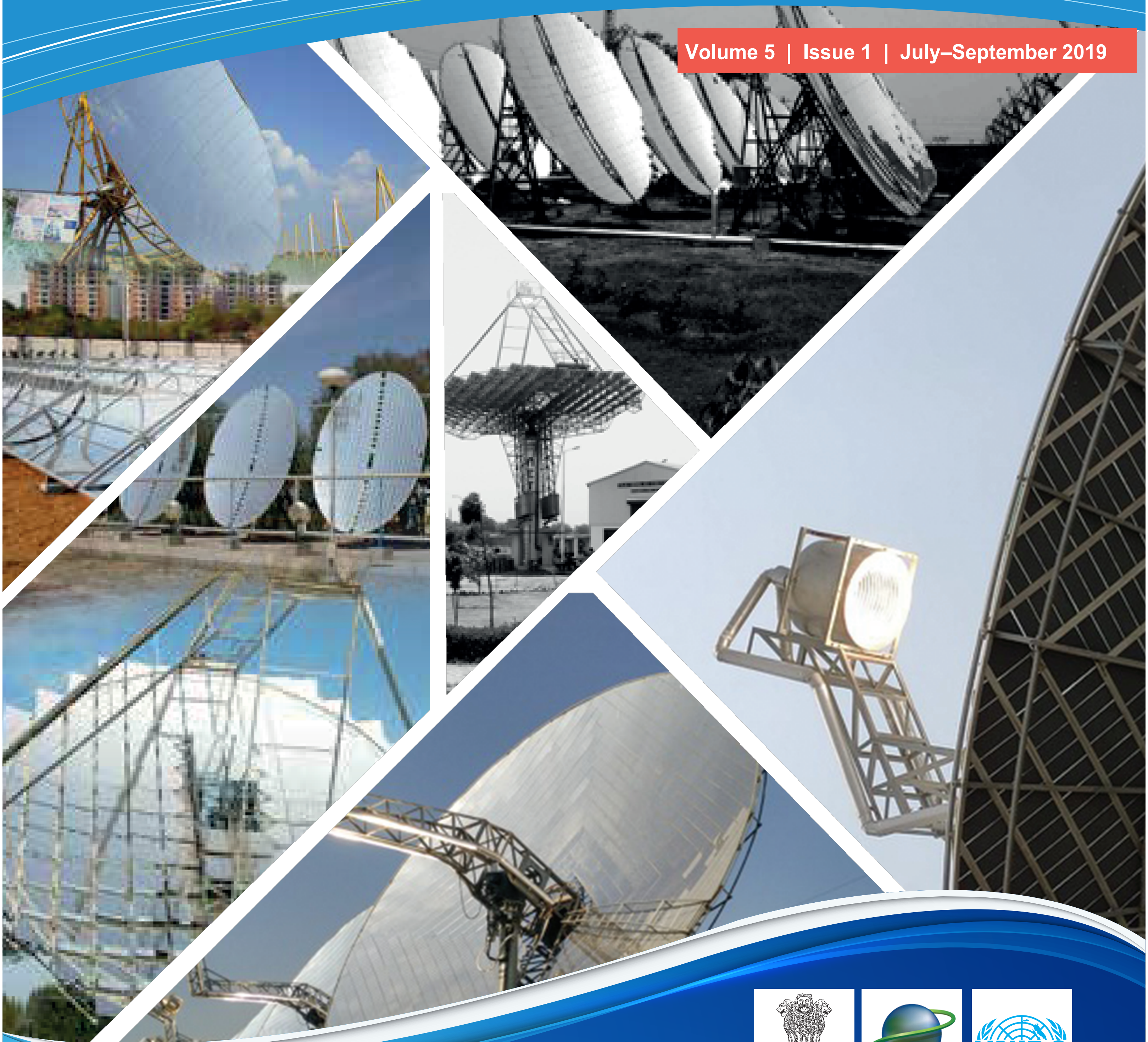
a quarterly magazine on **Concentrating Solar Thermal**

SUN FOCUS

Volume 5 | Issue 1 | July–September 2019



Ministry of New and Renewable Energy
Government of India

PROMOTING BUSINESS MODELS FOR INCREASING PENETRATION AND SCALING UP OF SOLAR ENERGY

MNRE-GEF-UNIDO Project

SUN FOCUS
Volume 5 • Issue 1
July–September 2019
a quarterly magazine on
concentrated solar heat

Produced and Published by
Project Management Unit
MNRE-GEF-UNIDO project on CST
&
TERI Press
TERI, Darbari Seth Block, IHC Complex
Lodhi Road, New Delhi – 110 003
Tel: +91 11 2468 2100, 4150 4900
Fax: +91 2436 3035, 2436 2288
Email: teripress@teri.res.in

INside...

Feature 2 12

Feature 5 21

CONTENTS

आनन्द कुमार
ANAND KUMAR

सचिव
भारत सरकार
नवीन और नवीकरणीय ऊर्जा मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

Message

Energy consumption of a nation is a signifier of growth. Currently, majority of the energy requirements of India are met by fossil fuels such as coal and petroleum. In today's era when the world is eyeing 'sustainable development', it has become necessary for humankind to adopt clean and green energy alternatives. In this regard, concentrated solar thermal technology (CST) has come out significantly promising clean energy supply for process heat applications in industries, institutions, hospital & hotels etc. where thermal energy is required at low to medium temperatures.

India is a signatory to Paris Agreement and has committed to reduce its GHG emissions by 33 to 35% by 2030 as compared to 2005 levels. Blessed with substantial amount of sunshine, the country has vast potential for utilizing CST technology. Recognizing this, the Ministry of New and Renewable Energy is implementing schemes and programmes for utilizing solar energy through CST technologies in process heating and cooling applications.

The *'Sun Focus'* magazine was first published in 2012 by UNDP in cooperation with MNRE covering useful information about the technology providers and the beneficiaries of this sector; and it reached the untapped audience through industry associations and State Nodal Agencies. Moving towards digital mode and saving papers by launching electronic version of the magazine by UNIDO, will further continue to present the complex CST technologies and their benefits in an easily understandable manner.

The *'Sun Focus'* e-magazine would definitely play a vital role in further popularizing the CST technologies, and also compliment the awareness generation objective of the Ministry's on-going scheme "Off-Grid and Decentralized Concentrated Solar Thermal (CST) Technologies for Community Cooking, Process Heat and Space Heating & Cooling Applications in Industrial, Institutional and Commercial Establishments".

I wish the entire team of *'Sun Focus'* e-magazine all success and enhanced readership.

[Anand Kumar]
19.08.2019

अक्षय ऊर्जा से देश विकास
गांव गांव बिजली, घर घर प्रकाश

ब्लॉक नं. 14, केन्द्रीय कार्यालय परिसर, लोदी रोड, नई दिल्ली–110003
Block No. 14, CGO Complex, Lodi Road, New Delhi - 110 003
Tel. : 011-24361481, 24362772 • Facsimile : 011-24367329 • E-mail : secy-mnre@nic.in
website : www.mnre.gov.in

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Regional Office in India

Message from UNIDO Representative in India

Sustainable development is possible only when it is an all-inclusive development and no country is left behind. Energy security of a country is critical in determining its economic growth, and with the surge in global energy demand, the scientific and technological communities are seeking innovative solutions. About 80 per cent of the global power demand is still sourced from fossil fuels, which has adversely impacted the environment. The industrial sector is the major consumer of the global energy; and in India, this sector consumes about 45 per cent of the country's total energy. With the upward trend in energy consumption and growth of the world economy, industrial emissions and fossil fuel consumption need to be minimized for sustainable development.

The total installed Concentrated Solar Thermal (CST) Power capacity is around 228.5 MW, with Linear Fresnel Reflector systems contributing around 125 MW, parabolic trough contributing approximately 101 MW and ST nearly 2.5 MW. India currently has the about 64, 000 m^2 collector area under implementation for the heating and cooling purposes with an installed capacity of 43.30 MW. Although CST technologies have not yet been adopted widely throughout India as compared to Photovoltaic (PV) technology, the higher efficiency of the technology and its ability to store thermal energy directly makes it an excellent option.

While the Government of India has been promoting CST technologies in the country recognizing their large scale benefits, UNIDO's project is specifically focusing on market mechanisms and financing to enhance the market size of the CST sector in India.

The revised edition of *Sun Focus* extensively covers the scientific and technical analyses, discussions, development and constant exchange of ideas among the industries, its experts, policy makers, and governments. We hope the magazine opens dialogues and discussions to herald a wider acceptance of CST technologies.

Rene Van Berkel
UNIDO Representative

UN House, 55 Lodi Estate, New Delhi 110003
Tel: +91 11 24643484 Fax: +91 11 24620913 Email: office.india@unido.org; Website: www.unido.org

राष्ट्रीय सौर ऊर्जा संस्थान
(नवीन और नवीकरणीय ऊर्जा मंत्रालय, भारत सरकार का स्वायत्त संस्थान)
National Institute of Solar Energy
(An Autonomous Institute of Ministry of New and Renewable Energy, Govt. of India)
गुरुग्राम–फरीदाबाद मार्ग, ग्वाल पहाड़ी, गुरुग्राम–122 003, हरियाणा, भारत
Gurugram-Faridabad Road, Gwal Pahari, Gurugram - 122 003, Haryana, India

21st August, 2019

MESSAGE

At the outset, I wish to congratulate UNIDO-MNRE-GEF project team on the publication of the revised edition of Sun Focus magazine and express my optimism in its furtherance of the wider propagation of Concentrated Solar Thermal (CST) technologies.

In view of the recognized benefits of CST in India due to the high irradiance, the Government of India has been consistently encouraging the development and usage of solar thermal technologies through advancements in technology, improving the policy and regulatory framework, increasing awareness amongst the stakeholders, and enhancing the options for financing viable CST projects and so on. The National Institute of Solar Energy (NISE), in its capacity as the apex national R&D institution in solar energy in the country, plays its role as an effective interface between the government and institutions and the industry and user organizations for the development, promotion, and widespread utilization of solar energy. NISE has established state-of-the-art test facilities for CST testing and so far has tested 12 numbers of CST products and technologies.

I hope this issue and the future issues of Sun Focus will serve to stimulate the growth of CST in India in an endeavor to achieve higher integration of CST technology in the energy landscape of the country.

Dr. Arun K. Tripathi
Director General
National Institute of Solar Energy

दूरभाष / Tel. No. : 0124-285 3060
ईमेल / Email : dgnise.mnre@gmail.com, nise.mnre@gmail.com, वेबसाइट / Website : www.nise.res.in

सत्यमेव जयते

Amitesh Kumar Sinha
Joint Secretary

भारत सरकार
नवीन और नवीकरणीय ऊर्जा मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

Date : 19.8.2019

Message

With vast solar energy potential, India is aiming to move towards cleaner energy sources. Concentrated solar thermal is one such technology with a promising prospective which can help in reduction of fossil fuel consumption in thermal applications. Ministry of New and Renewable Energy has been making continuous efforts to grow and develop the concentrated solar technology sector through different subsidy programs. Now, concentrated solar heat is a niche market and in recent times has been evolving fast as per the industry demands.

The publication of *Sun Focus* was an initiative made, under the MNRE-GEF-UNDP, to reach out to various stakeholders of CST sector. *Sun Focus* was first published in 2012. The past issues provided potential information on CSTs such as policy, technology developments, new applications, and national and international developments relevant for the sector. These issues have played an important part in awareness generation and information dissemination about the CST sector. They also covered specific case studies involving CST based poly-generation system generating hot water and thermic fluid heating, thermal sector developments in Leh area, tracking and control system for parabolic trough collectors.

Articles on case studies, field experience and schemes and finance models from banks developed specially for the CST sector have been very useful in the decision-making process for adopting CST technology.

It is of immense pleasure that, along with UNIDO, MNRE is relaunching the *Sun Focus* as e-magazine, which will help in increasing the readership base.

I hope you will find this issue and forthcoming issues interesting and informative as all the previous issues. I look forward the participation of all stakeholders in making this e-magazine a huge success.

19/08/19

(AMITESH KUMAR SINHA)

Block No. 14, CGO Complex, Lodi Road, New Delhi-110003
Tel.: 91-11-24362288, Fax : 91-11-24367413, E-mail : amitesh.iras@gov.in • Website : www.mnre.gov.in

GEF SUPPORTED UNIDO PROJECT PROMOTION OF CONCENTRATING SOLAR THERMAL TECHNOLOGIES IN INDIA

Background

Solar thermal has the capacity of fulfilling the industrial demand for heating and cooling applications to a substantial extent. The rapid expansion of solar sector in India makes the GEF-UNIDO project relevant and complementarity to the national and international initiatives aimed at the commercialization of solar heat technologies, avoid GHG emissions and help India in its transformation towards low carbon development.

For industrial processes where temperatures above 80°C are required, concentrating solar collectors such as parabolic trough, paraboloid dish, non-imaging concentrators, a Linear Fresnel based system are required to be used.

The analysis of various industrial processes shows that solar concentrators could be technically and commercially viable in many industries. The industries showing good potential for implementation of CST are food processing, paper and pulp, chemical, fertilizer, breweries, electroplating, pharmaceutical, textiles, refineries and leather sectors.

The GEF-UNIDO project on "Promoting Business Model for increasing penetration and scaling up of solar energy" was designed to complement Ministry (MNRE) support programme by helping to remove barriers associated with Concentrating Solar Thermal (CST) technologies, its awareness, capacity building, market and financial barriers. The duration of the project is from January 2015 to December 2019 (being extended till December 2020). The driving solar support initiative in India has been the Jawaharlal Nehru National Solar Mission (JNNSM) of the Ministry of New and Renewable Energy (MNRE), Government of India.

The project was conceived with an aim to contribute to the GEF Climate Change Strategic Objective namely, promoting investment in Renewable Energy (RE) technologies by transforming the market for solar energy for industrial heat applications in India through investment, market demonstration, development of appropriate financial instruments, development of technical specifications, capacity building and contributions to establish a favourable policy and regulatory environment.

The project strategy builds on the existing favourable framework for solar thermal in India. Factors in favour of the project include the high commitment by the government to the development of its solar thermal industry, and significant interest by the industrial sector to reduce its reliance on fossil fuels.

Primary target beneficiaries of the project are energy policy-making and implementing institutions, primarily MNRE, MSME, IREDA, industrial unit owners (end beneficiaries), CS manufacturers, designers, installers, training institutes, energy professionals and service providers and the financial sector.

Implementation Arrangement

The implementing partners of the CST project is Ministry of New and Renewable Energy (MNRE), Indian Renewable Energy Development Agency (IREDA), and National Institute of Solar Energy (NISE).

Expected outcome

- Systems based on Concentrating Solar Thermal (CST) technologies are installed with 45,000 m2 of solar collector area through demonstration projects resulting in saving of 39,200 tonnes of CO_2 emission.
- Knowledge documents and standardization of performance measurement developed with barriers removed for large scale promotion of CST Technology.

Main features of the project

UNIDO has partnered with IREDA (Indian Renewable Energy Development Agency) to develop and implement an innovative finance/loan scheme to further promote the deployment of CST projects in India for heating and cooling applications in potential industries to reduce energy consumption and Greenhouse Gas (GHG) emissions. The highlights of the currently available financial incentives are as follows.

- The beneficiary's or project developer's contribution would be 25%.
- The financial incentives provided for CST installation include CFA (Central Financial Assistance) from MNRE at 30% of the benchmark solar project cost, and accelerated depreciation benefit.
- Additional support is available from UNIDO project in terms of technical feasibility and soft loan from IREDA.
- Bridge loan against subsidy and at normal interest rate would be available.
- Support is available also for improving the manufacturing of CST system/components.

Loan for the CST project would be provided at an interest subvention of 5% from the current rates using funds under the project. Both the loan and MNRE subsidy would be bundled in form a financial package by IREDA. The details of the loan scheme and the application form are available on the MNRE, IREDA & UNIDO websites.

The project developers and beneficiaries may contact UNIDO for further information on the loan scheme and the technical support available from UNIDO for CST projects for industry process heat applications.

Anil Misra
National Project Manager
UNIDO, UN House, 55 Lodi Estate, New Delhi 110003
Email: a.k.misra@unido.org

CONCENTRATING SOLAR THERMAL INDUSTRIAL HEATING SYSTEM AT MOTHER DAIRY, PATPARGANJ

Pioneering Delhi dairy industry with concentrated solar technology

Siddharth Malik*

Commissioned in the year 1974 and initiated under the Operation Flood Programme, Mother Dairy is a fully owned cooperative by National Dairy Development Board (NDDB). Mother Dairy, Patparganj is one of the largest milk processing units in Delhi catering up to 15,00,000 litre milk per day (Figure 1). Mother Dairy is committed to promote renewable technologies and aims to integrate solar to save fuel expense and minimize carbon footprint. To minimize the consumption of natural gas, the co-operative had decided to install concentrating solar thermal (CST) system at its processing unit in October 2016.

System Details and Process

The dairy unit utilizes steam across heat exchangers with automatic control to generate hot water at high temperature (up to 90°C) for two important processes, that is, clean-in-place (CIP) and cleaning. These processes are critical since milk batches are processed after CIP cycles and cleaning of food-grade processing equipment is critical to ensuring the highest quality of milk.

Challenge

It was a daunting task taken up by Mother Dairy as no data on solar radiation was available when the project was conceived. Hence, various estimations were done and various databases were accessed to arrive at the best estimate of the solar radiation at the site or DNI (direct normal irradiance). Based on the same, it was proposed to design the system. While estimates were

Figure 1: A view of CST system at Mother Dairy

*Megawatt Solutions Pvt. Ltd.

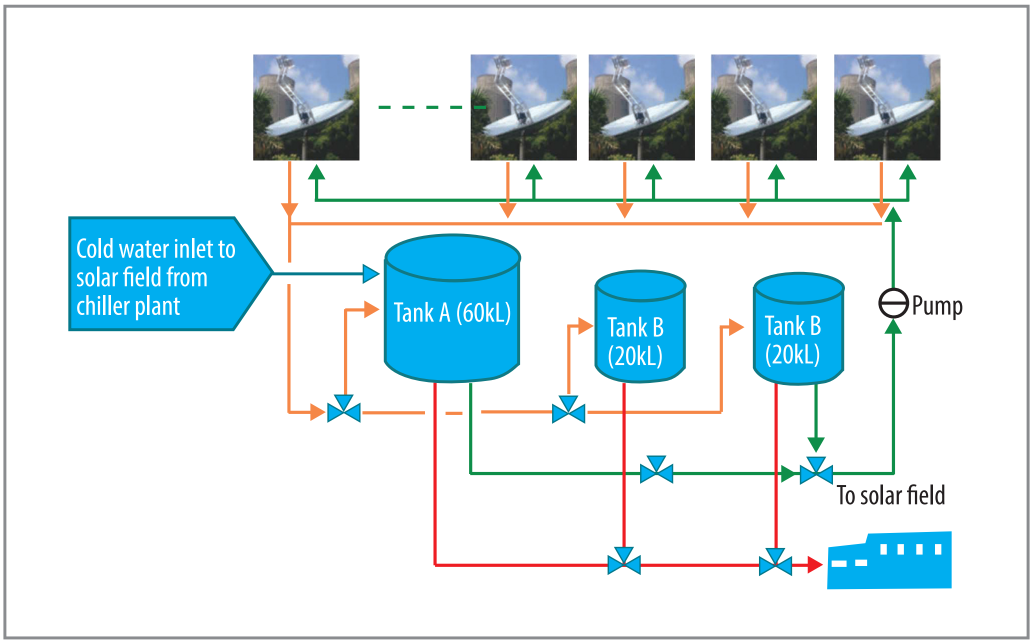


***Figure 2:** Schematics of CST installation at Mother Dairy*

arrived at using information publicly available, the challenge was the low grade of solar radiation in an urban city, such as New Delhi, attributed to pollution, dust and aerosol scattering. Hence, there was the need to adopt a technology with high concentration ratio that allowed a wide range of operating conditions across low DNI levels while being able to deliver high temperature heat. Two-axis paraboloid dishes meet this unique set of criteria.

Mother Dairy has adopted 'MWS Solar Field', a collection of CST units based on two-axis tracking paraboloid dishes, designed, engineered and supplied by Megawatt Solutions Pvt. Ltd. (MWS). The system consists of 16 solar thermal paraboloid dishes M95, each of 95 m^2 area for generating peak 30 lakh kcal/day in the form of hot water per day at up to 95°C. This is one of the largest solar thermal projects for the industrial process heating application the with total solar field collector area of 1520 m^2.

The system is unique in that MWS solar field system incorporates one of the largest thermal storage systems (Figure 2). The energy in form of hot water is stored in insulated thermal storage tanks of the cumulative peak capacity of 1,00,000 L so as to utilize it anytime as per the process requirement. Such a configuration allows 'delinking' generation and consumption of thermal energy. Movement of dishes is completely automated as per the industrial standard for such a mass scale industrial requirement, and the system is working seamlessly since commissioning. System performance is regularly monitored.

Details of installations are given in the following table:

S. No.	Parameter	Description
1	Project site	Patparganj, Delhi
2	Commissioning date	October 2016
3	Peak rating	Up to 30 lakh kcal/day at peak DNI of 5 kWh/m^2/day
4	Application	Process water for reduction of steam and PNG
5	Solar field size	1520 m^2
6	Solar field configuration	16 numbers of M95 dishes in parallel configuration
7	Solar dishes tracking	Two-axis solar tracking with full automation
8	Overall system operations	PLC/SCADA with remote access

System Performance

The performance of the system since commissioning is continuously monitored on a remote monitoring system and is accessed on daily basis by Mother Dairy. The system has made a significant impact in terms of fuel displacement and emissions displacement. The comprehensive maintenance contract adopted by Mother Dairy ensures the maximum uptime of the

MWS Solar Field and the maximum solar energy yield. The project has become a benchmark in the dairy industry and has created a sense of acceptability for CST in dairy industries, and now many other dairies across India have come forward to adopt it to save fuel and reduce carbon footprint. Mother Dairy is monitoring savings from the project on a day-to-day basis and is very much satisfied with the technology, delivering hot water at high temperature and meeting the requirements. Dairy now plans to replicate the same technology in their other plants to meet the needs.

Project supported by UNIDO

Low Specific Cost Concentrating Solar Dish System

Developed by Solwedish Solar Private Limited

The abundant solar radiation, clean character of solar energy, high cost of fossil fuels and negative emission consequences of fossil fuel consumption along with large requirements for process heat below 250°C are the key drivers of the strong focus on the development of solar thermal applications. The solar water heating industry in India is fairly well developed and is already on an accelerated growth path. The use of solar concentrators to meet the process heat requirement of industries is an emerging and exciting market opportunity in India.

Concentrating Solar Power (CSP) systems are one of the best sources for exploiting solar energy.

- Solwedish is a Low Specific Cost Solar dish concentrator system (dish) comprises of the concentrator (reflector), receiver (absorber), heat transfer media/storage and conversion/transmission of thermal energy with a dual-axis tracking system.
- The system acts as a source of thermal energy for industrial process heat requirements like Vapor absorption refrigeration system, milk processing, sugar industries, agro industries, chemical processing plants, thermic fluid heating in various industries, boiler make-up water and feed-water heating, metallurgy industries, hospitals, hotels and many more.
- In spite of all the advantages of the dish systems, we are not finding any of its applications around us. The main barrier is the cost involved in making the dish. The rise in the costs is because of that as the size of the dish increases, and then the wind loads (the strongest enemy for the concentrator systems) will be too.
- The major unique feature of the dish is its light weight structure and therefore low cost, thanks to go with the wind approach and ground hugging design. All this is achieved without any compromise in the performance. That supports why the project name is titled as Low specific cost dish system but not low cost system.
- Each Solwedish 550 dish system is in 24m width and 24m length with an aperture area of 576 m^2 and saves 250 Litre of diesel per day.

Feature 2

PERFORMANCE IMPROVEMENT OF 125 MW CSP SOLAR THERMAL POWER PLANT OF RELIANCE POWER, DHURSAR, RAJASTHAN, INDIA

Hem Raj Sharma[1], C Suresh Kumar[2], Shinu M Varghese[3] and Jino J Prakash[4]

Background

Rajasthan Sun Technique Energy Pvt. Ltd. (RSTEPL), a subsidiary of Reliance Power Limited, had installed a 125 MW CSP solar thermal power plant at Dhursar, Rajasthan, India based on the CLFR technology (Figure 1). This plant has been in commercial operation since November 2014. M/s AREVA Solar, a French Company was the CLFR technology provider of this plant. It worked as an EPC contractor of solar field under Reliance Infrastructure Limited. Reliance Infrastructure Limited, in turn, was an EPC contractor of RSTEPL for the project. Solar fields with 35 solar steam generators (SSGs) are designed to generate direct superheated steam. This SSG configuration is different from the configuration of AREVA's Kimberlina Solar Thermal Power Plant located in Bakersfield, CA, USA.

After erection, testing, commissioning and commercial operation, the plant faced technical and operational challenges related to LFR components and control systems for smooth operations and target energy generation. After the exit of M/s AREVA from this project and from CSP business globally, it was a big concern and challenge for RSTEPL to operate the plant and produce the desired load and PLF. Reliance Power took it as a challenge and converted it into an opportunity by understanding and analysing the basics of the technology and operation. Reliance Power engaged various consultants but did not realize the expected improvement in generation. Then Empereal-KGDS Renewable Energy Pvt. Ltd. was engaged as a third-party technology consultant to improve the performance and achieve reliable operation.

This solar thermal plant has a total mirror area of 1, 400, 000 m^2 and consists of 35 SSGs. Each SSG is 540 m long and has 33 mirrors, each having a width of 2.25 m. The receiver is 30 m above the plane of the mirrors. Nine receiver tubes are in the cavity. Eight tubes, called economizer-cum-evaporator tubes, travel from one end of the receiver to the other. The fluid carried by these eight tubes passes through a header at the end of the receiver and travels back the entire length of the receiver through a central tube called the superheater tube. In this once-through

Figure 1: A view of the Reliance 125 MW solar thermal power plant in Dhursar, Rajasthan, India

[1]Station Director, Dhirubhai Ambani Solar Park
[2]Empereal-KGDS Renewable Energy Pvt. Ltd.
[3]Empereal-KGDS Renewable Energy Pvt. Ltd.
[4]Empereal-KGDS Renewable Energy Pvt. Ltd.

boiler, water enters at one end at around 70–150°C. The design outlet condition out of the superheater tube is superheated steam at 390°C and 90 bar pressure. The turbine requires 568 tonne/h of steam of this quality to produce 125 MW.

Original control logic used by OEM distributes flow through each of the eight economizer tubes in the receiver by measuring the temperature at five different points along its length. Five RTDs were installed in each tube, resulting in a total of 40 RTDs for eight tubes. There were also eight RTDs for the superheater tube. There was no direct measurement of flow through individual tubes. Instead, it was calculated as a function of the total mass flow rate and control valve opening position of each tube. Wherever temperature rise is higher than a certain value, the automated valve controls will send more flow through that tube. The control logic was exercised every 15 or 30s. The intention was to distribute the flow rate according to the heat flux falling on that tube.

When even 1 out of 40 RTDs failed or had an error (it is difficult to conclude from the data whether there is definitely an error), over-heating or under-heating was possible. This, in turn, would result in the tubes bending due to thermal elongation. Complete control failure was a possibility, resulting in shutting down of the plant.

The feedback loop of global mass flow control to maintain exit temperature was based on thermal calculations and hence could be performed once steady state was achieved. This resulted in failure of control system to respond effectively and in right direction during transient weather or operating conditions. It was also required to optimize the initial filling of boiler during start-up to achieve quick superheat without causing starvation, tube expansion and possible tube bending.

Figure 2: *Reliance CLFR plant during operation at Dhursar*

Major performance improvement by an advanced control system

Reliance engaged Empereal-KGDS with the task of devising methods to produce 125 MW of power (Figure 2). This article describes how the control logic of the plant was completely re-engineered in order to bring about a design power output of 125 MW and in a stable manner. A well-coordinated detailed analysis, empirical database, development and implementation by the Reliance team and Empereal-KGDS team resulted in a substantial improvement in plant performance.

After a year-long analysis and field exploration, Empereal-KGDS arrived at a set of controls and operation philosophy for achieving required steam parameters for turbine throughout the day to capture available solar energy. There were also other responsibilities, such as avoiding RTD failures and the overheating and bending of absorber tubes.

The investigation concluded that using direct measurement of parameters and control based on those was an effective way for stable controls and plant operation. One objective was to minimize off-tracking, which is the act of not focusing primary reflectors in the cavity receiver under certain conditions. For example, off-tracking is used to avoid economizer tube overheating, a restriction imposed by tube metal temperature. Achieving a degree of superheat in steam as early as possible during morning start-up of SSG is very important for early synchronization and more generation of electrical energy. Reliance Power Limited team with its extensive technical and operational knowledge and experience provided suitable guidance for development of new control laws and logic as described next.

Various considerations driving the modified control

1. Global mass flow control

The outlet temperature of each SSG is controlled using input flow rate control and thermal tracking control. Higher outlet temperature can be achieved with lower input flow rate. But, lowering the flow rate to less than the optimum flow rate will cause higher off-tracking. Therefore, controlling the input feed water flow rate is optimized in line of available solar irradiance to get optimum flow of steam on desired parameters.

2. Parallel flow distribution

Each of the eight parallel tubes in each of the 35 SSGs has non-uniform heat flux across the length.

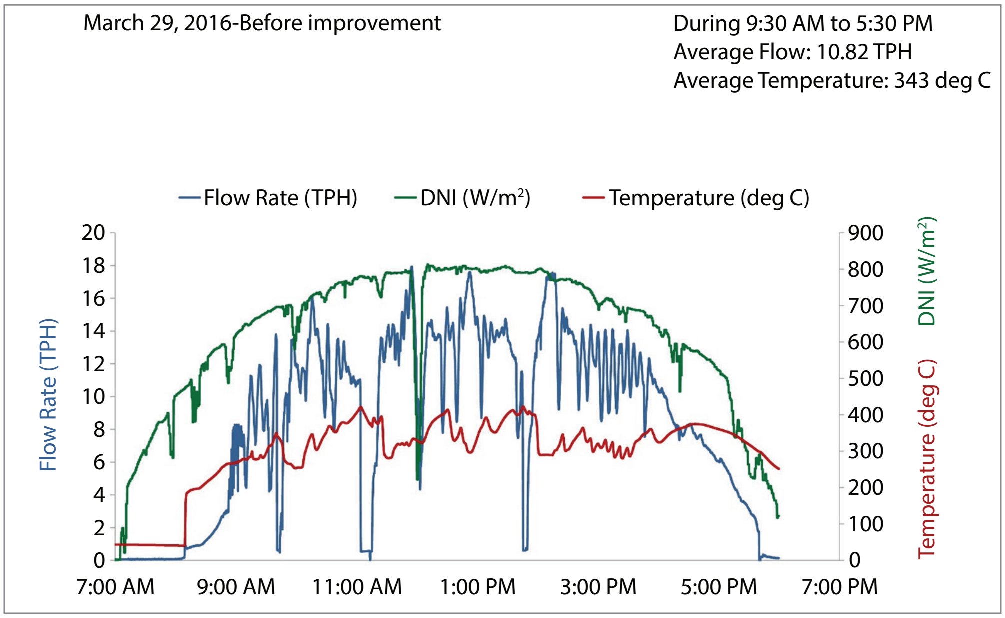


Figure 3: *DNI, flow rate and superheated steam temperature in the SSG before modification on 29 March 2016*

The global feed water flow has to be distributed according to the total heat flux in each tube, which is termed as tube balancing. In the previous control logic, tube balancing was based on the metal temperature feedback using RTDs and valve position control. Tube balancing was found to work better in some SSGs where RTDs showed good values. There were 32 RTDs used for tube balancing, out of which 24 RTDs were critical. If any of the consecutive RTDs in any tube failed (abnormal values) or if any RTD showed erroneous values and there was difficulty in judging the values, it would lead to improper tube balancing and reduced performance of the entire SSG. So an improvised method was developed to avoid RTD-based feedback and uniform tube balancing.

3. Start-up sequence algorithm with modification in inventory and tracking control

SSG start-up time depends upon the amount of inventory (amount of fluid mass inside the boiler tubes) and overall tracking percentage. The start-up time increases with higher inventory. But with reduced inventory, there would be a higher rate of increase in metal temperature and subsequent off-tracking, which result in further delay to achieve superheat. So an optimum level of inventory had to be provided to SSG based on the available DNI conditions for the proper start-up. The amount of inventory required depends upon target flow and time taken for the fluid to reach the farther end of the receiver. Proper inventory should prevent dry out conditions and heat transfer rate in the farthest end. 100% track power would be given from start-up with flow rate adjusted according to the DNI and sun angle. If tube expansion occurs due to low inventory, SSG is off-tracked and required inventory is established by the control.

4. Thermal tracking control

In the previous thermal tracking control, there was very frequent off-tracking in order to comply with design temperature gradient of superheater tube. Continuous off-tracking of all the segments was observed frequently. With the present control, an overall tracking loss of less than 6% is achieved, which was earlier more than 17%.

Modified control logic implementation, testing and validation

To test the modified control system, one of the 35 SSGs was designated as prototype for testing. The first step was to install mass flow transmitters and differential pressure transmitters between the inlet and the outlet in each of the eight tubes. Mass flow transmitters were required to find out the correct amount of flow in eight tubes of the receiver and differential pressure sensors were to give the feedback for heat flux distribution in each tube so

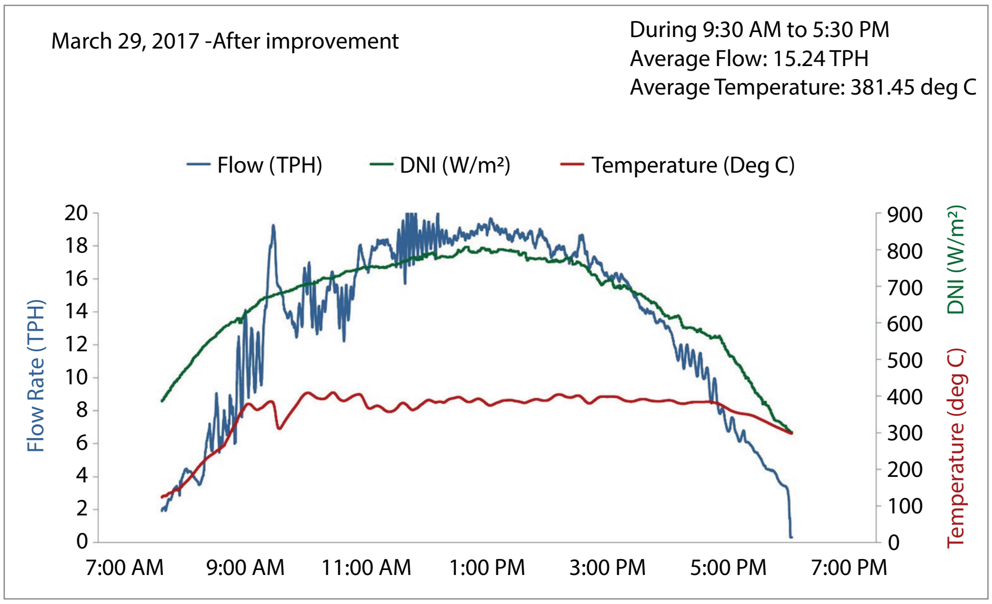


Figure 4: *DNI, flow rate and superheated steam temperature of the modified SSG on 29 March 2017, exactly one year later*

that perfect tube balancing could be performed. This avoided the major problem of RTD-based feedback and impact of RTD failures. The modified control algorithm worked well and the selected SSG showed significant and clear improvement in superheated steam production and also in the degree of superheat. Based on this encouraging result, it was decided by the leadership of the plant operation to modify all 35 SSGs. The resulting plant performance improvement was outstanding as shown in Figures 3 and 4.

One can observe that the two days selected for comparison were exactly one year apart, resulting in similar solar radiation levels. With the modified controls, the amount of steam produced is much higher and the degree of superheat is also higher. Also, the output steam temperature remains at a fairly constant level throughout the day.

After implementing the new control philosophy in all 35 SSGs, there has been a significant improvement in synchronization time and electricity production as shown in the table below.

	October 2016	October 2017
Synchronization time	10:37 AM	9:41 AM
De-synchronization time	5:15 PM	5:32 PM
% Increase in gross kWh/day	56.6%	
% Increase in net kWh/day	62.6%	

It took extensive scientific and technical analyses, discussions, understanding, as well as constructive and constant exchange of ideas between Reliance Power Limited and Empereal-KGDS, to produce these outstanding results. Design and execution of control system logic are very important to ensure successful performance and operation of an LFR based CSP plant.

DEVELOPMENT OF CONCENTRATED SOLAR THERMAL SYSTEMS IN WASTEWATER EVAPORATION AND SLUDGE DRYING

Prakash Bhalekar*

The QuadSun Concentrated Solar Thermal Parabolic Dish is the world's most efficient, smallest – 4.4m^2, easy to install, operate and maintain CST system. Testing at the National Institute of Solar Energy has results of 80% optical efficiency and an a1 loss coefficient of 0.25. This performance has also been demonstrated at several fields in the past few years. This level of performance is a result of design and manufacturing breakthroughs.

Figure 1: *CST for water evaporation*

High performance

The dish achieves a concentration ratio of 700x. This has been made possible by factory-curved mirrors which allow precise control of the mirror shape as opposed to approximate parabolas made by flat mirror arrangements. The mirror is also solar grade with a patented edge protection made by a world leader in the field.

The high concentration ratio requires very precise tracking which is achieved by the use of photosensitive devices which keep the focus on the sun with 0.01 degree accuracy.

The high concentration requires a very efficient receiver that will uniformly transfer heat from the receiver to the working fluid. The QuadSun receiver is a simple die cast aluminum piece thin film annular heat exchanger that even at high concentration does not get very hot.

Easy-to-install and Operate

The dish is also very easy to assemble in the field. No special equipment and special processes are required. QuadSun has a factory build foundation, which can greatly reduce time at site. The building of the dish requires on bolt tightening and a few fixtures to assure the geometry of the dish. This allows us to build dishes on all kinds of roofs, structures and elevations. We have installed dishes clamped to terrace columns, on steel structures on concrete roofs, in ponds.

Remote monitoring and Control

The QuadSun dish can be remotely monitored and controlled. All heat generation, temperatures are logged and reported so users can see the performance from anywhere in the world (Figure 2).

The increase in the field piping is a disadvantage of small systems; but QuadSun has developed a proprietary low-cost insulation system that allows a factory built plumbing approach and reduces cost and field work substantially.

QuadSun intelligent evaporator

QuadSun evaporators use artificial intelligence to control and enhance the phenomena of natural evaporation and allow effluents to be evaporated to salt.

Natural evaporation is complex, nonlinear phenomena of heat and mass transfer that depends on air temperature, effluent temperature, wind speed and

*QuadSun Solar Pvt. Ltd.

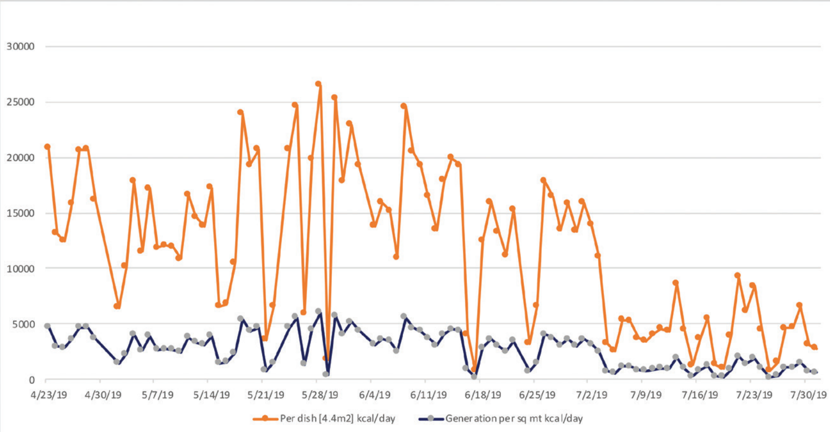


Figure 2: *Generation of heat*

relative humidity. The evaporation of water causes the surface water to decrease and this reduces evaporation rates. Also as the air picks up moisture and cools, the RH increases and also reduces evaporation rate. Thus, to continue evaporation we need heat to keep water surface hot and a wind to keep the surface air RH low. QuadSun studied this phenomenon extensively and has developed an algorithm to operate our evaporator with the lowest energy in the world.

The principle of the QuadSun intelligent evaporator is similar to drying floors after swabbing. A thin film of effluent is created and over this thin film, a high-speed wind is blown, resulting in rapid drying. QuadSun has an arrangement of several specially designed pans that are injected with high pressure effluent and dried. The quantity of injection, speed of the fan, and other parameters are optimized using artificial intelligence and the fresh information collected is used continuously to improve performance using machine learning techniques.

The construction of the evaporator is mostly plastic and because it does not operate at very high pressures and temperatures, it is extremely simple to operate and maintain.

The device can be used both to concentrate effluents as well as to dry salt.

QuadSun has integrated the CST dish with the intelligent evaporator to be able to deliver effluent to salt at prices between 10 and 20 PS per litre depending on the season and location.

QuadSun offers to operate and maintain the plant on behalf of customers and guarantee operating costs.

Sludge drying

Sludge that comes out of a filter press is 60 – 75% water. Disposing this sludge to a landfill means paying a high price to dispose water. Therefore, the sludge is dried in open areas to reduce water content and thus disposal cost.

QuadSun has a well-designed open pit drying system that can accelerate drying by 25 – 30% by using hot water from the solar dishes to heat the sludge.

Paint sludge is a more hazardous product and QS has specially designed boxes that dry it. The sludge dryer combines heat and air flow to accelerate the drying of sludge.

Commercialization of innovations

The QuadSun CST solution is slowly taking root as a means to reduce the use of fossil fuels for heating. In our projects we have provided strong economic benefits to reduce of LPG, diesel, propane and electricity. Coupled with the subsidy from MNRE, customers expect a 3–4 year payback period in most places in India.

The QuadSun evaporator saves even more and the return is within two years for most cases even when using biomass or coal with competing technologies such as Multi Effect Evaporation (MEE) and Agitated Thin Film Dryer (ATFD) combinations.

The list of applications continues to grow and include cooking steam and hot water, paint shop water heating, plating, food drying, domestic hot water in hospitals and hotels, sludge drying, evaporation, boiler pre feed, etc.

Make in India

The CST dishes and evaporator designs are protected by patents and manufactured in India. The assembly lines for the gearbox and electronics are world class and continuously upgraded to improve quality and cost. The latest generation of the QuadSun CST will have significantly improved tracking capabilities, higher wind speed survivability and higher optical efficiency and lower a1 losses.

Quadsun is now also developing markets in Europe, Korea, Japan and the USA. We have commercial installation in Spain and pilots in several other countries.

LEATHER INDUSTRY USING CONCENTRATING SOLAR THERMAL SYSTEM FOR DYE APPLICATION

Jaiprakash Karna*

Industrial development and improved living standards have resulted in a quantum jump in energy demand. The current global energy consumption is 180 trillion kWh/year, which is mostly met by fossil fuels. In order to protect the environment, major national and international institutions are working with the industry to develop and promote concentrated solar thermal (CST) systems for industrial and commercial applications to replace fossil fuel-based systems. The high-efficiency, non-tracking CST system installed at KH Exports in Tamil Nadu is an excellent example of successful implementation of this green initiative in industry (Figure 1).

While domestic solar water heaters may cater to low-temperature applications, higher temperatures for industrial applications need concentrating the solar irradiance. This concentration may be achieved with other CST systems, but it has its limitations of low efficiency, high maintenance costs and failure to operate under cloudy conditions. Research at the Merced facility of the University of California, led by Prof. Roland Winston, Father of Non-imaging Optics, has led to the development of the high-efficiency, non-tracking cross compound parabolic concentrator (XCPC) that accepts diffuse radiation under cloudy conditions.

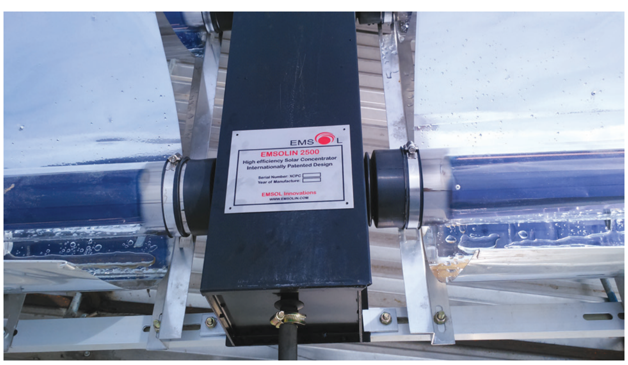


Figure 1: *Cross compound parabolic concentrator (US Patent): (www.emsolin.com)*

Technology Innovation

XCPC technology branded EMSOLIN is licensed to EMSOL Innovations (Figure 2). EMSOL Innovations Pvt. Ltd. is empanelled as a CST manufacturer of MNRE. A significant part of the EMSOLIN System is manufactured in India. EMSOL Innovations is a proud partner of the 'Make-in-India' campaign.

The technology is highly efficient and it is easy to integrate with the conventional boiler without interruption to the regular plant operation. The system requires less space with a low footprint area to produce approximately 2.5 kWh/m^2/day.

The principal advantages of the XCPC-based CST system for users of the EMSOLIN system are as follows:

- Custom designed engineering solutions
- Non-tracking system – no special skills required by the user
- No moving or wear parts – maintenance free system with no operating costs
- Minimal specific load – installed dead weight is under 20 kg/m^2
- Modular system – extra collector can be added as desired without interruption

Solar System Solution

KH Exports, Tamil Nadu is a leading leather goods manufacturer and exporter with state-of-the-art manufacturing and design facilities. The company manufactures and exports a range of leather goods for prestigious global brands. Additionally, the company is an accredited member of SAC (Sustainable Apparel Coalition, USA) and LWG (Leather Working Group, UK).

As a part of its CSR commitment, KH Group decided to replace briquette fired boilers at their

*EMSOL Innovations

Figure 2: *XCPC-based CST system*

plants by a CST system. After comparative evaluations of the technology, EMSOL Innovations was invited to develop a suitable CST system that would:

- Heat the permeate to the required process temperatures
- Fit within the limited space available for installation
- Integrate seamlessly in the current process without undue interruptions
- Have minimal operating and maintenance expenses
- Require no specialized skills to operate
- Demonstrate a measurable reduction in carbon emissions and footprint

Key Issues and Challenges

A detailed study by the KH technical team found the average available solar irradiance at the site to be 6 kWh/m^2/day from 7:30 a.m. to 6:30 p.m. The following data were obtained from the project:

- Corrugated metal roof of limited space was available at each plant.
- Two plants (KH and ATH) were using 25,000 L/day of permeate heated from 30°C to 65°C.
- A sample drum unit was using about 5000 L/day of permeate as above.
- Incoming permeate temperature varied from 28°C to 40°C.
- Flow rate in litres/hour varied over the working time from 8:00 to 16:30 hours.

Based on these data, the following key design parameters for the system were obtained:

1. Thermal load at each site was 1000 kWh/day.
2. Array size required with a conversion efficiency of 65% was 256 m^2.
3. Site coordinates were 12.95N and 79.32E. Design angulation was 23%.
4. Space required per site was 350 m^2. Floor load was less than 20 kg/m^2.

The EMSOL has designed and installed the high-efficiency XCPC-based system at KH Exports for dying process in the plant at Ranipet. The system was commissioned without any interruption in the plant working and it has been operating successfully since January 2018. The thermal requirements of units are 150 kWth at each plant and 30 kWth at the sample drum.

The solar system was designed to run effectively from 8:30 a.m. to 4:30 p.m. at Ranipet based on the geographical conditions. The average operating time was 7–8 h during the availability of sunshine.

At each unit of KG Export, 60 CPCs with 256 m^2 of the collector area are installed on the corrugated metal roof of limited space. Solar collector array consists of series and parallel connections of three different rows, each of 18, 21 and 21 collectors with an expansion tank, pump, and other accessories, such as pressure and air release valve, pressure balancing valve, and so on.

The cold-water line passes to collectors for process of leather dying, where the incoming permeate water is at the temperature range of 28–40°C and further it is heated up to 65°C through CST system (Figure 3). The organisation saves more than 0.6 tonne/day of fossil fuels and there is reduction in GHG emissions of 0.6 tonne of CO_2 per day.

KH Exports have been awarded a Gold rating by the LWG for this initiative that has reduced the carbon footprint by more than 180 tonne/year at each site. These benefits would multiply on carbon credits becoming internationally tradable.

Economics

The Project cost was around 70 lakhs per main Plant. There are 60 of XCPC with 256 m^2 collector area. As per the estimate calculated, the CST system will provide annual saving of 219 tonne of fossil fuels for 365 working days.

Key advantages of the solar thermal system are as follows:

- Seamless integration with the existing boiler in operation
- Maximum hot water temperature attained and the use of fossil fuels mitigated substantially
- Non-tracking maintenance free system with optimal capture of GHI & DNI.

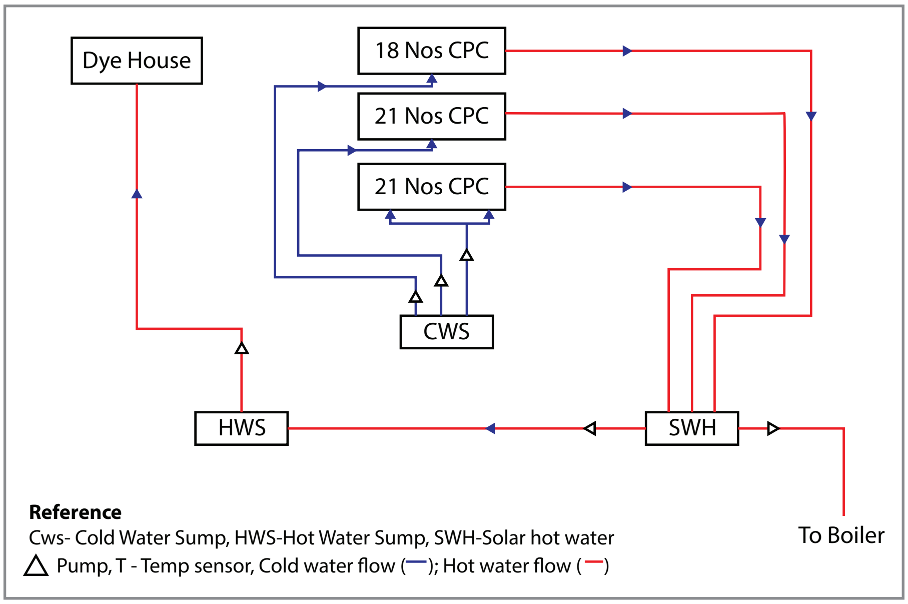


***Figure 3**: Schematic of dying process with CST integration*

» Evacuated tubes with three layers of solar selective coating with air maximum absorption of solar radiation by reducing thermal losses.

EMSOLIN installations are consistently successful in various applications across the world. Installations in India include the leather, textile, mining and effluent treatment industries.

The system is ideally suited for high-temperature industrial applications. Absorber evacuation is at temperatures above 500°C and the system is tested for stagnation temperatures up to 350°C. The high temperatures make EMSOLIN the ideal CST system for industrial drying processes. Successfully demonstrated drying processes include drying of lignite and RDF. The EMSOLIN system can also deliver low pressure steam (up to 4.5 bar pressure) directly from room temperature water. Such an installation is under progress at the Ranitec CETP. This is an MNRE-GEF-UNIDO Project with an IRDE loan. XCPC-based CST system is an ideal system for boiler support: to preheat the feed water or to provide low pressure steam during sunlight hours.

Conclusion

In the first system at Ranipet, Tamil Nadu, India's first XCPC-based process heating application for dying purpose was installed. The system has been designed by EMSOL Innovation to reduce the fossil fuel consumption in leather industry. The system has been performing satisfactorily and yielding hot water continuously at the required temperature of 60–75°C during the day as per the process requirement. The control mechanism helps the hot water generator seamlessly adjust its capacity in line with solar output. The system has been operating smoothly and delivering expected results as per the design and mitigating carbon emissions, while contributing to substantial fuel saving. We believe this system is unique and well integrated within the existing system setting a standard for waste water treatment applications in India.

PROMOTION OF CONCENTRATING SOLAR THERMAL TECHNOLOGIES FOR INDUSTRIAL, INSTITUTIONAL AND COMMERCIAL SECTORS IN INDIA

J. K. Jethani[1] & Arvindh MA[2]

The Government had launched the Jawaharlal Nehru National Solar Mission (JNNSM), which is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The aim of the mission is to focus on setting up an enabling environment for solar technology penetration in the country both at centralized and decentralized level.

The Ministry of New and Renewable Energy is implementing a programme on solar thermal aimed at peak shaving, conservation of electricity and fossil fuels and providing a clean, non-polluting solution to meet the process heat requirement in community, commercial and industrial sectors. Various promotional incentives in the form of Central Finance Assistance (CFA) are available for concentrating solar thermal projects under the JNNSM.

The first and second phase (up to March 2017) having achieved the required target and momentum, solar thermal component of JNNSM in balance period (up to March 2022) will now, inter alia, require focus on promoting off-grid systems, including hybrid systems to meet/ supplement heating and cooling energy requirements and power. These systems still require interventions and support to bring down costs and an enabling framework for entrepreneurs to further develop markets to reach sustainable proportions.

India is endowed with a vast solar energy potential. About 5,000 trillion kWh per year of solar energy is incident over India's land area, with nearly all of India receiving an average sunshine hours of 5 – 7kWh/m^2/day. The abundant solar radiation, clean character of solar energy, high cost of fossil fuels and negative emission consequences, along with large requirements for process heat below 250°C are the key drivers of the strong focus on the development of solar thermal applications in India. The use of solar concentrator to meet the process heat requirement of community, industrial and commercial establishments is an emerging and exciting market opportunity in India. The heat requirement is met by burning conventional fuels such as coal, furnace oil, natural gas and electricity. Use of solar concentrator technology integrated with system process heat demand can help replace / reduce conventional fuels which in turn will help reduce GHG emissions.

This article discusses the salient features of the MNRE programme for promotion of concentrating solar thermal projects in India.

Implementation through Channel Partners/ Manufactures/New Entrepreneurs

To improve the market reach and to accelerate the pace of implementation under the first and second phase of JNNSM, the Off-Grid Solar Scheme of the programme has been implemented through approved channel partners/manufactures/new entrepreneurs. These partners include the following categories:

- Renewable Energy Service Providing Companies (RESCOs)
- Financial Institutions including microfinance institutions acting as aggregators
- Financial Integrators

[1]Director, Ministry of New and Renewable Energy Government of India
[2]Scientist B, Ministry of New and Renewable Energy Government of India

» System Integrators
» Programme Administrators

The pattern of the subsidy scheme extended till March 2020 are as follows:

Funding Patterns

The funding pattern for the CST projects is as follow:

» 30% of the benchmark cost or actual cost whichever is less to all beneficiaries in all states
» 60% of the benchmark cost or actual cost whichever is less to non-profit making bodies and institutions in special category states, viz., N-E states, Sikkim, J&K, Himachal Pradesh, Uttarakhand and islands.
» There will be no upper cap on the subsidy to be provided on CST based systems. The pattern of subsidy as above will be continued up to March 2020 after that, it will be reduced to 20% and 40% respectively.
» The subsidy will be released to implementing agencies / channel partners / beneficiaries on reimbursement basis after successful commission of the project and on receipt of project commission report along with performance for 3-month, audited statement of expenditure and other relevant documents.
» Subsidy released on reimbursement basis after complete installation, commissioning and inspection of the system.
» In addition to above, there will be a 40% accelerated depreciation (AD) benefits.

The other financial support in terms of UNIDO-IREDA soft loan scheme for CST projects is also available under the MNRE-GEF-UNIDO project.

The scheme's primary objective was to accelerate commercialization of solar heating and cooling technologies in India; however, it has the following objectives:

» Promotion of investment in renewable energy technologies by transforming the Indian market through investment.
» Development of required financial instruments for CST technologies.
» Development of technical specifications, market demonstration and capacity building in CST sector.
» Favourable policy and regulatory environment to promote local manufacturing.

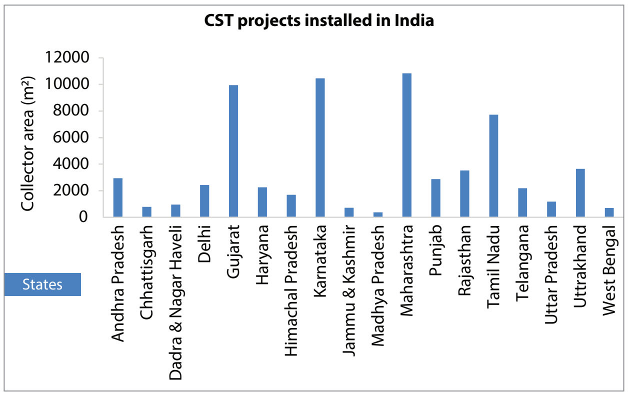


Figure 1*: State-wise installation of CST projects (more than 500m² collector area)*

Subsidy and benchmark costs

The capital subsidy per unit collector area, as given above, is based on 30% of the benchmark costs, which would be reviewed annually. Capital subsidy would be computed based on the applicable type of solar collector multiplied by the collector area involved in a given solar thermal application or project.

Table 1: Financial support for CSTs

Solar Collector Type	CFA (Rs/m²)	Benchmark Cost (Rs/m²)
Concentrator with manual tracking (dish solar cookers)	2,100	7,000
Solar collector systems for direct heating and drying and non-imaging/ Compound Parabolic Concentrators (NIC/CPC)	3,600	12,000
CSTs with single axis tracking (including Scheffler dish)	4,500	15,000
CSTs with single axis tracking, solar grade mirror, reflector and evacuated tube collectors	5,400	18,000
CST based on double axis tracking	6,000	20,000

The first two phases of JNNSM is over, and the third phase is awaiting approval and continuation. In the meantime, the Ministry has allotted funds received from the National Clean Energy Fund (NCEF) for implementation of CST based systems in institutional and commercial establishments for process heat, community cooking and cooling applications, under the Off-Grid Solar Thermal Programme for the financial years

2017 – 18 and 2019 – 20 along with an approximated annual target allocation of 20,000 m^2, 30,000m^2 and 40,000m^2 with total 90,000 m^2 collector area respectively.

Approval mechanism for selection of projects:

» All the channel partners will submit proposals in the prescribed formats along with a commitment for meeting the balance cost of the project other than the CFA to MNRE directly .

» For being eligible to receive subsidy from MNRE, the project should have been approved by the Ministry before implementing the projects. Projects which are started before sanctioning will not be eligible for the subsidy.

» The project will have to be completed within 12 to 18 months from the date of sanction depending on the size of the project. Non-completion of the projects within the sanctioned time might attract reduction or forfeiture of eligible subsidy from MNRE, unless approval for extension is taken in advance due to some unavoidable circumstances, beyond the control of the beneficiary.

» Mirrors of solar grade quality will be made mandatory for CST based systems.

» Proposals of state nodal agencies, Solar Energy Corporation of India (SECI),Indian Renewable Energy Development Agency Ltd. (IREDA) and other government agencies, NHB and PSUs will be directly processed by the division.

» 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 identify the beneficiaries.

Status of the CST projects installed in various applications in India

The total projects installed with the support from the Ministry are 65,436 m^2 of collector area. Out of these 244 projects, 153 projects with 29,986 m^2 collector area were installed for community cooking, 61 of 24,207 m^2 for process heat, 13 with 8,828 m^2 for cooling application and 17 projects of 2,416 m^2 for other applications.

The state-wise installations of CST projects used in different applications are shown in the Figures 1 and 2:

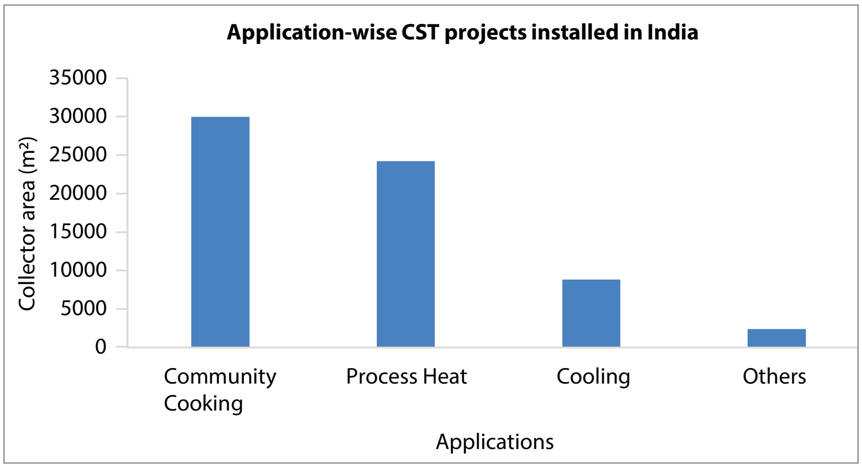


Figure 2: *Application-wise CST system installed in India*

Quality Control

The project is executed to the fullest satisfaction of the client. After commissioning, a third-party inspection called the joint inspection is conducted. This involves representatives of Regional Test Centers (RTCs)/ state nodal agencies/third party, the manufacturer/ suppliers/installer and the beneficiary.

POTENTIAL FOR IMPLEMENTATION OF CSTs IN INDIA'S INDUSTRIAL SECTORS

Anil Misra*

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 ₹ 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. This section provides an estimation of the potential of this sector for application of the CSTs.

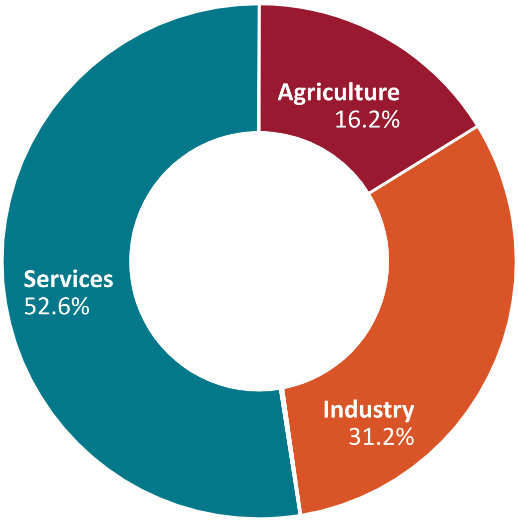


Figure 1: *GDP – Composition by sector (2017–18)*

Energy Consumption details of India's Industrial Sector

As depicted in Figure 1, India's industrial sector consumes over 50% of India's energy, with the dominant energy consuming sectors being 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 analyzed 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 National Industrial Classification (NIC), 2008 into 25 sectors.

As per the data available, coal and its derivatives account for more than 50% of the energy consumed. In terms of the Total Energy Consumption of Industries 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% (Figure 2).

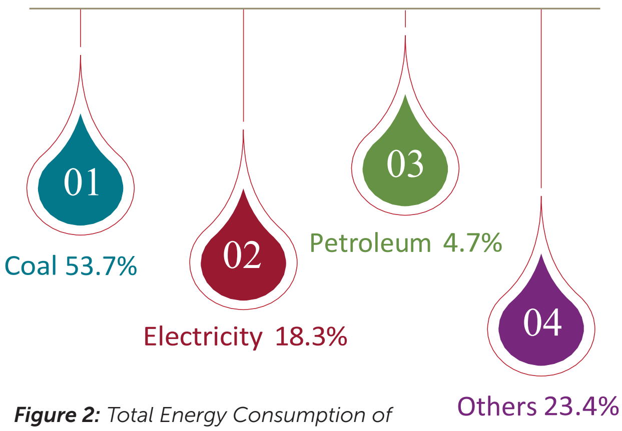


Figure 2: *Total Energy Consumption of Industries*

*NPM, UNIDO

Energy Consumption per Industry Sector (kWh)

The summary of the total energy consumption of the 25 sectors that have been categorized as one of the 150 NIC 2008 sectors depicted in the energy balance statement of the annual survey of industries (Figure 3). The total value of the energy consumed has been estimated by the annual survey of industries for the same year as ₹ 2.98 lakh crore.

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

Process Mapping of India's Industrial Sector

In order to ascertain in which processes CSTs 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.

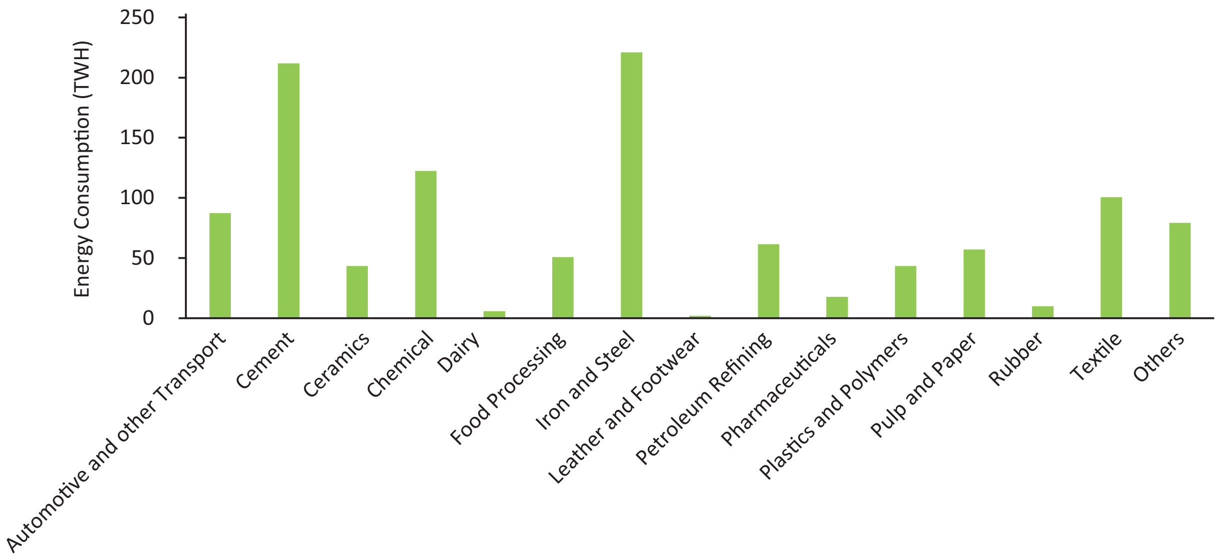


Figure 3: *Energy Consumed per Industry Sector (kWh)*

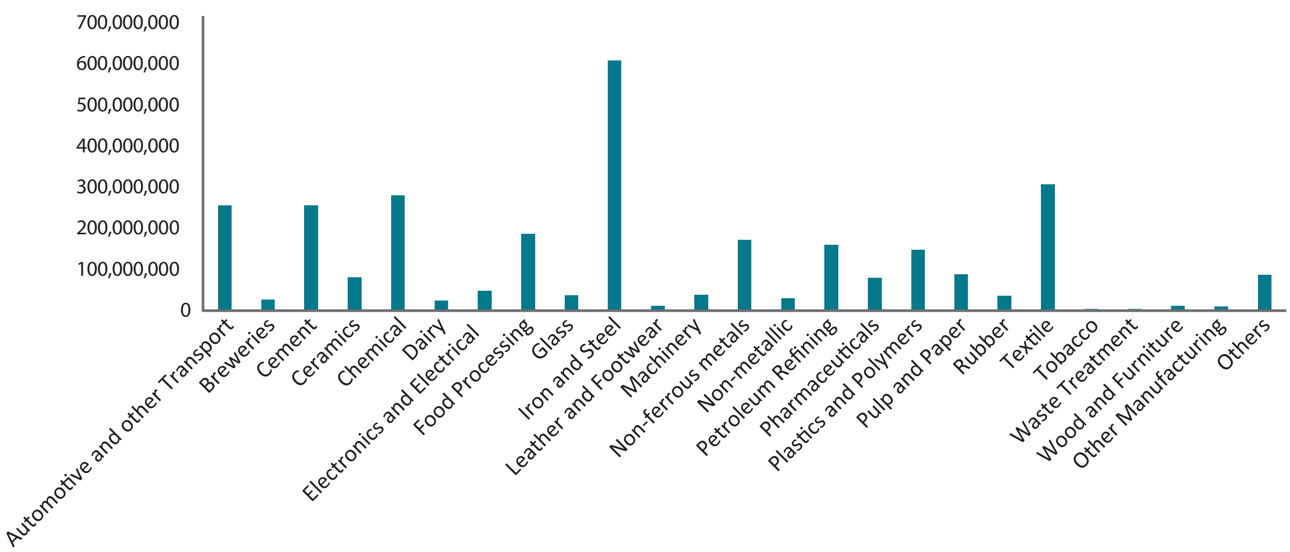


Figure 4: *Value of Energy Consumed per Industry sector ('000 INR)*

The industrial potential of CSTs across the 25 industries has been calculated individually to ascertain the overall potential of CSTs 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 CSTs has been measured across two different levels as shown in Table 1.

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 Figure 5 summarizes the overall process followed for computation and the total energy

Table 1: Measurement of the potential for CSTs

S. No.	Industry Sector	Cleaning	Drying	Evaporation	Distillation	Pasteurization	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 equipment										■
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	■	■				■				■
	Others	■	■	■	■	■	■	■	■	■	■

percentage potential that can be met viably by CSTs. 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 (individual steps have been detailed below).

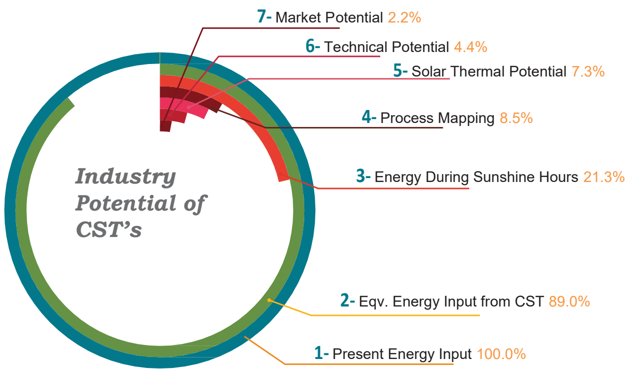


Figure 5: Total fuel consumption that is replacable by CST

Step 1: Present Energy Input

The total consumption of fuel by industries is 1,267 TWh based on the data available from the annual survey of industries 2013–14, which has been assumed as the total energy that can be replaced by solar thermal technologies and forms the initiating step of our analysis (Figure 5).

Step 2: Equivalent Energy Input from Solar Thermal Technologies

Since energy to be replaced is provided by fossil fuel sources, there is bound to be the role 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, which is predominantly coal, we have calculated the total equivalent energy required from solar thermal systems by equating their difference in efficiencies. The efficiency of the existing system for this purpose is assumed as 80%.

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

Assumption: Efficiency of existing system = 80 %

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.

Assumption: 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 the 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 Efficiency of existing system = 80% Sunshine hours in a year = 2100 particular industry (the values of these multipliers have been taken from other studies, for example, ComSolar report of GIZ on the identification of industrial sectors promising for commercialization of solar energy and based on the discussions with industry stakeholders and the experience of the project team).

Assumption: Process Mapping Multipliers for all 25 industry sectors identified above based on CSTs being able to substitute fuels only in processes belonging to a particular temperature range

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 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.

Assumption: Process Constraint Multiplier for the potential

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. It is assumed 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. The multiplier has been factored to account for only the potential of CST technologies.

Based on the analysis and six steps carried out above, the results of Step 3 will be multiplied with the process mapping multiplier and the process constraints multiplier to determine the overall technical potential of CSTs 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 CSTs across the industry.

The technical potential (Figure 6) for CSTs in industries based on the computation undertaken considering all the factors as mentioned above now comes out to be 13.18 GWth.

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%	Plastic 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%		

Technical Potential =

Potential for energy input during Sunshine hours
x Process mapping multiplier
x Process constraints multiplier
x Concentrated technologies multiplier

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.

Assumption: 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 below is for processes with a temperature between 100°C–400°C.
% of heating requirments met by CSTs from amongst below 100°C processes = 30%

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 CSTs may not have a suitable area in terms of both ground and rooftop to implement CSTs. Space availability to install the entire size of the required CST system may pose a problem.

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. An assessment of the weighted average of the fuel cost across all sources of energy per unit is required. 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 favorable 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

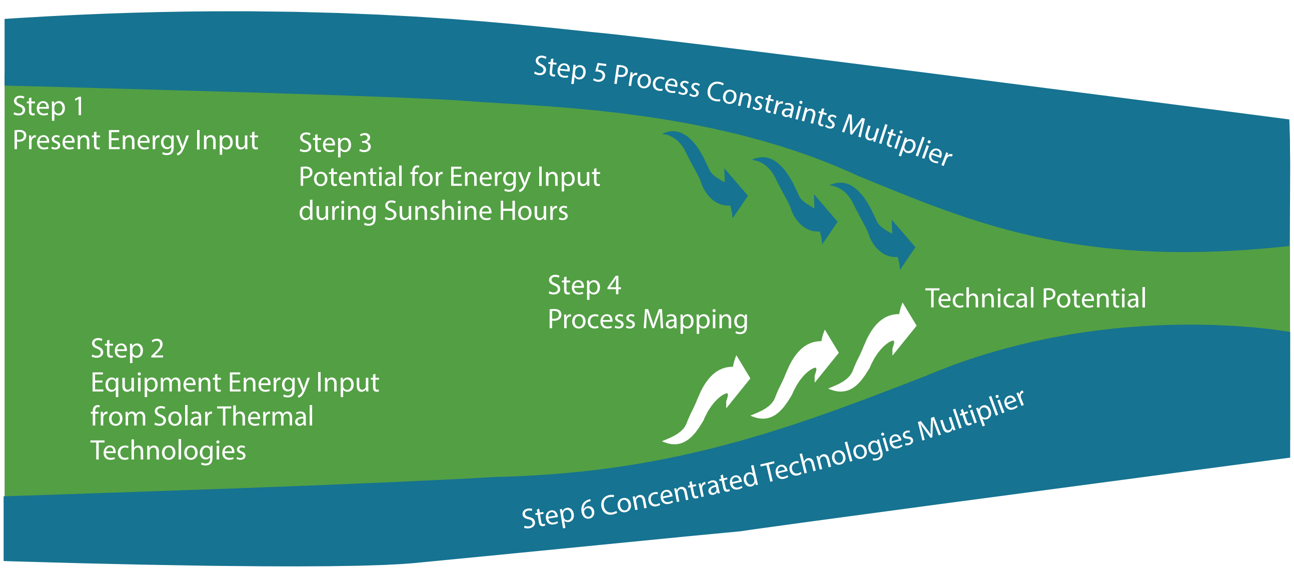
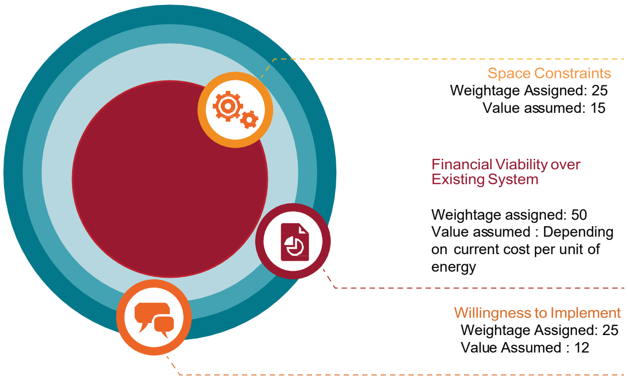


Figure 6: CST technical potential



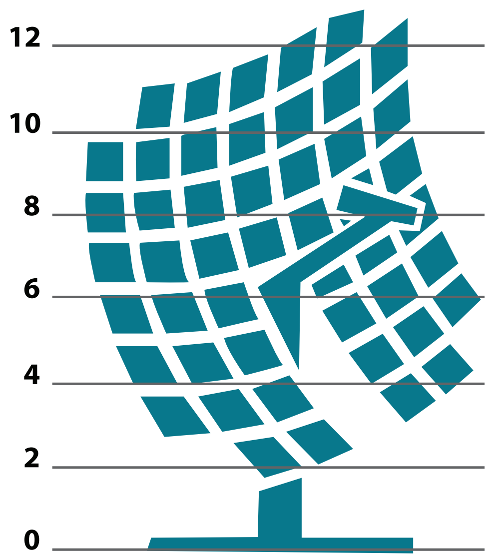
multiplied with the sector-wise technical potential to ascertain the market potential of all 25 sectors.

The total market potential of CSTs in industries has correspondingly been determined as 6.45 GWth. The technical and market potential of CSTs has been depicted below.

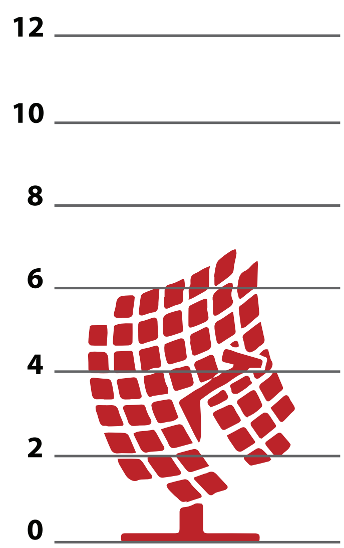
Market Potential = Technical potential x Market effect multiplier

Assumption: Based on the weighted assessment of the three factors mentioned above, the maket effect multiplier for the each of the 25 sectors was assumed as shown in the table below:

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%	Plastic 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%
Others	72%		



Technical Potential



Market Potential

FORTHCOMING EVENTS

NATIONAL

Renewable Energy India Expo
September 18–20, 2019 Greater Noida, India

Smart Asia India Expo & Summit (SA India)
October 17–19, 2019 Mumbai, India

Global RE Invest
October 31– November 02, 2019 Greater Noida, India

INTERNATIONAL NATIONAL

International Specialized Exhibition of Energy-saving Equipment and Alternative Energy Sources (ISTWE)
September 17–19, 2019 Kiev, Ukraine

AEE World Energy Expo and Conference
September 25–27, 2019 Washington DC, USA

Nexus Energy Water & (Bio) Industry
October 16, 2019 Vienna, Austria

3rd Annual CSP Focus Innovation 2019
October 24-25 Beijing, China

सत्यमेव जयते
Ministry of New & Renewable Energy
Government of India

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country. The role of the Ministry has assumed increasing significance with the growing concern for the country's energy security.

With energy self-sufficiency identified as the major driver for renewable energy in the wake of the two oil shocks of the 1970s, the Government of India established the Commission for Additional Sources of Energy in the Department of Science & Technology in March 1981, which was incorporated in 1982 in the Department of Non-conventional Energy Sources in the then Ministry of Energy; and which became the Ministry of Non-conventional Energy Sources in 1982. The Ministry was re-christened as the Ministry of New and Renewable Energy in 2006.

Global Environment Facility (GEF) is an international partnership of 183 countries, international institutions, civil society organizations and the private sector that addresses global environmental issues. It was established on the eve of the 1992 Rio Earth Summit to help tackle our planet's most pressing environmental problems. It serves as a financial mechanism for several environmental conventions.

gef

UNIDO

The United Nations Industrial Development Organization (UNIDO) headquartered in Vienna, Austria is a specialized agency of the United Nations to promote industrial development for poverty reduction, inclusive globalization and environmental sustainability.

The UNIDO Regional Office in New Delhi covers seven countries including Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal and Sri Lanka, and acts as a focal point to promote UNIDO's mandate of inclusive and sustainable industrial development. The core elements of UNIDO's technical cooperation services in India are to implement its activities in harmony with national policy priorities and development strategies; to build strong and long-term partnerships with donors; to increase UNIDO's visibility; and to focus its assistance in a manner that addresses international development goals, especially the Sustainable Development Goals.

Concentrating SOLAR Thermal Technologies

Proven technologies to save fossil fuels in industries for process heating and cooling needs to reduce reliance on fossil fuels thereby helping the environment

Salient Features

- Can provide steam / hot oil / pressurized water at 90 - 400 °C. Design and size of the system can be optimized based on requirements and site conditions.
- A typical system of 100 m^2 reflector area can save 5,000 to 10,000 litres of fuel oil per year depending on technology used and available solar radiation.
- Can be easily integrated with conventional boiler providing trouble free operations even during non-sunshine hours (heat storage is available).
- Around 200 systems of various capacities already installed in the country for different applications.

Financial Support for Installations

- The financial incentives provided for CST installation include CFA (Central Financial Assistance) from MNRE at 30% of the benchmark solar project cost, and depreciation benefit for profit-making companies. Higher subsidy for systems in special category states.
- Additional support is available from **MNRE-GEF-UNIDO project:**
  - a) Technical Feasibility by UNIDO and soft loan from Indian Renewable Energy Development Agency (IREDA)
  - b) Bridge loan against subsidy at normal interest rate.
  - c) Support for improving the manufacturing of CST system / components.

Interested Organizations may send their Expression of Interest before 30th September 2019.

For more details please visit the following websites:-
MNRE (https://mnre.gov.in/concentrating-solar-system-solar-cookers-steam-generating-systems)
UNIDO (https://open.unido.org/projects/IN/projects/130149)

UNIDO

National Project Manager
MNRE-GEF-UNIDO Project on Concentrating Solar Thermal Technologies
UNIDO, UN House, 55 Lodi Estate, New Delhi – 110003
Email: a.k.misra@unido.org

gef