhow on how to proceed with such an idea. Additionally, there are certain specific areas, where specialized training efforts would be needed to bridge the gap and bring proven technical expertise on board.

➢ **Attracting big investors and formation of joint ventures**

The establishment of a CST manufacturing facility will entail significant upfront CAPEX. The financial incentives will be critical in improving the commercial viability, it is however also essential to bring in bigger investors/ MNCs/ big corporate houses to have sustained commitments for atleast a period of 5-7 years in the sector. The support can be in the form of investments in manufacturing, deployments, machinery building, manpower training or other related avenues, which will aid in driving more Private Equity firms and large investors in the ecosystem.

➢ **Focusing on demand creation measures through policy and regulatory mandates**

Creating a sustained demand for any technology remains fundamental towards addressing the supply side issues. This has been cited as a major drawback by numerous system integrators and manufacturers, that they do not foresee much demand for such systems over longer term and thus are hesitant towards establishing a dedicated manufacturing line. The MNRE also has been reluctant to focus on demand creation avenues, similar to the ones planned for solar PV (such as CPSU tenders favoring domestic modules). The solar thermal roadmap for India, also emphasizes on the targets in the near term i.e. till FY 2022, whereas it does not necessarily focus towards long term trajectory till FY 2030 and associated demand creation measures to achieve those targets.

As per leading CST dish manufacturer, a strategy based on fuel cost should be used for mandating certain industries for uptake of CSTs. Industries having lower energy costs can be mandated to switch over to CSTs and procure fixed quantum of heat

Hence, to stimulate domestic manufacturing focus should be on providing a clear pipeline of projects to potential manufacturers and system integrators. The economies of scale usually tend to kick in to bring down costs, once demand can generate volumes. Incentivization is needed to address this very 'demand aspect'.

- **Innovative financing measures and programmes for manufacturing boost**

Although India has progressed significantly in terms of solar PV manufacturing (10 GW+ module manufacturing and 3 GW+ cell manufacturing)[3], solar thermal technologies in manufacturing context are still lagging, and this effect transcends to the understanding of financial institutions as well. Owing to this lack of know-how, financial institutions lack confidence in providing financing for solar thermal projects as well as solar thermal manufacturing installations. Also, the finance that may be accessible, may be at a higher rate of interest with more stringent collateral conditions. Another reason for this is the existence of systems that are not modular or standardized and are quite often manufactured as per customized specifications, which further leads to increased reluctancy to lend.

- **Possibility of introducing CAPEX subsidy for manufacturing**

While there have been efforts on the demand side to boost CST installation through numerous programmes run by MNRE, funded through GEF and supported through UNDP and UNIDO; very minimal has been done to boost supply side measures through financial incentives and other support mechanisms. The state level industrial policies and electronic policies have encouraged the promotion of domestic manufacturing to certain niche sectors (including renewables such as solar PV, EV manufacturing and energy storage/battery manufacturing), however the benefits in the form of subsidies exclusively targeted at stimulating solar thermal manufacturing, including its ancillary industries have been missing.

Several historical precedents at central level such as MSIPS policy (25% CAPEX subsidy), SEZ policy (plethora of fiscal benefits), etc. have articulated the role played by direct subsidy allocation to manufacturing. Similar thought process must be developed to incentivize solar thermal manufacturing.

- **Focusing on quality, R&D and material science**

To develop a robust market for solar thermal manufacturing, it is necessary to invest in research and development activities to make the technology economically viable and more efficient. Several R&D developments related to solar thermal heating and cooling systems have taken place worldwide, leading to improved designs and reduced manufacturing costs.

[3] https://www.thehindubusinessline.com/opinion/columns/energising-solar-module-manufacture/article34337665.ece

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List of Abbreviations

ADA	Aeronautical Development Agency
ADE	Aeronautical Development Establishment
ARCI	International Advanced Research Center for Powder Metallurgy and New Materials
BCD	Basic Customs Duty
BEML	Bharat Earth Movers Limited
BHEL	Bharat Heavy Electricals Limited
BPO	Business Process Outsourcing
CAPEX	Capital Expenditure
CETP	Common Effluent Treatment Plants
CEU	Coastal Economic Units
CFA	Central Financial Assistance
CPSU	Central Public Sector Undertaking
CRS	Central Receiver System
CSP	Concentrating Solar Power
CST	Concentrating solar thermal
DISCOM	Distribution Companies
DNI	Direct Normal Irradiance
DRDO	Defence Research and Development Organisation
DTA	Domestic Tariff Area
EMC	Electronics Manufacturing Cluster
EV	Electric Vehicles
FCI	Fixed Capital Investment
FDI	Foreign Direct Investment
FY	Financial Year
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gas
GOM	Government of Maharashtra
GSDP	Gross State Domestic Product
GTRE	Gas Turbine Research Establishment
GW	Giga Watt
HTF	Heat Transfer Fluid
ICD	Inland Container Depot
IISc	Indian Institute of Science
IMC	Integrated Manufacturing Clusters
IOT	Internet of Things
IPDS	Integrated Processing Development Scheme
IREDA	Indian Renewable Energy Development Agency Ltd.
IRENA	International Renewable Energy Agency
ISRO	Indian Space Research Organisation
IT	Income Tax
IT	Information Technology

JV	Joint Venture
KIADB	Karnataka Industrial Area Development Board
KSIIDC	Karnataka State Industrial Investment Development Corporation
LF	Linear Fresnel
MNC	Multi National Companies
MNRE	Ministry of New and Renewable Energy
MSIPS	Modified Special Incentive Package Scheme
MSME	Micro Small and Medium Enterprises
MW	Mega Watt
NAL	National Aerospace Laboratories
NISE	National Institute of Solar Energy
PCM	Phase Change Materials
PT	Parabolic Trough
PV	Photo Voltaics
R&D	Research and Development
RE	Renewable Energy
RPO	Renewable Purchase Obligation
SEZ	Special Economic Zones
SGST	State Goods and Services Tax
SH	State Highways
SIPCOT	State Industries Promotion Corporation of Tamil Nadu
SMEs	Small & Medium Enterprises
SNA	State Nodal Agencies
TES	Thermal Energy Storage
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
VAT	Value Added Tax
YOY	Year on Year

1. CST manufacturing landscape in India

1.1. Overview of CST Technologies

Solar thermal technologies utilize sun's energy as an input to convert solar radiation energy into thermal energy through a transfer medium. CST or concentrated solar technologies comprise of reflectors that reflect sunlight onto a collector that absorbs the solar radiation in the form of thermal energy. The heat thus generated from CST technologies finds use in various industrial & commercial processes that require heating or in some cases cooling as well. In case of concentrating solar based power plants, this thermal power triggers Rankine, Brayton or Sterling cycles and the final mechanical energy is converted into electricity through an electric generator which can be further injected into the transmission grid.

The key component of any solar thermal energy system is solar collector, this is the device that collects the solar radiation, converts it into heat which is transferred to a fluid (air, water or oil depending on temperatures). CST technologies are often equipped with a heat storage system to store heat during sunny hours and utilize it later or.

CST technologies are broadly classified into two categories based on their ability to track the motion of the sun across the sky; i.e. tracking and stationary. These are further subdivided into various types based on the technology used to collect and concentrate the heat. It must be noted that CST systems which can track the sun are much more efficient than stationary systems but come with a higher capital cost and complexity due to the additional tracker mechanism. A flow diagram depicting the various CST technologies has been illustrated here.

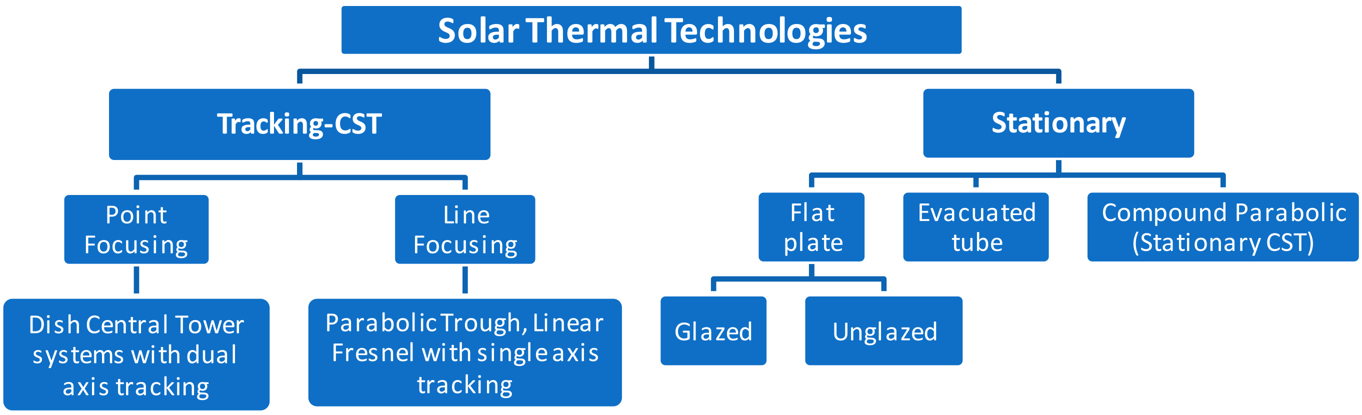

Figure 1: Solar Thermal Technologies

Based on the application, technology and heat transfer medium, CST systems can achieve a variety of temperature ranging from 150 °C for conventional water heating systems to over 400 °C through parabolic dishes, central towers, etc. The systems can typically be classified into low, medium, and high temperature systems as described in the table.

Type	Temperature range[4]
Low temperature heat	< 150 ° C
Medium temperature heat	150 – 400 ° C
High temperature heat	> 400° C

Table 1: Temperature based CST Heating

[4] IEA SHC Task 49, Technical Report A.1.3

Technology Overview:

The sector has converged into four main concentrating solar technologies which are currently being deployed and operated- Linear Fresnel reflector (LF), Parabolic trough (PT), Power tower system or central receiver system (CRS), and Parabolic dish engine (PD). A brief description of these technologies and their use cases has been presented in the table below.

Technologies Type	Temperature Range (˚C)	Heat Transfer Medium	Tracking
Fixed solar concentrator (Power Towers)	Above 400˚	Steam, Molten Salt	Dual Axis
Parabolic trough Collectors (PTC)	150-250˚	Thermic oils, water	Single Axis
Linear Fresnel reflectors	150-250˚	Thermic oils, water	Single Axis
Parabolic dishes	Upto 400˚	Steam, thermic oils	Dual Axis

Table 2: CST based Technolgies

Linear Fresnel reflectors: LF systems work at low operating temperatures and low solar field efficiencies and therefore they tend to be less efficient than other technologies. These systems have great opportunities for implementation in organic Rankine cycles, solar preheating, integrated solar combined cycle systems, and other low temperature applications, such as solar air conditioning systems.

Parabolic trough Collectors (PTC): These are a mature concentrating solar thermal technology with commercial applications in service for over 20 years. Predominantly developed for CSP plants, the modular design of these systems allows them to be implemented for various applications providing great versatility and capacity. PTC systems can be also used as pre-heaters for various industrial and commercial applications.

Fixed Solar Concentrators: Power tower systems or central receiver systems (CRS) are commonly used for high temperature applications, due to the high radiation fluxes reaching the receiver. It is possible to work at very high temperatures without significant thermal losses, which makes it possible to integrate this module in more efficient thermodynamic cycles. Heliostats spread around the central receiver concentrate the radiation onto the tower, allowing these systems to reach high temperatures, above 400^0C with ease.

Parabolic Dishes: Parabolic dishes consist of a mirrored dish that collects and concentrates sunlight onto a receiver mounted at the focal point of the dish. These systems have a higher capital cost (per MW or in metre square terms) compared to CST technologies of similar capacities but are completely modular and operate with higher efficiencies.

Flat Plate Collectors: The flat-plate solar collectors are the most fundamental and common solar thermal technologies. These are mostly used for heating water and air for domestic and commercial purposes and also for preheating fluids for industrial purposes. This technology makes use of evacuated or non-evacuated pipes with selective absorbent coatings to increase efficiencies of these systems.

Thermal Energy Storage: Thermal storage systems are used in conjunction with CST technologies to increase the capacity factor of plants by allowing them to store excess thermal energy and utilize at a later time. Various storage options like insulated tanks are proven globally, however there are various options still under development and must be proven at a large scale before widespread adoption takes place. The most common modes of thermal energy storage are based on storing thermal energy by heating or cooling a liquid or solid storage medium (e.g. water, sand, molten salts, rocks), with water being the cheapest option.

1.1.1. CST Technology Applications

The industrial and commercial sector is one of the leading consumers of energy, a significant portion of this energy consumption is in the form of heat. This heat is traditionally supplied by burning fossil fuels including coal, oils and natural gas especially for large scale heat generation applications. Some industries like paper, textile and glass, consume large amounts of thermal energy and inevitably produce significant greenhouse gas emissions through the combustion of fossil fuels.

Advancements in concentrated solar technologies have now enabled the deployment of CST technologies in these sectors to not only just off-set the traditional heat generation but in some cases also entirely replace fossil fuel/electricity as the primary medium for heat generation. Today, in India CST technologies can be deployed across various industrial and commercial applications, the diagram below shows the varies sectors that CST technologies could be deployed to increase process efficiency by reducing dependence on fossil fuels or electricity for heating purposes.

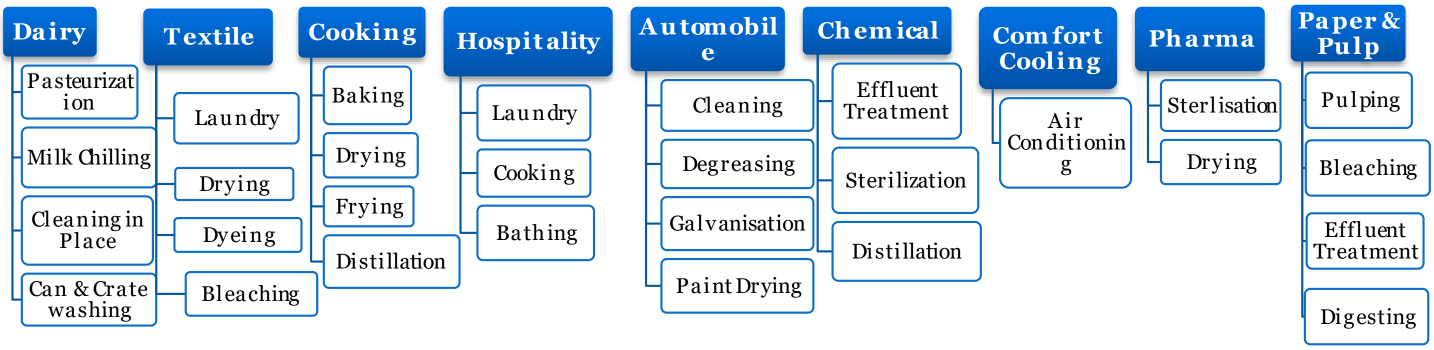

Figure 2: Applications for CST Technologies

Based on the application temperature requirements and space considerations, any of the CST technologies can be deployed to cater to the process heat requirements in the Industry. CST technologies classified as low and medium temperature systems can be utilized for processes such as heating water or air, cleaning, drying, evaporation, pasteurization, sterilization, melting, distillation, etc. across multiple industries. These CST technologies can be of both tracking and stationary type. High-temperature CST technologies are used for heating requirements in more heat intensive sectors up to 400˚C/20 bar pressure and for electricity generation (through CSP).

Industrial applications of Solar Thermal

Industrial heat is characterized by a wide diversity with respect to temperature levels, pressures and production requirements to meet the varied industrial process demands. Based on the CST technology deployed, the heated fluid or steam can be generated between low to high temperatures, off-setting more expensive fuel consumption.

Advantages of CST's to Industries

- De-risks existing business by reducing dependance on conventional fuels
- Reduced fuel consumption and operational costs
- Incentives as may be offered on usage by the Government from time to time
- Emission reduction and help in green branding

Process heat is not the only requirement that can be met directly through CST, as there are other options where deployment of CSTs can be explored:

- **Process Heat, Steam generation**
- **Boiler pre-heat**
- **Water Desalination**
- **Space and Process Cooling**
- **Hybridization with biomass/gas**

1.1.2. CST Deployment in India

India is endowed with good solar insolation receiving almost 300 sunny days in a year on average across the country. The calculated solar energy incidence on India 's land area is about 5000 trillion kilo-watt hours per year and there is lot of untapped potential of solar energy in India. The National Institute of Solar Energy (NISE), an autonomous institute under Ministry of New & Renewable Energy, Government of India has estimated the total solar potential of India at a little less than 750 GW. The daily average solar energy incident over India varies from 4 - 7 kWh/m2 with 1,500 – 2,000 sunshine hours per year (depending on the location). The map alongside provides an estimation of the variance in solar radiation across India. Western part of India has maximum radiation and this level decreases gradually as we progress from the west towards the east.

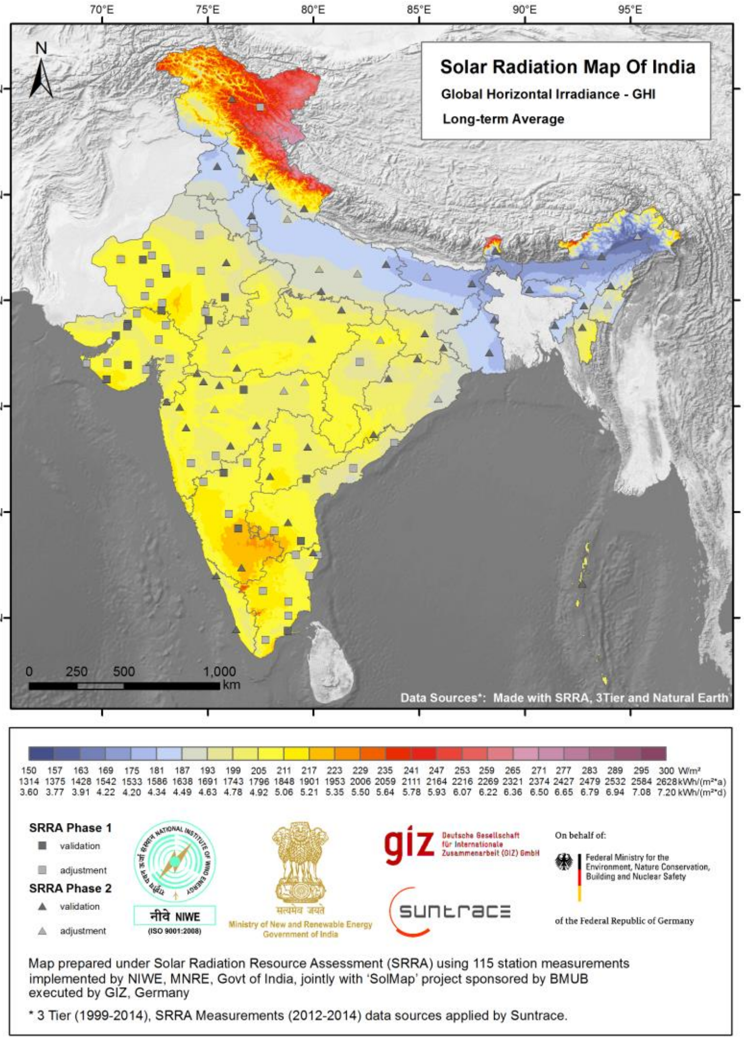

Figure 3: India Solar Irradiance

The National solar mission had established targets of implementing a cumulative solar thermal collector area of 15 million square meters by 2017 and 20 million square meters by 2022. India currently has a cumulative installed collector area of approximately 11.6 million m^2 (Dec 2019) and the country as of 2019 had also installed a total of ~225 MW of installed CSP capacity[5]. Though it must be noted that Solar water collectors dominate the market with majority market-share and the rest is for process heat in industrial and commercial operations.

In 2019, the MNRE has sanctioned eight projects with a cumulative collector/reflector area of about 1630 m^2 for various applications in different parts of the country. The lion's share of the area under implementation comprises of solar water heating systems. The growth can be attributed to a number of policy enablers to increase the usage of solar thermal technologies that even made their installation mandatory on certain categories of buildings with high energy demand. As a result, solar thermal water systems of capacity 1.25 GWth were installed in 2019 in India, taking the nation's total installed capacity to around 9 GWth by the end of 2019.

Cumulated Collector Area in Operation by the end of 2019				
Water Collectors (m^2)		**Air Collectors [m^2)**	**Concentrators (m^2)**	**Total (m^2)**
Evacuated	*Glazed*	*Glazed*	*PTC, Fresnel, Paraboloid Dish etc.*	
74,25,876	40,56,399	12,150	87,473	**11,576,648**

Table 3: Installed collector area for solar thermal in India (Source: REN21)

[5] REN21: https://www.ren21.net/wp-content/uploads/2019/05/gsr_2020_full_report_en.pdf

India is seen as a favourable market globally for the growth of CSTs. This is primarily because of the high irradiance, rapid economic and industrial growth and intent of the country to reduce fossil fuel imports and generate energy in sustainable manner. The country however has its own barriers to growth, such as the non-existence of solar grade reflector manufacturers.

CST technology not only presents an opportunity for decarbonization the highly emission intensive industrial sector but also generates savings for the end user by off-setting/replacing the reoccurring expense of fuel purchase for heating/cooling.

India currently has the maximum area under implementation for CSTs for process heating and cooking purposes and therein lies a viable opportunity to become the unanimous global market leader for CSTs for such utility.

The CST roadmap for India estimates a total market potential of 6.45 GWth for CSTs, which will be driven by various market forces including financial viability of the projects, willingness to implement such projects on the part of the industry and most importantly the availability of land for these projects. In monetary terms, this roughly translates into an investment opportunity of INR 25,800 Cr (considering the cost to be INR 40/Wth).

MNRE Scheme for Off-Grid Decentralized Applications of CST

The MNRE has been running an incentive program for promotion of solar concentrated thermal energy usage in industrial and domestic applications through a capital subsidy based mechanism. With support from the United Nations Industrial Development Organization (UNIDO), a project for "Promoting business models for increasing penetration and scaling up of solar energy' has been operational to assist in commercialization of concentrating solar technologies by focusing on policy interventions, awareness creation and addressing various technical and financial barriers.

In 2019, the MNRE has sanctioned eight projects with a cumulative collector/reflector area of about 1630 m^2 for various applications in different parts of the country.

A financing scheme was developed jointly with Indian Renewable Energy Development Agency (IREDA) and MNRE, providing financial support to CST projects by bundling the MNRE's subsidy and a soft loan from IREDA, thereby providing capital for upto 75% of CST project cost. Through this modality the project aimed to support the high upfront capex requirement during the design and installation phase of the project.

1.2. Analysis of CST manufacturing landscape

1.2.1. Key elements of a CST supply chain

The supply chain of a solar concentrator conversion technology involves integration of various components required for converting the solar radiation to thermal energy, using a collector system (mirrors, reflectors etc.), thermal energy conversion system (boilers, heat exchangers), heat transfer medium and system control equipment. The thermal energy generated through collectors can also be stored in storage devices for subsequent usage.

The key sub-components required for these systems are generally manufactured by specialized manufacturers and then assembled by various technology integrators based on the type of application of the system. Some components such as tracker mechanisms have benefited by adopting technologies from the solar PV.

Increased efforts towards renewables have enabled manufacturers, integrators and installers of concentrating solar thermal technology to establish supply chains for critical components such as the reflectors and mirrors where other available existing technologies like boilers and steam turbines can be in most cases procured domestically.

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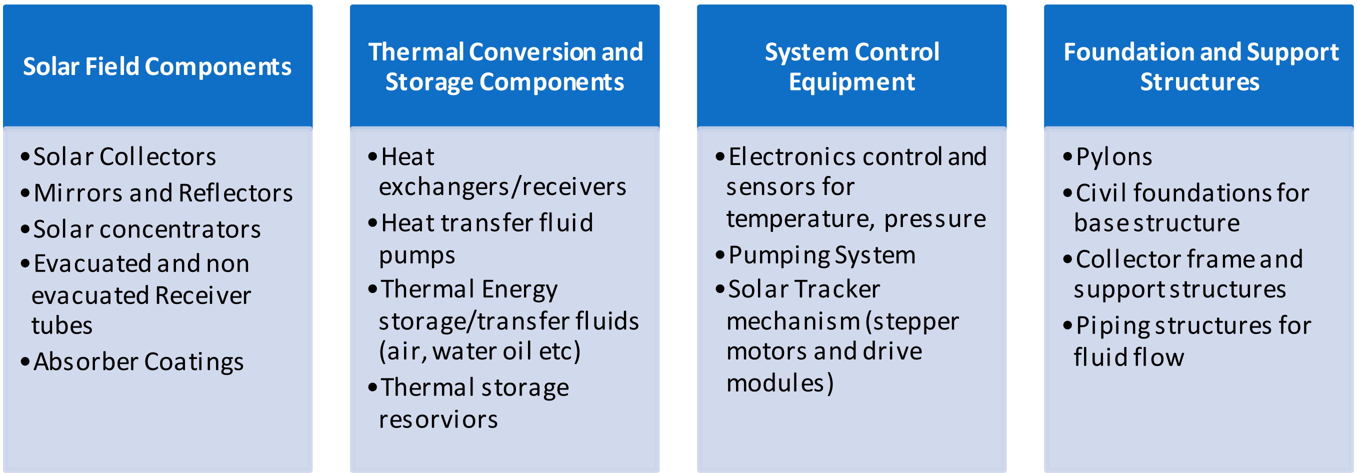


Figure 4: Sub components of a CST System

CSTs use the energy from solar radiation to collect the heat energy for usage in a thermal power cycle, or heat exchange cycle based on their applications. An effective concentrating solar thermal system's supply chain consists of key components:

- **Solar Field Components**
  - **Concentrators**

Since the solar radiation incident on the surface of the earth has very low power density per unit area, the irradiation is concentrated using an optical system of mirrors and reflectors on a receiver where all the energy is concentrated. There are several methods for concentrating the solar radiation most involving mirrors and high reflective coatings that can direct the sunlight to the receiver.

  - **Receivers**

The concentrated solar radiation is collected at the receiver which converts the radiation into thermal energy that is then transferred though the heat transfer fluid for transport to the desired application. Based on the type of CST system, receivers can be broadly classified into point receivers (parabolic dish, central tower receivers, etc.) and line/pipe receivers (linear Fresnel reflectors, flat plate collectors, Parabolic Trough Collector, etc.)

- **Thermal Conversion and Heat storage**

The collected/concentrated radiation from the receiver is converted to thermal energy using heat exchangers and the energy is generally is transferred either through conduction or through convection. The thermal energy is transported and stored for conversion into other forms. These primary and secondary circuits of the heat exchange of the process employs materials with high thermal conductivity such as copper or similar metal alloys piping with special coatings to prevent degradation as well as heat loss.

Based on the final application of the solar thermal system, this collected thermal energy is transformed using a thermal cycle (steam boilers, de-salination, heat exchangers, etc.) to convert the heat energy into other forms of energy based on its end use application. The energy can also be stored via a thermal storage medium (hot water tanks, molten salt storage, etc.) in an insulated reservoir to be utilized later on, during hours without sunlight.

- **System Control Equipment**

The system operation is optimized for maximum efficiency using a control system that can monitor and control all processes in the solar thermal system, this includes the functioning of the collectors and receivers, heat pumps, thermal medium controls, steam boilers, thermal storage tanks and solar tracking

- **Support Structures and Civil Works**

For most optimal system operation, it is necessary that the CST system is installed in a shadow free location on a stable and flat base preferable facing south (w.r.t to deployment in India) to receive the maximum amount of sunlight throughout the year. The mounting structures for these systems vary from one technology to another, with flat plate and evacuated tube collectors being mounted on structures similar to solar PV panels; whereas parabolic dish systems and Fresnel reflectors having a slightly more complex mounting structure because of their tracking motion.

1.2.2. Key Sub-Component Manufacturing Supply Chain of CST systems

In order to develop the domestic capabilities required to manufacture low cost and effective CST systems, we must first analyse in detail various components that constitute a CST system. Though the final application of the system might determine some of the components, the overall design of the system will require some common components like the solar field components to reflect/concentrate the sunlight ,the receiver components to absorb and transfer the heat to a transfer medium and the tracking mechanisms and support structures to mount and operate the system at the desired efficiency.

In this section a manufacturing overview of the critical sub-components of a CST system have been discussed.

Solar Field Components

- **Reflectors and Mirrors**

The key function of this component is to concentrate the incident radiation on focal point or along the focal line of the absorber/receiver tubes. While maintaining a high reflectivity rate, the reflectors also need to have low thermal absorption to perform efficiently. Mirrors and reflectors used in CST plants are different from traditional mirrors in reflectivity, durability, and strength. The fabrication of the needed extra clear glass requires low-ferrous sand and needs to be coated with protective/reflective surface coatings to further increase their efficiency and durability. Mirrors made for certain CST systems including paraboloid dish Fresnel reflectors have to be curved, requiring special expertise and setup to manufacture.

The mirrors need to be coated with high reflectivity and low conductivity coatings to increase their efficiency and reduce thermal absorption, thereby increasing their lifespan. Due to their specialized design & manufacturing, these types of mirrors have limited applicability outside of CST and CSP systems in the country; and given the low demand for these types of mirrors, the leading glass manufacturers do not have the incentive to setup dedicated lines for the manufacturing of these solar grade mirrors.

The logistics and transport of these mirrors also depending on their size can present a key challenge as specialized transport vehicles and custom built support structures are required to handle the vibrations and impacts during transport to final site.

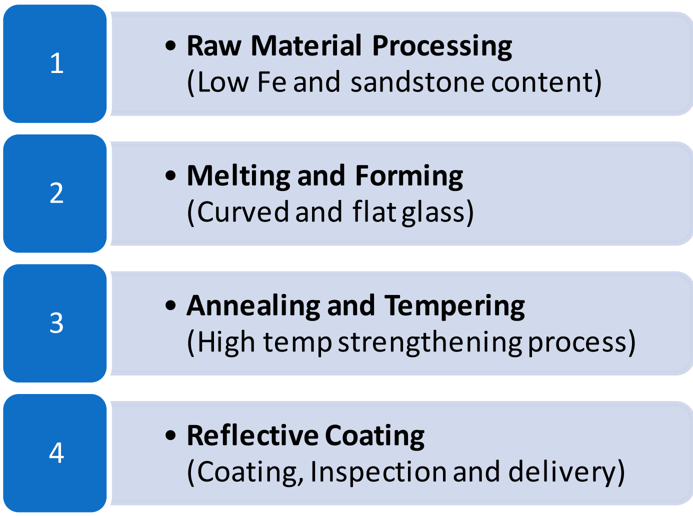


Figure 5: Manufacturing process of solar grade reflectors

- **Receiver/Absorber System**

The optical and thermal properties of the receiver tubes enable them to transfer the heat from the solar radiation received from the reflectors/mirrors to the heat transfer fluid (HTF). The receivers and absorbers (heat transfer medium) are specifically designed based on the final application of the CST system including to characteristics like temperature, pressure requirement, etc.

Fluid based receivers (steam) are generally more versatile in nature since they can be naturally adapted to existing heat process cycles but suffer from low efficiencies due to low heat transfer in the gaseous medium and complexities in thermal storage. Liquid based receivers are very common for low-medium temperature applications that involve heating water/air for medium and high temperature applications. Use of thermic oils and molten salts increases the complexity of the systems but allows for heat storage for longer durations that increases efficiencies.

The choice of material for the absorber/receiver due to relatively high temperatures is generally metal alloy or ceramics. System designs for these components include tubular and mesh structures through which the heat exchange fluid is pumped to evacuate the thermal energy received by the absorber/receiver.

The surfaces of these tubes are coated with optically selective coating that maintain the high absorbance for the required spectrum of solar radiation. These coatings should be able to withstand the high temperatures due to the concentrated solar radiation but also maintain the high thermal conductivity required to transfer the heat to the process medium. The solar absorber coating is characterized by its absorptance in the visible range which should be as high as possible and emissivity in the infrared range which must be as low as possible.

- **Support Structures and Pylons**

Support structures for the typical CST system include the mirror support, pylons, central stem and support arms. The concentrator mirrors/reflectors are installed on a rigid metal structures, which gives them the shape and orientation necessary to concentrate the radiation in their focus. These structures need to be manufactured by high-precision fabrication processes with galvanized steel or aluminum as the raw material. Since the structures need to last for more than a decade, under adverse weather conditions, specific grades of steel are required.

The manufacturing process for these structures depends on the requirements for different types of CST technologies. The design and type of support structure and the layout and cost of the manufacturing line are determined by the CST technology. The support structures and covil structure (e.g. foundation) of the CST systems are critical as they provide the support for the reflectors, absorbers and tracking system to rest on.

Given the maturity of the steel and metal fabrication industry in India these fabricated components have been made locally for several applications and across industries. Companies in the automotive component industry are capable of manufacturing support structures. Standardization of design and technologies can increase the manufacturing base within the country and eventually reduce the price of these components in the domestic market.

System Control Equipment

- **Solar Tracker Mechanism**

In order to ensure that the focal point of the incident solar radiation is always concentrated on the receiver/absorber tubes during all times of the day, the reflectors of the CST system must track the motion of the sun in the sky daily as well as seasonally. Thus, these mechanisms are a decisive parameter to attain a high degree of efficiency for CST systems.

Electric motors or hydraulic drive systems controlled by sensors which track the sun's elevation and position in the sky to point the system in the most appropriate direction are deployed for this purpose.

These systems can be broadly categorized into the hardware to move the reflectors and software to ensure the right orientation of the CST system relative to the sun's position in the sky. Some of the components for these tracking devices are similar to the ones being used in the wind power industry, as well as in Solar PV.

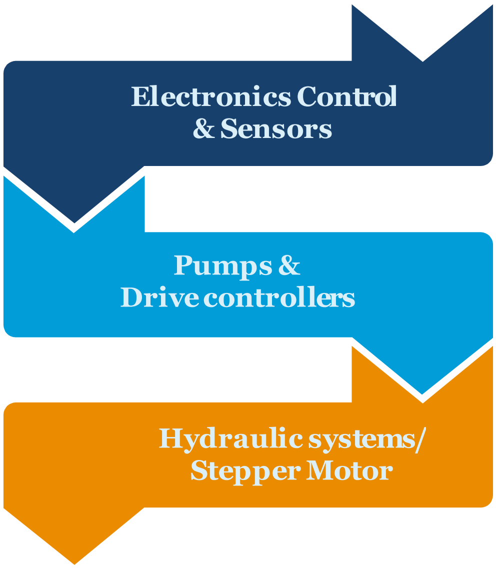


Figure 6: System control equipment of a CST system

Thermal Conversion and Storage Components

➢ **Heat Transfer Fluids (HTF)**

The heat transfer fluids in CST systems include air, water, molten salts and synthetic oils. Based on the temperature of the process/application, the appropriate heat transfer fluids can be decided. While water and steam work great for low and medium temperature applications, high temperature processes need to use thermic oils or molten salts to handle the higher temperature gradients.

The heat transfer fluid (HTF) that circulates through the receiver tubes absorbs the solar radiation from the absorber tube in the form of thermal energy, increasing its temperature as it goes through the loops in the receiver. The output heat of a CST system is restricted by the HTF properties, which means that the fluids that can perform these functions are also limited. Commercially proven technologies are currently limited to a temperature of around 400-500 °C. High-purity propylene crude and ethylene crude are the main raw materials to produce these synthetic fluids.

➢ **Thermal Storage**

Thermal energy storage (TES) systems enable CST systems to use the heat collected during times of high insolation, to be used during times of low insolation. Molten salt, concrete storage, phase change materials, saturated steam or pressurized air are some of the storage mediums used in CST system.

Thermal energy storage is useful to store the heat energy in i) phase change materials (PCM) where the heat energy is stored/extracted when the storage material undergoes a phase changes at constant temperature, ii) sensible heat materials: heat energy is stored by increasing the temperature of the storage material and heat is extracted from the material by lowering the material's temperature and iii) thermo chemical storage: a reversible endothermic chemical reaction that consumes the solar energy.

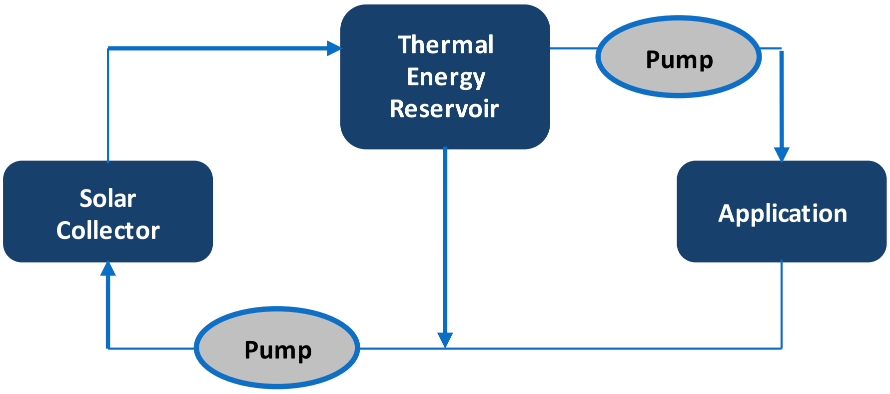


Figure 7: Thermal Storage and control equipment of a CST system

The storage tanks and pumping system are designed keeping in mind the deployed storage technology, the duration and size of thermal energy requirement and process characteristics like temperature, pressure, etc. Various types of thermal energy storage that are currently deployed in CST systems have been described in the table below.

Single Phase (sensible storage)	The temperature differential is used to store thermal energy	Eg: Molten salts (nitrates, carbonates, chlorides), Solids storage (ceramic, graphite, concrete)
Phase Change Materials	Using the latent heat to store thermal energy	Eg: Molten salts, metallic alloys
Thermo-chemical storage	Converting the solar radiation into chemical bonds for energy storage	Eg: Chemical decomposition/synthesis, redox reactions

Table 4: Thermal storage technologies for CST systems

1.2.3. Reliance on Imports

Indian CST industry is currently reliant on imports of a few key sub-components. While the industry has capabilities to domestically cater to the structural, civil, and mechanical requirements of these systems, some of the other critical components, such as mirrors, receiver tubes, heat transfer fluid (HTF), thermal energy storage technologies are currently imported. These imported components increase the capital cost of these technologies, while also relying on imports for such spares once the project is operational. Further cost reductions could be achieved in the future through local manufacturing of tracking devices, receiver tubes, parabolic mirrors, and structures (parabolic trough).

The specific cost of the solar thermal systems has come down in recent years, especially in the developed markets of Spain, North America, Germany, and China. This decrease is owing to the technological prowess (improved collector designs), increased awareness and large number of manufactures and project developers, ultimately making the market more competitive.

Manufacturers that are market leaders in certain components of CST technologies (reflectors, receivers) can produce components at lower cost. Due to lack of domestic manufacturing capabilities In India, most of the components of a CST plant, especially the solar field components (mirrors, absorber tubes) are currently imported. This in turn has increased the price of installation for CST systems, a study conducted by the World Bank estimated that there were up to 25% savings that could be accrued across various components by promoting a domestic manufacturing base in India.

The lack of a domestic manufacturing ecosystem for these components can be attributed to the technological complexity of these components as well as the low market volumes for them, which reduces the investor interest in such manufacturing projects. India already has strong domestic manufacturing expertise in some of the adjacency areas required for CST component manufacturing, however a lack of market volumes and limited capacity deployment translating into low revenue generation has deterred domestic manufacturing.

CST component manufacturing mapping to current Indian Scenario

In order to gain an overall view of the CST manufacturing landscape in India, the industrial manufacturing capabilities within the country have been mapped to the capabilities required for manufacturing specific CST components. For India to exploit the enormous market potential for CST systems, the domestic manufacturing of CST components needs to be amplified.

Component	Technology Complexity	Present Manufacturing Capability
Receiver Absorbers and Heat Exchangers	Specialized	Low
Mirrors and Reflectors	Specialized	Medium
System Controls and Tracker System	Specialized	Low/Medium
Heat Transfer Fluids (Synthetic Oil and Molten Salts)	Specialized	Low
Support Structures and Pylons	Specialized	Medium/High

Table 5: Complexities and manufacturing capabilities of CST system components

One of the critical challenges for CST is lack of reliable indigenous manufacturing, leading to reliance on imported components. This drives up the overall systems costs and deters adoption amongst consumers in a price sensitive market like India.

Mirrors and Reflectors

Manufacturing of mirrors in India is primarily to cater to the glass industry. Since glass manufacturing is CAPEX intensive, there are handful of active players in this sector. The manufacturing process for glass involves a high temperature kiln that operates at over 1,500° C. Silica, soda ash, calcium oxide, and feldspar are mixed in set proportions and the entire batch is fed to a furnace. This process is a continuous flow and there can be only a few modifications to the type of glass produced, once the furnace has started.

In order to make highly reflective solar grade glass, a specialized blend of raw materials is required to achieve high reflectivity, low absorption and heat retention properties. This deviation from the standard manufacturing process is deemed as unviable by glass manufacturers that have the facilities for production of these components. This is because the market demand and volumes do not justify their costs to develop capabilities for solar grade mirrors. Even the curved mirrors required for parabolic dishes and troughs require a high degree of expertise that needs to be developed by Indian mirror manufacturers, specifically for serving the CST market.

Keeping in mind that the volume for these types of reflectors is not significant in the current market, many of the large mirror manufacturers do not find financial value even by importing high-quality, low-iron, sand flat float glasses and setting up manufacturing for bending and mirroring processes which can be carried out locally with specialized equipment available in the market.

Receiver/Absorbers and Heat Exchangers

The receiver contributes to most of the energy losses - optical as well as thermal, and needs to be most efficient, thereby requiring specialized manufacturing expertise. India has been able to domestically manufacture flat plate collectors with relative ease, leading to high solar water heater deployments. However, the country is yet to develop capabilities to manufacture receivers for higher temperature applications requiring deployment of evacuated tube collectors and CSTs.

The selective surfaces of the receivers must be highly absorbent and have low thermal emissivity at the operating temperature. These coatings are also applied through an electroplating process which can be duplicated in India, but the market does not have the volumes that justify the investments into such a manufacturing facility.

The vacuum seals required for the evacuated tube collectors are also specific to CST technologies and remain imported, in absence of indigenous manufacturing. Though there are some overlaps with the industries such as paper, pulp and steel tubing, the receivers and absorber tubes in CST systems need to be of the highest quality.

Heat Transfer Fluids

There are diverse types of HTF starting with water (de-ionized), air, heavy oil and molten salts; and are used in CST systems to transport the heat from the receivers/absorber tubes to the end use application or thermal storage. Thermic oils and molten salts are a preferred material for CST technologies for medium and high temperature processes as they do not have to deal with the issue of high pressure linked with steam. Water under high temperatures also gets oxidized quickly, that can encourage the materials of the absorber tube to react and can cause corrosion in the inner parts of the receiver.

The problem with heavy oils, however, is that the hydrocarbon breaks down quickly if heated to around and beyond 400° Celsius. Therefore, chemical composition of oil limits the temperature CST systems can operate at. It is also important to select HTF considering the usage of corrosion inhibitors and purity level of fluid to be used. With the demand being uncertain, it appears less probable that Indian players will invest in R&D and manufacturing facilities for production of HTFs and thermic oils.

Criteria for a suitable HTF:

- High operating temperature
- Stability at high temperature
- Non-corrosive and safe to use
- Low vapor pressure
- Low viscosity
- Low material maintenance and transport costs

1.2.4. Analyzing need to push CST manufacturing in India

The Indian government has ambitious plans to increase the adoption of clean energy technologies to promote sustainability and reduce its dependency on imported oil of which a significant ~80% is imported. To ensure country's energy security and reduce emissions, the government has announced its target to achieve 175 GW[6] of renewable energy (RE) by 2022.

India has made significant progress towards this target in the adoption on clean energy and has begun transitioning towards a clean energy economy, but further rapid advancements are still required for adopting sustainable energy technologies. The renewable energy market in India is growing at a rapid pace with over 35 GW of solar installations, 37 GW of wind installations and a total renewable energy capacity of ~88 GW as on June 2020[7]. There is a healthy ecosystem for manufacturing of wind turbines and Solar PV with giga scale manufacturing being deployed, however such an ecosystem is missing for solar thermal.

India's total final energy consumption has been steadily increasing and has gone up by 50% in the past decade, with industry and transport contributing to the largest increase[8]. The Industrial sector in India, meeting its energy needs through a mix of fossil fuels coal, oil, natural gas, electricity and biofuels represents a total of 56% of the total final consumption of energy in the country, followed by the residential sector at 29%[9].

A majority of the low to medium temperature heating applications across the industrial, commercial and residential sector are reliant on electricity or direct combustion based heating systems for thermal energy generation. For such applications, CST technologies can play a significant role in off-setting the energy consumption through while reducing carbon footprint.

Industrial Decarbonization: Industrial sectors which employ thermal heating processes in India like dairy, food processing, textiles, chemical, automobile and pharma for instance could benefit from adoption of concentrated solar thermal technologies to not only reduce their emissions and carbon footprint but also decrease the exposure to volatile fuel prices. Adoption of CST technologies can also contribute to lowering the country's import bill on account of fossil fuel imports. It has been estimated that emission of almost 400 tonnes of carbon dioxide will be reduced from 1MWth capacity addition of CST s. Further, on a project lifetime basis, this will result in emission reductions of 8000 tonnes of carbon dioxide from 1 MWth CST capacity over the lifecycle of the projects.

Increased adoption amongst the industrial and commercial sector for even preheating and cooling would present a huge opportunity for these sectors to decarbonize. To support the clean energy sector through a local manufacturing ecosystem, the Government of India has launched several programmes like Make in India, the National Policy on Electronics (NPE) along with various incentives given by the states through their respective industrial policies to promote renewable energy to push the agenda of domestic manufacturing in India. Individual states have also put in place conducive manufacturing policies and incentives to boost investments into local manufacturing. Similar to how the auto industry developed the design and then manufacturing capabilities in India, a domestic manufacturing base for CST technologies can also assist in increasing penetration of renewable energy technologies not only in India but also globally.

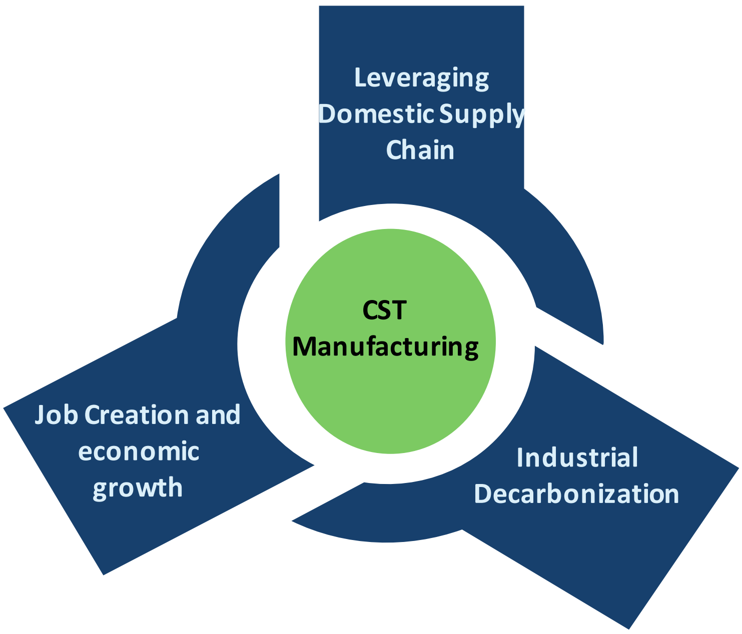


Figure 8: Advantages of CST component manufacturing in India

[6] https://mnre.gov.in/file-manager/annual-report/2018-2019/English/pdf/chapter-1.pdf
[7] MNRE Physical Progress: https://mnre.gov.in/the-ministry/physical-progress
[8] IEA: https://www.iea.org/data-and-statistics?country=INDIA&fuel=Energy%20consumption&indicator=Total%20final%20consumption%20(TFC)%20by%20source
[9] IEA 2020: https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy_0.pdf

Job Creation: A thriving CST industry would create opportunities for employment not only in manufacturing but also project development including, construction and maintenance of projects. The employment database for renewable energy technologies including concentrated solar power and solar heating and cooling at IRENA has estimated that as of 2018 there have been about 33,600 jobs created through CSP and 801,400 people employed in solar heating and cooling systems[10].

In India there are estimated to be approximately 20,575 people working/employed in solar heating and cooling industry[11]. The skill capabilities and resource knowledge from this segment can by expanded into the concentrated solar thermal industry. The additional employment generated through increased local manufacturing of CST system components can be a mixture of both direct and indirect employment.

The reducing cost of CST technology triggered by cost reduction through local manufacturing would accelerate the adoption of CSTs and eventually lead to higher savings for consumers. Lower customs duties for manufacturing machinery and raw or processed material, and the lower cost of logistics and development of local supply chain would further reduce cost and increase deployment, thereby employment generation in this sector.

Leveraging Domestic Supply Chain: India can leverage its existing strengths in various industries to develop domestic manufacturing capabilities to increase the country's competitiveness on a global level in CST technologies. Expertise in sectors including glass and mirror manufacturing can be enhanced through JVs and partnerships with global players for technology collaboration to develop and manufacture CST components in India. A large number of domestic and global companies have set up manufacturing in the country and many of them have been using it as a base to cater to the domestic as well as overseas markets. Industries such as glass, steel, and electronics are developed and mature enough to diversify into manufacturing of more value added components like solar grade mirrors, and trackers for the CST industry.

Various incentives offered by the states through their respective industrial and manufacturing policies can be utilised to develop domestic capabilities for CST manufacturing as well as adoption.

Existing Industry	CST Component Manufacturing
Glass	Curved mirrors and solar grade reflectors
Chemical Industry	High Temperature Fluids (thermic oils, molten salts), Surface absorbent and reflective coatings
Power	Power block, Heat exchangers, Balance of Plant
Electronics and Machine tools	Control Systems and Tracker Mechanisms
Steel and Fabrication	Piping systems (evacuated and non-evacuated tubes), Pylons and support structures

Table 6: Leveraging domestic industries and supply chains for CST component manufacturing

Solar thermal technologies can offer a low cost and sustainable solution for process heat, cooking, waste-water treatment and hot water applications amongst others. It also offers innovative solutions in commercial and industrial heating & cooling applications as well as for desalination plants. The industrial and commercial sectors in India can benefit from improved penetration of CST technologies, which can be achieved through localization of CST component manufacturing to reduce system costs and boosting adoption

[10] IRENA: https://www.irena.org/publications/2019/Jun/Renewable-Energy-and-Jobs-Annual-Review-2019
[11] IRENA: https://www.irena.org/Statistics/View-Data-by-Topic/Benefits/Renewable-Energy-Employment-by-Country

1.3. Opportunities for Solar thermal Manufacturing in India

There are several industrial and commercial applications of solar thermal systems. It can be used in the iron and steel, paper and pulp, textile, ceramic and tile, food processing and dairy industries, amongst others. Solar thermal energy has the potential to replace the conventional fuel these industries currently use.

Considering India's increasing energy consumption over the years, the intervention of CST technologies into the overall energy mix presents a perfect opportunity for India to reduce its reliance on conventional resources, especially in the industrial and commercial sectors.

The intent to promote these systems has observed in the policy and regulatory mechanisms that the government of India has laid out for the adoption of CST technologies in the country. Through the National solar mission, the country is aiming to install 20 million sqmt of total collector area[12] by FY 2022. Under the MNRE scheme for off grid decentralized applications, subsidy support has been provided for the installations of CST systems. Developers and owners of CST plants can also avail accelerated depreciation (AD) of up to 40% per annum on these projects. Solar water heaters currently form a major chunk of India's collector utilization, which can be largely attributed to mature technology, higher awareness, ease of deployment and even mandatory obligations in some cases for certain categories of buildings.

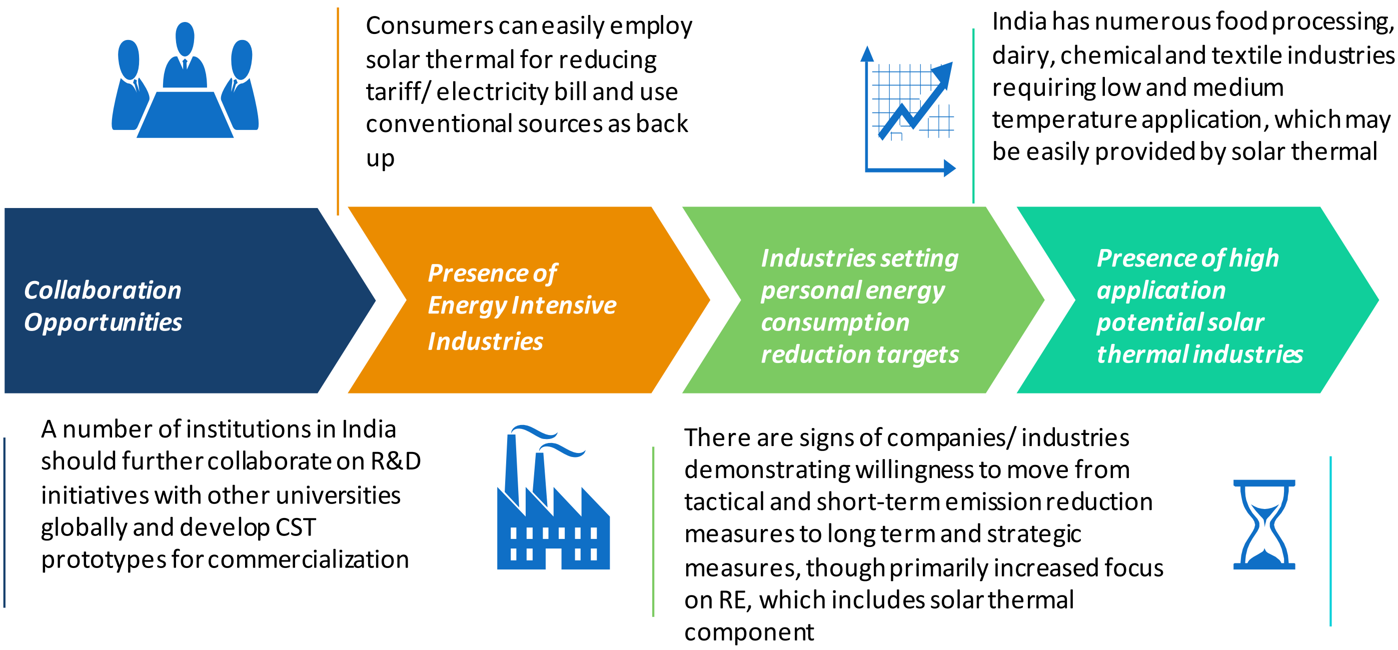


Figure 9: Opportuinities for CST component manufacturing in India

The MNRE has also stipulated the minimum technical requirements for solar thermal technologies as per IS standards[13]. Solar water heaters and cooking application-based technologies like flat plate collector, evacuated tube and box and dish type cookers are quite common for domestic applications and have standards in place for ensuring performance of the products. CST based technologies are still in the developing stage and lack the standardization to drive down the costs of systems of system deployments. Most of the CST applications are often customized as per the user demand.

The MNRE has put in place minimum technical requirements and performance ratings for the components used to generate solar thermal based steam and heat through concentrated and non-concentrated technologies. Further standardization of CST systems based on their technology and design can help reduce system costs and improve adoption.

[12] http://164.100.94.214/sites/default/files/uploads/mission_document_JNNSM.pdf
[13] https://mnre.gov.in/img/documents/uploads/067178dfba7c4777819aef0bc79afea6.pdf

Another approach the government can take to improve the rate of CST adoption is to stipulate industries with heat processes (e.g. Dairy, textile, chemicals, pharma, automobiles) to procure a certain percentage of their heat requirements from CST technologies. This can be through incentives such as tax rebates, capital subsidy and other fiscal benefits that would incentivize the industries to adopt CST systems.

One such example is Scheme for Integrated Processing Development Scheme (IPDS)[14], offering 50% of the project cost by way of grant from Govt. of India for deployment of water treatment & effluent treatment plant and technology. State government have also been mandated to contribute 25% of the project cost, besides providing requisite clearances and assist in identification and procurement of requisite land.

The scheme is also similar to Scheme of Common Effluent Treatment Plants (CETP), implemented by Ministry of Environment, Forests and Climate Change offering 50% central assistance and seeking commitment from state governments to bear 25% of the capital cost of CETP[15].

There are already a few suppliers and developers manufacturing solar thermal systems, catering to the existing market in India. Domestic manufacturing can further strengthen on the back of increased demand for these systems. A number of institutions (SERIIUS-IISc Bangalore, ARCI) in India are also collaborating on R&D initiatives with other universities and institutions to develop prototypes for commercialization. All these attributes highlight the credentials of India towards emerging as a prime contender for a progressive market for solar thermal technology.

To gauge the value capture that could take place in India, a component wise cost distribution for a larger solar thermal system has been plotted below[16]. Though it must be noted that the price can vary based on the technology, application and location of the concentrated solar thermal system.

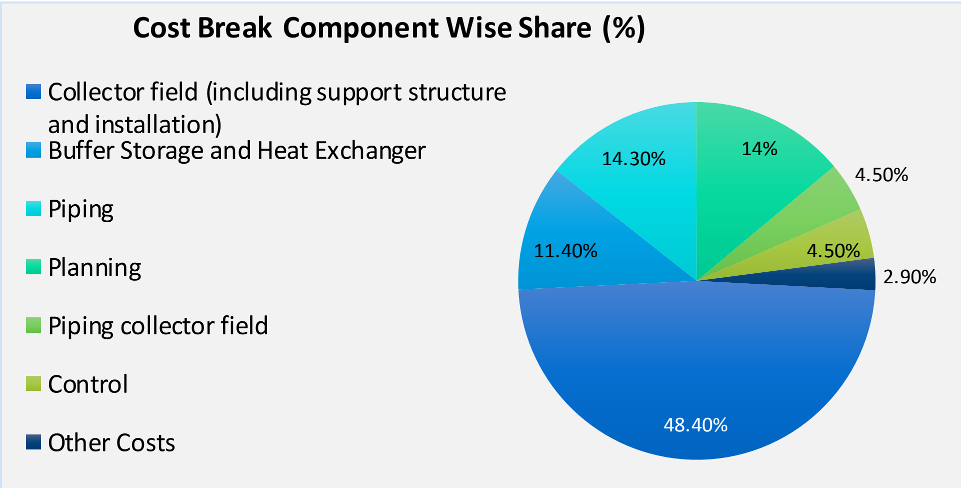


Figure 10: Component wise cost breakdown of a CST system

There is already a presence of domestic manufacturers that operate in adjacency area's to CST component manufacturing like solar grade mirrors and evacuated absorber tubes. It is crucial to create a pipeline of CST projects that would persuade these players develop capabilities to produce CST related component manufacturing expertise. Some of the manufacturing capabilities for specific CST components along with companies in India that can develop components for the CST have been listed in the section below.

[14] http://www.texmin.nic.in/sites/default/files/GUIDELINES_FOR_IPDS.pdf
[15] http://www.ppcb.gov.in/Attachments/Financial%20Support%20under%20Schemes/Scheme%20for%20CETP.pdf
[16] https://www.solarthermalworld.org/sites/default/files/story/2015-06-07/solar_hotwater_dg.pdf

1.3.1. Strengths to Leverage for promoting domestic manufacturing

In order to promote the manufacturing of CST components in the country, India must first utilize the already existing manufacturing expertise that it has in many industries. For instance, the glass and mirror industry, metal fabrication, oil and chemical industry have adjacency with certain CST components that can be manufactured without developing the entire supply chain from scratch.

While these could be the easiest form of value capture for India to achieve, it would also have to work towards developing the capabilities in the manufacture of thermic oils and HTFs, absorber and reflective coatings as well as receiver/absorber tubes to maximize the domestic value capture of CST systems that would be deployed in the country.

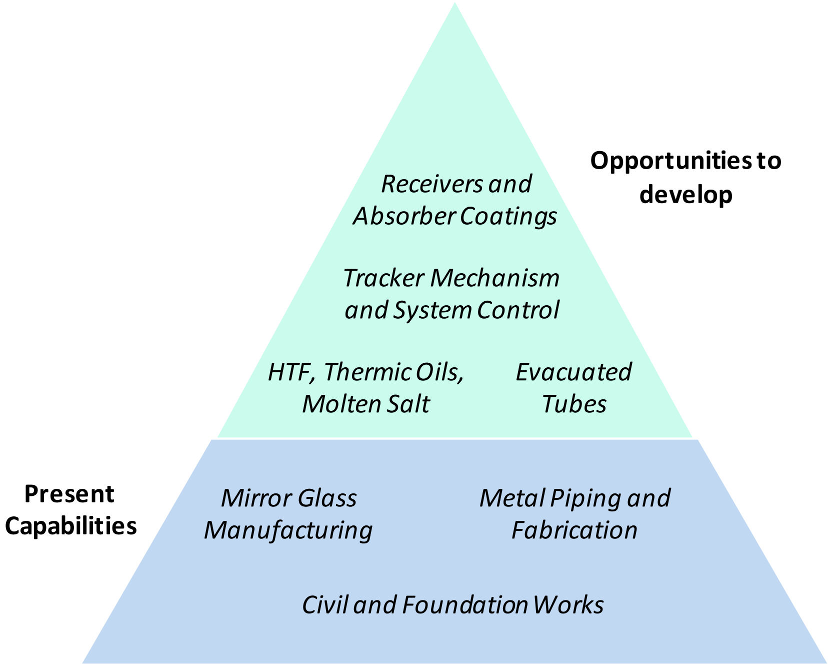


Figure 11: Opportuinity mapping and leveraging domestic capabilities for CST component manufacturing

Mirror/Glass Manufacturing Industry

The glass industry in India has a production capacity of around 2.6 Mtons per year, with the production of float glass taking a majority share of the total glass production in India. The glass industry in India is segmented into automotive, architectural and food and beverage industry, out of which, architectural industry hold the major share.

More recently, the solar industry has also been segment of interest for the glass manufacturing companies in India. By creating the appropriate incentives to drive the solar mirrors segment, the glass industry in India can easily cater to the domestic requirements of CST technologies as well becoming an export hub particularly within south east Asia.

In India, the majority of glass manufacturers and industry clusters are located in Ahmedabad, Baroda, Bengaluru, Firozabad, Hyderabad, Kolkata, Mumbai, New Delhi and Pune; with Firozabad being India's biggest glass cluster. The challenges preventing the domestic manufacturing of solar grade mirrors has been primarily the high capital cost and the low demand which needs to be increased for achieving efficiencies.

Since the float glass manufacturing facilities already exist in the country, only the raw material has to be imported so that extra clear glass can be made. There is also availability of technology with international players that have been manufacturing in India. Some of the top glass manufacturers that could be capable of producing solar grade mirrors have been listed in the table below.

Piramal Glass Private Limited	Asahi India Glass Limited	Saint-Gobain India
Nippon Sheet Glass Co., Ltd	Goldplus Group	Sejal Glass Ltd
Fuso Glass India Pvt. Ltd	Glass Wall Systems	Hindustan National Glass & Industries Limited

Table 7: Domestic glass industries and supplier in India

Steel and Metal Fabrication Industry for Support Structures

The steel and metal fabrication industry in India is fairly mature and high precision metal fabrication for local industries and applications is easily available across the country. For CST mirror frames and support structures construction, Indian companies can easily enter the market using JV route or collaboration with foreign counterparts. Some companies in India have already taken this route for eg: Jyoti structures Ltd under license from SBP, and Megha Engineering under license from Albiasa are already in the fabrication sector for CST projects.

There are some more potential players in the other sectors that have similar capabilities including Bharat Forge, AMW Auto Component, Anand Motor Products (automobile component manufacturers), L&T, Tata Steel (manufacturing, engineering, and construction) and HEC (Engineering Fabrication).

Though it must be noted that due to the high precision requirements of these fabrications, there mu st be established testing protocols for the quality of products to be supplied by companies that are attempting to fabricate these components for the first time.

1.3.2. Opportunities to develop indigenous CST Component manufacturing

Receiver and Absorber Tubes Manufacturing Industry

While there are manufacturers of water heaters catering to the water heater market in India, these players are mostly manufacturing flat plate non-evacuated tube collectors. The receivers and collectors used in tracking systems including the parabolic troughs, dish engines and linear Fresnel systems are also currently imported by CST systems integrators. It is crucial that the country develops expertise in the metal-glass sealing technology to be able to develop these type of medium-high temperature CST systems. This can be achieved with some support from the electronics industry where such seals are manufactured albeit on a much smaller size.

The absorber coatings for the receiver play a vital role in increasing the efficiency of the CST system. In India NAL, and KG Design Services have developed a high temperature solar selective coating for the receivers. Milman Thin-film Pvt Ltd is another organization from India that has developed PT receivers.

Currently there are limited to no players in the Indian market are capable of manufacturing quality evacuated tube collectors, which is due to the high complexity of the metal glass joints that need to be vacuum sealed while being able to flex with the heating and cooling needs of the system in operation.

Heat Transfer Fluid

The output temperature is generally restricted by the Heat transfer fluid. While water can work only upto 100˚C, steam and super-heated steam are complex to handle due the pumping stages and high pressures required. Currently there are no local players that produces HTF for high temperature applications and the market is dependent completely on imports.

But there are some domestic players within the country like Lanxess, Indian Oil, and Reliance Petrochemicals which have the potential and capability to manufacture HTF within India. However, with the low demand from the market it is unlikely that they would also invest into the R&D and manufacturing of these fluids.

2. Assessing key areas of intervention to boost CST manufacturing

Building upon the CST domestic manufacturing as-is assessment conducted in the preceding sections, there are numerous roadblocks when it comes to realizing 100% indigenous manufacturing in India. There are certain components, for which manufacturing is done by only a couple of players (such as incase of solar grade mirrors) which clearly points to the lack of market players in the supply chain itself.

Hence, the manufacturing aspect of CST needs to be incentivized at the very basic level i.e. 'sub-component level' to garner interest from the industry to participate and focus on localization of supply chain elements to reduce overall imports. In this regard, some of these potent areas of intervention have been analysed below.

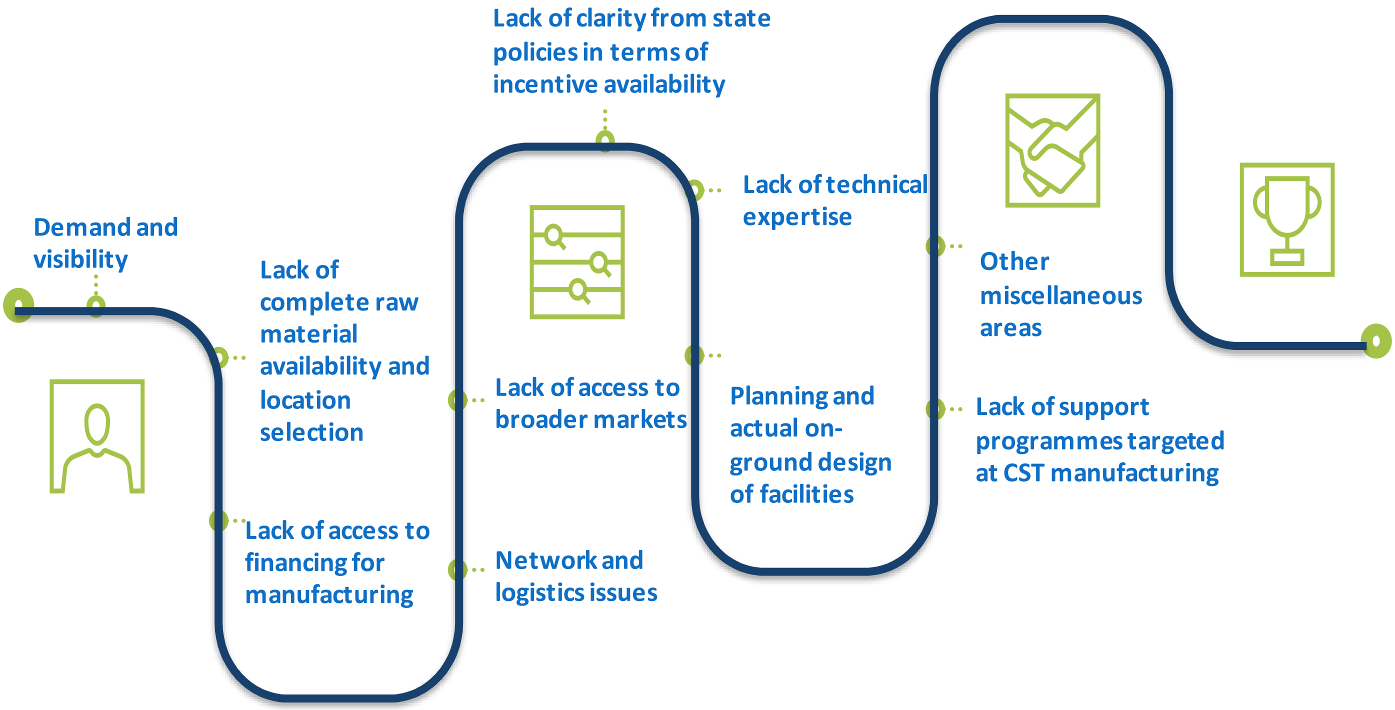


Figure 12: Key areas of intervention to boost CST manufacturing

2.1. Demand and Visibility

The demand visibility remains one of the critical aspects in terms of ensuring uptake of CST systems, which will indirectly influence the domestic manufacturing landscape. If there are no timely demand creation avenues, the sector will lose momentum and eventually lead to lack of interest from domestic players to scale up. In this regard, drawing on success factors from solar PV such as domestic content requirement (DCR), tendering norms prioritizing domestic uptake and other regulatory obligations can be useful in case of CST technologies as well.

In fact, CST tenders with obligations mandating the use of only few domestically procured components (broad components can be defined such as solar grade mirrors, tracker system, etc.) to kickstart things will also prove to be a big driver.

2.2. Lack of complete raw material availability and location selection

> ***As per one of the leading CST system integrators, 'there is complete lack of raw materials pertaining to coatings for the receiver and receiver tubes and thus have to be imported.***

As discussed in the as-is assessment exercise, absence of critical components in the supply chain is a major roadblock in establishing a vertically integrated value chain, with maximum domestic value capture. The maximum domestically realizable value in the country is a function of the actual resources in terms of state of art infrastructure requirement (critical machinery and tools) and raw material availability. In terms of raw material availability to manufacture critical components for CST systems, about 80-90% is readily available in the Indian market itself. However, material constraints do exist in the manufacturing of thermic fluid, receiver parts and certain coatings, which are largely imported. This again is indirectly co-related to the low levels of demand for such systems in India.

Additionally, selecting the right location for manufacturing plant is a critical process and must be done keeping several constraints in mind including the stakeholders, raw material sourcing, logistical constraints, associated costs, presence of ancillary industries and the incentives on offer. As the plant and machinery, including key raw material for manufacturing plant shall be imported, it is only obvious to explore locations in close proximity to port to reduce the lead times in production as well as distribution.

2.3. Lack of access to financing for manufacturing

Easy access to cheap capital is an important aspect of any investment decision. One of the reasons for the lack of India's cost competitiveness in solar manufacturing is higher cost of capital, which among other fluctuating market indicators such as economic growth and inflation, can also be attributed to a lack of in depth understanding of the solar thermal technologies. Also, the cost of indigenously produced components and sub-components may be on a higher side, owing to lack of economies of scale, market access, technology, machine requirements and increased competition from international markets. The key issues that remain integral in financing of CST manufacturing has been presented alongside.

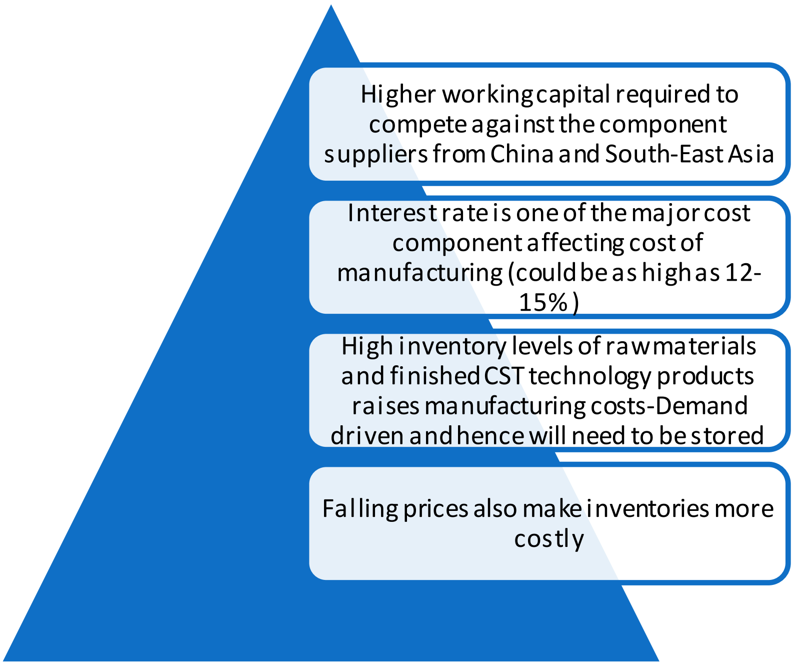


Figure 13: Lack of access to financing for manufacturing

The establishment of solar thermal manufacturing units with required ancillary industries, including sophisticated machinery and research facilities would attract a large amount of upfront CAPEX. Although, a certain portion of the financing requirement can be met through state level policy instruments (including special zones, where there are numerous other subsidies/incentives in the form of utilities, gas, power), but still a substantial funding will be needed.

> ***As per one of the local CST players, we have faced issues in trying to scale up production primarily due to unavailability of finance, since majority of products are used by rural entrepreneurs and thus we are forced to sell systems at a scale with low margins***

2.4. Network and logistics issues

Logistics and maintaining sound connectivity to and fro from the ancillary industries to the mother unit requires establishing a concrete network, which can lead to cost reduction and reduce time overruns in terms of procurement and delivery schedule. It is quite likely that such manufacturing facilities will be established in SEZs, closer to the port, owing to the proximity of sea-connectivity for imports (components which cannot be realized in the country) and well-connected internal road network for movement of vehicles and material unloading.

Currently, since many of the critical components are imported there is a heavy dependence on the port infrastructure for the transport of these materials, but since most of the component's sizes are not too large, shipping and transportation to the project sites is not very complex. However, given that CST industry is generally made to order, the lead time on the project construction is mostly taken up by shipping and transportation of these components.

2.5. Lack of access to broader markets

This remains one of the fundamental challenges, as geographical access beyond the Indian markets in terms of realization of both the raw material requirements and complex machineries are difficult. Large players, having well-connected market outreach and superior knowledge of the broader markets entities engaged in manufacturing of relevant CST components, can get the required components at a cost-competitive price and are able to integrate the system in India. On the other hand, smaller players having complete lack of access (or geographically partial access) or lack of 'connect with relevant sub-component manufacturers' does not provide a level playing field.

As per one of the local CST players, critical components like receivers are imported from Germany, although options were explored domestically. However, indigenous cost was too high and also had quality issues during procurement stage.

The problem is further aggravated when there is geopolitical tension between 2 countries, leading to trade wars and indirectly changes in the import-export duty structure. Hence, CST players having suppliers of critical components such as tubes and receivers located in countries such as China often face issues leading to project implementation delays.

As per one of the local CST players, 'Trade wars with China do affect us from time to time as India suddenly increases the import duties on several components. As these components are most crucial for our CST systems, it does affect our overall project delivery timelines.'

2.6. Lack of clarity from state policies in terms of incentive availability

Existing state policies, specifically, industrial policies do provide numerous benefits to manufacturing facilities, belonging to any industry type depending upon the size of investment. Majority of states in India, have such a dedicated policy in place, which is usually applicable for a control period, usually 5 years. A typical example of key incentive offered under industrial policy for Gujarat[17] (released in August 2020) has been presented below.

Solar thermal manufacturing falls under the umbrella of 'Sunrise Sector' within 'Green energy' (solar/wind equipment manufacturing) segment and thus can avail numerous capital and operational incentives. Additionally, the state has also identified the importance of 'gap analysis of skill requirement of industries and available workers' to develop a roadmap for training manpower in relevant skills.

[17] https://imd-gujarat.gov.in/Document/I%20Branch_2275_30_Jul_2020_614.pdf

	Incentive	Gujarat
Capital Incentives	Exemption of Registration and Stamp Duty	Yes
	Capital Subsidy	Yes
	R & D Subsidy/Incentives (including testing)	Yes
	Interest and infrastructure interest Subsidy	Yes
	Infra subsidy for green measures taken by firm	Yes
	Land rebate/incentives	Yes
Operational Incentives	Indirect Tax Concession	No
	Power Subsidy/Power connection charge reimbursement	Yes
	Incentive Related to Employment	No
	Entry Tax Exemption	No
Bespoke incentives package based on investment size		Yes

Table 8: Lack of clarity from state policies in terms of incentive availability

Additionally, many of the incentives are already applicable to the ancillary industries (electronics and electrical equipment manufacturing, pipe manufacturing, glass manufacturing, etc.) which are part of CST supply chain.

While the incentive availability may be there for the CST component manufacturing (disguised under the bracket of industrial sector), the main challenge in this context remains the lack of awareness and know-how about the exact procedures and documentation requirements to avail those incentives. The industry, in general is not aware about the possible benefits which may be extended to many ancillary industries associated with CST. Hence, there is a need to for state industrial departments to address this gap, by either conducting awareness campaigns in combination with UNIDO and SNAs or issue amendments targeted at inclusion of CST manufacturing in existing state policies.

2.7. Lack of technical expertise

Apart from the infrastructural requirement, India, presently lacks the required technical expertise in terms of skilled manpower needed to carry out operations related to CST manufacturing with many practical experiences involving the following key attributes.

- **Steel sheets with different thickness and surface roughness**
- **Copper in the form of tubes or sheets**
- **Glass handling**
- **Designing absorber coating**
- **On-site installation**
- **Quality control of different manufacturing**

As per NISE, some of the raw materials used in CST manufacturing are already available in India, however the critical aspect is the lack of expertise and process know-how to convert these raw materials into the components to be used in CST system

In general, upstream Indian manufacturers have lacked the capacity to innovate in production technologies and related process engineering aspects necessary to produce superior quality components. Coupled with the lack of available skilled resources, many manufacturers may be forced to rely on foreign technology suppliers to lead or manage their Indian ventures, a practice which necessarily escalates labour costs and have a significant impact on total manufacturing costs.

Additionally, as aforementioned, there are permanent gaps in the supply chain in terms of having large number of dedicated market players for a certain component. In most cases, the technologies used by the existing players (domestic or international) are patented and hence not available for replication. Hence, Indian manufacturers are not able to build their capacities in the necessary areas needed for manufacturing those vital components.

2.8. Planning and actual-on ground design of facilities

Since such an integrated facility will be first of its kind, the actual on-ground planning and establishment of relevant associated infrastructure would be challenging task. This would require in-depth understanding of key processes involved, associated machinery requirement, approximate floor area/spacing needed, in-housing essential testing requirements, ensuring automation and quality control, waste disposal and other basic requirements of land (land use, land readiness, land rights/ownership, etc.), water and power. Over the past decade or so, issues revolving land acquisition and rehabilitation have resulted in many large-scale investments being delayed or stranded, particularly in case of solar PV.

Some of the key processes in CST manufacturing include machining, stamping, moulding, pipe bending, laser cutting, arc welding, selective coating, punching, rolling and sandblasting. Also, as aforementioned there will be substantial efforts required in planning of spaces (storage, inventory, dedicated spaces for ancillary services) with proper demarcated floor area in an integrated facility.[18] Some of the essential segments part of the manufacturing facility have been presented below.

Since, there are no historical precedents for such integrated facilities for CST manufacturing, planning and design of such facilities will be a critical area, where sufficient know-how is needed.

[18] https://www.industrialenergyaccelerator.org/wp-content/uploads/Best-Practice-Manual-SHIP-final-version_By-UNIDO_edited-FINAL2-copy.pdf

2.9. Lack of support programmes targeted at CST manufacturing

As per NISE, specialized manpower requirements for CST manufacturing and construction is a key challenge and unlike regular solar PV, there are not as many skill developments programmes or technical workshops for this sector

In terms of actual support mechanisms or policy programmes available, CST manufacturing has been at the backfoot and garnered lowe interest, especially when compared to solar PV component manufacturing. The Ministry has successfully encouraged domestic solar manufacturing in the country through numerous initiatives such as;

- Regulatory mandates in tendering guidelines by stipulating use of domestically procured modules for installation of PV projects (CPSU scheme, Railways, etc.)
- Introduction of basic customs duty (BCD)
- Introduction of safeguard duty and anti-dumping to discourage imports from key countries
- Long term target and demand visibility ensured by the government through 100 GW solar mission and 450 GW RE target by FY 2030

On similar lines, the agenda of using 100% indigenously manufactured components for CST needs to be targeted across the country. The manufacturers need to be incentivized through innovative policy instruments at both central and state level. Some of the measures may include:

- Exclusive subsidies/incentives targeted for CST, much along the lines of MSIPS scheme, that provide upfront CAPEX to an extent of 20-25% depending upon SEZ/Non-SEZ area
- Better access to finance-low interest working capital loans
- Improved demand visibility (guaranteed opportunity) by defining CST targets for future beyond 200 MW_{th} FY 2022
- Mandating deployment of indigenously manufactured systems across select industries

2.10. Other miscellaneous areas of intervention

Apart from the areas of intervention discussed in the preceding section to boost domestic manufacturing, there are certain other avenues, which have been cited by stakeholders that require further strengthening. These include:

- Quality concerns to be addressed to ensure superior manufacturing practices and performance attributes are being improved. There have been issues in quality with regards to domestic procurement, leading to sub-standard system performances and hence the reliance on international markets for critical components still persists.

- Special emphasis is needed w.r.t. manufacturing for CST technologies, as high degree of customization is required even for manufacturing of specific tubes, as per applicability. This customization leads to difficulty in ascertaining the benchmark and standardization of components.

- Backward integration for establishing at CST manufacturing facility can also be an option, which can be explored

- Limited testing facilities for various components like solar mirror/glass. In several cases, there are test facilities available, however the facilities are unknown or inaccessible to manufacturers.

- Policy framework addressing the root cause should be developed, which targets not only project components but also sub-components. (Incentivization of complete CST manufacturing facility might be difficult, but promoting sub-component manufacturing such as solar grade mirror will be a more feasible approach)

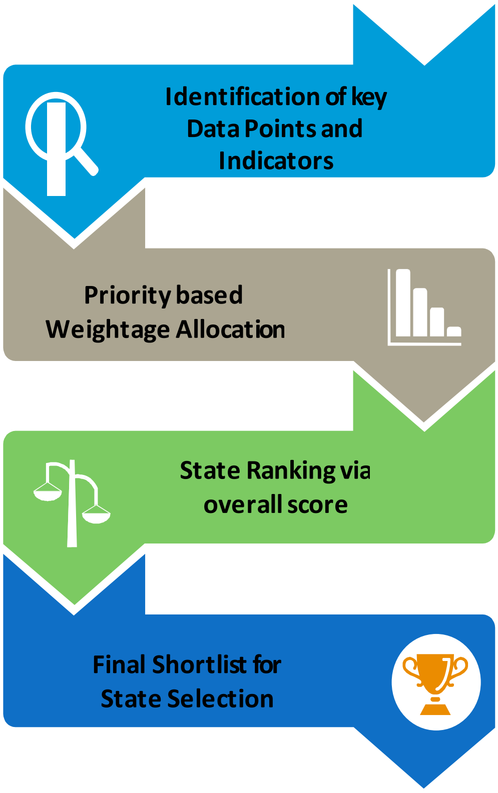
3. State selection framework

In order to specifically target the states with the most suitable landscape for CST manufacturing, a state selection framework has been designed to select the most appropriate states for the purpose of this study. There are numerous favourable locations in SEZ, DTA, EMC, CEU or in the vicinity of port, which offer strategic advantages to maximize the overall efficacy of industrial operations. These areas are already endowed with a number of industries which enjoy numerous benefits and in-house facilities in terms of superior quality infrastructure (24*7 water availability, electricity, and communication), incentivized framework (capital subsidies, power subsidies, land rebates, tax concessions, etc.), connectivity to both domestic and international markets, streamlined logistics network (proximity to container ports, ICD, internal road network), including cost of labour which depends from state to state and has further categories in terms of unskilled/semi-skilled/skilled/highly skilled. Undoubtedly, it seems there are pros and cons associated with every site location and it need be assessed which is the 'best out of the rest'

The methodology for state selection was based on a comprehensive review of various data points and parameters which would have an impact on the CST and related component manufacturing in the state. Based on the impact of these individual datapoints/indicators on manufacturing of various CST components, weightages have been assigned based on the priority for their impact on overall CST manufacturing within the country. These individual scores were added up for each state to determine the final overall ranking of the state across the country.

3.1. Approach and Methodology for State Selection

To analyse the capabilities required for manufacturing of CST component in across various states in India, a comprehensive review of various data points and indicators was conducted. Since not all criteria have an equal amount of impact on the manufacturing of CST components, individual weightages have been assigned for the data points based on the priority and impact of the manufacturing landscape.



- **Exhaustive classification of 9 data pointers-** both qualitative and quantitative, along with classification into sub-parameters
- These parameters have been discerned to be the most influential when it comes to understanding inclination to setting up CST and related component manufacturing units

- **Allocation of these parameters, against certain weightages to identify an individual score for each data point based on its influence on CST manufacturing.**

- **Classifying the top priorities**, keeping in mind the industries and expertise required for CST manufacturing
- **Calculating the overall score after allocating different weights/numerical values to these priorities**

In this step a huge emphasis is laid on the manufacturing angle to prioritize key variables like land pricing, labour rates and DIPP ranking, which defines the overall ease of doing business

- **Developing final overall ranking to distinguish the most feasible option, based on maximum score achieved**

Figure 14: State selection Methodology

The key datapoints/indicators identified for this exercise included the installed capacity of CST area, state manufacturing and electronics policy, infrastructure costs (land, electricity, and labour), presence of manufacturing industries i.e.: mirrors, reflectors, absorbers, reflective and thermal coatings etc. These have been selected in-order to gain insight into a state's capabilities and future opportunities to develop CST manufacturing industry.

For each of the selected parameters, benchmarks have been set in the form of 'ranges' and a score has been allocated out of a maximum of 5 (minimum 1) for each variable for every state. Some qualitative inputs like 'presence of SEZ's and port infrastructure' having binary output, denoted using 'Yes/No'. Availability of land at cheaper rates, proximity to container ports and ICD are extremely crucial for a solar thermal manufacturing unit, hence have been allocated a highest priority. On the other hand, policy incentives although playing a significant role in bringing down costs are not very vital from a strategic perspective in driving investment decision (more on infrastructural parameters) and have been allocated a lower priority.

The output score of each data points was based on the priority-based weightage allocation for that individual data point. These individual scores were then added up to obtain an overall score for each state which would determine the final ranking of the various states in the country.

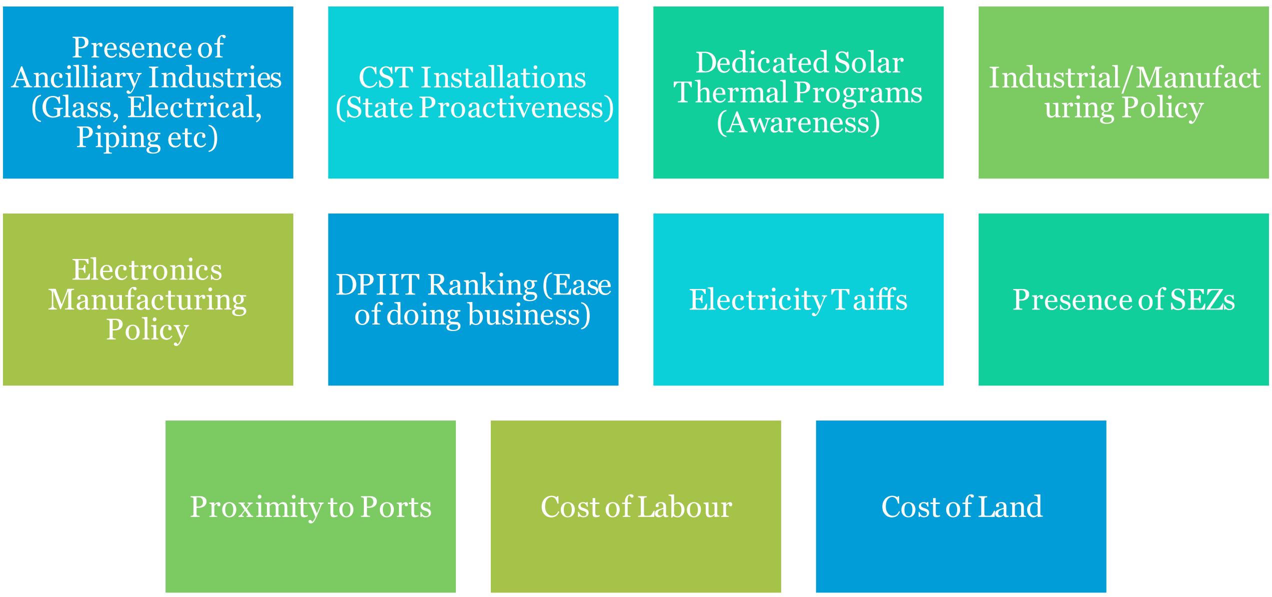
3.2. Identification of key Data points and Indicators

In order to map the manufacturing capabilities of various states w.r.t to CST manufacturing a list of indicators and data points pertinent to manufacturing of CST related components was developed. These indicators included various metrics to track the current manufacturing scenario related to CST components including, installed collector area, state industrial and manufacturing policies, infrastructure costs, and presence of ancillary industries (glass, tracking mechanisms, etc.).

The indicators selected would cover a range of sectors vital for setting up as well as enhancing manufacturing industries specifically for CST components. These datapoints would be used objectively to rank the states by mapping the industrial capabilities applicable to the manufacturing of components for CST systems.

This exercise would serve as the starting point for developing the final list of states of the in-depth study of CST component manufacturing capabilities in India. Various states offer varied incentives to attract investment, with few offering customized packages based on investment size, employment and location. Prior to an in-depth analysis, a comparative assessment of policies across the target states has been conducted to shortlist the final set of states using the data from the parameters mentioned below.

The parameters which are both qualitative and quantitative have been classified below:



3.3. Priority based Weightage Allocation

Prioritization of data points/indicators across various categories was assigned through suitable weightages for each data-point. Based on the impact of the data points/indicators on the manufacturing of components used in a CST system, a total score was calculated for each state to determine its rank.

The priorities were assigned to the criteria based on their impact towards the manufacturing of CST components or systems within that state. For example, presence of ancillary industries in glass and mirror manufacturing, boiler manufacturing and piping industry has been assigned a higher weightage in comparison to the cost of land or labour which would subsequently be given a lower priority. The weightages assigned to each of the individual parameters has been listed in the table below.

Similarly, presence of testing and certification infrastructure within a state for CST components would facilitate the faster development CST manufacturing industries. The country has various autonomous institutes including National Institute for Solar Energy (NISE), Gurugram and Savitribai Phule Pune University etc. To develop advanced material properties of the components and improving the system design these institutions are essential to conduct research and lead innovation in CST systems and manufacturing processes.

Parameter	Weightage (%)
Land Cost	5
Labor Cost (Average wages)	8
DPIIT Ranking (Ease of doing business)	10
CST Installations (Collector Area - Proactiveness)	10
Ancillary Industries (Glass & Mirrors)	10
Testing Lab for CST Applications	8
CST Heating/Thermal Manufacturers	10
Presence of Ancillary Industries (Electrical and electronics)	5
Presence of Ancillary Industries (Boilers and Piping)	8
Casting and Forging	5
Electricity Tariff (11 kV-HV)	8
Presence of SEZ	5
Major/Minor Ports	8
Total	**100**

Table 9: Priority based Weightage Allocation of parameters

The MNRE has set the benchmarks and standards for CST systems to ensure that these projects perform at rated efficiencies. To certify these systems the government has also released a list of laboratories in the country that the manufacturers can approach to get their systems validated. To avail the benefits from Ministry of New and Renewable Energy (MNRE), it is critical that CST manufacturers get their products tested and certified through these facilities. Thus, states with such institutes naturally gained a geographic advantage for CST manufacturing.

Since the infrastructure and related capital costs required to setup these manufacturing facilities was also crucial, the land cost and presence of SEZ's within these states has also been quantified. The presence of casting and forging industries which are vital for the support structures and frames of CST components were also quantified to highlight the capabilities of a particular state which could make it conducive to CST manufacturing.

There can be numerous favourable locations across the country, which can offer strategic advantages to maximize the overall efficacy of industrial operations for the CST sector. Each area is already endowed with a number of sectoral industries which enjoy numerous benefits and in-house facilities in terms of superior quality infrastructure (24*7 water availability, electricity, and communication), incentivized framework (capital subsidies, power subsidies, land rebates, tax concessions, etc.), connectivity to both domestic and international markets, streamlined logistics network (proximity to container ports, ICD, internal road network), including cost of labour which depends from state to state and has further categories in terms of unskilled/semi-skilled/skilled/highly skilled.

To identifying the target states for an in-depth analysis a priority-based approach was taken to arrive at a simplistic and decisive mechanism to rank the final list of states.

3.4. Final State Ranking and Selection

The final list of top 5 state selected for evaluation were established through the state selection framework as described in the previous section. Based on assessment of various factors in the state selection framework, consequent analysis of the various data points described and applying the methodology described above, a final overall state ranking was determined which was then utilized to identify the top feasible states for the in-depth evaluation of industrial landscape, policy and manufacturing framework within those states.

Described below is the ranking of all the states based on the methodology described above, the final list of states has been arrived after the respective weightages of the data points used were given assigned priority based on their impact on the CST manufacturing within those states.

Based on various data points and parameters assessed, the capabilities of various states in the country were characterized and mapped to CST manufacturing. The data points in detail for these have been represent in the Annexure.

S. No	Initial list of States
1.	Maharashtra
2.	Andhra Pradesh
3.	Gujarat
4.	Karnataka
5.	Tamil Nadu
6.	Rajasthan
7.	Uttar Pradesh
8.	Madhya Pradesh
9.	West Bengal
10.	Telangana

S. No	Final list of States
1.	Gujarat
2.	Maharashtra
3.	Tamil Nadu
4.	Uttar Pradesh
5.	Karnataka

Table 10: Final State Selection

4. Recommendations to develop enabling CST manufacturing ecosystem

4.1. Key considerations

In order to gain a deeper perspective of CST and related component manufacturing in India, an in-depth analysis of the industrial and manufacturing policies of the shortlisted states has been conducted to identify the strengths as well as the challenges associated with CST component manufacturing within the target states. This analysis would assist in recommending policy and regulatory frameworks to further promote CST manufacturing in India.

A brief presentation of the industrial and manufacturing policies in the target states has been presented along with the SEZ regulations for setting up a CST manufacturing plant. An industrial landscape analysis has also been presented to estimate the various types of industries present within these states that can replace traditional heat generation with renewable energy through the installation of CST systems.

4.1.1. Review of SEZ policy

Special Economic Zones (SEZ) are areas designated by the Government as Customs Territory outside India – duty free enclaves treated as deemed foreign territory for trade operations, duties and tariffs, governed by SEZ Act, 2005 and SEZ Rules, 2006; and has Economic / fiscal laws more liberal than laws applicable to a Domestic tariff area ('DTA').

SEZ's are bestowed a number of benefits to SEZs in terms of fiscal incentives and state of art infrastructure. Special Economic Zones (SEZs) have been recognized as an important mechanism for trade and investment promotion, creation of infrastructure, employment generation, promotion of regional development, increase in foreign exchange earnings, improving export competitiveness and transfer of skills and technology.The incentives and facilities offered to the units in SEZs for attracting investments into the SEZs, including foreign investment include:

- Duty free import/domestic procurement of goods for development, operation and maintenance of SEZ units
- 100% IT exemption on export income for SEZ units under Section 10AA of the Income Tax Act for first 5 years, 50% for next 5 years thereafter and 50% of the ploughed back export profit for next 5 years.
- Exemption from Central Sales Tax, Exemption from Service Tax and Exemption from State sales tax. These have now subsumed into GST and supplies to SEZs are zero rated under IGST Act, 2017.
- Other levies as imposed by the respective State Governments. Single window clearance for Central and State level approvals.

Figure 15: SEZ Policy Review

As per SEZ rule 53, The Unit shall achieve Positive Net Foreign Exchange to be calculated cumulatively for a period of five years from the commencement of production. The export Under the SEZ Scheme, the goods cleared from the Zone are treated as imported goods. Therefore, in case of DTA clearances, though the duty charged is central excise duty, this duty is taken as equal to the aggregate of all duties of customs. In other words, the SEZ units are required to pay full customs duty (applied duty) on their DTA clearances. Several states have DTAs alongside SEZs as the common infrastructure can be pooled by manufcaturers to manufacture competitively.

4.1.2. Review of state level policies of target states

A brief of the incentives and benefits available in each of the target states has been listed in the table below.

State	Incentives Applicable to Manufacturing			
	Capital Subsidy	SGST	Electricity	Additional Benefits
Maharashtra	• Capital subsidy for large industrial units based on size of investment in any region within state • Capital subsidy of upto 100% for MSME's based in certain areas	Reimbursement of net VAT and CST or the net amount deposited in State's account visa-vis share of the state under GST (MSME)	Reimbursement of net VAT and CST or the net amount deposited in State's account visa-vis share of the state under GST	• Reimbursement of net VAT and CST or the net amount deposited in State's account visa-vis share of the state under GST (Large Industries) • MSME's eligible for power subsidy based on the region
Karnataka	• Capital subsidy for supporting R&D activities • Invest promotion subsidy for MSME's based on size of industry and location within the state • Invest promotion subsidy applicable to large industries based on the zones within the state.	-	Tax exemption on electricity tariff for MSME's	• Exemption from stamp duty and concessional registration charges as well as Reimbursement of land conversion fee, Subsidies for sustainable operations strategies and Power subsidy for MSME's • Stamp duty exemption for large industries in certain zones
Tamil Nadu	• Subsidy up to ~ USD 0.3 million (INR 2.25 crores): 50% additional subsidy for industries setup in SIPCOT industrial parks	SGST Reimbursement for > USD 70 million investment for manufacturing	100% exemption of tax on electricity purchase from the state DISCOM for 5 years	• 50% Stamp duty concession to industries located in SIPCOT parks • Environmental Promotion Infra subsidy of USD 42,857 (INR 30 Lacs) or 25% of capital costs, whichever is less

	• Capital subsidy on case to case basis for > USD 70 million investment			
Gujarat	• MSMEs will be eligible for Capital Subsidy upto 25% of eligible loan amount and interest subsidy of 7% upto INR 35 lakhs • Upto 12% of fixed Capital investment will be given to large industries	-	-	• Support upto 65% of the cost of acquiring foreign patented technologies for MSMEs • Support for Common environment infrastructure facilities of 40% of the project cost upto INR 50 crore • Support upto INR 5 crore to private companies/institutions for setting up R&D and product development centres • Sustainable Manufacturing through financial assistance for Cleaner production measures • Long term leases for govt lands for upto 50 years at 6% of market rates
Uttar Pradesh	• Capital Interest and infrastructure Subsidy to the extent of 5% per annum for 5 years • Stamp duty exemption of 100% in Bundelkhand & Poorvanchal, 75% in Madhyanchal & Paschimanchal (except Gautambuddhnagar & Ghaziabad districts) region of the state and 50% in Gautambuddhnagar & Ghaziabad districts.	Reimbursement of net VAT and CST or the net amount deposited in State's account visa-vis share of the state under GST (based on size of Industry)	Exemption from electricity duty to all new industrial units set up in the state for 10 years	• A dedicated Single Window Clearance Department to be the sole interface of the Government for providing all industrial services/ clearances/ approvals/ permissions/licenses. • Improving flow of capital and credit for MSMEs through creation of a corpus fund and an SME Venture Capital Fund for promoting Start-ups and emerging Small & Medium Enterprises (SMEs).

Table 11: Statewise manufacturing Incentives Applicable to CST Component Manufacturing

Gujarat

Gujarat is one of India's most industrialized states in India and the state hosts a variety of industries including general and electrical engineering for chemical, automobile and pharmaceutical sectors. Gujarat is also a hub for the chemicals, petrochemicals, drugs & pharmaceuticals, dairy, cement & ceramics, and gems & jewellery.

The state also has one of the highest installed capacities of wind and solar with 8,042 MW and 3,638 MW respectively. The state has a robust policy and regulatory framework for the adoption of clean energy technologies and is the ideal candidate for the in-depth analysis for CST manufacturing.

Support for CST manufacturing

Gujarat has unveiled its Industrial policy 2020, through which incentives for CST component manufacturing in the state can be realized. Gujarat already has a strong manufacturing base and has the potential to accelerate further on a global scale. Since the state is already one of the leading states for clean energy technologies in India, the state government through its latest industrial policy is aiming to promote the state as a manufacturing hub for these technologies as well.

Under the latest industrial policy 15 Thrust Sectors have been conceptualized with a view on global investment trends, the need for strengthening the integrated value chains, exports, policies by government of India, NITI Aayog etc. While the core sectors within these thrust sectors would find applicability for CST systems, the sunrise sectors defined under this industrial policy will have a significant potential for technological advancement and can contribute to sustainable economic development. The thrust sectors for which the state provides incremental incentives as part of the policy have been indicated alongside.

Green Energy (Solar & Wind Equipment)

Electric Vehicle and its components

Industry 4.0 manufacturing

Eco-friendly compostable material

Waste management projects

100% export-oriented units

Gujarat has also de-linked the incentives from SGST. Upto 12% of fixed Capital investment will be given to large industries for setting up manufacturing operations in the state in the form of capital subsidy. There is also no upper ceiling on the amount of incentive to be given to any unit. This will help in grounding major investments in the state.

The thrust sectors would be eligible for greater incentives in fixed capital investment (FCI) based on their taluka category.

Taluka Category	General Sectors	Thrust Sectors (15)
Category 1	10% of FCI	12% of FCI
Category 2	8% of FCI	10% of FCI
Category 3	4% of FCI	6% of FCI

Table 12: Taluka based incentives in Gujarat

Besides this, new industries will continue to get exemption from Electricity Duty for 5 years. Additionally, the state is also providing a host of incentives for MSMEs with an aim to make the domestic MSMEs globally competitive. The government will also support MSMEs in upgradation of technologies, adopting globally accepted certifications and in marketing their products internationally.

Gujarat’s strengths as a manufacturing base for the various industries including glass and steel along the proximity to ports enable the creation of a conducive environment for the manufacturing high solar grade reflectivity mirrors as well as evacuated and non-evacuated tubes required for CST systems within the state.

These policies provide the right impetus for CST component manufacturing in the state given there are presence of industries within the state that can create the demand for the uptake in CST installations (mentioned in the section below).

Presence of suitable industries for promotion of CST

In Gujarat 12 major industry groups together account for 86% of factories, 96% of fixed capital investment, 94% of value of output and 95% of value addition in the states industrial economy. Gujarat is home to over 3.5 million MSMEs which are a major source of employment and form an important part in the larger industrial ecosystem. The state's strong industrial base provides multiple opportunities for the adoption of CST systems for reducing heat demand which would otherwise be met from traditional sources mostly combustion. The paper and food industries have the biggest heat demand, considerable heat demand also exists in the textile and chemical industries.

Solar process heat installations used for industrial for those applications where only low (< 150°C) to medium (150°C – 400°C) temperatures like textiles, food processing and dairy which form a significant portion of the Industries in Gujarat, can benefit from the promotion of CST based technologies.

Some of the industrial sectors where CST could be applicable that are present in the state of Gujarat have been mentioned below.

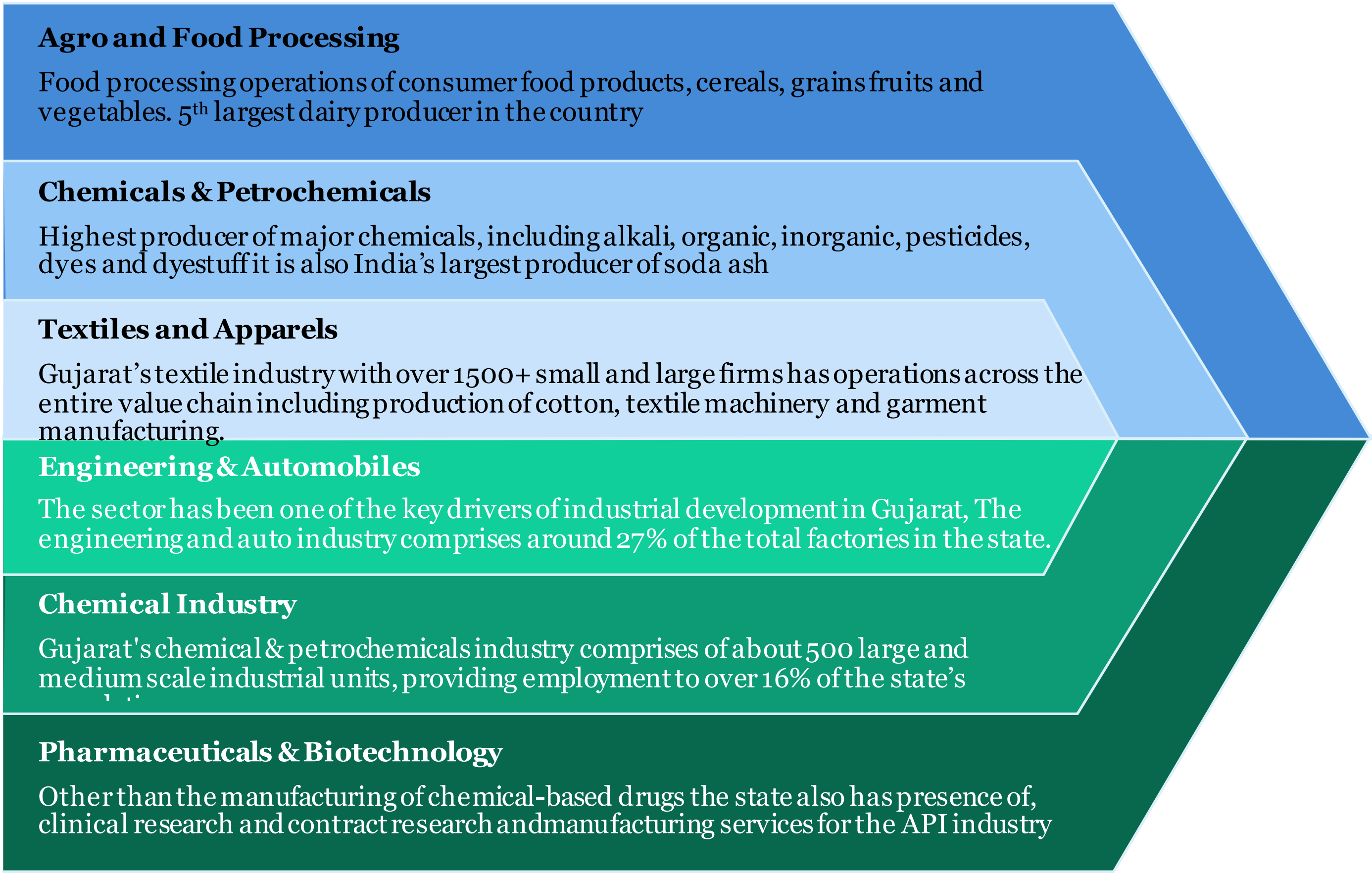


Figure 16: Presence of relevant industries in Gujarat

Maharashtra

Maharashtra is one of the most industrialised states in the country, with Mumbai as its capital city and the financial hub of the country. The state has developed industrial sectors including auto, engineering, electronics, textile and defence as focus sectors along with agriculture and its allied activities. The state is responsible for 15% of India's annual economic output, making it one of the most import states in the country.

The Government of Maharashtra (GOM) has identified several thrust areas in manufacturing, which include, EV, Aerospace, Defence, Green Energy, ESDM, IT, Biotechnology, Medical Devices, Textile, Food Processing, and Logistics. Development of these sectors presents a valuable opportunity for the state to also develop CST manufacturing capabilities as well as increase CST deployment for process heat in these areas.

Maharashtra has a high installed capacity of renewable energy with ~18,68 MW of installed solar PV capacity and ~5,000 MW of onshore wind capacity. With over 250-300 days of clear sun with an available average radiation of 4 to 6 kWh/sq. metre over a day, Maharashtra has the potential to become the leader in CST deployment in the country.

Support for CST Manufacturing

Maharashtra plans to become a $1 trillion economy, to support industrial development in the state it has released the "Maharashtra New Industrial Policy 2019", the incentives in the policy are in the form of power subsidies, interest subvention, stamp duty exemption, electricity duty exemption, and subsidy on state GST.

Through this policy the state is targeting to by 2024

i) Increase manufacturing sector growth rate to reach state GDP of share of 25%

ii) Attract investments worth Rs.10 lakh crore

iii) Create employment opportunities for 4 million people. The state plans to achieve this by promoting thrust sectors that would be eligible for priority in land allotment and incentives.

These thrust sectors include:

- EV Manufacturing
- IT, ITeS and Data centers
- Green Energy
- Nuclear Plant Equipment
- Textile Manufacturing
- Agro and Agro Processing
- Electronics Systems manufacturing
- Aerospace and Defense

Presence of industries for promoting CST

Maharashtra has well developed industrial ecosystem for various industries including Automobile (Pune and Aurangabad region), Electronics System Design and Manufacturing (Pune region), Pharmaceuticals & Chemicals (Mumbai- Thane, Aurangabad and Pune region), Engineering (Ahmednagar, Nashik, Pune and Aurangabad region, FMCG (Pune region), Textile (Solapur and Nagpur-Amravati region), Food Processing (Solapur, Ahmednagar-Nashik, Nagpur, Amravati region), Logistics (Mumbai-Thane and Nagpur-Amravati region), Cement and Steel industry (Vidarbha-Marathwada region) and IT & ITES (Mumbai-Thane, Pune and Nagpur-Amravati region). Most of these industries would employ heat driven processes that can be targeted by CST installers. Even off-setting part of the heating demand through pre-heating can help industries save on expensive fuel costs.

Industries in Maharashtra

- Textiles
- Chemicals
- Machinery
- Electricals
- Transport
- Metallurgy

The state contributes about 10.4% to India's textile and apparels output, 27.4% of India's chemicals, petrochemicals and oil and gas output as well as nearly 38% of the country's output of automobiles by value.

The presence of these industries presents a positive sign for the development of CST industry in the state. Industries mentioned above such as FMCG, food processing, chemicals, pharmaceuticals, auto manufacturing and textile have a huge demand for industrial process heat that is traditionally met through conventional combustion that incur constant fuel expenses as well as contribute to GHG emissions.

CST technologies present the opportunity for enormous fuel saving potential on traditional process heat generation for a variety of industries in Maharashtra. The most dominant industries in the state are as mentioned below:

Karnataka

Karnataka is one of the leading state for renewable energy in the country, with 4.83 GW of installed wind capacity and 7.31 GW of solar capacity. The state has taken various proactive measures including policy and regulatory development for increasing the adoption of clean energy technologies.

The state has more than 80 fortune 500 companies and about 700 Multinationals. Karnataka is one of the leading state in IT and biotech companies mostly present in and around Bangalore. The state also has a presence of industries including automotive & Aerospace, Textiles & Apparel, Agro & Food processing, Machine Tools, Mining & Minerals, Education, Energy, etc.

The state has robust industrial infrastructure and is connected with six neighboring states and other parts of India through 14 National Highways (NH). Its district centers are linked through 114 State Highways (SH). The state has two major ports known as Mangalore & Karwar ports. Karnataka Industrial Area Development Board (KIADB) and Karnataka State Industrial Investment Development Corporation (KSIIDC) are jointly responsible for the development of industrial infrastructure including manufacturing in the state.

Support for CST Manufacturing

Karnataka had laid strong emphasis on building quality infrastructure in the form of product clusters, SEZs and special investment regions to support industrial development and growth. The state has strong industry focus with 26 MSME product cluster, 132 industrial estates and 8 growth centres. The state has taken positive actions for the development of renewable energy resulting in Karnataka reaching first position in the production of renewable energy in India.

The latest industrial policy released in 2020, which has a prime focus on the development of manufacturing for renewable energy technologies in the state. The main objectives of the new industrial policy in Karnataka are

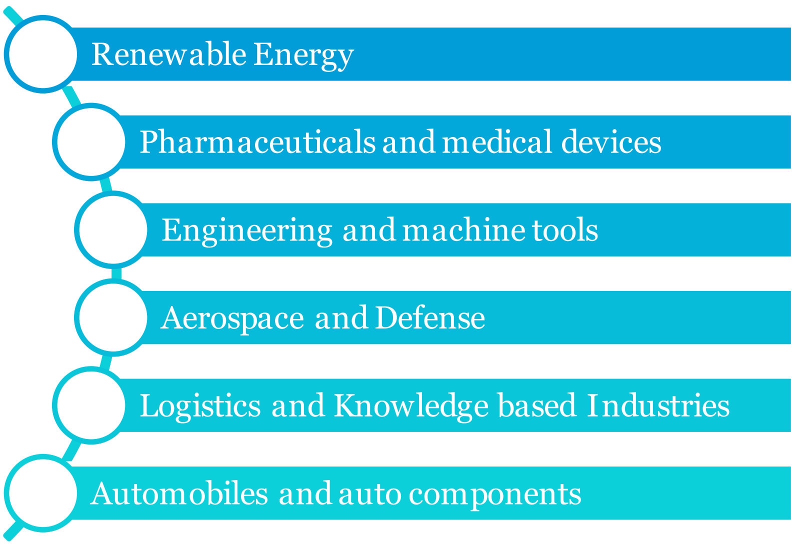
i) Create at least 2 million jobs

ii) Facilitate investments in advanced R&D, manufacturing and innovation,

iii) Maintain an annual industrial growth rate of 10%,

iv) Attract investments of at least 5 lakh crores,

v) Reach the 3rd rank amongst Indian states for merchandise exports in the next 5 years



The key sectors identified for support under the policy include renewable energy, pharma and medical devices, aerospace and defence, automobiles and auto components and logistics. Under latest industrial policy, the state has the opportunity to develop manufacturing for renewable energy including CST components.

Presence of industries for promoting CST

Karnataka has vibrant automobile, agro, aerospace, textile and garment, biotech, and heavy engineering industries. The state has sector specific Special Economic Zone (SEZs) for key industries such as IT, biotechnology, and engineering, food processing and aerospace.

The state attracted Foreign Direct Investment (FDI) equity inflow worth US$ 46.61 billion between April 2000 and March 2020 according to the data released by Department for Promotion of Industry and Internal Trade (DPIIT). Merchandise export from Karnataka reached US$ 17.36 billion in 2018 19 and US$ 12.94 billion in April-December 2019.

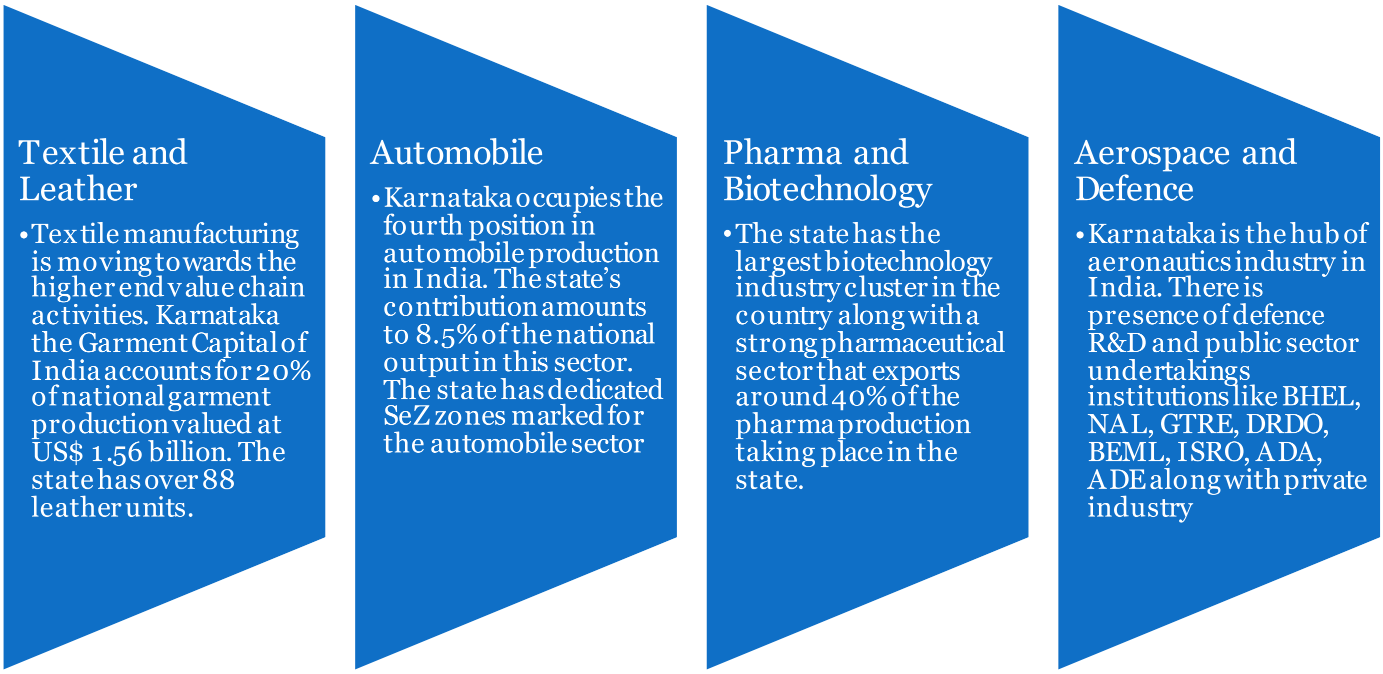


Figure 17: Presence of sutiable industries in Karnataka

As of February 2020, the state has 32 operational, 52 notified SEZs and 63 formally approved SEZs. The Karnataka Industrial Areas Development Board has developed 141 industrial areas spread across the state. The state plans to develop and upgrade eight clusters around Bengaluru with an investment of US $ 348.4 million in coming years.

Uttar Pradesh

Uttar Pradesh is the fourth largest state in India in terms of land area covering 7.3% of the country's geographical area. The state has a population of 19.98 crores (as per 2011 census) which is around 16.5% of India's population and is the highest amongst all Indian states. With a GSDP of Rs.11, 45, 234 crores in 2015-162, Uttar Pradesh is the third largest economy of India contributing 8.4% to the country's economy. Uttar Pradesh has an installed capacity of 3.3 GW of renewable energy, with 1.2 GW of solar power and about 2 GW of biomass/bagasse power generation.

The state has the longest network of rivers and canals at 28,500 km fostering a robust agriculture and food processing sector. Uttar Pradesh is one of the largest producers of electronic goods and is a significant exporter of software products from the country. The state with its human resource potential, proactive policies and commitment to ensure encouraging climate to the investors is poised to emerge as a manufacturing hub for CST components in the country.

Support for CST Manufacturing

With a robust industrial and infrastructure development policy the state is creating a facilitative administrative system by reduce lead time in setting up of industries, removing bureaucratic hindrances and providing internationally competitive infrastructure for establishing globally competitive businesses.

Uttar Pradesh through its industrial and infrastructure investment policy 2017 has identified and created special policies for Encouragement of Priority Sectors. These priority sectors include; IT/ITeS industry and IT Start Ups, Electronics Manufacturing, Agro & Food Processing, New & Renewable Energy, Handloom & Textile Industry, export-oriented units and tourism.

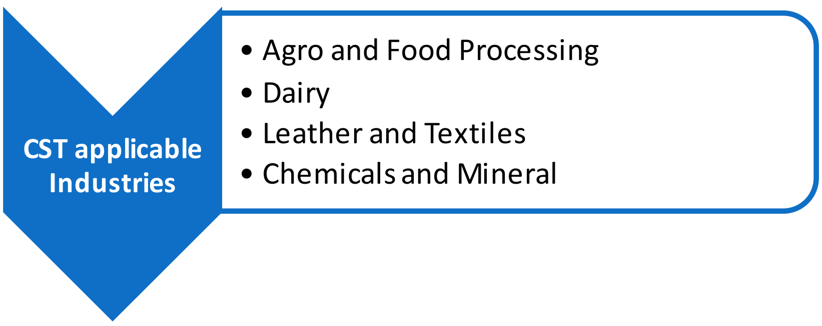
The state has also three Integrated Manufacturing Clusters (IMC) including Auraiya – Etawah - Kanpur Cluster, Allahabad-Varanasi Cluster and Agra-Aligarh Cluster have been identified along the eastern dedicated freight corridor for giving boost to the manufacturing sector in the State.

Uttar Pradesh is also amongst the top manufacturing destinations in India contributing more than 8% of national manufacturing output. The state is a leading electronic hardware exporter in the country and has also emerged as a key hub for IT/ ITeS and service sector including software, captive business process outsourcing (BPO) and R&D services. The focus of UP towards new and renewable energy and the development of manufacturing in the state is an affirmative sign for the development of CST component manufacturing.

Presence of industries for promoting CST

Uttar Pradesh is the leading producer of sugarcane, pointed gourd, peas, potato, muskmelon, watermelon, pumpkin, milk and milk products in the country. The state has the highest number of Micro, Medium and Small enterprises in India. UP has a number of locally specialised business clusters such as sports items in Meerut, brassware in Moradabad, perfumes in Kannuaj, leather in Kanpur, shoes in Agra, embroidered sarees in Varanasi, carpet in Bhadohi, chikan work in Lucknow, etc.

The presence of these industries including agro and food processing, dairy, leather and textiles, and mineral based industries can be a catalyst for the promotion of CST technologies in Uttar Pradesh. Since most of these industries would require heat applications in their processes, CST technologies can be effectively integrated into these industries.



Tamil Nadu

Tamil Nadu is the second largest state economy of India, with a gross state domestic product of growth (YOY) of 8.2%, higher the national GDP of 6.8%. The state accounts for approximately 7% of the FDI inflows into India. Its automobile sector is the largest in the country accounting for one-third of automobiles and auto parts exports from India, it is also the largest exporter of leather products in India. The state has a robust industrial ecosystem with 4.95 million MSMEs in areas such as Engineering, Auto Components, Textiles, Gold Jewellery, Power, Steel.

Tamil Nadu has a strong logistical advantage with a coastline of 1,076 km covering ~15% of India's total coastline. Major ports in Tamil Nadu include Chennai, Ennore and Thoothukudi. The state is also rich in natural resources with reserves of lignite, natural gas (utilized), limestone, petroleum (crude), magnetite, garnet (abrasive), graphite, bauxite and vermiculite. Agriculture is also a major industry in Tamil Nadu with the production of bananas, tapioca, cloves, flowers and oilseeds being the major crops.

Tamil Nadu is one of the leading states for renewable energy installation with a wind energy capacity of over 9.4 GW and solar capacity installation of ~4.2 GW. The state is one of the potential sites for India's first offshore wind project as well.

Support for CST Manufacturing

The Tamil Nadu government under the industrial policy of 2014 had identified four thrust sectors that it would boost, which included Automobile and Auto components Sector, Renewable Energy Equipment manufacturing Industries, Aerospace industry and, Bio-technology and Pharmaceuticals Sector. With the declaration of renewable energy equipment manufacturing sector as a priority sector, CST component manufacturing can be accelerated in Tamil Nadu.

Priority Sectors

- **Renewable Energy Equipment manufacturing**
- Automobile and Auto components Sector
- Aerospace industry
- Bio-technology and Pharmaceuticals Sector

Tamil Nadu has a well-developed infrastructure with an excellent road and rail network, three major ports, 15 minor ports, and eight airports across the state providing excellent connectivity. Tamil Nadu has 23 SIPCOT industrial complexes in 12 districts, the state also has 54 formally approved Special Economic Zone (SEZs), 50 notified SEZs and four with in- principle approval SEZs and has total 40 exporting SEZs.

Tamil Nadu is home to a large number of glass industries including Saint-Gobain, which has invested in a single largest location in Sriperumbudur. Given the state's dominance in manufacturing of glass and automobiles, it can become a hub for manufacturing of CST components, making Tamil Nadu the leading state for mirror and reflector manufacturing for CST in India as well as globally.

Presence of industries for promoting CST

Tamil Nadu being one of the most industrialized state in the country has presence of a large number of industries in the state. The major sectors include services which contributes to 45% of the economic activity in the state, followed by manufacturing at 34% and agriculture at 21%. Tamil Nadu has a diversified manufacturing sector and features among the leaders in several industries like automobiles and auto components, engineering, pharmaceuticals, garments, textile products, leather products, chemicals, plastics, etc. It ranks first among the states in terms of number of factories and industrial workers. The presence of a large number of industries makes Tamil Nadu a suitable place for the deployment of CST technologies.

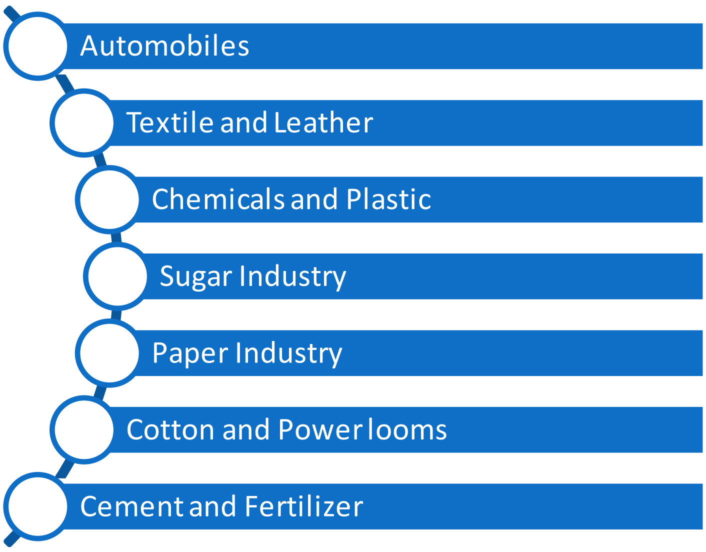


Figure 18: Presence of sutiable industries in Tamil Nadu

The CST systems can find applicability in a variety of industries in Tamil Nadu to provide heat for low and medium temperature processes as well as for preheating applications. Almost all of the industries have heat consuming processes where traditional heating systems can be augmented with CST technologies to reduce cost of fuel as well as emissions.

4.2. Recommendations

4.2.1. Issuance of amendment to existing policy framework

The current policy framework at the state and central level does offer some incentives to number of ancillary industries for CST, though not directly. The CST sector can take advantage of the existing expertise in the Indian industry. Policymakers should work towards creating incentives for the manufacturing of CST components while boosting domestic deployment and reducing cost of CST systems.

There must be incentives for CST component manufacturing in India as we already have the capabilities in the adjacent industries like steel, glass and electronics. A separate manufacturing policy might not be necessary but there may be a program to incentivize manufacturing of key systems components like mirrors and receivers.

Individual states with expertise in industries with technology or process overlap like glass and metal fabrication an d piping sector can through amendments in their industrial, electronics and solar policy can target specific manufacturing of CSTs. This could encourage domestic manufacturing of the key components while driving down costs, increasing the rate for CST technology adoption.

- **Amendment to Industrial Policy**

The industrial policy of various states has already started to emphasis the manufacturing of clean energy technologies. Most of the CST components except the reflectors and absorbers have significant overlap with other industrial applications including boiler, piping, chemicals (coatings), electronics (motors and control systems). These overlaps can be leveraged, followed by special incentives for the solar grade mirrors and reflective/absorber coatings. Though there are policy incentives in most states geared towards manufacturing of solar PV, wind and biomass technologies, there can be amendments to these to include CST technology components that can also be covered under the industrial policy.

Amendments to these policies can also be structured as demand drivers by mandating or ince ntivizing industrial process heating to be augmented with CST technologies. This would increase the demand for CST systems which can also be leveraged to drive domestic manufacturing.

- **Amendment to Solar Policy**

While current solar policies of most states are biased towards solar PV, there can be amendments to the solar policy to include CST systems specially for the commercial and industrial consumers. By offering an ancentive or a mandate for the adoption of CST systems, commercial and industrial consumers can be pushed to explore CST systems for their respective heating or cooling requirements. Creating provisions in the state solar policy to include incentives for low-medium temperature CST applications can create the demand growth required to scale up domestic manufacturing within the state. Various states policies also endeavor to offer incentives to solar manufacturing and for creating of zones/clusters for solar PV manufacturing, which can be extended to solar thermal, particularly CSTs.

States should capitalize on national priorities such as the “Make in India” to develop domestic manufacturing capabilities for CST systems. Mandating industries which show good potential for implementation of CST including food processing, dairy, paper and pulp, chemicals, textiles, fertilizers, breweries, electroplating, pharmaceuticals and rubber must be incentivized by the states to install CST systems to further drive demand.

4.2.2. Awareness, manpower training and planning for manufacturing setup

Manpower training and acquaintance with planning for setting up a CST manufacturing facility forms the bedrock for upscaling domestic manufacturing in India. Since, there are no historical evidences of proven success w.r.t. an integrated CST manufacturing facility, there is obvious lack of technical-know how on how to proceed with such an idea. Additionally, there are certain specific areas, where specialized training efforts would be needed to bridge the gap and bring proven technical expertise on board. These objectives can be achieved through following targeted measures.

- Creation of a technical manual/guide on CST manufacturing: This will involve creation of a planning document, which will enlist all the major steps, one needs to adopt to set up a CST manufacturing facility. The guide must include the following attributes (not restricted to);
    - Key stages of CST manufacturing, including in-house division
    - Information about the floor area requirements for different processes in an integrated CST value chain
    - Key equipment, machineries and resting infrastructure requirements
    - Total costing (CAPEX and OPEX) for setting such a facility
    - Possibilities of scale-up
    - Handling of logistics and procurement
    - Approvals and clearance procedures
- Organization of seminars and technical workshops at local levels, targeted at skilling CST players about the latest technology trends and best practices related to CST manufacturing, which can be adopted from the global arena. This can include sensitizing the CST stakeholders about key area such as;
    - Cost reduction measures across CST value chain in manufacturing
    - Possibilities of improving efficiency and thermal output, using better technical and compact designing
    - On-ground/field training on installation of CST system to ensure quality and performance
    - R&D on material science and alternatives
- Building partnerships at local level between CST players and leading educational institutions such as IITs, should be targeted to ensure latest R&D, including commercialization of prototypes with respect to adoption of effecting manufacturing strategies.
- Bringing in international experts from Europe (Spain, Germany, Austria, etc.) having subject matter expertise w.r.t manufacturing of sub-components, which is currently absent in India. This can include technical workshops pertaining to manufacturing of receiver tubes, reflector coatings and heat thermic fluids (HTFs) covering broad avenues as listed below. Exchange of knowhow shall also pave way for formation of JVs or other arrangements through which domestic manufacturers shall be able to source technology and manufacture in India.

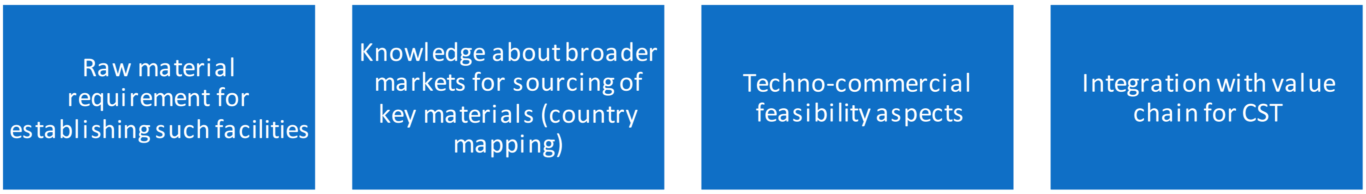


Figure 19: Awareness, manpower training and planning for manufacturing setup

4.2.3. Attracting big investors and formation of joint ventures

The establishment of a CST manufacturing facility will entail significant amount of upfront CAPEX, which will be well beyond 100 Crore investment. Although, financial incentives will be critical in improving the commercial viability, it is also essential to bring in bigger investors/ MNCs/ big corporate houses to have sustained commitments for atleast a period of 5-7 years in the sector. The support can be in the form of investments in manufacturing, deployments, machinery building, manpower training or other related avenues, which will aid in driving more PE firms and large investors in the ecosystem.

Opportunities for partnership between domestic and foreign players to form joint ventures (JVs) through international collaboration/tie-ups should be explored so that domestic manufacturing setups in India can be kickstarted. Additionally, on the technology front, much of complex CST manufacturing is 'patented' and hence technology partnership must be explored, which allow for knowledge transfer and subsequent deployment at domestic level.

4.2.4. Focusing on demand creation measures through policy and regulatory mandates

Creating a sustained demand for any technology remains fundamental towards addressing the supply side issues. This has been cited as a major drawback by numerous system integrators and manufacturers, that they do not foresee much demand for such systems over longer term and thus are hesitant towards establishing a dedicated manufacturing line. The MNRE also has been reluctant to focus on demand creation avenues, similar to the ones planned for solar PV (such as CPSU tenders, manufacturing linked tenders favoring domestic modules). The solar thermal roadmap for India also emphasizes on the targets in the near term i.e. till FY 2022, whereas it does not provide a long term trajectory till FY 2030 and associated demand creation measures to achieve those targets. Hence, to stimulate domestic manufacturing focus should be laid on demand creation.

As per leading CST dish manufacturer, a strategy based on fuel cost should be used for mandating certain industries for uptake of CSTs. Industries having lower energy costs can be mandated to switch over to CSTs and procure fixed quantum of heat

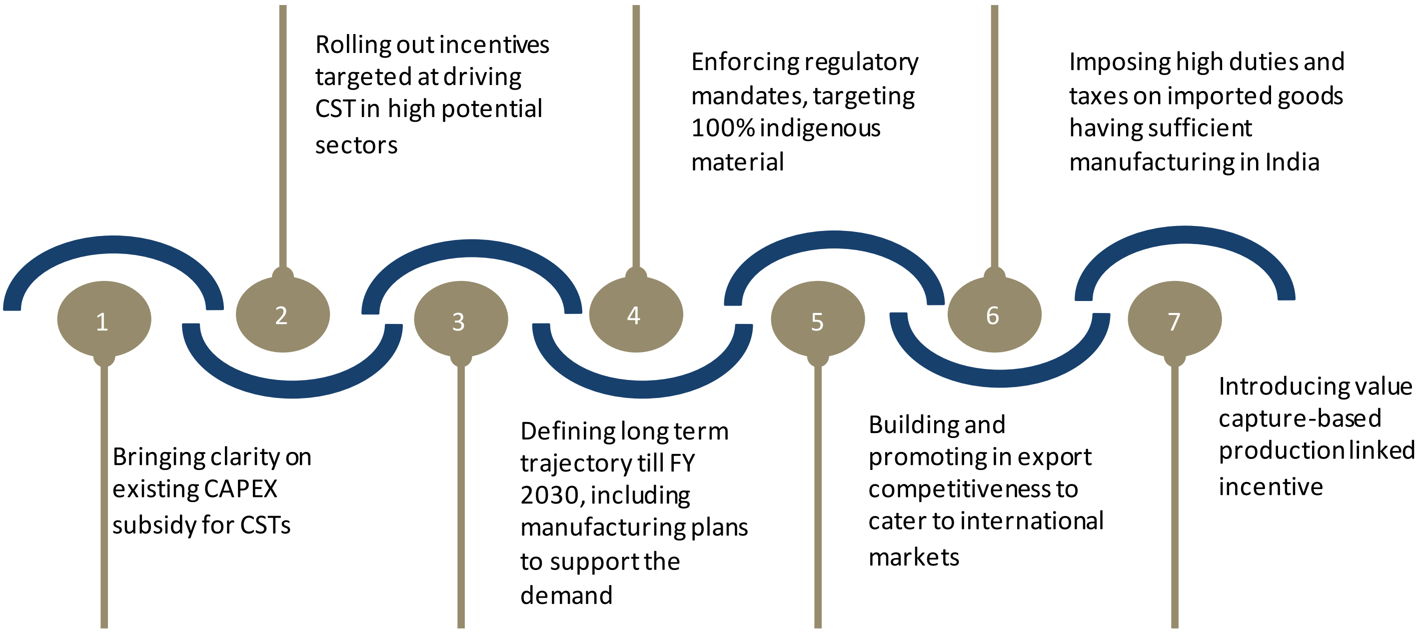


Figure 20: Demand creation measures through policy and regulatory mandates

- Bringing clarity on the existing CAPEX subsidy, including financial incentive available through low interest loans for CST systems. The subsidy scheme for CST installation was available only till March 31, 2020 and hence there is lot of ambiguity in terms of possible extension or not. The MNRE should front end this issue and bring more clarity (similar to the enthusiasm and proactiveness seen for solar PV during COVID times, but no update or similar measures were targeted for CST to stimulate demand)

As per one of the local CST players, policy instruments for generating demand is needed as once there is demand in the market, manufacturers will also start setting up facilities which will drive the costs down.

- Rolling out policy instruments and schemes targeted at driving CST installations, specifically in those industries (such as dairy, textile, chemical, auto, food processing, etc.) where potential is high and there have been considerable number of precedents for success in the past. The purview for the scheme can be expanded later to include more industries.

- Defining long term trajectory till FY 2030 with year wise plans for CST installations (including at regional level) and undertaking necessary supportive measures to achieve those targets. Accordingly, year-wise manufacturing targets can be developed to meet the demand.

As per NISE, MNRE can mandate certain key applications for CST that can be immediately targeted, such as dairy and textile processing plants, that generally have the typical heat load profile that can be addressed using CST systems.

- Enforcing regulatory mandates, which dictate the use of 100% indigenous material for system integration and installation. Few states have mandatory restrictions for installation of solar water heating (SWH) systems on the roof area, such obligations should be expanded to CST systems as well with inclusion of domestic quota in the installation. Other measures include regulatory mandates in the form of solar thermal heat obligation (along the lines of RPO for solar PV) and building byelaws, which have the potential to stimulate demand. Industries employing conventional fuel boilers can be mandated to meet certain portion of heat requirement through solar thermal.

- Building in export competitiveness: CST products, including sub-components such as solar grade mirrors (used in CSP technologies) have huge demand globally. Players in India do export CST products in countries such as Australia, Middle east, Europe and other markets. Hence, measures intended to promote export competitive nature of such products by allowing domestic players to cater to other geographies through simplified regulatory and legal provisions can also help in demand creation.

As per one of the leading CST system players, financial incentive upto 50% would be needed, with a loan moratorium period longer than usual for establishing a facility

- Imposing high duties and taxes on goods part of CST supply chain imported from other countries, especially for the ones which can be easily manufactured in India. Conversely, the duty structure for intermediate raw materials, currently unavailable in India needs to be relaxed.

As per one of the local CST system integrators, the subsidy disbursal should not be based on the CST collector area but rather the minimum heat/energy output of the system. This can have a two-fold benefit as the developers would now have to guarantee a minimum amount of energy that will be generated as well as the ensure the quality and standards for system installation

- Introducing value capture-based production linked incentive: MNRE can develop an innovative policy instrument, whereby the Ministry provides additional incentives to CST players who realize a significant portion of their manufacturing within India itself. The incentive can be linked to the 'percentage of value capture' which happens in India.

4.2.5. Innovative financing measures and programmes for manufacturing boost

Although India has progressed significantly in terms of solar PV manufacturing (10 GW+ module manufacturing and 3 GW+ cell manufacturing), solar thermal technologies in manufacturing context are still lagging, and this effect transcends to the understanding of financial institutions as well. Owing to this lack of know-how, financial institutions often lack confidence in providing financing for solar thermal manufacturing installations. Also, the finance that they provide may be at a higher rate of interest with more stringent collateral conditions. Another reason for this is the existence of systems that are not modular or standardized and are quite often manufactured as per customized specifications, which further leads to increased reluctancy to lend.

Since there is no operating fuel for the CST system, it has very low/minimal operating cost and thus the entire project feasibility is dependent on the initial CAPEX. There must be low cost financing option available to the manufacturing industry, to get the technology more competitive. Some of the other measures include:

- Training and capacity building of financial institutions/banks to sensitize them towards lending for solar thermal manufacturing
- Developing innovative financial instruments to support CST manufacturing. UNIDO and IREDA can develop soft loan programme to encourage uptake.
- Interest subvention scheme for CST manufacturing
- Other financial incentives, which can be extended to such facilities include;

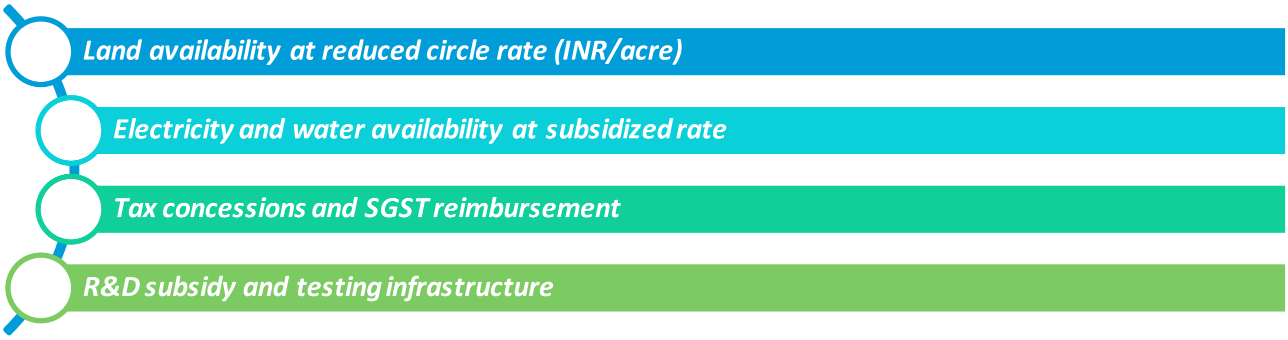


Figure 21: Innovative financing measures and programmes for manufacturing boost

Financing is already huge problem for many industries, the govt can include certain CST component manufacturing as a priority sector for easier access of funds to developers or set a pricing mechanism for domestic manufacturers to produce components in India.

4.2.6. Possibility of introducing CAPEX subsidy for manufacturing

While there have been efforts on the demand side to boost CST installation, also through programmes supported by UNDP and UNIDO, very minimal has been done to boost supply side measures through financial incentives and other support mechanisms. The state level industrial policies and electronic policies have encouraged the promotion of domestic manufacturing to certain niche sectors (including renewables such as solar PV, EV manufacturing and energy storage/battery manufacturing), however the benefits in the form of subsidies exclusively targeted at stimulating solar thermal manufacturing, including its ancillary industries have been missing. Several historical precedents at central level such as MSIPS policy (25% CAPEX subsidy), SEZ policy (plethora of fiscal benefits), etc. have articulated the role played by direct subsidy allocation to manufacturing. Similar thought process must be developed to incentivize solar thermal manufacturing. The economies of scale usually tend to kick in to bring down costs, once demand can generate volumes. Incentivization is needed to address this very 'demand aspect'.

For kickstarting purposes, MNRE can look to incentivize vital components, which comprise a significant portion of the domestic value capture in terms of CAPEX requirements. This can include incentivization of 'solar grade mirror manufacturing facility', as the Ministry has also mandated the use of such mirrors for CST installations in India. Additionally, there are primarily only 1-2 players engaged in supplying such components domestically and to encourage competition and bring in more players in the ecosystem to bring down costs, there is a need to incentivize such facilities. Subsequently, the Ministry can look to provide subsidy for sub-components, which are completely absent in India, but are critical towards realizing a complete integrated value chain. This can include incentivization of facilities involving manufacturing of receiver tubes, thermic fluids and coatings.

Hence, there is a need to introduce upfront CAPEX subsidy for setting up solar thermal manufacturing facility, especially for few critical components at initial stages.

As per leading solar grade mirror manufacturer, the Ministry needs to provide a CAPEX subsidy in the range of 30-40%, specially for component manufacturing such as solar grade mirror facility, along the lines provided by Chinese govt.

4.2.7. Focusing on quality, R&D and material science

To develop a robust market for solar thermal manufacturing, it is necessary to invest in research and development activities to make the technology economically viable and more efficient. Several R&D developments related to solar thermal heating and cooling systems have taken place worldwide, leading to improved designs and reduced manufacturing costs.

- Improved collector designs can lead to reduced losses and improved efficiency, reduced overall costing, improved versatility in temperature range, including possibilities of reduction in material usage. Such collector designs are not being manufactured presently in India. Some of the interventions undertaken internationally in this regard include the following.
  - Use of polymeric collectors for improved efficiency
  - Advanced liquid or gaseous fluids for heat and cold transfer for reduced losses. R&D in HTF to increase high heat density, stability, thermal conductivity and latent heat is needed.
  - Cost reduction using higher grade of standardization
  - Design for greater operability (i.e. for applications possibility beyond 400 ˚C)
  - Developing compact design of overall system to reduce losses (reduction in pipe lengths and losses)
- Digitization and performance monitoring: Manufacturing equipment's and building software's targeted at improving digitization and enhanced performance monitoring tools and algorithms have definitely become the need of the hour.To understand the performance of solar thermal systems on long term basis and the factors impeding the output, it is imperative to have 'state of art performance monitoring systems and tools 'to design a robust framework ensuring quality standards in place during installation and operation and maintenance period. Some of the interventions undertaken internationally include;
  - Predictive modelling: Developing algorithms for efficient communication technology for monitoring of solar thermal system: For example in developing predictive models based on climate forecasts (DNI), so that approximate heat delivery in the future may be estimated and backup measures can be adequately adopted (Such forecasting measures persist to an extent for solar PV and wind)
  - Superior data analytics on performance generation data: Benchmarking of different CSTs for comparison and scope of improvement, including designing policy instruments and development of performance standards
  - Enhanced use of digitization techniques: The enhanced usage of digitization techniques like smart phones apps for remote monitoring for reduced efforts for maintenance of systems. Integrating IOT solutions for predictive situation (for example pressure or temperature fall below a certain threshold) is another crucial area of intervention

  The manufacturing and development of such digital tools and related equipment in India will certainly assist in improving the project performances for CST technologies, including investor confidence.
- Storage: Support for the R&D of new storage materials, as well as policy measures and investment incentives for TES integration in buildings, for industrial applications, and for variable renewable power generation, is essential if its deployment is to be fostered. Further research on the possibility of thermo-chemical energy storage and the further development of PCMs is needed for this option to be widely adopted in a more cost-effective manner.
  - Improving energy storage density through composite materials
  - Enhancing the thermal conductivity of heat transfer fluid
  - Heat exchanger design for optimization of overall heat transfer between the HTF and energy storage materials
  - Improving efficiency of overall thermal energy storage

- Using nano compounds with PCM materials to enhance thermal conductivity, storage and fast charging and discharging
- For selecting best suitable composite PCMs, a test bench may be designed to test various composite PCMs.

Annexures

A.1. State Selection

State	Land Cost	Labor Cost (Average wages)	DIPP Ranking (Ease of doing business)	CST Installations (Collector Area Proactiveness)	Ancillary Industries (Glass & Mirrors)	Testing Lab for CST Applications	CST Heating/ Thermal Manufacturers	Presence of Ancillary Industries (Electrical and electronics)	Presence of Ancillary Industries (Boilers and Piping)	Casting and Forging	Electricity Tariff (11 kV-HV)	Presence of SEZ	Major/Minor Ports
Maharashtra	High	310	13	27	Yes	Yes	Yes	Yes	Yes	Yes	7.55	Yes	48
Andhra Pradesh	Medium	314	1	10	No	No	No	Yes	No	Yes	6.7	Yes	12
Gujarat	High	255	10	44	Yes	Yes	Yes	Yes	Yes	Yes	4.45	Yes	46
Karnataka	Medium	345	17	20	No	No	Yes	Yes	Yes	Yes	6.95	Yes	9
Tamil Nadu	High	434	14	34	Yes	Yes	No	Yes	Yes	Yes	6.35	Yes	16
Rajasthan	Medium	364	8	14	Yes	No	Yes	No	No	No	7	Yes	0
Uttar Pradesh	Medium	294	2	5	Yes	No	Yes	Yes	No	No	7.1	Yes	0
Madhya Pradesh	Low	221	4	4	No	Yes	Yes	No	No	No	6.8	Yes	0
West Bengal	Medium	291	9	1	Yes	No	No	Yes	No	Yes	8.9	Yes	5
Telangana	Medium	302	3	7	No	No	No	No	Yes	No	6.3	Yes	0

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