UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GOVERNMENT OF INDIA
MINISTRY OF NEW
AND RENEWABLE ENERGY

India's CST Sector - Vision 2022

MNRE-GEF-UNIDO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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Executive Summary

The current assignment is a part of the MNRE-GEF UNIDO project that aims to complement MNRE's support programme on Concentrated Solar Thermal Technologies (CSTs) as a part of off-grid decentralised solar thermal scheme. In this assignment, a roadmap for the deployment of 200 MW_{th} CST development in India by 2022 has been prepared with inputs from multiple stakeholders from across the value chain including Government agencies, private players, industry experts, technology providers, existing system beneficiaries, etc.

Globally over 80% of the energy that is consumed comes from fossil sources, while solar and wind sources account for the generation of only around 1% of the total primary energy consumed. Based on trends in the consumption of energy and the overall growth of the economy with emission standards becoming more and more stringent, world will see a rise in the total energy consumption. As per IEA estimates, the consumption will rise to 12,487 Mtoe annually by 2040 from the consumption of 9,301 Mtoe in 2013. Even under a scenario in which the World releases adequate policies to restrict the rise in Global temperature to 2ºC, this consumption should then stand at 10,748 Mtoe. There is hence a dire need to focus attempts on saving the environment and reducing pollution.

Industrial units are amongst the biggest consumers of energy; and in India alone account for the consumption of energy worth around USD 45 billion per annum. Owing to the immense pollution caused as a result of this, industries must realise their role as forbearers in supporting a healthy environment by making efforts to operate as sustainably and with as minimal pollution as they can.

This fact is further underscored by the growing importance given to the environment and also considering that it is constitutionally the right of everyone to protect their environment and surroundings. CST technologies herein provide a viable solution for meeting the process heat demands of a majority of industrial processes.

In terms of solar thermal technologies, China is the global leader and has over 70% of the total area under implementation of solar thermal systems. India on the other hand figures seventh in the list of top players with around 1.3% of the total 622 million square meters collector area that is globally implemented.

India is currently the leading country in the installation of CST systems with around 55,578 square meters of collector area under implementation as of March 2018. This translates to a total of 39 MW_{th} and the roadmap targets further implementation of 161 MW_{th} by 2022. Based on the industrial consumption of energy figures of the year 2017-18 and a multitude of factors including process mapping of industrial processes, process constraints, market forces, etc., the industry market potential of CSTs is 6.45 GW_{th}.

This report presents a roadmap that has been developed to address the main barriers for take-off of this industry. The barriers have all been classified under six headers comprising of technical, awareness, supplier limitations, financial, policy and regulatory and other miscellaneous barriers. It aims to create an enabling framework that will have active involvement of all stakeholders to propel the sector forward.

Amongst the key recommendations provided, one recommendation is to bring economies of scale into the implementation of CST systems by promoting the installation of large systems. This will then attract players with greater capabilities and access to finance, resulting in a reduction in system costs of these technologies. Just as it did for solar PV in India, this entire process will resonantly improve the willingness of beneficiaries/consumers to shift to these sources of generation and at the same time promote improvements in the technologies.

The enablers for scaling up installation of CST systems in the current scenario include grant subsidies being provided by MNRE and the subsidized loan being offered by IREDA as a part of the MNRE-GEF-UNIDO CST project. Earlier additional support was being provided by the United Nations Development Programme's (UNDP's) CST project in the form of grant. The project ended in March 2017.

Ensuring quality infrastructure in the CST sector is a critical issue, often resulting in the implementation of inferior systems that subsequently lend a bad name to the technology due to sub-optimal performance. A key recommendation herein is also to develop standards for the development, testing, inspection, certification and calibration of CST technologies. This will ensure that systems perform as per expectations and reduce the risks that beneficiaries perceive from these systems. Guidelines for various stakeholders pertaining to the roles mentioned above will further enable them to follow and abide by these standards.

Enhancing awareness of these technologies is another pertinent requirement as a significant portion of the population is unaware of CSTs and their utility. Educational initiatives such as inclusion of a brief on these technologies along with solar PV at the school or college levels, specialised courses on these technologies at the Diploma or above level and organisation of events to increase awareness of global players will serve to enhance awareness. Another recommendation proposed is for MNRE to establish partnerships with other Ministries to promote CSTs via leveraging their forums or reaching out to their industries in partnership with these Ministries.

Amongst other key recommendation of the roadmap are to develop a role of system integrators in the CST market so that there is differentiation and specialisation in the roles of manufacturers and integrators, to promote manufacturing of these systems in the Nation and encourage applied R&D in India's Centres of R&D excellence.

Implementation of systems of this magnitude in the coming four years will require substantial efforts on behalf of the sector stakeholders including the Government and will require a total investment to the tune of USD 60 million. The benefits of these systems will however be immense as they will generate direct employment for around 1500 people and at the same time lead to the emission reductions of around 1.4 million tonnes of Carbon Dioxide over the lifecycle of these plants.

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List of Abbreviations used

AD	Accelerated Depreciation
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CBB	Central Boiler Board
CFA	Central Financial Assistance
CRS	Central Receiving Station
CSO	Central Statistics Office
CSP	Concentrated Solar Power
CST	Concentrated Solar Thermal
DHI	Diffused Horizontal Irradiance
DNI	Direct Normal Irradiance
DST	Department of Science and Technology
ESCO	Energy Services Company
FY	Financial Year
GEF	Global Environment Facility
GNI	Global Horizontal Irradiance
GSR	Global Status Report
GST	Goods and Services tax
IDA	International Development Association
IEA	International Energy Agency
IIT	Indian Institute of Technology
IREDA	Indian Renewable Energy Development Agency Ltd
IRENA	International Renewable Energy Agency
IT	Income Tax
JNNSM	Jawahar Lal Nehru National Solar Mission
MHRD	Ministry of Human Resource Development
MNRE	Ministry of New and Renewable Energy
MoSPI	Ministry of Statistics and Programme Implementation
MTOE	Million Tonnes of Oil Equivalent
NABARD	National Bank for Agriculture and Development
NBFC	Non-Banking Financial Corporation
NCEF	National Clean Energy Fund
NIC	National Industrial Classification
NISE	National Institute of Solar Energy
NIWE	National Institute of Wind Energy

NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
POSHIP	Potential for Solar Heat in Industrial Processes
PV	Photovoltaics
R&D	Research and Development
REN21	Renewable Energy Policy Network for the 21st Century
RESCO	Renewable Energy Services Company
SECI	Solar Energy Corporation of India
SERI	Solar Energy Research Initiative
SHC	Solar thermal collectors for Heating and Cooling
SNA	State Nodal Agency
SRRA	Solar Radiation Resource Assessment
TERI	The Energy Resources Institute
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organisation
USA	United States of America
VAM	Vapour Absorption Machine

Units and Prefixes

o	Degrees
cal	calorie
E	Exa
G	Giga
INR	Indian National Rupee
J	Joule
k	Kilo
m	Meter
M	Mega
T	Terra
USD	United States Dollar
W	Watt
Wh	Watt Hour
W_{th}	Watt thermal equivalent

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Objective of the MNRE - GEF - UNIDO Assignment on Concentrated Solar Thermal Technologies

This report has been prepared as a part of the MNRE-GEF-UNIDO project titled “Promoting Business Models for Increasing Penetration and Scaling Up of Solar Energy” that aims to complement MNRE’s support programme to CST’s. The overall objective of the project is to remove barriers associated with the technology, increase awareness and eventually increase the deployment of CST technologies. Increased deployment of these technologies’ aims to reduce fossil fuel consumption and greenhouse gas (GHG) emissions. The aim of this assignment was to prepare a roadmap for the deployment of 200 MW CST development in India by the year 2022.

This roadmap has been prepared to serve as a guiding document to take strategic actions for large scale deployment of CST technologies, particularly in the Industrial sector. The roadmap fully supports and is compatible with the on-going MNRE CST support programs under the off-grid decentralised solar thermal scheme. It aims to initiate a self-sustaining and replicating phase of growth of these technologies by supporting the sector in improving technology and driving down costs, increasing awareness and demand for these technologies and supporting their implementation.

The approach for this assignment involves extensive consultations with stakeholders from across the value chain including Government agencies, private players, industry experts, existing system beneficiaries, industry owners, etc. Utmost focus has been given to ensure that the roadmap is practically implementable to achieve maximum results.

Background

Global Energy Scenario

Data published by the IEA in 2017[1] indicates that the world depends on fossil fuels like petroleum, natural gas and coal to satisfy most of its energy needs. Over 80% of the total global energy requirement is met by oil, natural gas and coal. The supply pattern for primary energy shows that there has been an increase in the share of coal and natural gas usage. Notably, the share of nuclear energy, hydro energy and other forms of renewable energy in the global energy mix has increased, majorly in electricity generation.

Figure 1 depicts the fuel wise energy supply of the total global primary energy mix in 2017 as per statistics released in 2017. The total energy supply was 13,541 million tonnes of oil equivalent (Mtoe). Figure 2 depicts country wise final energy consumption for the same year. The final energy consumption in 2017 was 9,384 Mtoe as against the 13,687 produced. The difference visible is the energy spent on converting the primary form into another form or transferring it to the point of consumption. Amongst the figures provided above of consumption in various regions, China accounts for the lion's share of energy consumption. It consumes around 20.4% of the total final energy consumption worldwide.

In comparison the Non-OECD countries in Asia combined account for only the remaining 13.2%.

As per IEA estimates, the world is likely to witness a rise in the total energy consumption to 12,487 Mtoe annually by 2040. Under a scenario in which the World releases adequate policies to restrict the rise in Global temperature to 2°C, this consumption will stand at 10,748 Mtoe.

In 2015, approximately 32.3 $GtCO_2e$ were released into the atmosphere only from the combustion of fuel for primary energy supply. China accounts for almost 8.9 $GtCO_2e$ tonnes and India accounts for 2 $GtCO_2e$ of Carbon Dioxide emissions.

Internationally, solar PV installed capacity as of the end of 2016 stood at over 303 GW with over 75 GW of capacity being installed in the year 2016 itself. For cumulative capacity, the top countries were China, then Japan which passed Germany, and the United States. Concentrated Solar Power accounted for another 4.8 GW as of end 2016.[2]

Primary Energy Supply – Fuel wise
IEA Statistics 2017

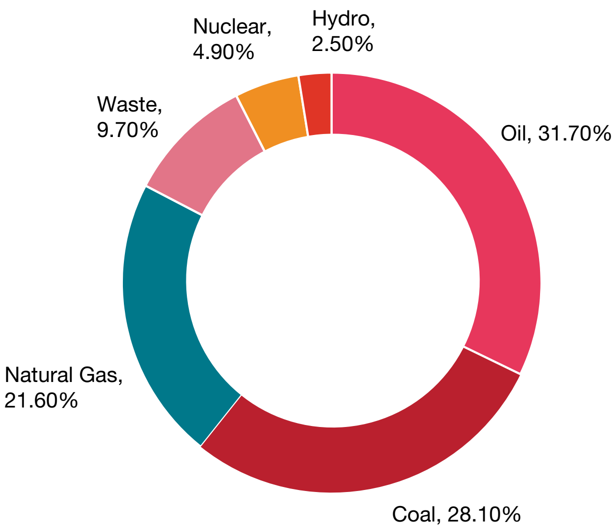


Figure 1: Primary Energy Supply

Final Energy Consumption – Region Wise
IEA Statistics 2017

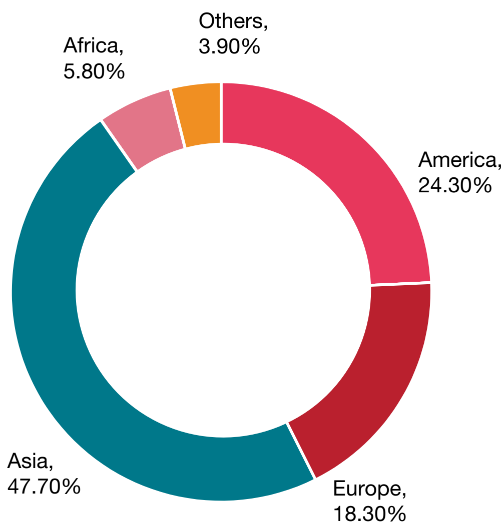


Figure 2: Final Energy Consumption

(Source: Data from IEA- 2017 Key World Energy Statistics)

1 Key World Energy Statistics – 2017, IEA
2 http://www.ren21.net/wp-content/uploads/2016/06/GSR_2017_Full_Report1.pdf

Solar Thermal technologies Scenario

Specifically in terms of solar thermal technologies, the global installed capacity at the end of 2016 stood at $456GW_{th}$, translating to a total collector area of approximately 622 million m². China accounts for the maximum installations out of this, comprising 71% of the total with 309.4 GW_{th} installed. China is followed by USA, which accounts for another 4%. Predominantly glazed collectors are used in installations, whereas unglazed collectors account for less than 10%.[3]

The year 2016 witnessed 21 GW_{th} equalling 53.1 million square meters of collector area being installed globally. This represents roughly 6% of the total installed capacity. China has emerged as the leader in such installations with 71% of 2016's newly installed solar water heating capacity taking place in the country. Where as India added around 0.9 GW thermal capacity in domestic water heating applications.[4]

Out of the total capacity additions in 2016, vacuum tube collectors make up around three-fourths of the total installed capacity. In installation terms, China was followed by Turkey, Brazil, India and the United States of America. In absolute terms, the additions in China were 30.45 GW_{th} which was over 21 times more than Turkey in the second place.[5]

Although there is a contraction of markets in China and Europe, the deployment of solar thermal technologies has increased in the previous year. This is primarily attributed to the emergence of new business models such as ESCO contracts and the easier availability of finance at better conditions. A model that has been much appreciated in this regard is the Danish cooperative model of consumer owned renewable district heating that involves projects being owned by non-profit consumer cooperatives. These cooperatives are responsible for running and maintaining the projects and all decisions of authority related to its operation. They thus have direct

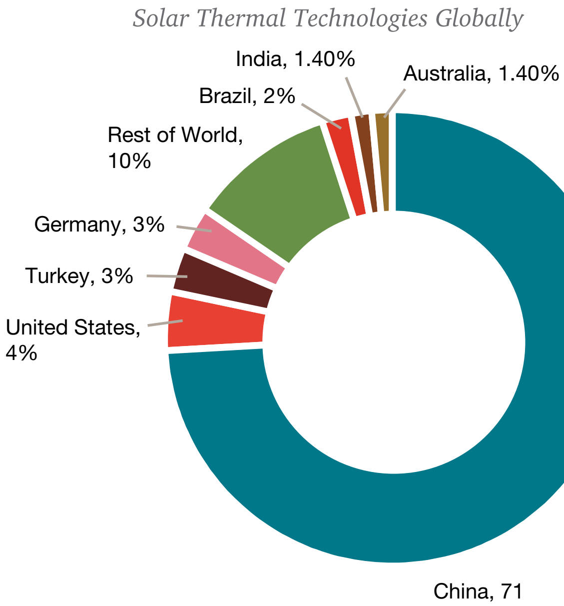


Figure 3: Solar Thermal Technologies Globally

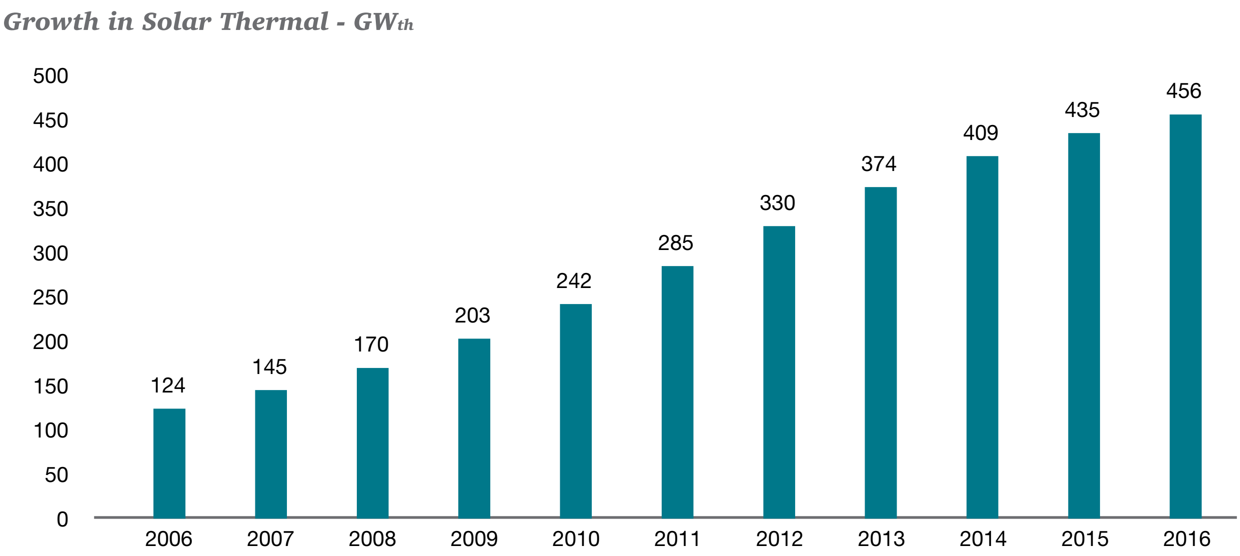


Figure 4: Growth in solar thermal technologies

3 http://www.ren21.net/wp-content/uploads/2016/06/GSR_2017_Full_Report1.pdf
4 http://www.ren21.net/wp-content/uploads/2016/06/GSR_2017_Full_Report1.pdf
5 http://www.ren21.net/wp-content/uploads/2016/06/GSR_2017_Full_Report1.pdf

authority over their community's district heating program and are direct beneficiaries of the energy generated.

This growth is also augmented by the increased deployment of large scale solar thermal systems for district heating and industrial uses. In the year 2015, construction of the 1 GW_{th} solar thermal plant - Miraah in Oman was initiated.

German flat plate collector manufacturers Bosch, Viessmann, Vaillant, Thermosolar and Wolf figure amongst the leading manufacturers, placing Germany as the leading Nation for manufacture of flat plate collectors. Chinese manufacturers Sunrise East Group, Himin and Linuo-Paradigma place China as the leading Nation for vacuum tube collectors. Specifically in terms of concentrating solar thermal technologies, India has emerged as the Global leader in terms of area under implementation and currently has 15 channel partners of the Ministry of New and Renewable Energy that manufacture a range of customised solutions for customers. There are in total 27 manufacturers that actively operate in the market and have led to its growth over the years.

Until now the global deployment of renewable energy is primarily for power generation segment and limited investments and emphasis has been laid for utilizing renewable energy for heating applications, specifically in the industrial segment. These resources have huge potential in replacing fossil fuels consumption in the industrial segment. Biomass as a primary energy source in industrial segment has a share of around 15% however solar is still in its infancy stage. Although solar energy is harnessed worldwide to generate electricity, processing heat for industrial procedures through CST applications still accounts for less than 1% of global solar thermal capacity[6]. Solar technologies have the potential to grow faster than any other renewable technology since their costs have reduced significantly in recent years and have less operation and maintenance requirements than any other renewable source.

International Energy Agency (IEA) technology Roadmap for Solar Heating and Cooling[7] estimates the long-term potential for solar thermal applications in industrial applications[8] at 7.2 EJ/year and 1.5 EJ /year for solar cooling. In order to show the magnitude of these figures, the solar collectors for low-temperature process heat (<120°Celsius) could reach an installed capacity of 3,200 GW (producing 7.2 EJ solar heat per year) by 2050, which would be the equivalent of 20% of energy use for low temperature industrial heat by that time. Reaching the above mentioned deployment levels for solar heating and cooling can avoid some 800 million tonnes of CO_2 emissions per year by 2050.

Indian Energy Scenario

India is the seventh-largest country by area and the second-most populous country. India's total primary energy supply for the year 2015-16 was estimated at 675.4 Mtoe. Out of the total supply, coal accounted for 364.09 Mtoe and crude oil accounted for just over 239 Mtoe. In comparison, the previous year primary energy supply was 769.3 Mtoe with coal accounting for 66% of the total. The share of natural gas has immensely increased from less than 40 Mtoe in 2014-15 to over 49 Mtoe in 2015-16.

Data from India Energy Statistics 2017, published by Central Statistics Office (CSO), Ministry of Statistics & Programme Implementation (MOSPI) clearly highlights that India is heavily reliant on Coal and Oil for its primary energy needs. In terms of coal, India has large reserves but huge demand from power and industrial sector pushes the country to import coal from countries like Indonesia, Australia and South Africa.

A major problem is that India imports 36% of its total coal requirement and 85% of its total crude oil and oil products' requirements to meet its primary energy

Primary Energy Supply - Fuelwise
India Energy Statistics 2017

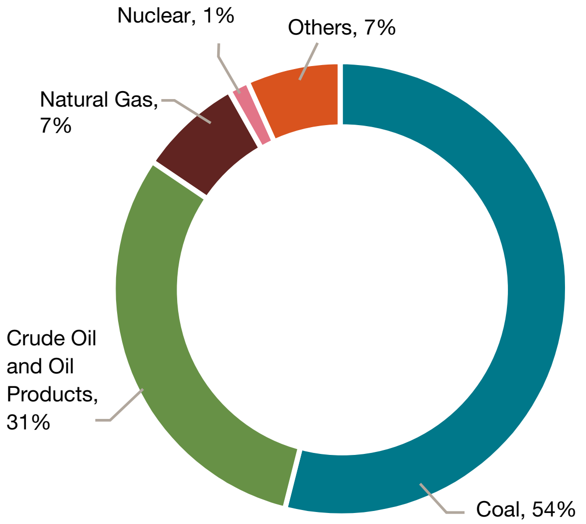


Figure 5: Fuelwise Primary Energy Supply of India

6 http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf
7 Technology Roadmap for Solar Heating and Cooling, International Energy Agency (IEA), August 2012
8 Renewable Energy in Industrial Applications – potential towards 2050; E. Taibi, D. Gielen, M. Bazilian, UNIDO Working Paper, 2010

supply. In comparison, the same figures for the year 2015, for coal and crude oil (including oil products) stood at 27.1% and 83.5% respectively. Therefore, the Nation has increased the percentage mixture of coal that is imported for meeting its primary energy requirements.

India's industrial sector accounts for the consumption of about 56.91% of India's final energy and is followed by the transport sector. The agriculture sector accounts for only 3% of the final energy consumption, that if put into perspective is broadly equivalent to just over one-eighteenth of India's industrial sector's consumption.

The final energy consumption of the Nation for the year 2015-16 is 519.28 Mtoe of which electricity comprises of 81.10 Mtoe, translating to 16.5%. Coal here accounts for 42.2% of the total and oil (including oil products) for 36.3% of the total. In comparison, the total final energy consumption of India in 2014-15 was at 483.9 Mtoe with electricity contributing to 16.7% of the total final energy consumed mix.

Final Energy Consumption – Sector Wise India Energy Statistics 2017

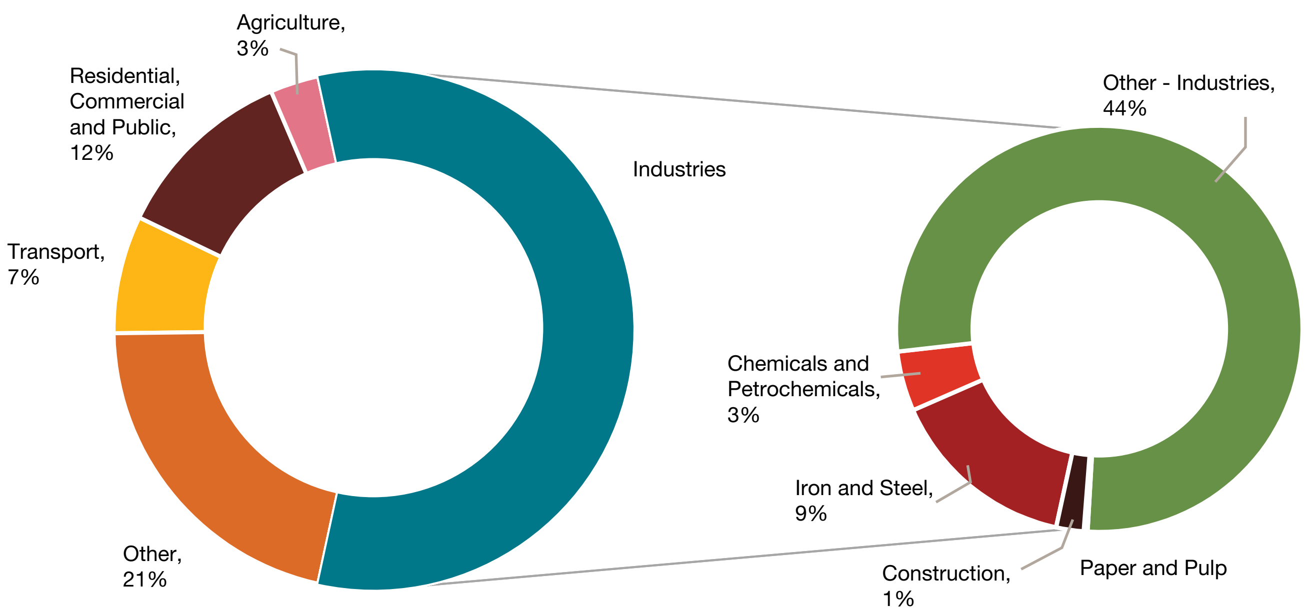


Figure 6: Sector wise final energy consumption of India

India's electricity sector

India's total installed electricity capacity as of February 2018 stood at 334 GW, with coal fired plants accounting for over 58% or 193.8 GW of the total installed capacity.[9] Renewable energy sources combined surpassed the Hydro capacity in 2016 and now comprise of the second largest share with a total installed capacity of 64.3 GW.[10]

As of February 2018, India's grid connected renewable energy sector mainly comprises of wind energy that contributes 32.87 GW to the total and is followed by solar energy at 18.45 GW. Biomass and Cogeneration plants account for 8.41 GW, small hydro power plants for 4.45 GW and waste to energy plants for the remaining 114 MW.

Renewables in India have significantly grown over the past few years and have gained momentum ever since the launch of India's 175 GW scale-up plans. This plan established by the Government of India targets installations of 100 GW grid connected solar, 60 GW grid connected wind, 10 GW from biomass technologies and 5 GW as small hydro power by March 2022. The 100 GW solar energy target set up under the Jawaharlal Nehru National Solar Mission (JNNSM) comprises of 40 GW as solar rooftop installations and 60 GW as large and medium scale grid connected projects. The Government

9 http://www.cea.nic.in/reports/monthly/installedcapacity/2017/installed_capacity-01.pdf
10 http://mnre.gov.in/mission-and-vision-2/achievements/

is very actively promoting these targets, as a result of which India has witnessed the fifth highest investments globally in renewable energy in the year 2015 after China, USA, Japan and UK.[11]

In the year 2016, the investments in RE plummeted compared to 2015, albeit the installation capacities grew at rapid phase surpassing the previous year 2015. Due to fierce competition and technology advancement the landing cost of renewable technologies has come down, attributing to overall reduction in investments. Investments in Solar energy are increasing, and for the first time in history of India the investment in solar surpassed the investment in wind sector.

India's Electricity Mix - February 2018

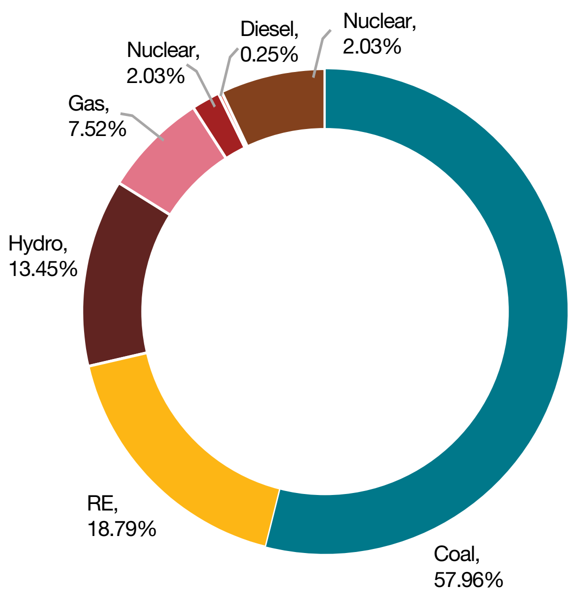


Figure 7: India's Electricity Mix

India's Renewable Power Mix - February 2018

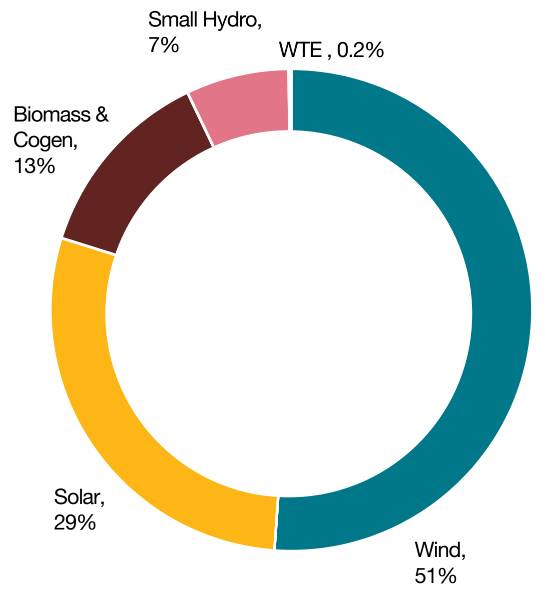


Figure 8: India's Renewable Power Mix

Scale-Up Plan - 2022	JNNSM - 2022		
Grid Connected Solar Power	Off Grid Solar Power	Solar Thermal Collectors Area	Solar Lighting Systems for House holds
100 GW	2 GW	20 million square meters	20 million

Investments in RE in India

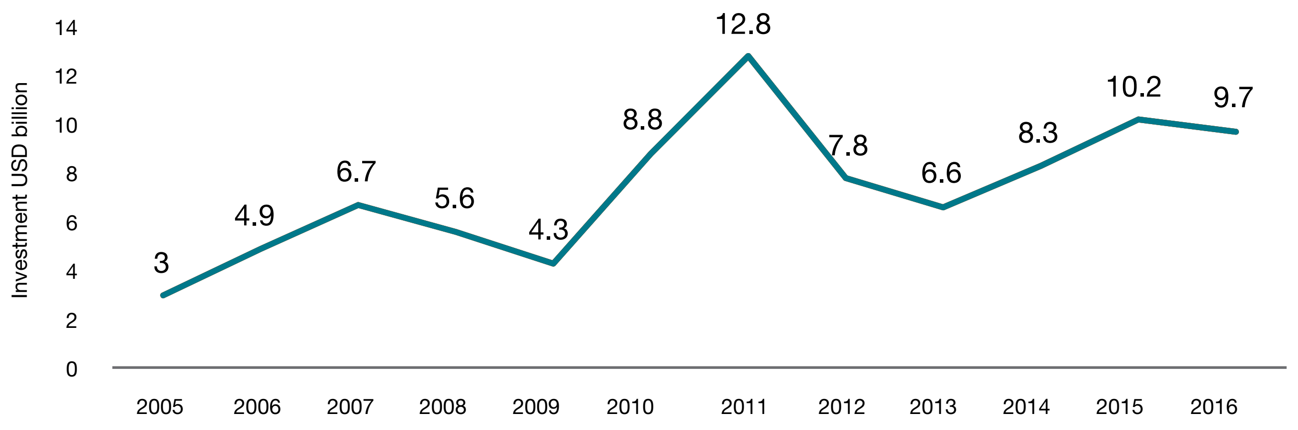


Figure 9: RE Investments in India[12]

11 http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

12 Global Trends in Renewable Energy Investment 2016, Frankfurt School – UNEP Collaborating Centre for Climate & Sustainable Energy Finance

Solar Thermal technologies in India

India is endowed with vast potential for solar energy. 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. With about 300 clear, sunny days in a year, India's theoretical solar power reception, only on its land area is about 5,000 trillion kWh per year. 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)[13]. 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.

JNNSM had established targets of implementing a cumulative of 15 million square meters by 2017 and 20 million square meters of solar thermal collector area by 2022. As of March 2018, India had a installed capacity of 55578 sq.m under solar CST projects.[14]

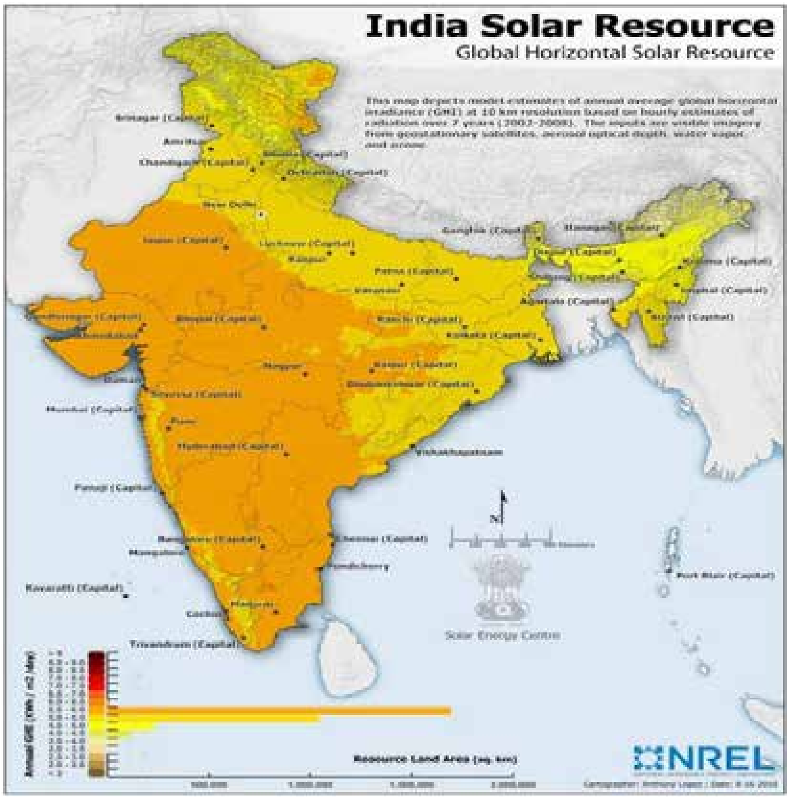


Figure 10: India's Solar Resource Map

Source: NREL

Solar Radiation in India

In order to provide investor grade and bankable solar radiation data, MNRE initiated a Solar Radiation Resource Assessment (SRRA) project, by setting up 115 SRRA stations in the country. This project is being implemented by National Institute of Wind Energy (NIWE), Chennai, an autonomous R&D institution under the Ministry of New and Renewable Energy. Each of the SRRA station is equipped with state-of-art equipment/sensors for measuring solar radiation and associated weather parameters. Configuration of these stations include measurement of Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), Diffused Horizontal Irradiance (DHI), Wind Speed and Direction, Ambient Temperature, Relative Humidity, Atmospheric Pressure and Rainfall.

The data is sampled every second and averaged over a minute. This then transmitted online to a Central Receiving Station (CRS) facility at NIWE with Automated data quality control mechanisms as per international norms.

Figure 11: SRRA Network in India

Source: http://niwe.res.in/department_srra_stations_map.php

13 51 solar radiation resource assessment (SRRA) stations have been installed by the MNRE to monitor the resource availability across India.
14 Annual Report 2015-16, Ministry of New and Renewable Energy

The lion's share of this area under implementation comprises of solar water heating systems, whose growth over the years has been depicted in the graph below. 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 systems of capacity 900 MW_{th} were installed in by the end of 2016 in India, taking the Nation's total installed capacity to 6.92 GW_{th} as on March 2017.[15]

Growth of Solar Water Heating Systems in India

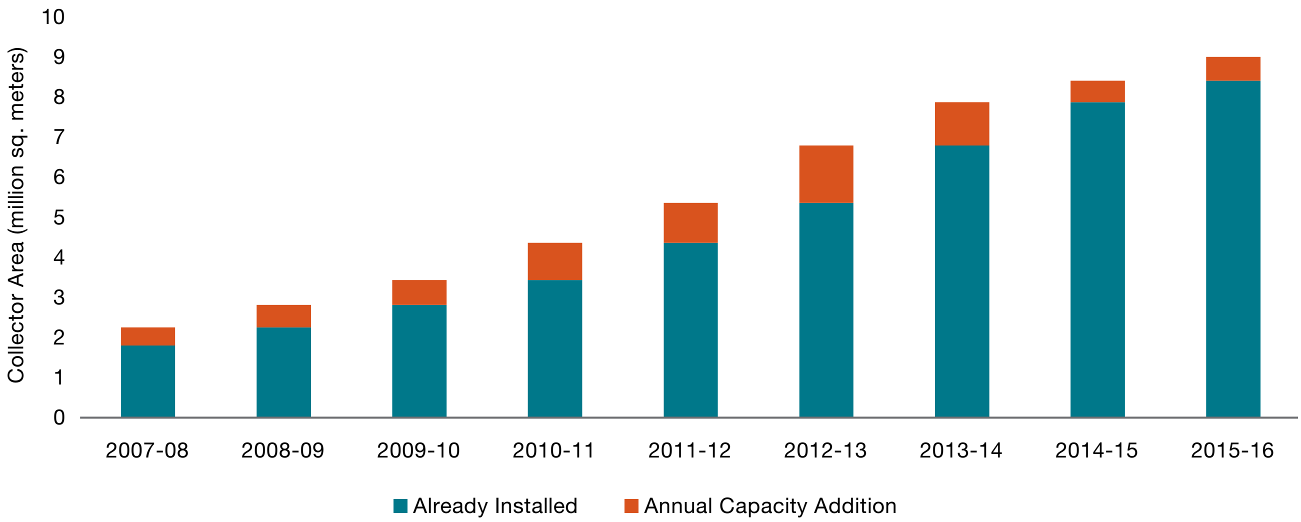


Figure 12: Growth of Solar Collector area in India[16]

15 http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report1.pdf
16 Annual Report 2015-16, Ministry of New and Renewable Energy

1

Concentrated Solar Thermal (CST) Technologies

Solar thermal technologies harness solar energy to generate thermal energy or electrical energy for use in industry, and in the residential and commercial sectors. Solar thermal collectors are classified as low, medium, or high temperature collectors. Low-temperature collectors are used for smaller non – intensive requirements. Medium – temperature collectors are used for heating water or air for residential and commercial use.

High-temperature collectors concentrate sunlight using mirrors or lenses and are used for fulfilling heating requirements up to 400 ^{o}C / 20 bar pressure and for electric power production. High temperature solar thermal energy comprises of two categories, which includes CST Technologies for fulfilling heat requirements in industries, and Concentrated Solar Power (CSP) when the heat collected is used for power generation. The classification of solar thermal technologies on the basis of temperature range has been provided below.

Low Temperature Heat
< 150°C

Medium Temperature Heat
150°C - 400°C

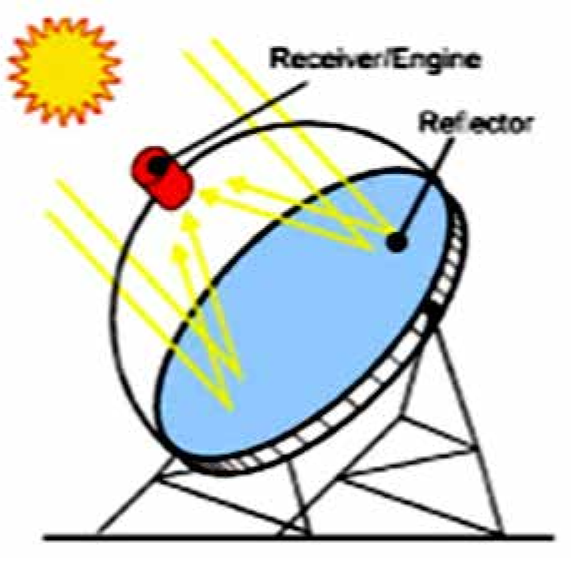
High Temperature Heat
>400°C

1.1 Working Principle of CST's?

CST's essentially comprise of reflectors/collectors for reflecting incoming solar radiation onto a receiver, thus concentrating a large area of sunlight onto a single receiver. This principle is similar to how a small lens generates enough heat to burn a piece of paper, except that here the small lens is much bigger to the tune of 100 square meters or more depending on the type of technology. This heat energy received is then used to heat a heat transmitting fluid depending on the end requirements of the process.

These systems utilise solar radiation to generate heat – as hot water, air or steam that can be readily deployed for meeting numerous applications in different sectors such as industrial process heating, space cooling and power generation on a large scale. These applications make use of solar energy collectors as heat exchangers that transform solar radiation energy to internal energy of the transport medium (or heat transfer fluid, usually air, water, or oil). The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which can it be drawn for use at night and/or cloudy days.

Under the concentrating type – there are imaging and non – imaging technologies. Imaging technologies have a smaller range of acceptance angle compared to that of non – imaging technologies. For example,

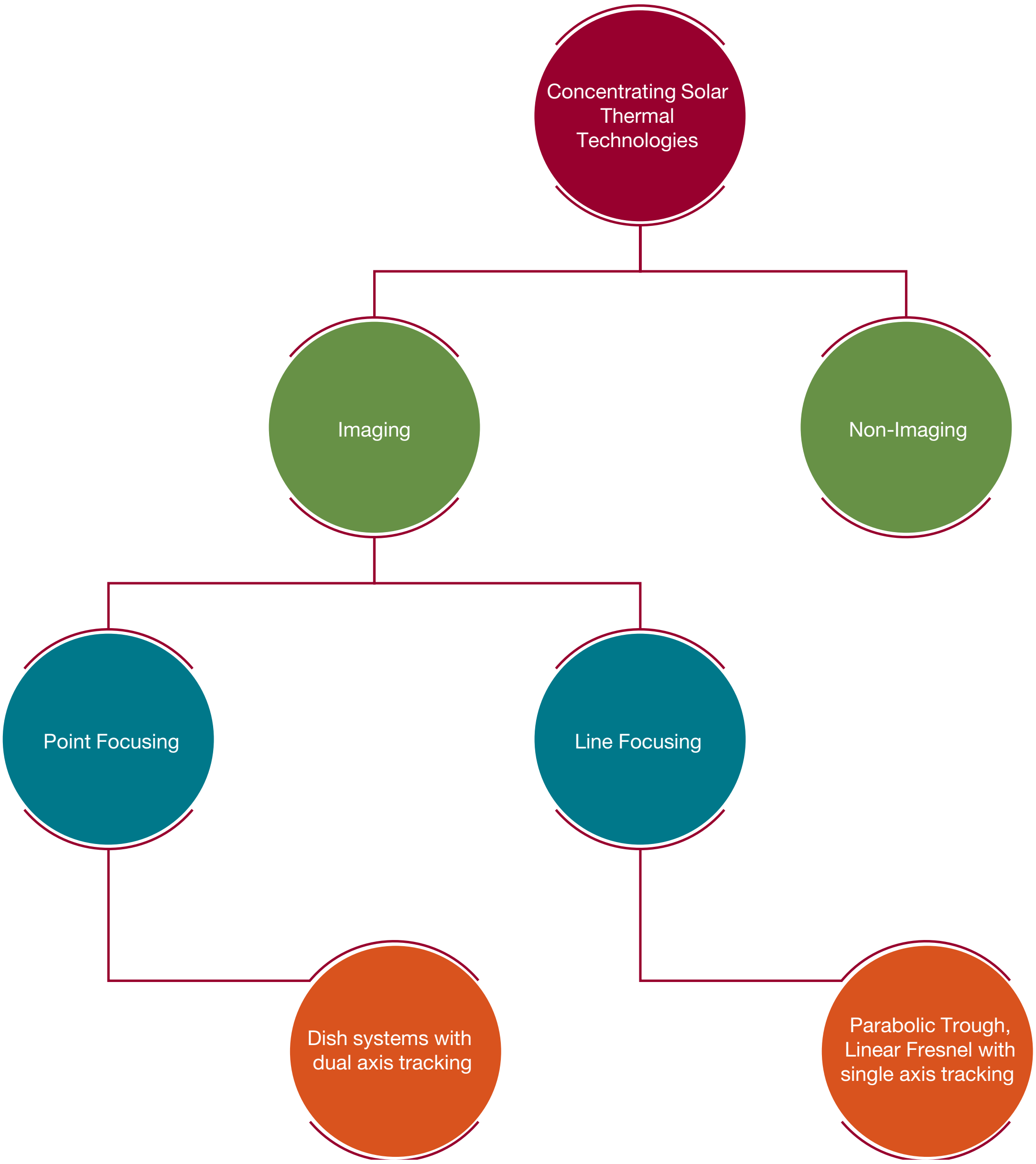


imaging concentration gives about 1/3 of the theoretical maximum for the design acceptance angle, that is, for the same overall tolerances for the system. Non – imaging optics, which have a larger acceptance angle range, can be used to approach the theoretical maximum.

The collector systems of concentrating systems are of two types, either the line-focus collectors or the point focused collectors. Line focus collectors focus the radiation onto an entire line focus, as in the parabolic trough, whereas point focus collectors focus the entire energy onto a point rather than a line, thus achieving a much greater concentration ratio at that point, just as in Arun dish. The various types of technologies have been described in the subsequent section.

1.2 CST Technologies

The most mature type of solar thermal technologies have been depicted in the chart below. The technologies provided below belong to one of these types and have been explained individually below and a comparison table has also been provided.



1.2.1 Non-Imaging technologies

1.2.1.1 Non Imaging Concentrators

Also known as Compound Parabolic Collectors (CPC), NICs consist of specially coated absorber tubes that are enclosed in concentric vacuum glass covers to reduce convection losses. The fluid to be heated passes through these tubes and is transferred via a header to the central receiver tube on top.

Working Temperature: Upto 150°C
Concentration Ratio: 5-25 suns
Tracking: Not Necessary

Pros

- Low O&M and adjustments
- Low Investment per unit area

Cons

- Not proven in India;
- Low Temperature

ITC Factory, Pune, Maharashtra

SKF, Mysore, Karnataka

1.2.2 Line Focus Technologies

1.2.2.1 Parabolic Trough Concentrator

Parabolic Trough Concentrators comprise of troughs that are made from parabolic shaped metal. This metal is coated with a reflecting material such as highly polished metal or metallised plastic which can withstand the effect of external agents such as rain and also sunlight as well. These trough shaped surfaces reflect the incident sunlight on to a metallic collector pipe (the receiver) that runs axially along the trough.

Working Temperature: 150°C - 250 °C
Concentration Ratio: 10-100 suns
Tracking: Single Axis

Pros

- Proven Technology
- Storage Available
- Commercial
- R&D Experience

Cons

- Complex Structure
- Flat area required
- Maintenance

Schematic of a Linear Fresnel

1.2.2.2 Linear Fresnel

Linear Fresnel Reflecting Concentrators (LFRC) are similar in line focus to parabolic troughs, except that instead of the parabolic shaped reflecting surfaces, these are made from strips of straight reflecting material These surfaces also reflect the incident sunlight onto a metallic collector pipe (the receiver) that runs axially above the array of reflectors.

Working Temperature: 150°C - 250 °C
Concentration Ratio: 10-100 suns
Tracking: Single Axis

Pros

- Simplified Design
- Low Investment per unit area
- Storage Available
- Pre-Commercial

Cons

- Area requirement
- Low Efficiency
- Large size mirrors tougher to replace

1.2.3 Point Focus Technologies

1.2.3.1 Fixed Focus Elliptical Dish

Also known as Scheffler concentrators, this setup comprises of a single dish system that is made up of large number of mirrors. All of these mirrors reflect the sun's rays onto a fixed receiver that contains the heating fluid. The dish which automatically tracks the sun in the E-W direction from morning to evening is single axis tracked system.

Working Temperature: Upto 250°C
Concentration Ratio: 20-100 suns
Tracking: Single Axis

Pros

- Relatively Cheap
- Commercial, Simple Fabrication

Cons

- Limited Temperature
- No Storage

Brahamakumari, Mount Abu, Rajasthan

1.2.3.2 Fresnel Reflector Based Dish

Also known as Fresnel Reflector Based Dishes, these comprise of a dish composed of panels of flat mirrors mounted on a frame with a cavity receiver connected to the dish. The receiver is at the focal point of the dish and such that it is held in a fixed position in relation to the reflectors by means of a suitable structure. The entire array of panels and receiver moves to track the Sun. The reflector and the receiver move in synchronisation to track the Sun, such that the dish faces incoming sunlight at all times and concentrates that on the central receiver.

Working Temperature: Upto 400°C
Concentration Ratio: 10-100 suns
Tracking: Double Axis

Pros

- Relatively Cheap
- Commercial
- Simple Fabrication

Cons

- Operation and Maintenance
- High tracking accuracy required
- Mirror cleaning a hassle

Mahindra and Mahindra, Pune, Maharashtra

Universal Medicap Limited, Vadodra, Gujarat

1.2.3.3 Paraboloid Dish

Paraboloid Dish comprises of a dish with mirrors mounted on a truss structure such that the incident sunlight is reflected on to a central cavity receiver which is specially designed to reduce convective and radiation heat losses. In comparison to the Fresnel dish, these systems have lighter structures and can integrated wherever space permits and are hence suitable for retrofitting in congested layouts. These dishes are pole-mounted and thus have small footprint.

Working Temperature: Upto 400°C
Concentration Ratio: 20-100 suns
Tracking: Double Axis

Pros

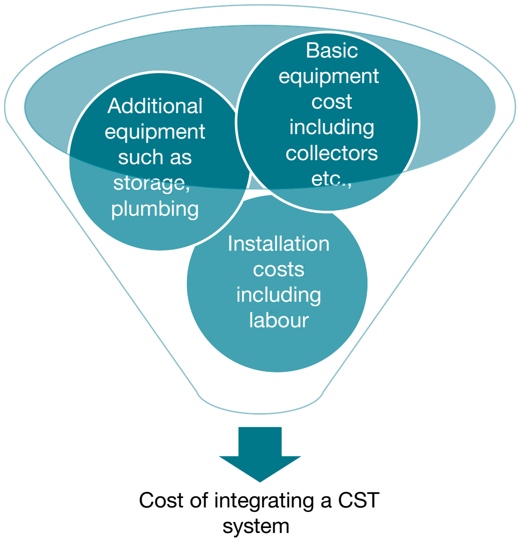
- Commercial
- Modular
- Highly efficient

Cons

- Operation and Maintenance
- Higher cost per dish

1.3 Cost components of CST's

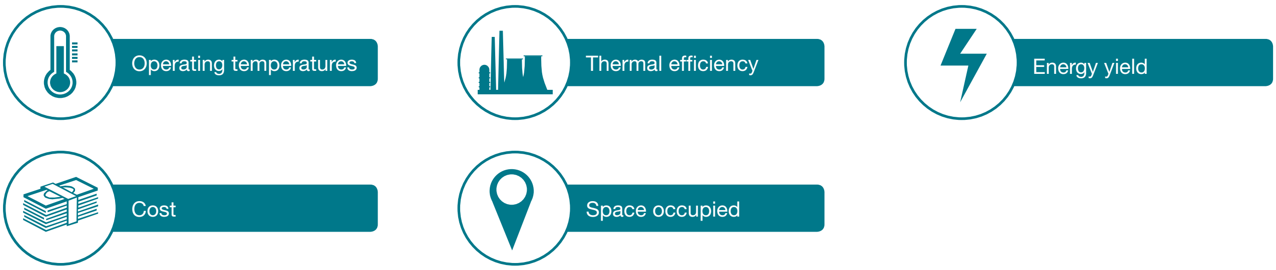
Like most of the renewable energy technologies, CST's are characterised by higher upfront costs and significantly lower variable costs like operational and maintenance costs because of absence of paid fuel requirements. The O&M costs are generally a part of the with the system manufacturer, involving fixed periodic charges that may or may not include component replacement charges. The essential upfront cost components of integrating a CST system have been depicted in the chart alongside. The set-up costs vary significantly with the technology being implemented. Installation costs typically amount for a very low percentage of the overall system cost in developing Nations such as India, however in developed Nations these may account for upto 50% of the total system cost.[17]



1.4 Selection of Appropriate Technology

The selection of an appropriate solar collector basically depends on five factors .[18] For medium temperatures, in the range of around 250°C, generally line focus technologies such as parabolic troughs and linear Fresnel technologies were used, but lately solar dish technologies have started gaining prominence. In the case of higher temperatures, only point focus technologies can be used, thus limiting the options that are available in the selection of technology criteria. A brief representation of the suitability of the type of technology based on the temperatures to be achieved has been provided below for representation purposes.

Amongst the other criteria, another limiting criteria can be the availability of space and the suitability of a particular technology within the available space. For instance, certain rooftops might be built in such a manner that they might not be able to bear the load of a parabolic dish, etc. A brief on the industrial applications of CST's based on the temperatures to be achieved and broad process constraints has been presented in the subsequent section.



17 Technology Roadmap 2050 : Solar Heating and Cooling, IEA
18 Kulkarni, et al., 2009; Fernandez-Garcia et al., 2010

1.5 Industrial Applications of CST's

Industrial heat is characterized by a wide diversity with respect to temperature levels, pressures and production processes to meet the many different industrial process demands. CST Technologies track the sun's incoming radiation with mirror fields, which concentrate the energy towards absorbers, and then transfer it thermally to the working medium. The heated fluid or steam may reach high temperatures and may be used for various processes requiring heat.

Advantages of CST's to industries	De-risks existing business by reducing dependance on conventional fuels
	Reduces fuel and operational costs
	Incentives as may be offered on usage by the Government from time to time

CSTs can produce a range of temperatures, between 50°C and up to over 400°C, which can be used in a variety of industrial process heat and space cooling applications. The industries showing good potential for implementation of solar concentrators are food processing, dairy, paper and pulp, chemicals, textiles, fertilizer, breweries, electroplating, pharmaceutical, rubber, desalination and tobacco sectors. Any industrial/ commercial establishments currently using steam/hot water for process applications can also employ CSTs with a minimum tinkering to the existing setup. For industrial processes where lower temperature range (less than 120 °C) is required, technologies such as the non-imaging concentrators are common and for higher temperature range applications, technologies based on tracking mechanisms with a higher sun concentration ratio such as parabolic trough, Linear Fresnel and paraboloid dish are preferred.

According to a study (Ecoheatcool 2006), around 57% of the total industrial heat demand is required at temperatures below 400°C, thus falling within the purview of CST technologies. Further 30% of the industrial heat demand is at temperatures below 100°C.

Another study (POSHIP 2001) reveals that in specific industry sectors, such as food, wine and beverages, transport equipment, machinery, textiles, pulp and paper, the share of heat demand at low and medium temperatures (below 250°C) is around 60%. Tapping into this potential would provide a significant solar contribution to industrial energy requirements.

A potential assessment of the usage of renewables in process heat applications in industries carried out by UNIDO estimates that solar thermal technologies have the potential to provide 5.62 Exa Joules of energy to the industrial sector in the year 2050. Almost 50% of this energy will be provided to the food and tobacco industry.[19]

As per data released by the "Solar Heating and Cooling Technology Roadmap" developed by the "European Technology Platform on Renewable Heating and Cooling", as of June 2014, less than 120 operating solar thermal systems for industrial purposes were reported worldwide.

Industrial Potential of Solar Thermal 2050

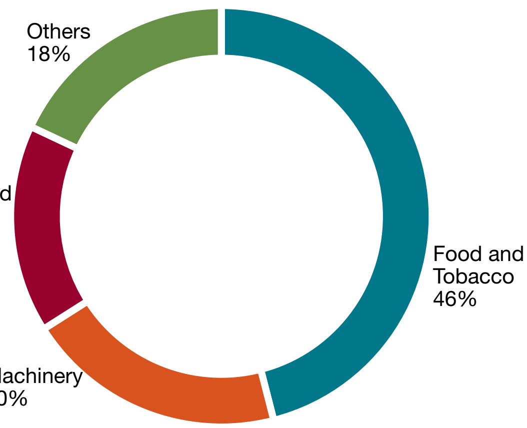


Figure 13: Industrial Potential of Solar Thermal 2050

These systems combined had a total capacity of over 40 MW_{th}.

As per a report released in 2015 by IEA-ETSAP and IRENA, the number of systems providing energy to Industries had grown to 140, with a total collector area of around 136,000 m^2. Out of these systems, only about a third had a collector area of greater than 500 m^2.[20] The report also explains that industrial process heat accounts for over two-thirds of the total energy consumption of industries.

19 Renewable Energy in Industrial Applications – An Assessment of the 2050 Potential, UNIDO
20 Solar Heat for Industrial Processes, IEA-ETSAP and IRENA

2

Status of Concentrated Solar Thermal Technologies

2.1 Global Status

Globally, CST systems of various types have been implemented, that too for varied uses ranging from industrial applications to cooling and cooking applications. Owing to the unique conditions at the site of implementation and limiting factors in the process, these systems are customised so as to serve the best possible

The systems implemented globally may differ in terms of the technologies that are used however the basic underlying principle is the same. On a global average, broadly amongst the different types of concentrated solar systems implemented, Parabolic Dish Collectors

El Nasr, Egypt

Source: Fichtner Solar

have costs ranging from USD 400 – 1,800/kW, Parabolic Trough Collectors have costs ranging from USD 600 – 2,000/kW, and Linear Fresnel collectors have costs in the range of USD 1,200 – 1,800/ kW. As per a study conducted in 2014, the heating costs for solar concentrating systems fall in the range of 6 – 9 Eurocents/kWh with a target of 4 – 7 Eurocents/kWh by 2020.[21]

There are several systems that have been implemented in India, USA, France, Australia, Israel, the Gulf and Germany. In terms of area under installation, India is the global leader. It has several manufacturers that have designed their own versions of dual-axis dish based systems. The status of CST's in India has been explained in the subsequent section.

One notable example from across the World is the Odeillio installation in France that has a very high concentration ratio of 10,000 suns and can achieve temperatures as high as 3500° C. The installation is used as an industrial oven for testing the resistance of new materials.

Another notable example is the El Nasr Plant in Egypt that has a collector area of 1900 m^2. The plant is based on the parabolic trough technology and is capable of achieving temperatures of around 175° C. The plant delivers saturated steam at a temperature of 173° C and a pressure of 8 bar for processes of the pharmaceutical industry.

Odeillio, France

Source: IEA

21 ESTIF, 2014

2.2 Status in India

In the year 2017-18, around 11 systems with 3,130 m² of area were completed.[22] As per most recent data collated by MNRE for their 2017-18 annual report, the total number of CST projects under various phases of implementation are 318 representing a total collector area of 73,764 sq. meters. The total completed projects occupy just over 55,000 sq. meters and have a total energy generation potential of 39 MW thermal. India currently has the maximum area under implementation for CST's for process heating and cooling purposes and has herein a very viable opportunity to become the unanimous global market leader for CST's for such utility.

India is seen as a favourable market globally for the growth of CST's. This is primarily because of the high irradiance and also the existence of local manufacturers with access to cheap labour. Although the country has its own barriers to growth, such as the non-existence of solar grade reflector manufacturers, CST's in India find diverse used with systems being used for cooking purposes, in automotive industries, textile industries, food industries, etc. for varied uses. Further details of CST's and their status in India have been detailed in subsequent sections.

An application wise break up area and number of projects funded under UNDP-GEF is depicted in the figure below. As of March 2017, over 44949 m2 of total area has been implemented with financial assistance UNDP-GEF with a total number of projects summing to 154 including 16 projects for repair and renovation. This may be in the form of subsidies or incentives as has been described in the subsequent section. A list of the channel partners of MNRE has also been attached with this report as an annexure.

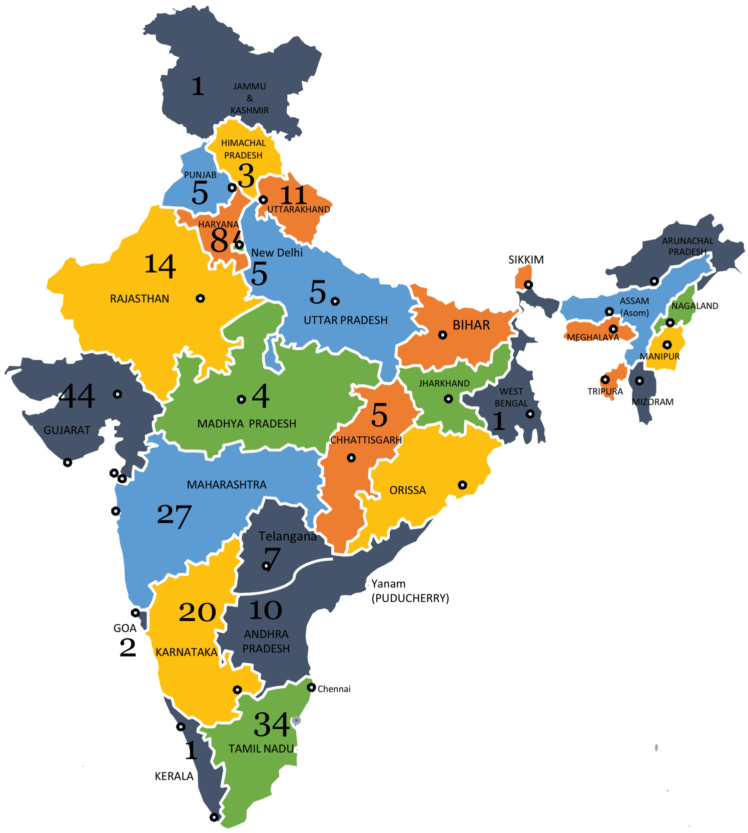


Figure 14: CST projects installed in India as on December 2017 (m²)

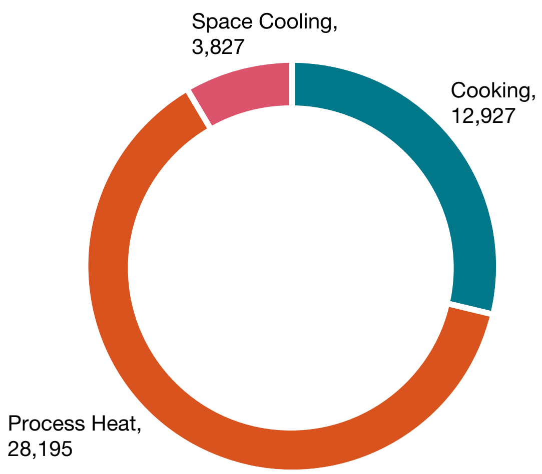


Figure 15: Field Projects Supported under CSHP under GEF-UNDP

22 MNRE Annual Report 2015-16

3

Implementation and Support to CST Projects in India

Indian government has been consistently pushing this technology deployment on the backdrop of recognized societal benefits attached to this technology. The two main efforts by the Government include allowance of accelerated depreciation in Income Tax (IT) Act and the payment of subsidy from MNRE. In cases this subsidy is supported by additional subsidies released from developmental agencies.

Under the provisions of the accelerated depreciation benefit unit owners can claim depreciation of the capital cost of the solar field for the purpose of calculating profits earned in their books of accounts. The IT act allows for a 40% depreciation benefit for the first year and a 40% benefit on the remaining value for the subsequent years thereafter. Under the JNNSM scheme, MNRE also provides a capital subsidy of 30% on the benchmark cost/project cost, which under the current scheme is paid to the project developers. Apart from these, customs duty exemptions for solar components is also available.

3.1 MNRE scheme for off-grid decentralized applications

MNRE provides subsidies to support the installation of CSTs. The subsidies provided by MNRE as of February 2018 are 30% of the benchmark costs, which depends on the technology that is implemented. The size of the system is determined by the collector area that is implemented. There is an additional subsidy of 30% if the project is implemented in a special category state, which comprise Uttarakhand, Himachal Pradesh and North-East states.

As per the scheme document, funding under the scheme will be in Project mode. The total project cost shall be funded through a mix of debt and incentives where the promoters' equity contribution would be at least 20%.

MNRE provides financial support through 30 % subsidy (60% for special category states), subject to the bench mark project cost. The subsidy pattern for different types of solar collectors and solar concentrators is shown in the table below.

An amount of Rs. 70 Crore has been earmarked under National Clean Energy Fund (NCEF) for implementation of MNRE program on Market development of Medium and high temperature CSTs in industrial, commercial and institutional establishments for community cooking, process heat and cooling applications. Through this support, about 200 CSTs totalling approximately 90,000 m^2 will be provided support from 2017-20.

Table 1: MNRE Subsidy for CST systems

Solar thermal systems/devices	Capital subsidy (Rs./ sq.m. of collector area) or 30% of project cost whichever is less
Dish solar cookers & steam generating systems based on following type of collectors	
Concentrators with manual tracking (Dish type solar cookers)	2,100
Non- imaging concentrators /Compound Parabolic Collector	3,600
CSTs with single axis tracking (including scheffler dishes)	4,500
CSTs with single axis tracking, solar grade mirror reflector and evacuated tube collectors	5,400
CSTs with double axis tracking	6,000

3.2 Accelerated Depreciation Benefits

System beneficiaries can avail accelerated depreciation (AD) of up to 40% per annum on systems implemented from April 2017 onwards. This is calculated on written down value of the asset throughout its life. Accelerated depreciation has the potential to serve as an effective enabler in the case of industries and other entities that are making profits and have significant tax implications.

3.3 Institutional Structure for CST in India

Institutional framework for development of industrial CST technologies in India involves MNRE as the federal Ministry with the responsibility of both Policy and administration. The overall structure follows an umbrella institutional structure with both accredited and autonomous technical, project implementation and financing agencies.

- **Policy Making Institute**

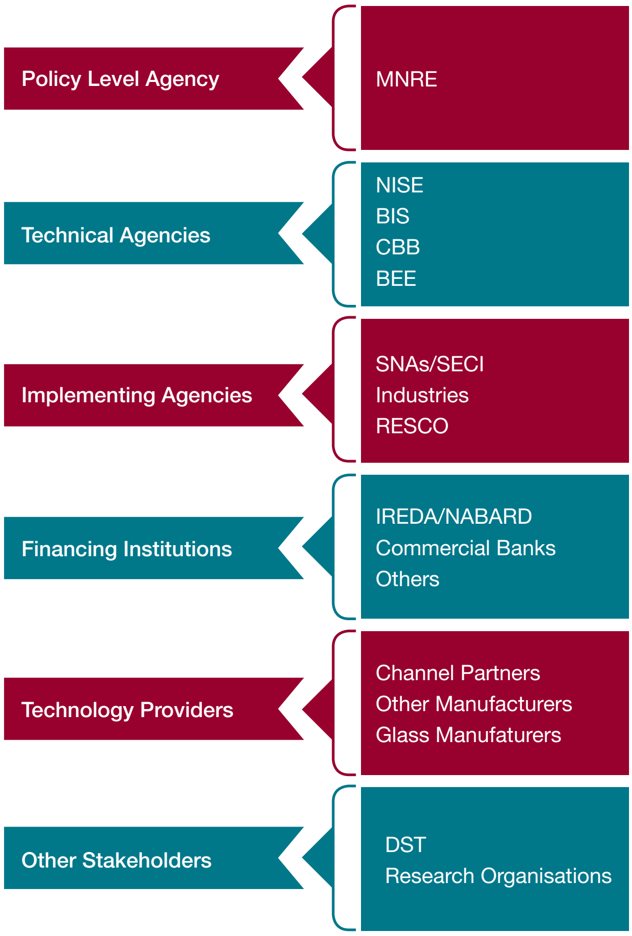
  – MNRE administers the entire CST technologies sector and also frames its policies and implementing programs. MNRE is also supports the development and promotion of such technologies by promoting investments through its financing arm IREDA, facilitating R&D (through various agencies) for the adoption of new RE technologies including, capacity building and awareness generation. It also administers subsidies for increasing the uptake of such technologies.

- **Technical Agencies**

  – National Institute of Solar Energy (NISE), Bureau of Indian Standards (BIS) and Central Boiler Board (CBB) are most active technical agencies in the context of CST's in industrial technologies. NISE is an autonomous institution, serving as the apex National R&D institution in the field Solar Energy. The institute is involved in demonstration, standardization, interactive research, training and testing of solar technologies and systems. It is an effective interface between the Government and institutions, industry & user organizations for development, promotion and widespread utilization of solar energy in the country. NISE has national solar thermal power testing, research and simulation facility.

  – BIS is the National Standards Body of India concerning standardization, certification and quality of various consumer products and equipment. BIS has already set standards for pipes, wires, etc.

  – CBB, constituted under Section 27A of the Indian Boilers Act 1923, is responsible for establishing regulations for boiler materials, design, construction, as well as for registration and inspection. As steam generating CST technologies fall under the purview of the Indian Boilers Regulation, CBB may expedite approvals for new solar concentrator applications and technologies used for steam generation. Although CBB hasn't been much active in this area, however its involvement is important once the technology reaches market development and replication stage.



- **Implementing Agencies:**

– State Nodal Agencies (SNAs) serve as the implementing agencies for each state and are responsible for development of CST technologies in respective states. All federal policies and programs are implemented by SNAs in their respective states. An important responsibility of the SNAs is to disburse the MNRE subsidy to project developers.

– Solar Energy Corporation of India (SECI) is a section 25 company under MNRE that is entrusted with facilitating the implementation of solar projects under the JNNSM.

– Industrial players can install CST technologies at their facilities or can also seek the help of Renewable Energy Service Companies (RESCOs) in project implementation/management. There could be several business models wherein deployment of CST technologies at industries can be implemented.

- **Financing Institutions:**

– Indian Renewable Energy Development Agency (IREDA) is a dedicated financial institution for the promotion and development of renewable energy projects. It is currently operating the solar off-grid program under the JNNSM as is a major financing institution for CST industrial applications.

– National Bank for Agriculture and Development (NABARD) is run by the central government of India, and has launched a capital subsidy-cum-refinance scheme for installation of solar off-grid (photovoltaic and thermal) applications under the JNNSM program. NABARD can play a major role in sharing the risk of other commercial financing institutions through its refinance scheme.

– National commercial banks in India can finance CST applications in future. A few commercial banks have already funded CST applications in industries

– Multilateral and Bilateral agencies are also active in development of renewable energy technologies including CST industrial applications. UNIDO and UNDP have been assisting multiple programs under which both technical and financial assistance are provided.

- **Technology Providers:**

– Technology providers comprise of both channel partners and other manufacturers, which includes the manufacturers of part equipment. As per the growing competition in the industry and to increase the market of these products, these manufacturers constantly align themselves with changing technology trends globally and innovatively upgrade their products and offerings so as to increase the utility and ease the integration of CST's, hence achieving the best possible performance standards during the given conditions.

- **Other Stakeholders:**

– There are also some stakeholders other than those mentioned above that are involved in development of CST industry in India. Notably, Department of Science and Technology (DST) and other research organizations are important ones. DST is supporting the Solar Energy Research Initiative (SERI) in India. SERI supports research, development and demonstration of solar technologies. CST technologies and applications are one of the identified areas of SERI work.

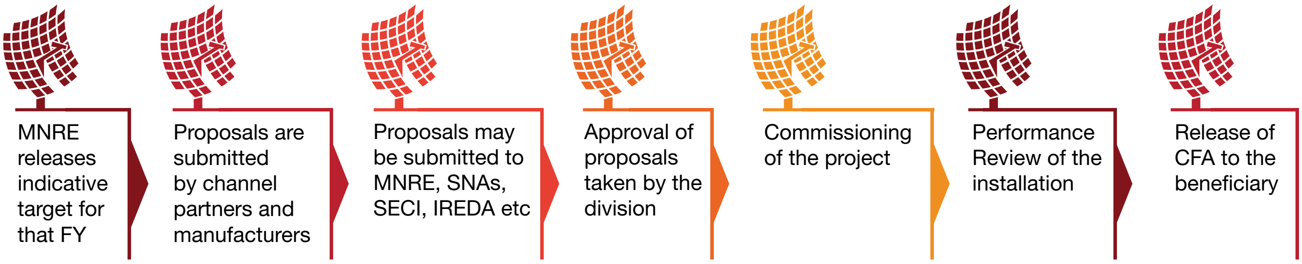
– National and International research organizations such as IIT Bombay, The Energy Resources Institute (TERI-India), Fraunhofer Institute (Germany), Solar Institute Julich (Germany) etc. are involved in both basic and applied research. Further, most of these institutes provide testing, training and simulation facilities.

– Solar Thermal Federation of India (STFI) is a pan-India not-for-profit body working towards the larger interest of the solar thermal industry in the country.

3.4 Implementation Method for CST Projects in India

At the beginning of each half-year, MNRE releases an indicative target for that period. All the Channel Partners then submit, within a 15 day period to be prescribed by MNRE, proposals/ targets in the prescribed formats along with a commitment for meeting the balance cost of the project other than the CFA to MNRE. Targets are then approved and communicated, post which the channel partners can start implementation at their own risk and investment.

There is a Project Appraisal Committee that frames rules and prescribe formats etc. for project approval, within the overall framework of this scheme, so as to make the entire process transparent. The in-principle approval of the targets/ proposals may be granted by the programme division in advance to the States Departments/SNAs/ Channel Partners and other implementing agencies to enable them for planning their strategies in identifying the beneficiaries and formulating the specific proposals.



3.5 Support provided under the GEF funded projects by UN Agencies

Both United Nations Industrial Development Organisation and United Nations Development Programme with funding from the Global Environment Facility (GEF) are working to promote the deployment of CST's in India. They have support schemes that are in addition to the already existing MNRE support schemes. The targets of these projects are to develop business models for promoting concentrated solar energy based projects in industries and commercial sectors with a purpose to replace conventional fuels and emissions.

These project focus on demonstrating technical and financial viability of CST's, enhance local manufacturing capabilities, strengthen the policy and institutional frameworks at both the national and state levels, capacity building and development of both technical and financial packages.

3.5.1 Support provided by UNIDO

As a part of the MNRE-GEF-UNIDO assignment, UNIDO is working with MNRE on a multitude of programs to increase the deployment of CST's. This involves conducting events throughout the country to raise awareness on the deployment of such technologies to development of this roadmap to facilitate increased and targeted deployment.

Additionally, a loan scheme has been developed under the framework of this project focusing on promotion of concentrating solar thermal system for process heating and cooling applications in selected industrial sectors to reduce greenhouse gas (GHG) emissions. CST equipment manufacturing and other CST ancillary activities may also be supported under this scheme.

Loan Scheme highlights are provided below:-

The Loan scheme aims to provide upfront financial assistance to beneficiaries to overcome the financial constraints faced in the adoption and penetration of CST technologies.

Under this scheme, financial assistance is available for up to 75 % of the CST project costs and the minimum loan eligibility from IREDA will be Rs. 50 lakhs.

Part A: Soft Loan from IREDA

Rate of Interest	7 %	After considering UNIDO interest subvention
Repayment Period	7 years	1 year moratorium + 6 years repayment

PART B: Bridge Loan against MNRE Subsidy

Rate of Interest	12 %	The rate is applicable till the project is commissioned. On commissioning, the MNRE subsidy will be passed to the project and the bridge loan will be closed

Note: *The Project would be eligible for interest rebate of 1 % in the event of Borrower furnishing security of Bank Guarantee/ Pledge of FDRs as the primary security, equivalent to the amount sanctioned by IREDA for both soft loan and bridge loan.*

Indicative Project Cost Structure:

Minimum Promoters Contribution -	25 %
Soft Loan -	45%
MNRE Subsidy -	30 %
Total -	100 %

Submission of the loan application:

On completion and submission of Loan Application through online, a confirmation will be generated and forwarded to the applicant via email. Hard copy of the application along with other required documents signed by the authorised person (all in duplicate) along with applicable fee are required to be submitted to the following address within
7 days of electronic submission.

Chairman & Managing Director
Indian Renewable Energy Development Agency (IREDA)
Core 4-A, India Habitat Centre Lodhi Road,
New Delhi 110003
Tel.: +91. 11. 2468 2201;
Fax: +91. 11. 2468 2202;
Email: cmd@ireda.gov.in,
if any query related to loan for CST project may please also contact to National Project Manager, UNIDO,
UN House, New Delhi
Email id: a.k.misra@unido.org

*3.5.2 Support provided by UNDP**

**This support is no longer available due to the completion of the UNDP-CST project*

In addition to the MNRE subsidy and support activities mentioned above, UNDP also provides an additional support of 20% of the MNRE benchmark cost.

Projects being granted subsidy are categorised as either demonstration or replication projects, wherein demonstration includes all projects with a size of 500m² and above. Additional support is provided if the project is implemented under the ESCO mode or a new VAM is installed along with the CST technologies. This support by UNDP was provided till March 2017.

Details of the support provided have been tabulated below:

Category	Criteria	Support under CSHP
Demonstration	Minimum size should be 500 m²	20% of MNRE benchmark cost to a maximum of INR 75 lakh
Replication	Sizes below 500 m² Excludes Scheffler dishes for direct cooking	20% of MNRE benchmark cost but not less than INR 2 lakh for projects of sizes 45 sq. m. & above on dish and 64 sq. m. & above on other CSTs. For projects below that INR 1.5 lakh will be available.
Space cooling where new VAM is installed (Up to a maximum of 5 projects)	Minimum 30 Ton capacity of VAM	10% of MNRE benchmark cost in addition to above
Projects implemented in ESCO mode	ESCO Mode	10% more of MNRE benchmark cost to a maximum of INR 15 lakhs in addition to above only for systems availing 30% MNRE subsidy and not higher in special areas.

4

Recent Developments

The CST sector is growing at increasing rates due to increased focus being provided to the sector by the Government and the increase in awareness towards the sector. Some of the recent developments in the sector that have occurred in 2016 so far have been mentioned below.

4.1 Loans Available from Banks at Priority Lending Rates

MNRE had conducted 4 training programs in 2015 for bankers across the Nation, in order to apprise them of the CST sector and the viable returns that this technology offers to beneficiaries. As a result of this exercise, several banks were motivated to initiate/ increase lending to the CST sector and issue formal notifications to this effect. Four banks released formal circulars, with one establishing a specialised scheme for CST's, as per the lending scheme advised by MNRE.

The four banks that have released circulars are the State Bank of Bikaner and Jaipur (Jaipur), Syndicate Bank (Bengaluru), United Bank of India (Kolkata) with the specialised scheme being released by State Bank of Patiala (Patiala). Some highlights of the scheme released by State Bank of Patiala are that the repayment period of the loan will be a maximum of 10 years with a 6 months moratorium period and the rate of interest of the loan will be the base rate + 1 %. These developments in the financing aspect are expected to significantly enhance the lending to the CST sector.

4.2 National Workshop on CST's cum Award Distribution Function

MNRE organised a National Workshop on CST's cum Award Distribution Function in New Delhi on April 29, 2016 to felicitate 102 awardees and release 9 critical knowledge documents to promote the sector and the deployment of CSTs. The workshop was inaugurated by Hon'ble Minister Shri Piyush Goyal, who also presented the excellence awards to recognize and encourage notable achievements in off grid and decentralized solar thermal applications.

Initiatives such as these confirm the increased interest and focus of the Government in the CST sector and also attract players towards the vast potential of this market.

4.3 Developments expected in the near future

There are a few critical changes that can be foreseen which will have a significant impact on the CST sector. The Goods and Service Tax (GST) rolled out in July 2017 to subsume the different across the value chain. There is no specific slab rate for CST or its components unlike solar water heaters which are under the 5 percent slab. It is recommended to consider under the 0 % slab of GST to foster manufacturing and investments in the CST sector. Further, the introduction of anti-dumping duty on solar grade glass may increase the costs of this glass in the short term, but promote manufacturing in the Nation leading to long term benefits and reduction in costs for the sector.

4.3.1 Introduction of GST in India

Government of India has rolled out the Goods and Services tax (GST) Constitutional Amendment Bill. This aims to put a comprehensive consumption tax on the supply of goods and services and will be amongst the biggest tax reforms in history.

As per the act, electricity is expected to be an exempted product under the GST regime, thus signifying that the overall tariff of power should remain the same. However, as of now there is only half-done mention in particular the GST paid on inputs, capital goods and services for renewable energy projects and no mention on CST and its components. If exemptions are not considered for these components, the landed price of energy produced from such sources will increase because of the higher capital expenditure. Secondly, there might be an increase in the prevalent tax rates of certain components/services. For eg., service tax was 15% before July 2017, which for services has been increased to 18%, however MNRE has not issued any clarification for consideration of CST in lower tax schedule, similar to what has been proposed for Solar PV.

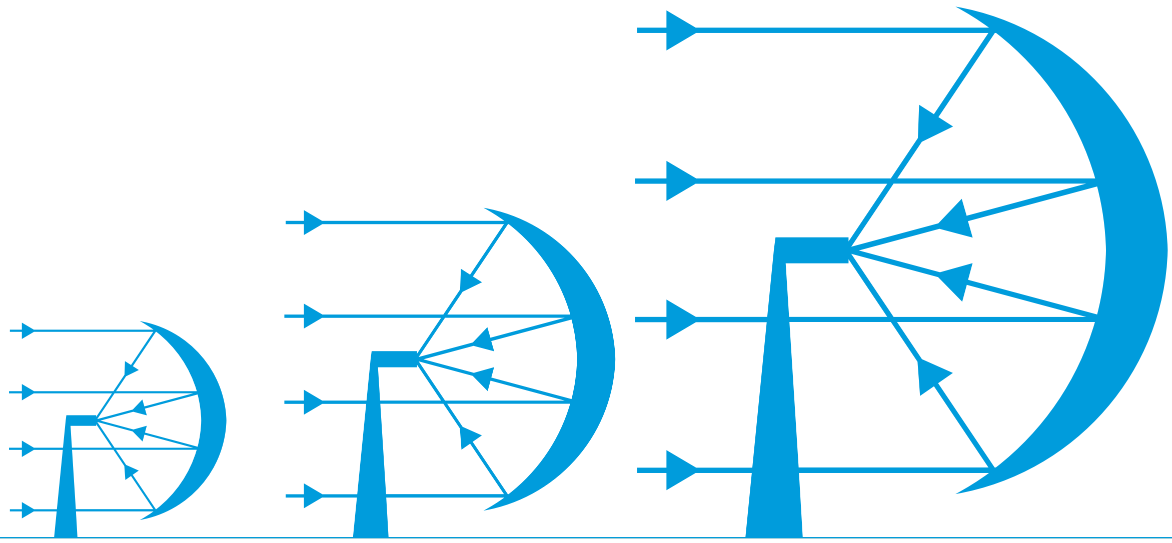
In case of inter-state procurements, a concessional rate of Sales tax of 2% was provided against issuance of statutory form (Form C) in case the goods are to be used in generation or distribution of electricity. Post GST, an applicable CGST, IGST or SGST to a total of as high as 18 % is applicable.

However, if provisions are made to negate this effect, this can serve as a time of opportunity for the CST sector if similar exemptions are granted to the overall solar energy sector rather the solar power sector. This will benefit CST's as they do not have equivalent exemptions as compared to the solar power sector.

4.3.2 Anti-Dumping Investigation concerning imports of Solar Grade Glass from China

The Directorate General of Anti-Dumping & Allied Duties, Government of India received an application from an Indian manufacturer Borosil, of glass used in CST systems mentioning that Chinese manufacturers of similar glass products were supplying glass with the same performance characteristics to the Indian market at cheaper rates than that were prevalent in the market, because of which the business and operations of Indian manufacturers were suffering.

To this effect an investigation is currently underway to substantiate this claim and if possible impose an anti-dumping duty on this glass being imported. This will have mixed effects on the sector in the short term as it might result in an increase in the costs of glass as beneficiaries will have to either purchase the more expensive Indian glass or import glass after paying an additional duty. However, over the long term, this will result in an improvement in the operations of Indian manufacturers and hence provide advantages to the Indian CST manufacturer industry.



5

Potential for Implementation of CST's in India's Industrial Sector

5.1 India's Industrial Sector

The Industrial sector in India has witnessed substantial growth over the past few years and now contributes around 31% of India's Gross Domestic Product. The leading industries in India include textiles, cement, chemicals, iron and steel, food processing and non-metallic minerals amongst others.

As per the latest data released by the Annual Survey of Industries, the total number of factories in operation in India at the end of the year 2013-14 were 1,85,690. These industries produced an estimated output of INR 65,55,251 crores during the same year. The leading states in terms of the output generated were Gujarat and Maharashtra, while those in terms of the employment generated were Tamil Nadu and Maharashtra.[23] This section provides an estimation of the potential of this sector for application of CST's.

GDP- Composition by sector (2017-18)

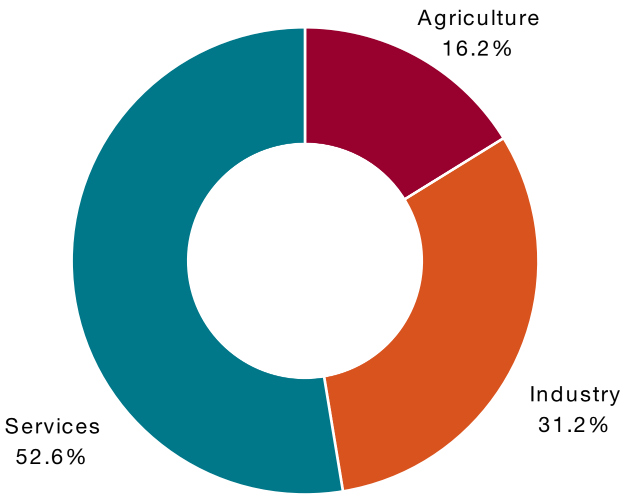


Figure 16: India's GDP composition by sector (2017-18)

5.2 Energy Consumption details of India's Industrial Sector

As has been depicted in the previous section of India's energy scenario, India's Industrial sector consumes over 50% of India's energy with the dominant energy consuming sectors as iron and steel, cement, chemicals, pulp and paper.

To gain an in depth insight into the consumption patterns across the various sectors of industries, we have analysed the latest data made available by the annual survey of industries that pertains to the year 2013-14. For ease of analysis and to ensure clarity, we have classified the data that was available for 150 sectors (as per the NIC Classification of Industries 2008 classification) into 25 sectors as have been listed below. Details of these 150 sectors and their classification into the sectors below have been provided in Annexures.

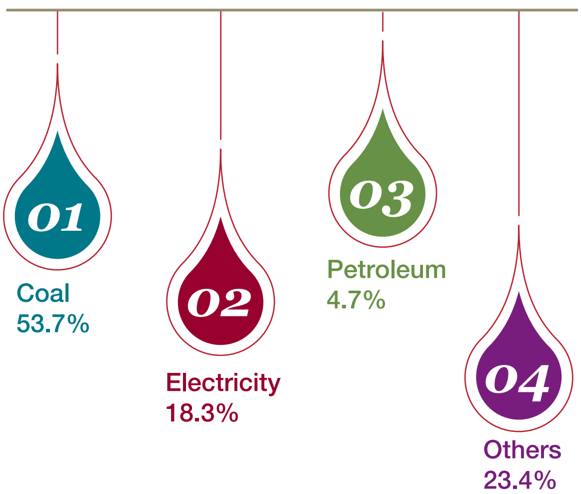


Figure 17: Total Energy Consumption of Industries

23 http://mospi.nic.in/sites/default/files/publication_reports/mospi_Annual_Report_2016-17.pdf

As per the data available, Coal and its derivatives account for more than 50% of the energy consumed. In terms of the value of the energy consumed, the electricity consumed accounts for almost 50% of the monetary value of the energy consumed, although its contribution in terms of the energy provided is less than 20%.

The following chart provides a summary of the total energy consumption from amongst the 25 sectors that have been categorised as one of the 150 NIC 2008 sectors depicted in the energy balance statement of the Annual Survey of Industries. The total value of the energy consumed has been estimated by the Annual Survey of Industries for the same year as INR 2.98 lakh crores.

Taking from the immense quantum of energy consumed by industries along with the immense costs associated with it, one can easily determine that the pollution caused by industries in the current case is immense. Being major contributors to pollution, industries should realise their role and make efforts to operate as sustainably and with as minimal pollution as they can.

Energy Consumption per Industry sector (kWh)

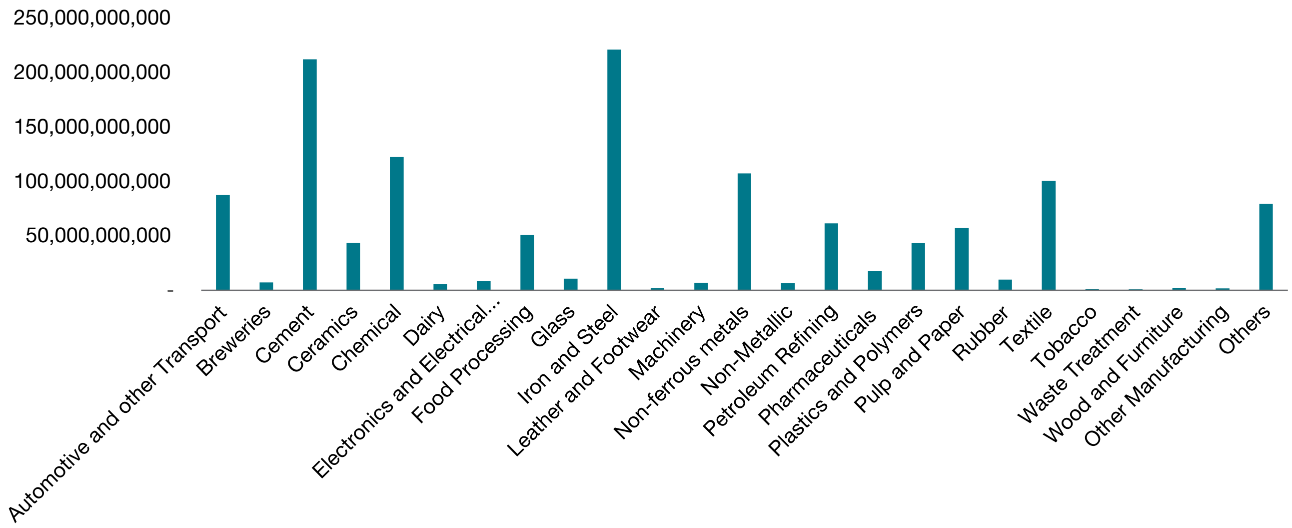


Figure 18: Energy Consumption per Industry sector (kWh)

Value of Energy Consumed per Industry sector ('000 INR)

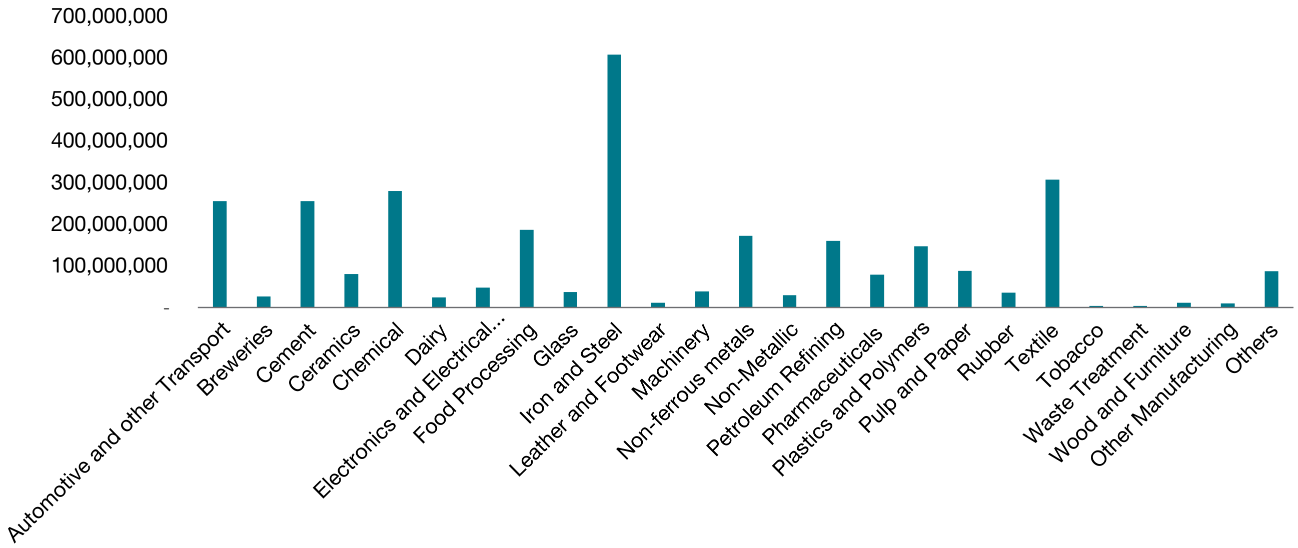


Figure 19: Value of Energy Consumed per Industry sector ('000 INR)

5.3 Process Mapping India's Industrial Sector

In order to ascertain in which processes CST's can be feasibly implemented in industries to subsequently assess the extent of fuel replacement, a process mapping exercise across the selected 25 industries was undertaken. The processes that can be powered viably using solar thermal energy have been described below.

S. No	Industrial Sector	Cleaning	Drying	Evaporation	Distillation	Pasteurisation	Sterilization	Cooking	Process Heating	Boiler Feed Water Heating	Cooling
1	Automotive and other Transport	✓						✓	✓	✓	✓
2	Breweries	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Cement								✓	✓	✓
4	Ceramics	✓	✓					✓	✓		✓
5	Chemical	✓	✓	✓	✓		✓		✓	✓	✓
6	Dairy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	Electronics and Electrical Equipments										✓
8	Food Processing	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	Glass	✓							✓	✓	✓
10	Iron and Steel								✓	✓	✓
11	Leather and Footwear		✓	✓				✓	✓	✓	✓
12	Machinery	✓									✓
13	Non-ferrous metals	✓							✓	✓	✓
14	Non-Metallic	✓	✓							✓	✓
15	Petroleum refineries	✓	✓	✓	✓		✓	✓	✓	✓	✓
16	Pharmaceuticals	✓	✓	✓	✓		✓	✓	✓	✓	✓
17	Plastics and Polymers	✓	✓	✓	✓				✓	✓	✓
18	Pulp and Paper		✓						✓	✓	✓
19	Rubber		✓	✓					✓	✓	✓
20	Textile	✓	✓						✓	✓	✓
21	Tobacco	✓	✓		✓				✓	✓	✓
22	Waste Treatment	✓	✓	✓	✓				✓	✓	✓
23	Wood and Furniture	✓	✓								✓
24	Other Manufacturing	✓	✓				✓				✓
25	Others	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

5.4 The Industrial Potential of CST's

The industrial potential of CST's across the 25 industries categorized in the previous section has been calculated individually to ascertain to the overall potential of CST's across industries in India. The summary of our findings and a brief on the methodology followed and assumption considered have been detailed in this section.

The potential for CST's has been measured across two different levels as below:

Technical potential: This describes the fraction of resource potential that can be used under the existing technical restrictions.

Market potential: This has been computed as the final CST potential incorporating the market dynamics (acceptability, financial viability, space limitations, etc.)

The chart below summarizes the overall process followed for computation and the total energy percentage potential that can be met viably by CST's. Progressing from the outer ring marked 1 of the total energy consumption of industries, we assess multiple parameters to compute the potential as per the present scenario, taking into consideration the various market factors that exist. 4.4% of the total current demand can be met by CST technologies and market factors support the installation of almost 50% of this potential. These individual steps have been detailed below.

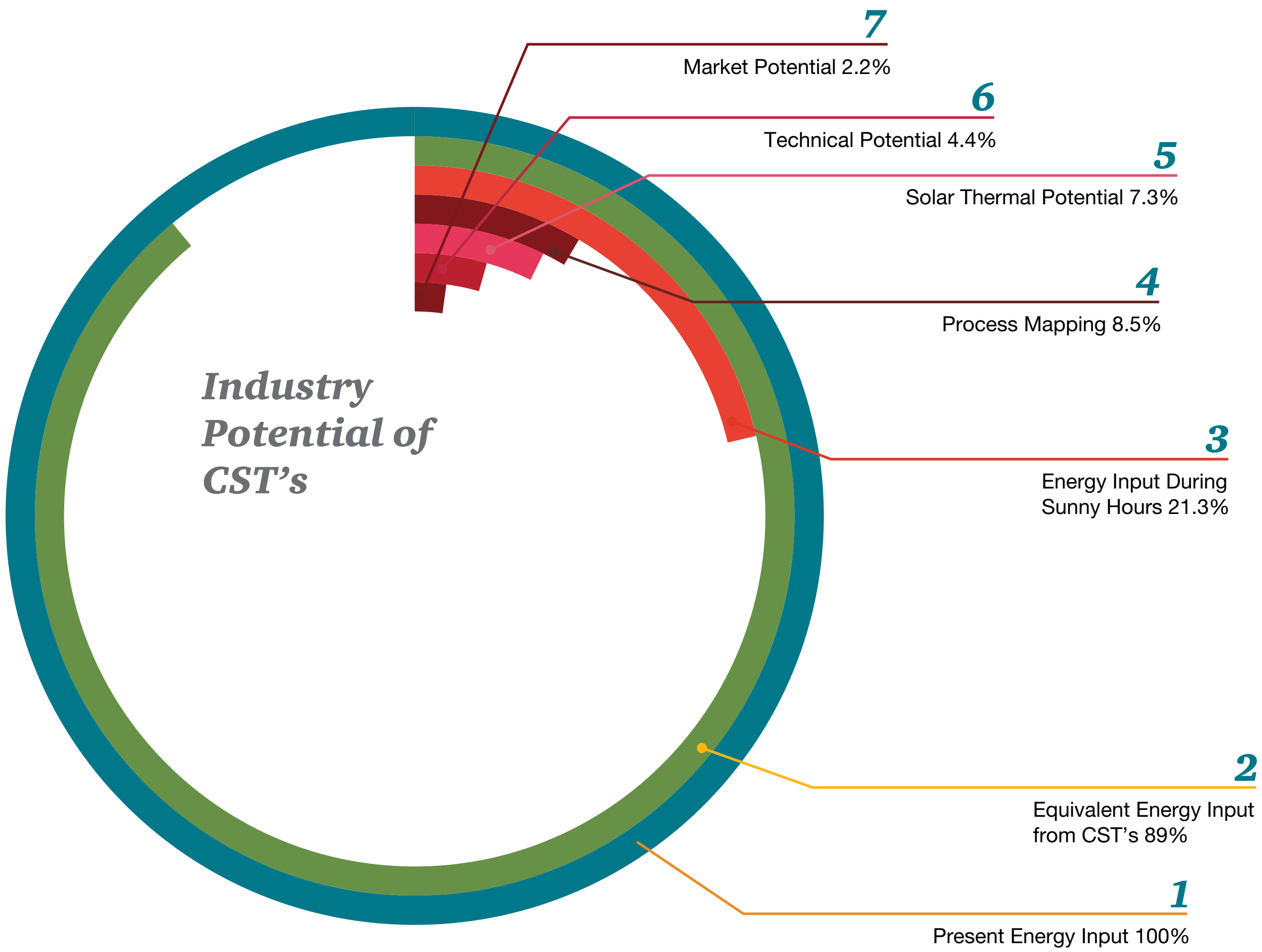


Figure 20: Industrial Potential of CST's

Technical Potential

Step 1: Present energy input

Based on the data available from the Annual Survey of Industries 2013-14, the total consumption of fuel by industries is calculated to be 1,267 TWh. This has been assumed as the total energy that can be replaced by Solar Thermal technologies and forms the initiating step of our analysis. This has been marked as 1 in the figure above.

Step 2: Equivalent Energy Input from Solar Thermal Technologies

Since energy predominantly provided by fossil fuel sources is being replaced, there is bound to be the effect of the efficiency of the energy delivery system on the actual energy that is transferred to the industrial process. Considering that the total energy input provided above is actually the calorific value of the input fuel that is predominantly coal, we have calculated the total equivalent energy required from solar thermal systems by equating their difference in efficiencies. For this purpose, we have assumed an efficiency of the existing system as 80%.

Likewise, there will also be an efficiency factor in the case of Solar Thermal technologies that will replace the energy provided. This has been assumed as 90%. The overall energy set for the solar thermal system that has to be met is thus 89% of the total input identified in step 1 above. This translates to a total of 1,128 TWh.

Assumptions

Efficiency of existing system = 80%

Efficiency of Solar Thermal system = 90%

Step 3: Energy Input during Sunny Hours

The CST systems will provide as much energy as they are able to harness while the sun is out. For ease of calculation and assuming that all the energy generated by the system is consumed as and when it is generated, we have assumed that these systems can at maximum replace only the amount of fuel that was consumed during the sunshine hours when the system was active.

Assumptions

All energy generated by the system is consumed as and when generated

Plant is operational and conventional fuel is consumed equally throughout the year, i.e. all 365 x 24 hours

Sunshine hours in a year = 2100

Step 4: Process Mapping

Based on the process mapping exercise carried out above and drawing upon past experience in quantitatively mapping the amount of energy that can be met by Solar Thermal systems based on the temperature range of operations, we have introduced a process mapping multiplier for each of the 25 sub sectors in order to proportionately reduce the total energy that can be replaced by Solar Thermal systems in a particular industry sector. The value of this multiplier ranges from 5% to 60% depending on the temperature requirements of the particular industry.

The values of these multipliers have been taken from a variety of sources including the POSHIP study carried out in 2001, Comsolar report on the Identification of Industrial Sectors Promising for Commercialisation of Solar Energy and based on the discussions with industry stakeholders and the experience of the project team.

Assumptions

Process Mapping Multipliers for all 25 Industry sectors identified above based on CST's being able to substitute fuels only in processes belonging to a particular temperature range

Automotive and other Transport	20%	Non-ferrous metals	5%
Breweries	60%	Non-Metallic	5%
Cement	10%	Petroleum Refining	5%
Ceramics	5%	Pharmaceuticals	30%
Chemical	20%	Plastics and Polymers	10%
Dairy	60%	Pulp and Paper	60%
Electronics and Electrical Equipment	5%	Rubber	20%
Food Processing	60%	Textile	60%
Glass	60%	Tobacco	40%
Iron and Steel	5%	Waste Treatment	20%
Leather and Footwear	40%	Wood and Furniture	20%
Machinery	60%	Other Manufacturing	10%
Others	10%		

Step 5: Technical Feasibility – Process Constraints Multiplier

Even though some processes may belong to a temperature range suitable for Solar Thermal technologies, there may be certain process constraints regarding the usage of a particular type of heating arrangement only. As an example, waste heat may be being recycled from another process in the bigger establishment and, the implementation of solar thermal technologies will not be viable. In order to account for this effect, we have assumed a process constraint multiplier of 85% across all industry sectors. This implies that 15% of total processes that can be implemented using solar thermal technologies may face constraints and hence will not be carried out using Solar Thermal technologies

Assumptions

Process Constraint Multiplier for the potential across all 25 Industry sectors as 85%

Step 6: Concentrated Technologies Multiplier

The potential that has been calculated in Step 5 represents the total potential that can be met by solar thermal technologies. It will be a mix of non-concentrating solar thermal technologies and concentrating solar thermal technologies. As of the current scenario, non-concentrating solar thermal technologies find increased implementation in low-temperature processes.

According to a study (Ecoheatcool 2006), out of the total industrial heat demand at temperatures below 400°C, falling within the purview of CST technologies, an estimated 52.6% is at temperatures below 100°C. As of the current scenario, non-concentrating solar thermal technologies capture an increased market share from amongst the low industrial heat processes that account for this 52.6% of the total requirement. We herein assume that 70% of the low temperature heating requirements will be met by non-concentrating solar thermal technologies and the remaining 30% can be met by concentrating solar thermal technologies.

Out of the remaining 47.4% of industrial heat requirements below 400°C, concentrating solar thermal technologies serve as the only option because of the unavailability of non-concentrating options to provide such temperatures. We have hence factored in a multiplier to account for only the potential of CST technologies.

Assumptions

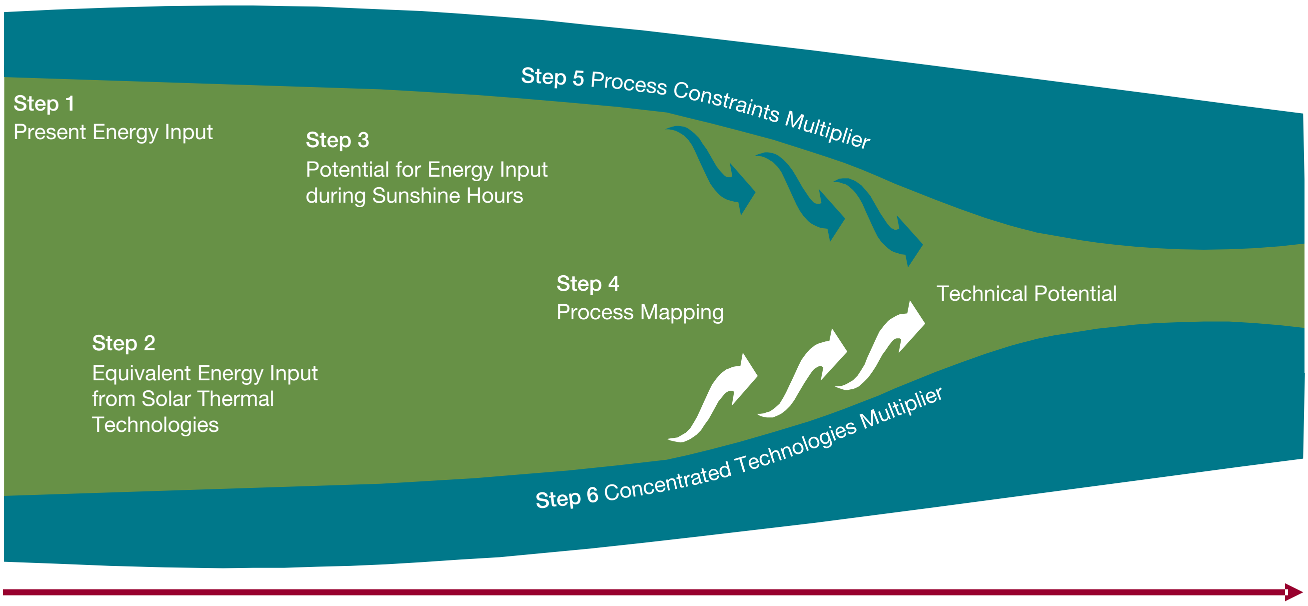
From amongst the thermal energy required by Industries for processes below 400°C:

52.6 % of Industrial heat requirements below is for processes with a temperature below 100°C

47.4 % of Industrial heat requirements is for processes with temperatures between 100°C - 400°C

% of heating requirements met by CST's from amongst the below 100°C processes = 30%

CST Technical Potential



Based on the analysis and five steps carried out above, the results of step three will be multiplied with the process mapping multiplier and the process constraints multiplier to determine the overall technical potential of CST's in the particular sector. The sum of this potential across the identified 25 sectors has then been added to compute the final technical potential of CST's across the industry.

Based on the computation undertaken considering all the factors as mentioned above, the technical potential for CST's in industries has been computed as **13.18 GW$_{th}$**.

Technical Potential = Potential for Energy Input During Sunshine Hours * Process Mapping Multiplier * Process Constraints Multiplier * Concentrated Technologies Multiplier

Market Potential

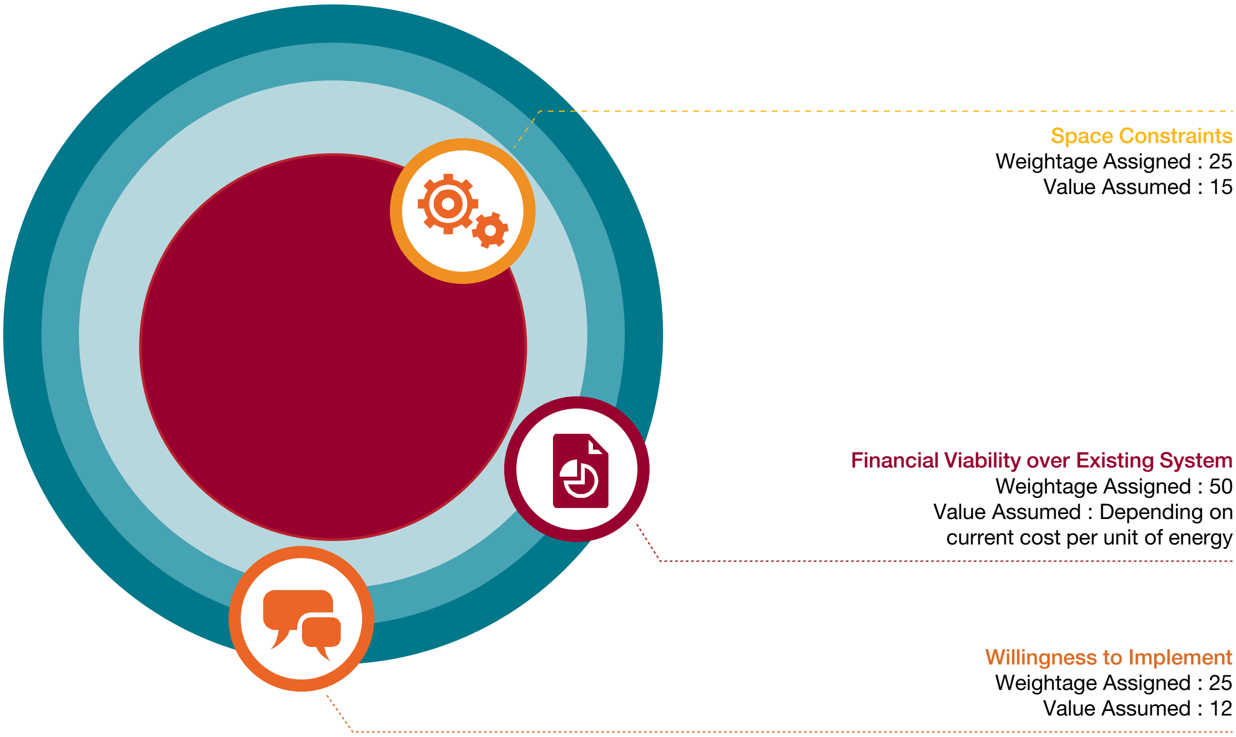
The market potential takes into consideration the sum of three factors. These three factors have been assigned a weightage out of hundred and include the willingness of the customer to implement the system, the availability of suitable space to implement the system and the financial returns of the system in comparison to the fuel and system that the industry is presently using.

Step 7: Market Potential

Space Constraints: This factor has been assigned a weightage of 25 out of 100 and considers the factor that certain industries looking forward to implement CST's may not have suitable area, in terms of both ground and rooftop area to implement CST's. In some cases they may also have limited area that can install CST's to only meet a part of their requirements.

Financial Viability over Existing System: This factor takes into consideration the current cost of energy of the installation. Installations that pay a higher price of fuel per unit of energy will be more willing to adapt to CST technologies as compared to those that currently use low cost fuels such as PET Coke, etc. In order to compute the value of this factor, we have considered a linear dependence of the factor on the cost of fuel per kWh of energy generated. For this, an assessment of the weighted average of the fuel cost across all sources of energy per unit was undertaken. The highest value has been assigned to the 'other' sector followed by the 'cement' sector as the weighted average cost of energy in these sectors is the highest. The minimum financial returns have been estimated for the sectors 'electronics and electrical equipment', 'leather and footwear', 'machinery' and 'other manufacturing'. The weightage assigned to this sector was 50 out of 100.

Willingness to Implement: This factor considers that even though the system may be financially viable and



technically feasible to implement and all other factors described above are favourable for implementation, the organization may not be able to implement the system.. This may be because of the hesitation of the organization to switch to a new system, a financial crunch that the organization may be facing, organizational practices that may make it difficult to implement a system, etc. This factor has been assigned a weightage of 25 out of 100.

The weighted sum of the three factors identified above was then converted to percentage terms and multiplied with the sector-wise technical potential to ascertain the market potential of all 25 sectors.

Assumptions

Based on the weighted assessment of the three factors mentioned above, the market effect multiplier for the each of the 25 sectors was assumed as:

Automotive and other Transport	44%	Non-ferrous metals	58%
Breweries	41%	Non-Metallic	38%
Cement	68%	Petroleum Refining	46%
Ceramics	54%	Pharmaceuticals	38%
Chemical	49%	Plastics and Polymers	42%
Dairy	39%	Pulp and Paper	59%
Electronics and Electrical Equipment	36%	Rubber	41%
Food Processing	41%	Textile	43%
Glass	41%	Tobacco	42%
Iron and Steel	45%	Waste Treatment	42%
Leather and Footwear	36%	Wood and Furniture	38%
Machinery	36%	Other Manufacturing	36%
Other Industries	72%		

The total market potential of CST's in industries has correspondingly been determined as **6.45 GW_{th}**. The technical and market potential of CST's has been depicted below.

Market Potential = Technical Potential * Market Effect Multiplier

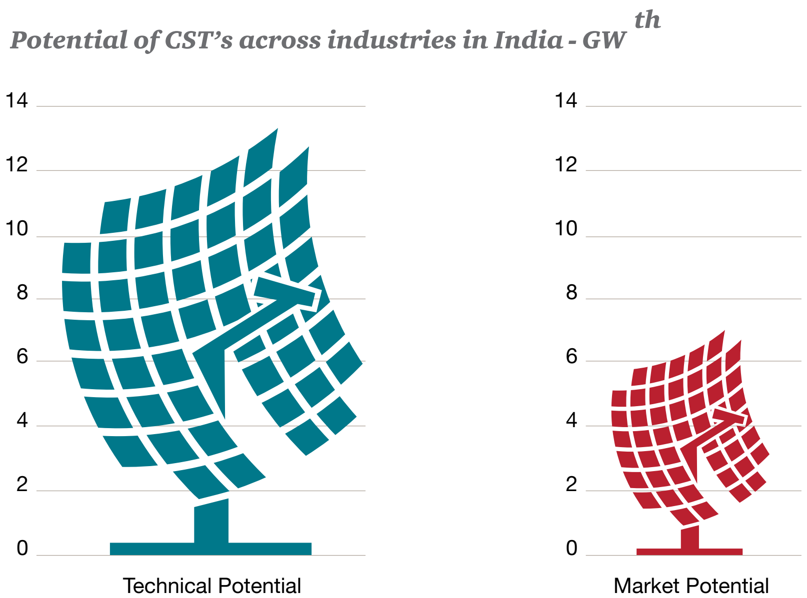
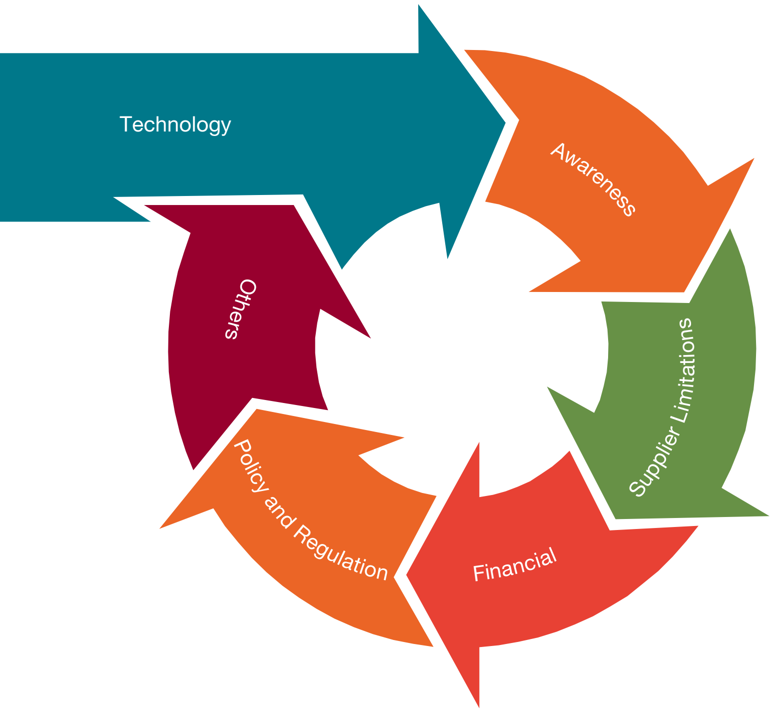


Figure 21 Potential of CST's across industries in India

6

Barriers

Although the potential for CST's as described in the previous section is quite significant, the current deployment of these technologies is less than 1%. Based on a series of interactions with multiple channel partners, developers, policy makers, systems owners, other stakeholders and leveraging our past experience of working with CST technologies, the project team has identified multiple key barriers to the growth of the sector and that have affected realisation of the actual potential.



Despite there being significant potential for CST's in India, these barriers have had a profound effect on the deployment of the technology, as a result of which the technology is still not widely adopted. Addressing these barriers is the key concern of the roadmap that is proposed and has been discussed at length with multiple channel partners and other important stakeholders. These identified barriers have been classified across 6 main headers which have been explained in the charts below.

The central focus which can be seen from the identified barriers is that although there is a push to the technology from the Government and other players, however effort is not comparable to the efforts and promotion being provided to technologies such as solar PV. Stakeholders highlighted that if the governing bodies provide financial incentives, conduct research in this sector to increase its applicability and outreach, then the entry of major players, opening of the market and investments in the sector will happen by itself. The deployment will increase at a fast pace.

Lack of Prioritisation

A relative lack of Focus

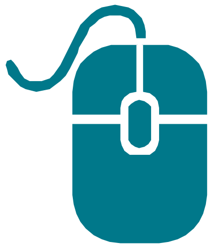
The Government is currently providing maximum focus on solar PV technologies and also significant focus on various other technologies in order to meet the ambitious targets that have been established for particular technologies. As a result there is reduced focus and importance on CST's

"CST's are overshadowed by Solar PV technologies. If all exepmtions that are provided to Solar Power are extended to Solar Energy as a whole, then the sector will most definitely experience much faster growth."

- A Channel partner

6.1 Technology Barriers

CST's as a technology have massive potential that can be tapped in much more inexpensive and feasible manner. Major issues surrounding the sector on the technology front include a relative lack of research and interest in the sector. Further, being relatively smaller in size, the performance norms of most of the equipment used are not established widely. Some manufacturers still use equipment/configurations that are not suitable and result in overall poor performance of the systems. Provided below is a list of technical barriers that the sector faces.



Standards of Individual components are not updated

Although there are standards defined for most individual components, however these are not updated and need revision based on the experience so far. Because of these, systems continue to be installed involving aluminium reflectors and other components that reduce the overall system efficiency

Non-Availability of overall system performance standards

CST systems are tailored as per the specific requirements of industries. Although individual components of CST's have been assigned certain standards that need to be met, the overall system as a whole has no performance standards. This sometimes results in the designing of inefficient systems, which draw away the interest of entire industry clusters because of one inefficient system.

Requirement of Defined Performance Benchmarks

There is a requirement of well defined and widely accepted benchmarks with respect to the performance of systems. Due to different performance metrics provided by different stakeholders, targeted owners face difficulty in estimating precise savings over the years and develop inhibitions regarding the performance and quality of operation of these systems and postpone their investment decisions following a 'wait and watch' mentality.

Focus on limited technologies

Indian installations are predominantly for a select list of processes and purposes. There is tremendous scope for implementation of CST's in multiple other processes with minor system/technology modifications. Further, focusing on innovation in the existing technologies will result in improvement in technologies and propel CST's towards increased deployment.

Innovation and Upgradation of technologies

India does not play an active role in the R&D of CST technologies. Also, there are hardly any systems with energy storage mechanisms. This reduces the growth avenues available for these technologies

Opinion

"As there are no performance standards established for CST systems, certain developers use inaccurate system arrangements or even low grade mirrors resulting in poor system performance, which in turn lends a bad name to the industry"

- A Channel partner

6.2 Awareness cum capacity Building Barriers

In comparison to PV technologies, people are relatively unaware of CST's and generally mistake them for PV technologies. Even in educational curriculum that serves as the major source of dissemination of knowledge, the generation of energy from renewable sources is mainly depicted by solar PV technologies, and CST's have no or very little mention. This unequal focus carries on to all forms of media including newsletters and publications as well. This lack of awareness has a cascading effect on the entire sector.

Need for educational initiatives

There is a need for specialised courses for CSTs. Even in courses where CSTs are mentioned, their basics are explained in very few texts. As a result even people who study/research related technologies may not be aware of such technologies

Awareness amongst industries

Industry owners are primarily unaware of CST's and often mistake them with solar PV technologies. They are unaware of the benefits of these technologies that these have the potential to save fuel and provide attractive returns over the long term

Promotion via partnerships with other Ministries

Awareness for CST's can be rapidly increased via events or in partnership with other Ministries/Departments. These partnerships have the potential to immensely increase the outreach of CST technologies. Such mechanisms are not implemented actively.

Awareness amongst financial institutions

Financial Insitutions have only recently started becoming aware of CST's, but are still hesitant to provide funding for CST installations. As per our interviews with channel partners, banks generally demand bank guarantees/collateral of very high values when providing funding for such projects

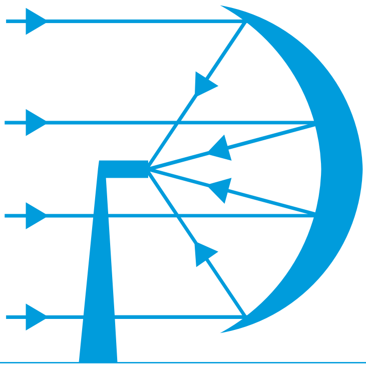
Low level of awareness of foreign players

Foreign players are also unaware of the market size, potential that exists for such technologies in the Indian market and the promising returns that these can offer. As a result there are no foreign inestments in this sector.

Opinion

"Over three-fourths of the customers that I have given my sales pitch to confuse CST systems with solar PV systems. They are mostly more interested in PV technologies because of the attention they have gained lately."

- A Channel partner



6.3 Supplier Limitations

The current market size of CST's is not very lucrative even though the sector has immense potential. The sector is currently at initial phases of its growth curve and the technologies and business models are yet to enter into a rapidly growing or maturity phase. As a result, the investments that the sector is witnessing are not very large and the scale of operations of players in the sector is nothing extraordinary. This small to medium scale of operations in a capital intensive industrial application results in growth at a slow pace. This further leads to several suppliers closing their operations in the market, leading to a loss of suppliers with substantial expertise for the sector.

Paucity of working capital

Owing to the small scale of operations of all channel partners and system installers of CST systems across India, the working capital available with them is less. These developers generally wait for subsidies of previous projects to get released before they take up new projects because of a crunch in working capital flow. Further, they are able to only implement a fraction of their potential because of this issue.

Limited number of installers

There are a select number of installers for CST's, and only 15 channel partner sthroughout India. There is an absence of major firms and clear market leaders.

Limited capacity and scale of installers

The installers of CST's have small scales of operations and do not possess signifcant experience or capacity to develop varied types of projects. These are generally small companies with the same team members involved in all operations of the firm including sales, installation, technical design and also Research and Development.

Limited availability of manpower

Companies engaged in the development of CST's are generally small in size with limited resources. As a result, these organisations have limited resources to train their staff. Due to these limiations, they are unable to attract very skilled manpower.

Limited International Exposure

There are limited interactions/interfaces between the Indian suppliers and International suppliers/experts. Due to this experience and knowledge does not flow freely between Indian suppliers and international experts.

Limited thrust on International Support/Tie-Ups

There are no significant tie-ups/support partnerships established between Indian players and foreign stakeholders that may result in investment to increase the scale of operations of Indian players or enhance their capacity

Absence of system Integrators

The limited capacities of current suppliers span the entire spectrum from manufacturing CST's to marketing them to subsequently integrating and maintaining them. Specialised system integrators can overtake most of these tasks to ensure better focus on manufacturing

Opinion

"We have orders in hand of around 15,000 square meters but can only execute less than 5,000 square meters per annum because of working capital issues"

- A Channel partner

6.4 Financing Barriers

The CST industry is burdened with high upfront costs on the installation of systems that are gradually realised via savings made over a certain period, after which the energy supplied is almost at zero cost because of the non-requirement of fuel. However, this upfront payment with slow paybacks is viewed by most industries as a risky proposition. Further, no significant models offered by that can benefit both the industry owners (to get cheaper energy without any upfront investment) and the investors (to get suitable returns of their investment). There is a dearth of energy service companies that offer such services.

Payback periods

CST's result in fuel savings across industrial processes. Owing to the low prices of solid fuels and also the drop in prices of most other types of fuels, the monetary benefits provided by CST systems suffer. This results in payback periods that are feasible but not very inviting in the case of solid fuels

Need of additional support for manufacturing

Although there are subsidies for beneficiaries targeted at increasing the deployment of systems, there are no incentives available to promote manufacturing and innovation in CST's. In comparison technologies such as solar PV benefit from schemes such as MSIPS. Promoting manufacturing will help attract increased investments towards the sector and provide a boost to the technologies being manufactured as well

Examples of ESCO models

No renowned examples of CST systems implemented under the ESCO mode exist in the Indian market. This concept has not yet picked up in CST's and there is still dependence on the upfront investment available with the system beneficiary. ESCO models have a significant potential of increasing the uptake of such systems by industries

Opinion

"Industry owners seem very interested initially, but generally their interest phases out as they get to know of the high upfront cost of the system and how their payback will gradually come over the following years"

- A Channel partner

High Upfront Costs

CST systems have substantial upfront costs of the systems, whereas the savings made are over the long term. Even though considering the medium and long terms, these technologies provide significant savings, industry owners are hesitant to invest high amounts of money upfront.

6.5 Policy and Regulatory Barriers

Although the Central Government provides subsidies, tax benefits and also has support programs, but the policies and regulations put in place have no major boosting mechanism for promoting the usage of CSTs. The policies and subsidies provided are with an aim of making the technologies viable and to an extent rewarding in the current market, however the return on investment is not very high in many cases. This absence of very high returns as were provided in the case of rooftop PV in Karnataka promote significant initial investments in the sector, taking it into a growth phase that replicates itself.

Need for coordinated Push from the State Governments

Solar PV technologies are on the rise because there is concerted action from both the center and state Governments. In the case of CST's, the state Government do not play an active role in increasing the deployment. There are no state policies specific for CST's and similarly states do not have well announced targets to promote such technologies.

Limit on maximum amount of subsidy for systems

The maximum subsidy available for a single system is limited. As a result, if installers obtain orders that are above the size limited mentioned, they are unable to obtain subsidy beyond a level. This increases the cost of large systems and hence their payback periods suffer. Whereas, the implementation of such larger systems would have provided a significant boost to overall deployment

Need for adequate guidelines and support for installation

Although MNRE provides capital subsidies, but guidelines for implementation of technologies or methodologies for selection, design of systems for availing subsidies are not available. There are also no guidlines to help nodal agencies in evaluation of proposals for subsidies

Requirement of a clear growth plan

CST's as a separate technology lack individual growth targets and a well defined plan for growth as exists in the case of solar PV technologies. A clear defined plan will increase confidence of investors and attract larger players to the sector. This will also facilitate a target oriented approach of the Government towards the growth of this sector

Availing customs & excise exemptions for components of CST systems

CST suppliers lose out on a significant number of customs and excise duty exemptions on direct purchase of mirrors in small orders from other countries. This is because of the absence of clarity on these exemptions and also because all components of the system are not exempt.

Opinion

"I had obtained an enquiry to install systems of an immense total capacity across one location, however their is a limitation on the maximum subsidy that can be availed per installation. This reduces the effective percentage of subsidy on the whole system and resulted in the loss of that order."

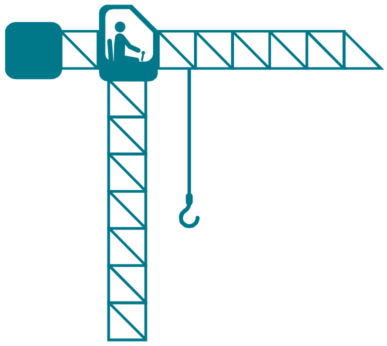
- A Channel partner

Mandates missing from Regulations/Policies

In order to initially boost the usage of CST technologies, there are no mandates that have been put in place. In comparison, solar water heaters have been mandated for certain categories of installations, whereas technologies such as solar PV on rooftops were intially implemented at preferential tariffs of net metering to promote initial deployment

6.6 Other Barriers

Apart from the barriers categorised above there are many other barriers that hamper the success of the sector. These may be on the side on the industrial installation, because of certain Governmental regulations pertaining to other departments or because of the solely profit making mind-set of select manufacturers. Such barriers that have repeatedly come up in discussions with stakeholders have been summarised below.



System Certification Missing in Labs

CST systems are not certified by labs and lack that basic benchmarking of standards. This to an extent reduces the confidence in the eyes of the beneficiaries and also leaves scope for compromise in performance. The concept of certifications will also promote the development of more efficient systems and lend a good image to the sector

Subsidy linked to the collector area and not system performance

Linking subsidies to collector area and not overall performance provides an undue advantage to inefficient technologies that occupy more space rather than efficient ones that deliver the same output from a much lesser area. This concept demotes innovation as manufacturers are able to make higher margins on less efficient technologies

Experience across limited processes

Even though India has the highest area under CST systems, the experience of Indian system installers is across a limited set of industrial processes and other purposes such as cooking, etc. Industries are unaware of the other processes wherein such systems can support their operations because of a lack of success stories across such sectors.

Availability of Suitable Land

A significant percentage of industries lack land that is available for the implementation of CST systems. Industries in urban areas are bound to keep a certain percentage of green cover out of their land and even for the remaining land, they generally prefer to expand their existing operations rather than implement a CST system, of which they have limited awareness

Domestic manufacturing on its way to maturity

Suppliers continue to import parts of CST systems such as solar grade mirrors because of the absence of a mature & competitive market for such products in India. This results in increased costs of the systems & time taken in the implementation of projects. The support for manufacturing components is also not significant as compared to technologies such as solar PV

Absence of a centralised portal for subsidy

The approval of subsidy for projects involves applications being forwarded by State Nodal Agencies and then a final approval in a steering committee meeting. This entire process generally involves delays on the part of the SNA's and further developers have to also submit some performance data for availing subsidy, which is only available after a substantial time. A centralised portal will expedite the entire process, resulting in better application tracking and increased access to working capital for developers.

Opinion

"If industries do not see very attractive payback periods, they are reluctant to use their land and capital investment for CST's. They generally prefer to expand their existing operations instead"

- A Channel partner

7

Roadmap for CST deployment

This roadmap is essentially being designed to foster the deployment of 200 MW_{th} of CST's in India by the year 2022. In terms of collector area, this translates to a collector area of approximately 2,85,578 m^2.[24] This implies an increase of about 500% over our installed capacity of 55,578 m^2 as of March 2018. In terms of MW_{th}, this implies an increase of 161 MW_{th} from 39 MW_{th} to reach a total of 200 MW_{th}. Further, the amount of shade-free area that is currently occupied by this installed capacity of 39 MW_{th}, which is around two times of the collector area. Considering the current installed and subsequently the area under implementation, the amount of shade free area that must be required is more than 2,30,000 m^2.

Based on the growth of the Indian economy, we can be certain that the potential of CST's in the Indian Industrial sector will only increase as the entire sector grows in size for the period under consideration. The current potential of over 6 GW_{th} grow and in no way will be a limiting factor for the deployment of 200 MW_{th} of CST's. A significant limiting factor due to which there is a massive difference in the value of the potential and the targets is the availability of shadow free industrial land to the tune of 7,00,000 m^2 for the implementation of 200 MW_{th} only.

Achieving growth of this magnitude will require active participation from multiple stakeholders of the CST sector chain including policy makers, implementing agencies, financing institutions and other relevant stakeholders as has been described in this roadmap.

These objectives are inter-related and will promote one other to initiate a self-replicating phase of implementation for the CST industry. Cost optimal systems will increase the demand of CST technologies and hence provide a greater focus upon the technology. This in turn will result in increased innovation and integration of these systems in relevant applications. This increased interest and innovation will also lead to the development of improved systems and innovative business methods which will further drive down the costs associated with these technologies.

The detailed roadmap as presented in the section below has been classified into sections to address each of the barriers identified above and achieve the targets as set forth. It also defines the roles of stakeholders and milestone and timelines for them to fulfil that role.

The action points presented aim to effectively achieve the targets discussed above.

24 https://www.iea-shc.org/Data/Sites/1/documents/statistics/Technical_Note-New_Solar_Thermal_Statistics_Conversion.pdf (Assumed a conversion factor of 0.7 kWth/sq.m)

7.1 Technology Development

In order to address the various technological barriers identified above, the roadmap focuses on improving the technologies, establishing benchmarks and integrating the systems in the industrial setup for maximum utility. The primary role is of the CST industry which will be supported in certain activities by other stakeholders. It will be essential to establish guidelines on standards, testing, inspection, certification and calibration. The roadmap for development of the technology is depicted below.

Stakeholder	Action	Timelines
MNRE, NISE, IDA's, CST Industry	Establishment of minimum technical specifications for components such as exclusion of aluminium reflectors, specifications of solar tempered glass, receiver tubes, etc.	July 2018
MNRE, NISE, IDA's, CST Industry	Establishment of system performance standards for different technologies including quality infrastructure and developing performance templates	September 2018
MNRE, NISE, Research Institutions	Enhancement of Testing Infrastructure and promotion of Applied R&D to increase Industrial Partnership of Research Institutes	December 2018
BIS, NISE	BIS standards must be in place and should be made mandatory for suppliers to avail MNRE subsidy. Procedure for marking BIS on CST and individual components should also be initiated.	December 2018
CST Industry	Development of innovative technologies to meet specific constraints of industries such as area limitations through reduced footprint, pole structures,light structures, etc.	December 2018
CST Industry, NISE, Research Institutions	Promotion of R&D and the Development of improved CST systems with increased efficiencies by Incentivisation	June 2019
CST Industry, Other Industry	Adapting CST systems to industry machinery standards especially for industries like chemical, food processing, pharmaceuticals, etc.	September 2019
NISE, University of Pune	Established CST Test set ups at NISE and University of Pune (both mobile and immobile) must be in full functional state and both the centres must get NABL accreditation. Clear cut guidelines/ procedure for testing of CSTs with well-designed format for submission of test reports. Manpower must be well trained on testing of products at test centres and in field.	December 2019
CST Industry, NISE, Research Institutions	Developing improved and cost efficient storage mechanisms with organic and inorganic materials and efficient heat transferring fluids which can be utilized for high temperature applications.	March 2020

7.2 Raising Awareness

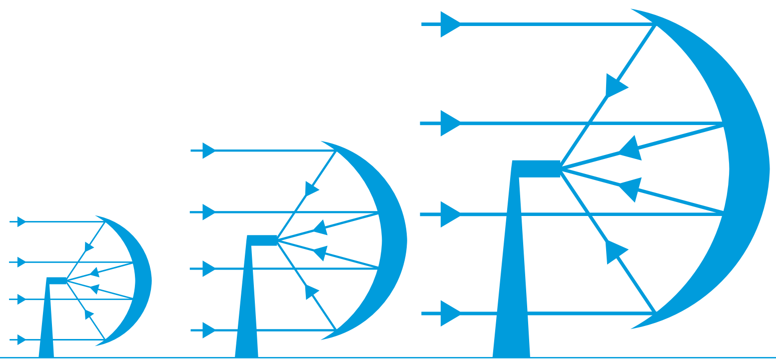
The barriers related to raising awareness are primarily centred on the fact that focus is mainly provided to solar PV technologies, with a majority of the population being unaware of CST's, their utility and potential for savings. Therefore, the market players also do not realise the market opportunity that this sector offers. The roadmap provided below aims to address these barriers

Stakeholder	Action	Timelines
MNRE	Establishing partnerships with other Ministries to issue circulars / promote CST's to their associated industries	July 2018
MNRE, IDA's, CST Industry	Increasing awareness of Global Players so that they participate in India's CST Market. This may include organisation of Investor meetings and exhibitions	August 2018
MNRE, MHRD, State Governments, CST Industry	Educational Initiatives for increasing the awareness of CST's. This may involve the inclusion of CST's in brief in school curriculum along with PV	August 2018
MNRE, CST Industry	Dissemination of performance data of CST's to raise awareness and instill confidence. This may be released online or via mobile applications	December 2018
CST Industry	Increasing the presence of CST's across ecommerce portals. This will increase online presence and also provide specifications of products increasing transparency	December 2018

7.3 Supplier Capacity Enhancement

Owing to the market size of the Indian sector and the scale of installations, currently the market is dominated by suppliers that have limited capacities in terms of execution and finance. Overcoming these barriers will require a mixture of activities to be undertaken by MNRE, the Industry and other stakeholders.

Stakeholder	Action	Timelines
MNRE, IDAs	Modifications in the subsidy disbursal process to ensure faster disbursal to reduce the burden on manufacturers. This may be released upon commissioning & revoked if performance is sub-standard	July 2018
MNRE, CST Industry	Promoting the entrance of CST system Integrators to provide improved after-sales support, provide better marketing and release capacity of manufacturers for manufacturing improved systems	September 2018
CST Industry, CII, FICCI, Other Associations	Creation of Associations for cooperation and mutual benefit of suppliers	October 2018
MNRE, IDA's, CST Industry	Increasing awareness of both Global and National Players towards the immense market potential to attract increased investments and larger firms	December 2018
CST Industry, Other Industries	Developing partnerships and tie-ups with international players and firms to enhance technology, overall capabilities and also financial strength	December 2018
MNRE, IDAs	Promotion of CST's across events such as RE-Invest, InterSolar to attract foreign players and facilitate partnerships with Indian players	December 2018
NISE, MNRE, CST Industry	Drafting Best practices guidelines and Training Manuals for installation and integration of various CST based systems in Industries. Training programmes designed and organised for installers of various manufacturers with training certificates post evaluation. Only certified trained installers shall be allowed to install the systems of various suppliers.	March 2019



7.4 Increasing Financial Viability

Amongst the foremost deterrents to the deployment of CST technologies is the slow payback on the high initial capital expenditure incurred. In order to overcome this, innovative financing mechanisms/innovative implementation mechanisms for systems need to be devised to support installations.

Stakeholder	Action	Timelines
IREDA, IDAs, other NBFCs and Banks	Devising schemes for obtaining debt financing at subsidised rates of interest with ease & involving lower collaterals to reduce the burden of upfront costs. This may involve creation of a dedicated fund	July 2018
CST Industry, IREDA	Promoting implementation of systems of large sizes resulting in economies of scale and attracting large players towards the market	July 2018
MNRE, BEE	Harmonizing benefits accrued via CST installation and allowing their provisioning under schemes such as the Perform Achieve Trade (PAT)	March 2019
MNRE, IDAs	Promoting manufacturing in the Nation by implementing schemes offering incentives such as subsidies, export concessions, etc. to increase the market opportunity and associated returns for manufacturers	September 2018
MNRE, IDAs, CST Industry	Promoting increased Implementation via innovative mechanisms of system deployment such as ESCO to reduce the financial burden on beneficiary. ESCO for larger projects will also attract larger manufacturers to the sector	January 2019
MNRE, IDAs	Promoting mechanisms as developed above by showcasing the utility and benefits of implementing systems under these	March 2019

7.5 Improving the Policy and Regulatory Landscape

Increasing the deployment of systems and creating an impetus in the market will require a major nudge by the Government that will come in the form of policy and regulatory changes that support installations.

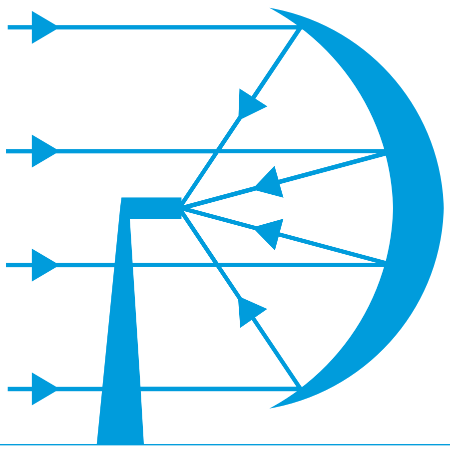
These changes should be certain, consistent, constant and have a long term focus. These reforms will attract increased interest towards the sector and create and image of growth and confidence.

Stakeholder	Action	Timelines
MNRE, IDAs	An increase in the total corpus of subsidy so as to subsidise the remaining 161 MWth of CST's. An estimated subsidy of around INR 229 crores should be earmarked	December 2019
MNRE, SNAs	There is a lack of clarity on tax slabs for components used under CST. Exemption for components of CST's and clarity on applicable tax slabs may be provided.	July 2018
MNRE, SNA's, CST Industry, Beneficiary Industry	A Draft contract to be issued that contains clauses to ensure adequate Operation, Maintenance and Performance of plants; for the guidance of targeted consumers	September 2018
State Governments, SNA's, MNRE	CST's specifically should be included in state RE policies & there should be targets at the state level. There may be provisions promoting/mandating CST's across buildings greater than a particular size or energy load	August 2018
State Governments, SNA's	Paperwork and the processing of applications at the state level for CST applications should be expedited to ensure effective filing in minimum time. This may also be replaced by a more transparent and faster online process	August 2018
MNRE	Under mandates for CST's across industries that meet a certain criteria of size and demand should also be included as an option	September 2019
MNRE	Establishing mandates for thermal power projects to setup combined cycle power projects by augmenting steam from CST's	September 2019
MNRE	Establishing emission reduction mandates for industries to promote the usage of CST's	September 2019
MNRE, CST Industry	Formulation of guidelines for implementation of systems and to support the installation of systems and the project appraisal process	September 2018
SNA's State Government	Establishment of state-wise deployment targets and additional state/district fund for the promotion of CSTs. States should participate actively in promoting CST technologies across various industries as per the targets envisaged by the MNRE and reap the benefits of potential energy savings thermal integration across the value chain.	September 2019
MNRE, State Government	Since the potential for CST's across industries is over 6 GW, the established targets may be revised and an action plan be formulated accordingly for increased deployment	March 2019

7.6 Miscellaneous Steps

A mixture of concerted activities if undertaken by respective stakeholders will propel the sector in leaps and bounds. These steps range from supporting the overall system implementation process to supporting the domestic manufacture of system components with a view to bring about cost reductions and reduce the implementation period.

Stakeholder	Action	Timelines
MNRE, SNA's, CST Industry	Development of a draft RfS/tender document for inviting bids from manufacturers for systems to ensure suitable quotations and performance	July 2018
MNRE	Development of a mission document detailing targets and an oriented approach for the growth of the sector. This will detail the roles of various stakeholders for a coordinated approach	July 2018
MNRE, NISE, other research organisations, CST Industry	Establishment of standards for system performance based on technology. This may also involve linking performance to payment to instill confidence in beneficiaries' minds	August 2018
MNRE, SNAs, IDAs	Delinking subsidy with collector area but instead using alternative methods for subsidy calculation that promote more efficient and innovative technologies	August 2018
MNRE, SNAs, IDAs	Formulation of schemes to promote manufacturing, this may involve linking with the Make in India scheme or on similar lines such as the MSIPS scheme, TUFS or the cluster scheme	January 2019
MNRE, CST Industry, NISE, IDAs, Other Industry	Demonstration of the installed CST systems in different industries with performance monitoring of the different parameters and energy saving potential through CST systems.	April 2019
MNRE, CST Industry, Associations	Establishment of a CSR fund to promote CST technologies	April 2019



7.7 Resource Requirements

Achievement of the targeted 200 MW_{th} deployment of CST technologies will require substantial resources and efforts from across the value chain. As has been calculated in the section above, the increase in collector area will be to the tune of 161 MW_{th}. An estimation of the resource requirements in terms of the finance and manpower required has been provided in this section.

The requirements are based upon the growth in deployment as has been depicted alongside. The figures are based on an increase in deployment of 33% per annum to achieve a combined growth of 200 MW_{th} by March 2022. For the year FY 2018, only the last month of March has been assumed for the analysis.

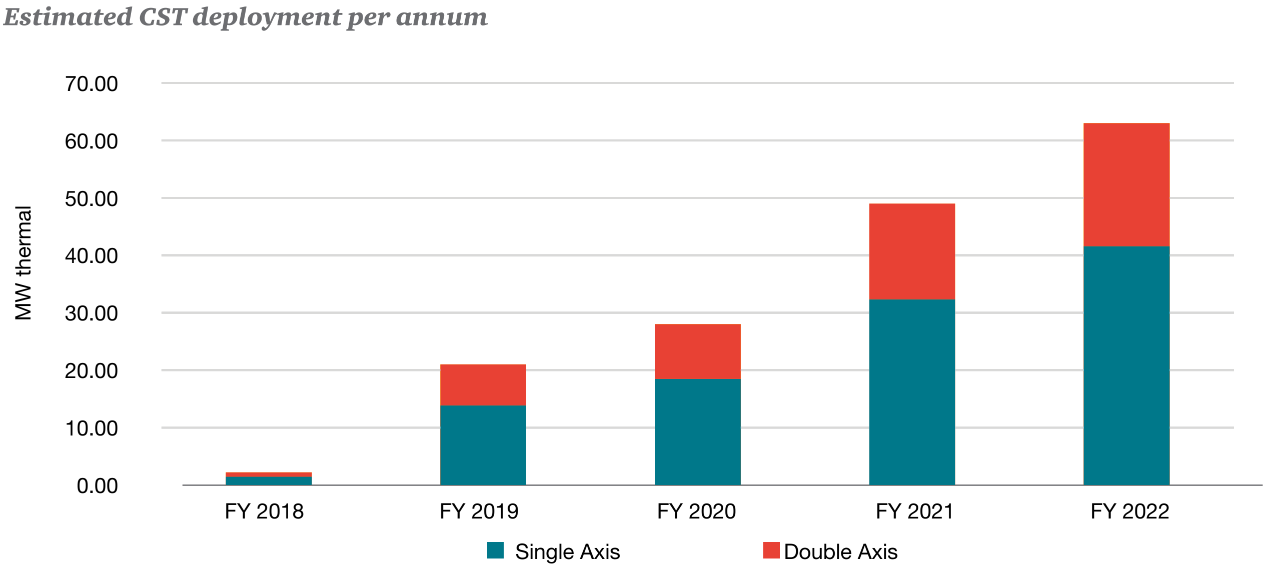


Figure 22: Year wise CST Deployment

7.7.1 Financing requirements

The financial requirements to meet the annually estimated growth in the deployment of CST's have been estimated based on the current market trends and scenario. We have assumed that a mixture of single and double axis technologies will be deployed and the ratio of deployment of such technologies will be 2:3

The benchmark costs that are applicable as of March 2018 for these technologies have been considered for calculating the investment requirement for the current year. Thereafter, a reduction in cost of 5% per annum in the cost per kWh_{th} of these systems has been assumed to account for the increase in their efficiency and the

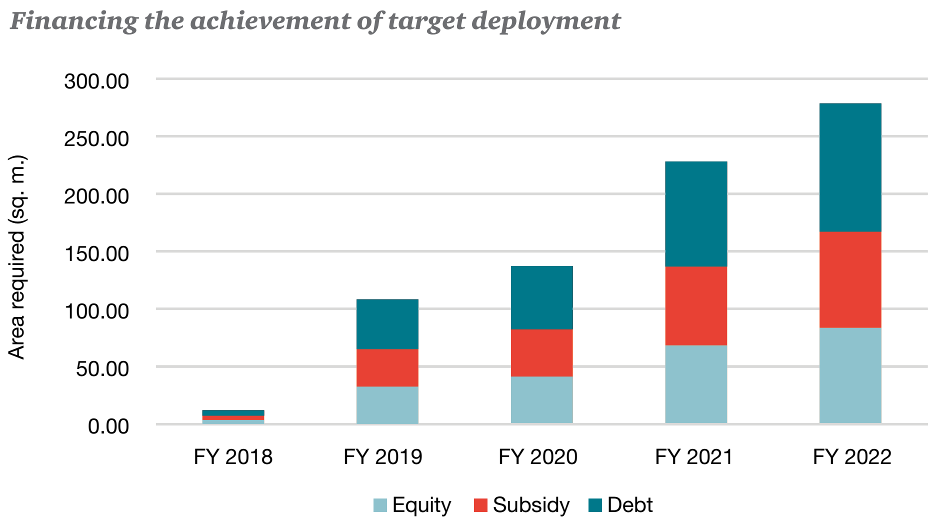


Figure 23: Financing the achievement of target deployment

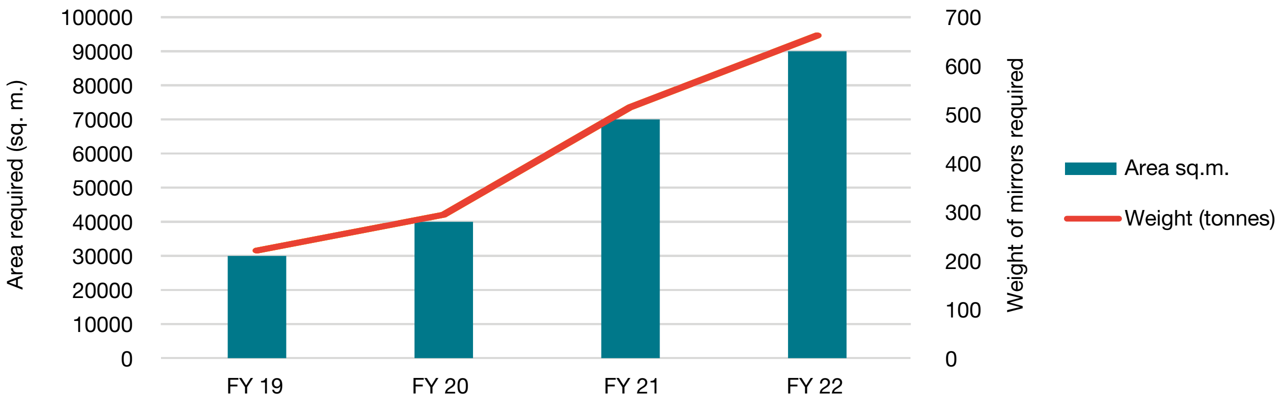
modifications in the price of these systems. The results of the financial analysis have been presented alongside and the calculations have been detailed as an Annexure to this report. The total investment required as per this analysis for the installation of the remaining capacity is estimated as INR 752 crores.

The required investment has further been split into equity investment required, the subsidy that may be released if continued as per the current norms and the total debt requirement. These have been assumed as 30%, 30% and 40% of the total cost respectively. The total equity requirement as per this assumption is INR 225 crores to complete the deployment of the entire 200 MW_{th} by 2022.

7.7.2 Material Requirements

Solar grade mirrors are essentially the most important component of any CST installation as they make up the concentrating arrangement for the sun's rays. Owing to the customised nature of CST installations in terms of other components such as pipes, meal parts, etc., we have only estimated the total amount of mirrors required in order to achieve the roadmap targets. These have been calculated based on our engagements with multiple stakeholders. The estimated size and weight of the remaining 161 MW_{th} solar grade mirrors has been depicted below.

CST Mirrors requirement



7.7.3 Additional manpower requirements

In addition to the financing required to achieve the targets mentioned above, another very important requirement is of skilled manpower to manufacture, install, operate and maintain the installed equipment. The employment generated will be a mixture of both direct and indirect employment. The direct employment that will be generated has been calculated in a year wise manner. The highest being during the final year when the capacity installations taking place will be maximum and installed capacity to be operated and maintained will be highest

Manpower required for manufacturing and installation: Based on discussions with multiple channel partners, we have assumed that the installation and commissioning of 1 MW_{th} of CST equipment in an annum provides direct employment to 8 persons.

Manpower required for operation and maintenance: Similarly, we have assumed that full time direct employment will be provided to 6 people for the operation and maintenance of 1 MW_{th} of CST equipment. This includes the part employment that may be generated for people working in installations and dealing predominantly with cleaning activities.

Based on the assumptions above, the total manpower required in the given year has been tabulated below:

Table 2: Manpower Requirement for Target Deployment

Manpower	FY 18	FY 19	FY 20	FY 21	FY 22
Manufacturing and Installation	121	185	246	308	407
Operation and Maintenance	343	482	666	897	1,202
Total	**464**	**666**	**913**	**1,205**	**1,609**

The direct employment generated is estimated to be for 1,609 people in FY 22.

7.8 Contribution to the environment

Deployment of CST's at this level will result in the reduction of carbon dioxide emissions both directly and indirectly. Directly these will be in the form of emissions that would have been made if the prevalent fuel had been used at the point where the installations are made. Indirect emissions are from a mixture of sources such as transportation of the fuel that would have been burnt.

We have estimated the amount of carbon dioxide emission that will be reduced if additional 161 MW_{th} of CST's that are required to achieve the 200 MW_{th} target are deployed.[25] The estimation reveals that annually emissions of 63,424 tonnes of carbon dioxide will be reduced from the year 2022, from the additional 161 MW_{th} capacity addition of CSTs. Further, on a project lifetime basis, this will result in emission reductions of 1,298,295 tonnes of carbon dioxide over the lifecycle of the projects.

25 The analysis has assumed a carbon dioxide abatement of 0.27 tonnes of carbon dioxide per m² of CST deployed in an annum and 4.91 tonnes of carbon dioxide per m² of CST deployed over the lifetime of the system. These assumptions are based on the results of the assignment "Promoting business models for increasing penetration and scaling up of solar energy" that was executed by UNIDO, MNRE, IREDA, MSME, DIPP and MoEF. This was submitted in the year 2013.

Appendix

1A

List of MNRE Channel Partners

S. No.	Name	Technology
1.	Unisun Technologies Pvt. Ltd.	Single axis tracked Scheffler dishes
2.	Thermax Limited	a) Parabolic Trough Collectors (Single Axis) b) Scheffler dishes (Both single axis and double axis tracked). c) Non- imaging concentrating system
3.	Clique Solar	Double axis tracked Fresnel Reflector based dishes
4.	Megawatt Solutions Pvt. Ltd.	Double axis tracked paraboloid dishes
5.	Taylormade Solar Solutions Pvt. Ltd.	Single axis tracked Scheffler dishes
6.	Ultra Conserve Pvt. Ltd.	a) Parabolic Trough Collectors (Single Axis) b) Non-imaging concentrating system
7.	Leveragenet Solutions Pvt. Ltd.	Parabolic Trough Collectors (Single Axis)
8.	Forbes Solar Pvt. Ltd	Paraboloid dish (Dual Axis)
9.	Sunbest	Non-imaging collector
10.	GreenLife Solutions Pvt. Ltd.	Double axis Tracked Parabolic dishes
11.	A.T.E Enterprises Pvt. Ltd.	(a) Double axis Paraboloid dishes (b) Non-imaging collector
12.	Oorja Energy Engg. Services Hyd Pvt. Ltd.	Single axis parabolic trough collectors Non imagine collector
13.	K energy	Single axis tracked Scheffler dishes
14.	VSM Solar Pvt. Ltd.	Non-Imagine collector
15.	Greenera Energy India Pvt. Ltd.	Parabolic Trough Collectors (Single Axis)

Appendix

1B

Potential for Implementation of CST's in India's Industrial Sector

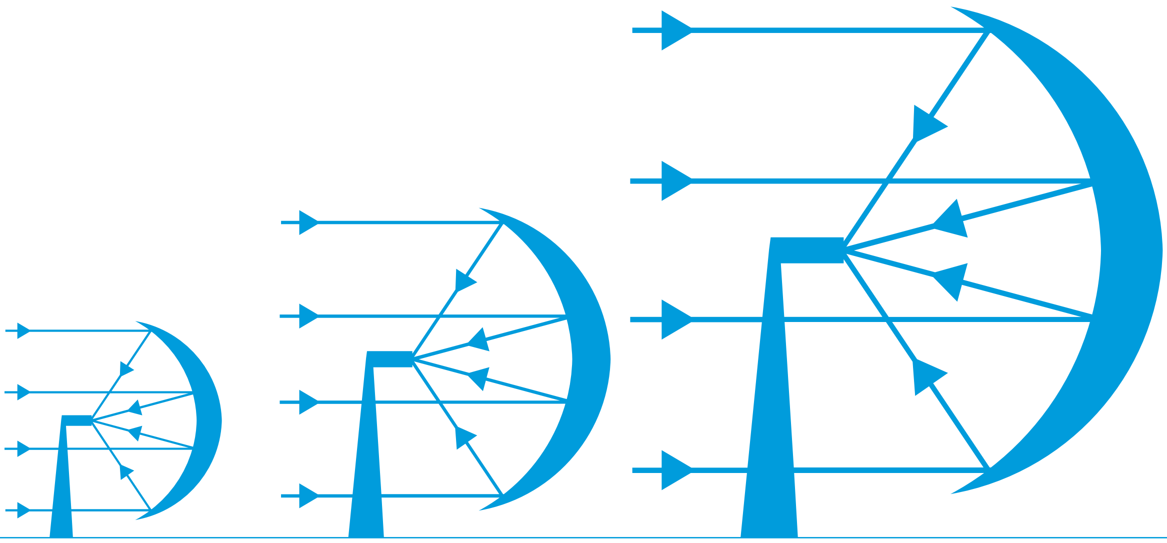
Classification of Industries into 25 sectors

We have classified the 150 industrial sectors (as per NIC – 2008 industry classifications in the Annual Survey of Industries report 2013-14) into 25 broad sectors. The classification has been listed below.

Broad Industry Sector	NIC	NIC Industry Description
Automotive and other Transport	2910	Manufacture of motor vehicles
	2920	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
	2930	Manufacture of parts and accessories for motor vehicles
	3011	Building of ships and floating structures
	3012	Building of pleasure and sporting boats
	3020	Manufacture of railway locomotives and rolling stock
	3030	Manufacture of air and spacecraft and related machinery
	3040	Manufacture of weapons and ammunition
	3091	Manufacture of motorcycles
	3092	Manufacture of bicycles and invalid carriages
	3099	Manufacture of other transport equipment n.e.c.
Breweries	1101	Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials
	1102	Manufacture of wines
	1103	Manufacture of malt liquors and malt
	1104	Manufacture of soft drinks; production of mineral waters and other bottled waters
Cement	2394	Manufacture of cement, lime and plaster
	2395	Manufacture of articles of concrete, cement and plaster
Ceramics	2391	Manufacture of refractory products
	2392	Manufacture of clay building materials
	2393	Manufacture of other porcelain and ceramic products

Broad Industry Sector	NIC	NIC Industry Description
Chemical	2011	Manufacture of basic chemicals
	2012	Manufacture of fertilizers and nitrogen compounds
	2021	Manufacture of pesticides and other agrochemical products
	2022	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
	2023	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
	2029	Manufacture of other chemical products n.e.c.
Dairy	1050	Manufacture of dairy products
Electronics and Electrical Equipment	2610	Manufacture of electronic components
	2620	Manufacture of computers and peripheral equipment
	2630	Manufacture of communication equipment
	2640	Manufacture of consumer electronics
	2651	Manufacture of measuring, testing, navigating and control equipment
	2652	Manufacture of watches and clocks
	2660	Manufacture of irradiation, electromedical and electrotherapeutic equipment
	2670	Manufacture of optical instruments and equipment
	2680	Manufacture of magnetic and optical media
	2710	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
	2720	Manufacture of batteries and accumulators
	2731	Manufacture of fibre optic cables for data transmission or live transmission of images
	2732	Manufacture of other electronic and electric wires and cables
	2733	Manufacture of wiring devices
	2740	Manufacture of electric lighting equipment
	2750	Manufacture of domestic appliances
	2790	Manufacture of other electrical equipment

Broad Industry Sector	NIC	NIC Industry Description
Food Processing	0163	Post harvest crop activities
	0164	Seed processing for propagation
	0893	Extraction of salt
	1010	Processing and preserving of meat
	1020	Processing and preserving of fish, crustaceans and molluscs and products thereof
	1030	Processing and preserving of fruit and vegetables
	1040	Manufacture of vegetable and animal oils and fats
	1061	Manufacture of grain mill products
	1062	Manufacture of starches and starch products
	1071	Manufacture of bakery products
	1072	Manufacture of sugar
	1073	Manufacture of cocoa, chocolate and sugar confectionery
	1074	Manufacture of macaroni, noodles, couscous and similar farinaceous products
	1075	Manufacture of prepared meals and dishes
	1079	Manufacture of other food products n.e.c.
	1080	Manufacture of prepared animal feeds
Glass	2310	Manufacture of glass and glass products
Iron and Steel	2410	Manufacture of basic iron and steel
	2431	Casting of iron and steel
Leather and Footwear	1511	Tanning and dressing of leather; dressing and dyeing of fur
	1512	Manufacture of luggage, handbags and the like, saddlery and harness
	1520	Manufacture of footwear



Broad Industry Sector	NIC	NIC Industry Description
Machinery	2811	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
	2812	Manufacture of fluid power equipment
	2813	Manufacture of other pumps, compressors, taps and valves
	2814	Manufacture of bearings, gears, gearing and driving elements
	2815	Manufacture of ovens, furnaces and furnace burners
	2816	Manufacture of lifting and handling equipment
	2817	Manufacture of office machinery and equipment
	2818	Manufacture of power-driven hand tools
	2819	Manufacture of other general-purpose machinery
	2821	Manufacture of agricultural and forestry machinery
	2822	Manufacture of metal-forming machinery and machine tools
	2823	Manufacture of machinery for metallurgy
	2824	Manufacture of machinery for mining, quarrying and construction
	2825	Manufacture of machinery for food, beverage and tobacco processing
	2826	Manufacture of machinery for textile, apparel and leather production
	2829	Manufacture of other special-purpose machinery
Non-ferrous Metals	2420	Manufacture of basic precious and other non-ferrous metals
	2432	Casting of non-ferrous metals
	2511	Manufacture of structural metal products
	2512	Manufacture of tanks, reservoirs and containers of metal
	2513	Manufacture of steam generators, except central heating hot water boilers
	2520	Manufacture of weapons and ammunition
	2591	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
	2592	Machining; treatment and coating of metals
	2593	Manufacture of cutlery, hand tools and general hardware
	2599	Manufacture of other fabricated metal products n.e.c.
Non-Metallic	2396	Cutting, shaping and finishing of stone
	2399	Manufacture of other non-metallic mineral products n.e.c.

Broad Industry Sector	NIC	NIC Industry Description
Other Manufacturing	3211	Manufacture of jewellery and related articles
	3212	Manufacture of imitation jewellery and related articles
	3220	Manufacture of musical instruments
	3230	Manufacture of sports goods
	3240	Manufacture of games and toys
	3250	Manufacture of medical and dental instruments and supplies
	3290	Other manufacturing n.e.c.
Petroleum Refining	1910	Manufacture of coke oven products
	1920	Manufacture of refined petroleum products
Pharmaceuticals	2100	Manufacture of pharmaceuticals, medicinal chemical and botanical products
Plastics and Polymers	2013	Manufacture of plastics and synthetic rubber in primary forms
	2030	Manufacture of man-made fibres
	2220	Manufacture of plastics products
Pulp and Paper	1701	Manufacture of pulp, paper and paperboard
	1702	Manufacture of corrugated paper and paperboard and containers of paper and paperboard
	1709	Manufacture of other articles of paper and paperboard
Rubber	2211	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
	2219	Manufacture of other rubber products
Textile	1311	Preparation and spinning of textile fibres
	1312	Weaving of textiles
	1313	Finishing of textiles
	1391	Manufacture of knitted and crocheted fabrics
	1392	Manufacture of made-up textile articles, except apparel
	1393	Manufacture of carpets and rugs
	1394	Manufacture of cordage, rope, twine and netting
	1399	Manufacture of other textiles n.e.c.
	1410	Manufacture of wearing apparel, except fur apparel
	1420	Manufacture of articles of fur
	1430	Manufacture of knitted and crocheted apparel
Tobacco	1200	Manufacture of tobacco products

Broad Industry Sector	NIC	NIC Industry Description
Waste Treatment	3811	Collection of non-hazardous waste
	3812	Collection of hazardous waste
	3821	Treatment and disposal of non-hazardous waste
	3822	Treatment and disposal of hazardous waste
	3830	Materials recovery
Wood and Furniture	1610	Saw milling and planing of wood
	1621	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board and other panels and board
	1622	Manufacture of builders' carpentry and joinery
	1623	Manufacture of wooden containers
	1629	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials
	3100	Manufacture of furniture
Others	1811	Printing
	1812	Service activities related to printing
	1820	Reproduction of recorded media
	3311	Repair of fabricated metal products
	3312	Repair of machinery
	3313	Repair of electronic and optical equipment
	3314	Repair of electrical equipment
	3315	Repair of transport equipment, except motor vehicles
	3319	Repair of other equipment
	3320	Installation of industrial machinery and equipment
	5811	Book publishing
	5812	Publishing of directories and mailing lists
	5813	Publishing of newspapers, journals and periodicals
	5819	Other publishing activities
	Others	All Other Sectors

Energy usage data available in Annual Survey of Industries Report 2013-14

The energy usage data has been sourced entirely from the latest available Annual Survey of Industries Report, i.e., 2013-14. The calorific values provided for various fuels have been converted to kWh in order to enable comparison between the energy sourced from various fuels and also to ascertain the total potential of CST's. These calculations have been made in the following manner:

1. **Coal:** The quantity provided in tonnes is converted to kcal and then these have been converted to kWh. We have taken the following assumptions:

   a. Calorific value of coal = 5,000 kcal/kg.

2. **Electricity:** The value is directly taken from the table in kWh

3. **Petroleum Products:** The value of Petroleum products was converted to number of litres of petrol using the average monthly price of petrol across 4 cities of India in 2013-2014 as per data made available by Indian Oil Corporation Limited. These four cities were Delhi, Bombay, Chennai and Kolkata. This data has been provided below for reference. The average price computed was INR 73.512/litre

Date\City	Delhi	Kolkata	Mumbai	Chennai	Average
01/04/2014	72.26	80.13	80.89	75.49	77.19
01/03/2014	73.16	80.96	82.07	76.48	78.17
05/01/2014	72.43	80.20	81.31	75.71	77.41
04/01/2014	72.43	79.55	79.52	75.68	76.80
21/12/2013	71.52	78.60	78.56	74.71	75.85
01/11/2013	71.02	78.07	78.04	74.22	75.34
01/10/2013	72.40	79.51	79.49	75.68	76.77
14/09/2013	76.06	83.63	83.62	79.55	80.72
01/09/2013	74.10	81.57	81.57	77.48	78.68
01/08/2013	71.28	78.64	78.61	74.49	75.76
15/07/2013	70.44	77.76	77.73	73.60	74.88
01/07/2013	68.58	75.84	75.79	71.65	72.97
29/06/2013	68.58	76.10	76.90	71.71	73.32
16/06/2013	66.39	73.79	74.60	69.39	71.04
01/06/2013	63.99	71.29	72.08	66.85	68.55
23/05/2013	63.09	70.35	71.13	65.90	67.62
01/05/2013	63.09	70.35	69.73	65.90	67.27
16/04/2013	66.09	73.48	72.88	69.08	70.38
02/04/2013	67.29	74.72	74.14	70.34	71.62
01/04/2013	68.31	75.79	75.21	71.42	72.68

The number of litres obtained was then multiplied with the calorific value of petrol to obtain the total energy supplied. The following assumptions were taken:

a. Calorific value of petrol = 9,000 kcal/l
b. Average cost of petrol = INR 73.512/l

4. **Other:** The value of others was taken to compute the total quantity of fuel used and this in turn was multiplied with the expected calorific content to derive the energy supplied. Since, we consider the others segment to predominantly consist of biomass sources, we have taken the following assumptions:

   a. Calorific value of others = 2,000 kcal/kg.
   b. Average cost of others = INR 5/kg.

The Market Effect Multiplier

In order to ascertain the market effect multiplier, we have assumed the following values:

a. Willingness to implement CST's = 12/25

b. Space constraints = 15/25

c. Financial Viability over Existing System: This parameter has been assigned a weightage of 50. In order to compute the value of this parameter, we have taken the cost per kWh of energy supplied to all industry sectors and have multiplied that with the total weighted score of 50. The following values were obtained for the different industry sectors:

Industry Sector	Weighted Average Cost/kWh	Financial Viability Score
Automotive and other Transport	0.34	17
Breweries	0.27	14
Cement	0.83	41
Ceramics	0.54	27
Chemical	0.44	22
Dairy	0.24	12
Electronics and Electrical Equipment	0.18	9
Food Processing	0.27	14
Glass	0.29	14
Iron and Steel	0.36	18
Leather and Footwear	0.17	9
Machinery	0.18	9
Non-ferrous metals	0.62	31
Non-Metallic	0.22	11
Petroleum Refining	0.38	19
Pharmaceuticals	0.23	11
Plastics and Polymers	0.29	15
Pulp and Paper	0.65	32
Rubber	0.28	14
Textile	0.33	16
Tobacco	0.31	15
Waste Treatment	0.29	15
Wood and Furniture	0.22	11
Other Manufacturing	0.18	9
Others	0.91	45

Estimating Resource Requirements

Financial Requirements

The financial requirements for the achievement of roadmap targets have been calculated as below:

Step 1: In order to estimate the finance requirements for the achievement of installations of 200 $MW_{th,}$ a year wise estimation of the additional installations to be made has been leveraged. This is based on a growth in installations of 33% per annum to achieve a total installation of 200 $MW_{th,}$ by March 2022.

Current Installations = 39 $MW_{th,}$ (based on a conversion factor of 0.7 kW_{th}/m^2 as per the conversion factor described above)

Remaining installations to be completed from from from March 2018 - March 2022 = 161 MW_{th}

Assuming a growth in installations of 33% per annum, the installation per annum will be:

Year	FY 19	FY 20	FY 21	FY 22
Installation (MWth)	21	28	49	63

Step 2: The yearly finance requirement for the deployment of these capacities has been calculated with the assumption that 60% of the systems implemented will be based on single axis tracking technologies and the remaining 40% on dual axis tracking technologies. The benchmark costs for these technologies as used by MNRE have been taken for calculating the cost of these systems for FY 18 along with the conversion factor of 0.7 kW_{th}/m^2.

For subsequent years, we have assumed a reduction in cost of 5% per annum in the cost per kWh_{th} of these systems to account for the increase in their efficiency and the modifications in the price of these systems.

Year	Installation (MWth)	Total Cost (INR crores)
FY 19	21	108.30
FY 20	28	137.18
FY 21	49	228.06
FY 22	63	278.56

Step 3: The total financial requirement has been split into 30% equity, 30% subsidy and 40% debt to obtain the total breakup of the finance required.

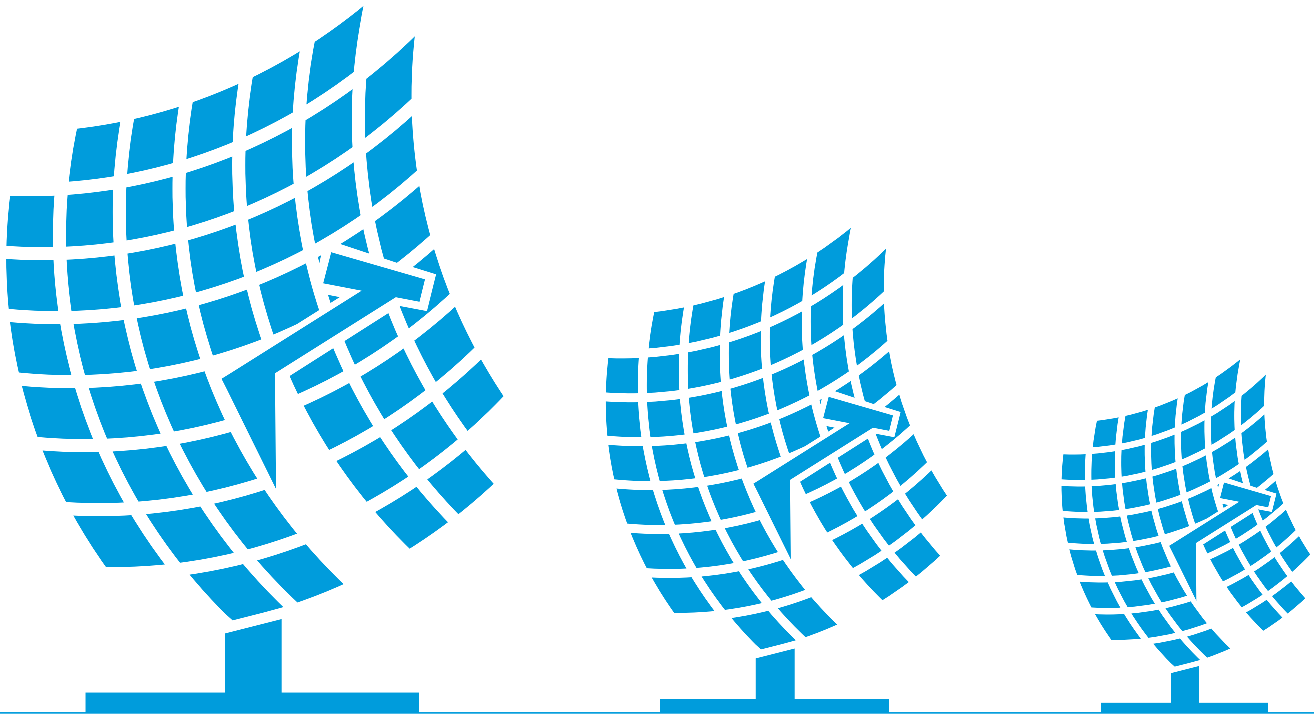
Year	Equity (INR crores)	Subsidy (INR crores)	Debt (INR crores)
FY 19	32.49	32.49	43.32
FY 20	41.15	41.15	54.87
FY 21	68.42	68.42	91.22
FY 22	83.57	83.57	111.42

Material Requirements – Solar Grade Mirrors

In order to calculate the solar grade mirror requirements, we have based on our engagements with stakeholders considered that ~21% extra mirrors than the proposed collector area are required. This is to overcome a multitude of factors such as breakage, wastage, damage, etc. Also the weight per kilogram of glass has been considered as 7.4 kg/m².

We have factored in these assumptions in the proposed yearly additions as per the previous section to calculate the total amount of glass required as:

Mirrors	FY 19	FY 20	FY 21	FY 22
Area of glass (m²)	30,000	40,000	70,000	90,000
Weight (tonnes)	220.75	294.34	515.92	662.66



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