a quarterly magazine on **Concentrating Solar Thermal**

SUN FOCUS

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

SUN FOCUS

A quarterly magazine on
concentrated solar heat

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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MESSAGE FROM UNIDO REPRESENTATIVE IN INDIA

Globally, heat production accounts for around one-half of energy demand. This demand is of utmost significance in tropical countries such as India, where cooking and heating applications are heavily dependent on heat. In India, heat accounts for two-thirds of total final energy consumption, and in the last decade, India's need for energy has amplified. With an increase in energy demand, the dependence on conventional fuels has consequently gone up. As a result, fuel prices have been impacted. Since the industrial sector meets most of its energy needs through use of fossil fuels, it is crucial to provide alternative and innovative solutions to meet the upward demands of the industrial sector. This is where the concentrating solar thermal (CST) technology comes to the fore as one of the most viable solutions to meet electricity and fuel oil demands of the country. Therefore, on-ground application of CST technologies in India must be evaluated so that the burden on fossil fuels is lessened considerably. Since India boasts of abundant sun energy, it is about time that this natural resource is harnessed through application of technologies such as CST.

India currently has about 64,000 m2 collector area under implementation for heating and cooling purposes with an installed capacity of 43.30 MW. While the government of India has been promoting CST technologies in the country recognizing their large-scale benefits, UNIDO's project specifically focuses on market mechanisms and financing to enhance the market size of the CST sector in India.

In August 2019, an agreement was signed between the National Institute of Solar Energy (NISE) and the United Nations Industrial Development Organization (UNIDO) to initiate a skill development programme for various levels of beneficiaries in the sector of solar thermal energy. This initiative was driven by the motive to support capacity building and skill development of technical expertise in the concentrated solar thermal (CST) energy technologies in an attempt to replace the use of conventional fossil fuels such coal, diesel, furnace oil, etc., and save costs and emissions in the industrial process heat applications. The need of the hour is that industrial emissions and fossil fuel consumption are minimized for sustainable development.

This edition of *Sun Focus* extensively covers the scientific and technical analysis, discussions, development and constant exchange of ideas among the industries, experts, policymakers, and governments. We hope the magazine opens dialogues and discussions to herald a wider acceptance of CST technologies.

Rene Van Berkel
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IMPACT OF COVID-19 ON CONCENTRATED SOLAR POWER (CSP)

Shirish Garud and Sarvesh Devraj, TERI

Market

The Coronavirus disease-2019 (COVID-19) outbreak has impacted millions of people worldwide and significantly reduced the overall global industrial growth. The lockdown and restrictions that have arisen due to the pandemic have caused the global economic imbalance, disturbing demand and supply chains, creating shortage of manpower, and delay in projects completion (Figure 1). As per estimates, around 53%[1] of the Indian businesses have seen a marked impact on their business operations because of the COVID-19 pandemic. Additionally, during the lockdown, the Indian electricity demand, specifically in industrial and commercial sectors, was reduced by 25%. The clean energy projects also have not been left untouched by this unforeseen crisis and it is forecasted that renewable energy (RE) capacity addition would decline by 13%[2] in 2020 compared to the year 2019. The prominent clean energy sector such as solar (80% solar cells), which are heavily dependent upon material import from China, has been severely affected due to delay in supply owing to large reductions in manufacturing capacities. Approximately 3 GW[3] of solar projects, of around $ 1600 billion worth, are at the of penalties for missing the scheduled commissioning deadlines.

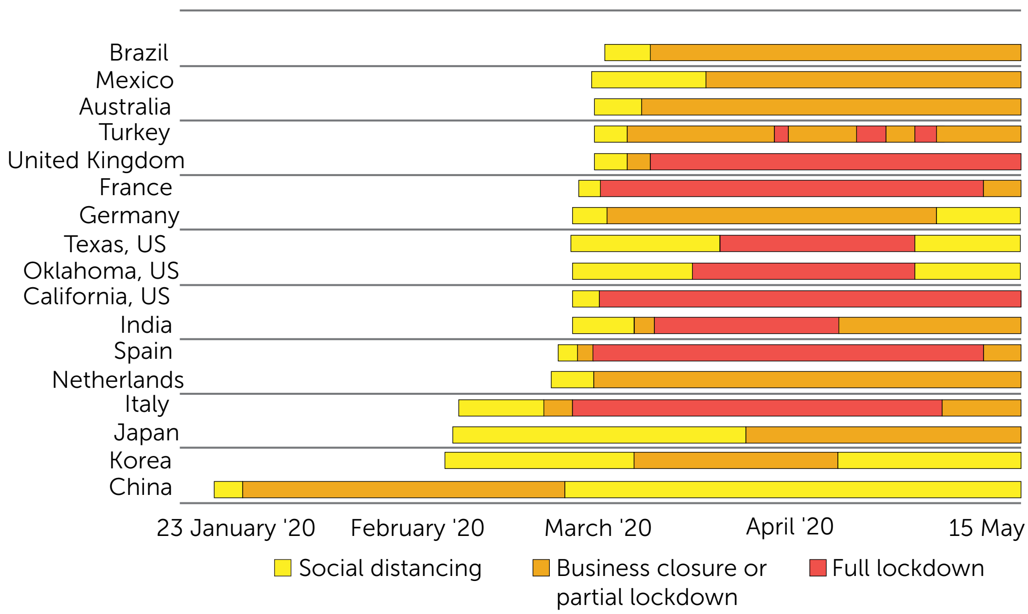

Figure 1: *Impact on top renewable growth markets*

Source: Renewable Energy Market Report, IEA (2010)

1 "Impact of COVID-19 on Indian Economy" report, FICCI, March 20, 2020

2 Renewable Energy Market Update Outlook for 2020-2021, IEA,2020

3 Details available at: https://www.crisil.com/en/home/newsroom/press-releases/2020/02/coronavirus-shadow-over-3-gw-solar-projects.html; last accessed on June 24, 2020.

In concentrated solar, the concentrated solar power (CSP) market has been projected to reach $18.41 billion[4] by 2025 and is estimated to grow 18.65%[5] of compound annual growth rate (CAGR) between 2020 and 2022. Currently, the Middle East & Africa and Asian countries (China) are dominating the global market. The impact on the CSP market is expected to remain limited due to the COVID-19 situation. However, the world's largest CSP project, Noor Energy-1 of 700 MW at Dubai has been also impacted due to COVID-19 restrictions in China. A project partner—Aalborg CSP subcontracted a Chinese firm for manufacturing the heat exchangers and pressure vessels, but production was halted for more than a month due to strict lockdown measures in China.

However, some projects like Chile's 110 MW CSP Cerro Dominador project with 17.5 hours molten salt storage is expected to come online.

In a nutshell, the key lessons for the CSP sector are as follows:

- Due to travel restrictions, international CSP projects were hampered to some extent. In this scenario, local contracting or hiring local manpower may become more effective. For instance, Alborg CSP hired around 900 local personnel in Dubai during the lockdown.
- Material transportation from one country to another is still a challenge and costly process. Setting up the local manufacturing capabilities for the CSP components locally can reduce the material cost, risk , and time.
- Acceleration on R&D can bring the cost down and developing low-cost hybrid technology will help combat the cost.

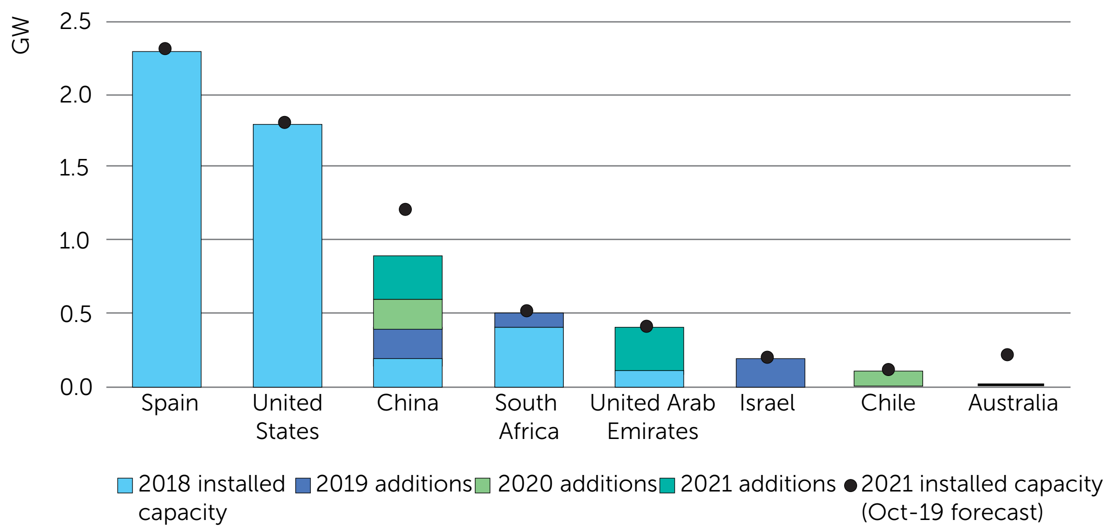

***Figure 2:** Expected CSP capacity additions of selected countries (2020–2021)*

Source: IEA (2019), Renewables 2019

Overall as per the IEA forecast, China will lead the CSP growth (Figure 2) in the near future but the growth rate will be lower for 2020–21 due to upcoming delays in projects and financial implications. In recent years, financing has been the main reason for cancelation of CSP projects in several countries including Australia.

[4] Details available at: https://www.marketresearchfuture.com/reports/concentrating-solar-power-market-2104; last accessed on June 24, 2020.

[5] Details available at: https://www.marketwatch.com/press-release/concentrated-solar-power-market-2020-to-2022-size-share-and-global-growth-rate-analysis-by-industry-overview-leading-players-market-opportunities-and-covid-19-impact-on-industry-2020-06-09; last accessed on June 24, 2020.

RECENT TRENDS, RESEARCH AND DEVELOPMENT (R&D) IN CST SECTOR

Senthil Kumar, Project Engineer, National Institute of Solar Energy

Renewable energy technologies become more essential day by day to tackle the global climate change. Especially, renewable energy technologies have to be promoted in all possible applications where fossil fuel consumption is very high. As per a survey by International Energy Agency (IEA) and IRENA, it was found that fossil fuels are majorly used for heat energy generation. In the industrial sector 74% of the primary energy consumption (85 Exajoule) is in the form of heat energy, and 90% of this requirement is met by fossil fuels. Concentrated solar thermal (CST) technology has been introduced as a solution to solve this need as it is a complete green energy. This technology is a matured and promising energy conversion which converts solar radiation into heat energy and has the ability to deliver hot fluid at temperature range from 80 °C to 700 °C .

Heat generated from CST technologies has been used majorly for two applications: power generation (CSP) and process heat for industries such as steam and hot water generation, cooking, and cooling. At the end of 2019, the global total installed capacity of CSP plants was 6.43 GW. Another 3.645 GW is under construction. Spain accounts for almost half of the world's capacity at 2.3 GW, though the country has not added any new capacity in commercial operation since 2013. The United States follows with 1.75 GW. North Africa, the Middle East as well as China are also interested in this technology. Similarly, as per the study by IRENA and IEA, the potential for process heat is 15 Exajoule and at the end of 2014, 93 MWth (>136, 000 m^2) of CST system have been installed worldwide. At the end of 2017, India had 55,000 m^2 of installed solar collector along with 23,000 m^2 of projects under installations.

Despite the technical potential as well as the potential economic benefits of using solar heat in the industry, the actual deployment levels remain quite low in this sector. The reasons for this slowdown include limited awareness among the industries, space constrains, cost, financing mechanisms, and faulty designs. Despite the general perception that CSP has developed fast, the installed CSP capacity is still less than 1% of wind and photovoltaic. The major hindrance of CSP from being commercialized at a large scale is the exorbitant nominal levelized costs of electricity (LCOE).

To overcome such hindrances and to promote the use of CST technologies, many research organizations across the world are researching and trying to develop new applications where CST technologies can be used as a heat source.

Trends and Recent R&D in CST Technologies and Its Components

Different CST technologies are widely available in the market. Many manufacturers are currently developing and supplying CST technologies such as parabolic trough collectors (PTC), compact linear Fresnel concentrators (CLFR), paraboloid dish, solar power tower, and Scheffler dish. Most of these technologies have matured over the years and are available commercially with better conversion efficiencies. However, there is still large scope in improvising each and individual components of CST technology. Following are the areas where major researches are being done.

- Receiver/absorber
- Selective coating material for higher absorption
- Thermal storage systems
- Heat transfer fluid with greater operating temperature range

- Engineered surface that prevents dust depositions
- Design optimization and material sourcing for cost optimization

Receiver

A receiver helps in absorption of concentrated heat energy from reflectors and transfers it to heat carrying fluids. It plays a vital role in CST technology and proper designing always aids in improving the performance of the system. Various aspects such as different designs, provision for direct steam generation, selective coatings are being studied and presented by researchers nowadays.

The National Technical University of Athens has conducted research on different designs of cavity receivers which are being used in Paraboloid dish concentrators. Figure 1 explains the various designs considered for the study. The conventionally used cylindrical cavity receiver was their fourth preference based on performance. The best design is the novel one with cylindrical-conical shape, while the conical and the spherical are the next choices.

Steam is one of the huge requirements for industries; however, steam generation through the conventional PTC receiver holds certain degree of complexity. The higher operating pressures and temperatures in the solar field while in operation affect the receiver tubes and interconnections between collectors largely. Moreover, control issues (such as temperature regulation and pressure fluctuations) will arise during transitory periods of radiation. Due to this Direct Steam Generation (DSG) has resulted in not yet being utilized in commercial plants.

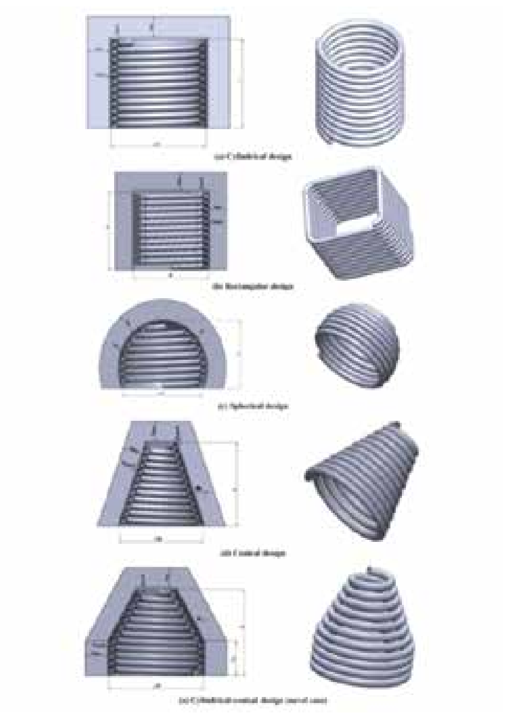

Figure 1 Different types of cavity receiver

To tackle these issues, pioneer research organizations like M/s German Aerospace Center (DLR), The Plataforma Solar de Almería (PSA), Spain and PTC manufacturer M/s Abengoa solar have been extensively working on direct steam generation in receiver of parabolic trough concentrator. According to their research, DSG from trough concentrator possess many advantages. These are increased efficiency of power generation, cost-efficient access to water (compared to other fluids and also in arid areas), and removal of heat exchangers between the solar field and the steam turbine process. Soon this technology is expected to be available commercially which will also help in meeting the industrial direct steam requirement.

Selective Coating Material

Selective coating is an important component of a receiver tubes. Proper selection of coating will result in improving the overall performance of the system. Extensive literature on solar selective (S.S.) coatings is available; in this section, we present the recent research being conducted in India and a few available selective coating materials available.

Recently, International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI),[1] Hyderabad, an autonomous institution under the Department of Science and Technology (DST), developed a cost-effective wet chemical process to prepare absorber coating on stainless steel tubes suitable for industrial process heat applications. The receiver tube with special coating developed by the company achieved around 93% absorptance and around 14% emittance along with good thermal stability and high corrosion resistance. As everyone knows, emittance is the amount of light emitted by an area of the surface of a radiating body and absorptance is the ratio of the absorbed to the incident radiant power.

[1] Details available at https://www.arci.res.in/patents-centre-for-solar-energy-materials.

Researchers from the Center for Translational Atomaterials (CTAM)[2] at the Swinburne University of Technology in Melbourne, Australia have developed a new graphene-based solar thermal film that can absorb sunlight with an efficiency of more than 90%. Also this solar heating metamaterial can heat up rapidly to 83 °C (181 °F) in an open environment with minimal heat loss.

Thermal Energy Storage System (TSS)

It is a well-known fact that in the future fossil fuels will be gradually replaced by renewable energy sources due to features such as inexhaustible supply and no pollution. However, the main concern that arises in renewable energy is managing their unpredictable fluctuation. If these technologies account for a large proportion of the total energy generation, they will seriously affect the stability of the energy system. To avoid this, secondary or buffer energy sources are required that are flexible to meet the demand. Thermal energy storage can be an effective way to regulate energy supply and demand, and can effectively increase energy flexibility. Hence, thermal energy storage has been strongly encouraged in recent decades. Thermal energy storage systems have the capability to store energy when the energy supply is surplus and release energy when the energy supply is insufficient, solving the gap between supply and demand of energy and overcoming the intermittence and fluctuation of renewable energy sources. Thermal storage material is more familiar in CSP sector; however, it has not penetrated the industrial process heat sector. The following research works and concepts will further help in promoting such systems to be deployed in real time applications.

TSS for Transporting Heat Energy

The space constrain in installing CST systems is one of the biggest concerns in this sector. Even though many industries can afford CST systems, they do not have the required space in their factory premises to install the system. There also cases where, because of pollution control, running conventional systems such as boilers and diesel engines are prohibited. In such places the proposed concept can resolve the said issue to a greater extent.

The concept iterates that heat can be harvested in remote locations using CST technology which can be further carried to the sites using mobile heat carrier with the help of TSS wherever it is needed in the limited surroundings. See Figure 2. In the long term, companies may also adapt RESCO model to sell heat energy to the needy customers. The fluctuations in energy harvesting during unpleasant climate, back up arrangement can be utilized or waste heat from industries can be used with the use of TSS.

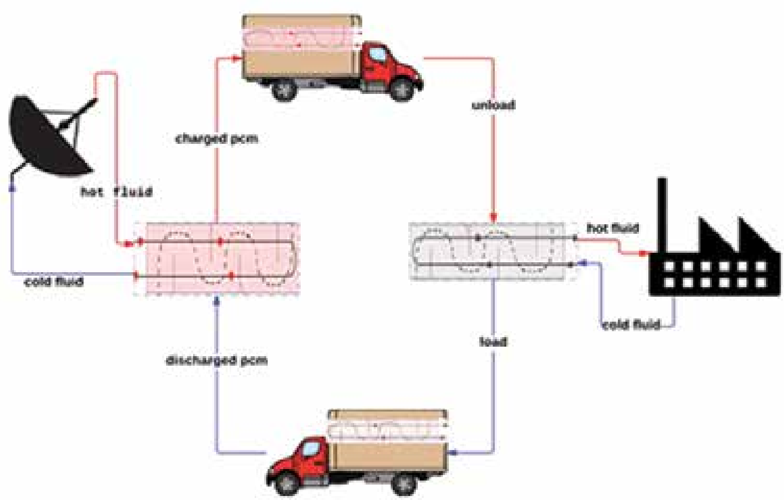

Figure 2 *Mobile heat carrier concept*

[2] Details available at https://ctam.org.au/action

TSS in Industrial Heat Recovery System

According to the research conducted by Nanjing University, China, there is huge potential in using industrial waste heat for meeting the energy demand of the industries. The metal industries and mineral processing industries discharge a great deal of waste heat, especially high temperature waste heat which has better potentiality of reutilization. Industrial heat recovery and reuse is vital for reducing CO_2 emissions and energy consumption. Nevertheless, industrial heat recovery has not been widely implemented so far, resulting in difficulties of technology and finance of conventional heat recovery methods, and time and geographical mismatch between heat release and heat demand. Thermal energy storage system can solve the problem of time and geographical mismatch as shown in Figure 3. Further, waste heat from steel industries, generally at high temperature, can be stored in high temperature PCM and for steam generation. Research from Hakkadio University, Japan also suggest the possibility of transporting heat via high-temperature PCM between different industries. In their study, they proposed the concept of transferring recovered waste heat with temperature above 300°C from steelworks to the chemical industry and then send it to the chemical plant. NaOH is used as PCM for the latent heat storage system, which has a solid-solid phase change temperature of 293°C and melting temperature of 320°C. The results revealed that for latent heat storage system, the heat storage density is 2.76 times that of sensible heat storage system, and energy demands, energy loss, and CO_2 emissions are far less than that of traditional system.

TSS in Building Along with Thermal Storage

The demand for thermal comfort in buildings is constantly increasing, leading to a corresponding increase in the energy consumption of buildings. Therefore, improving the building's thermal insulation and energy efficiency is necessary to reduce building energy consumption (for example, integrating energy storage medium PCMs into buildings). PCMs can be integrated into building envelopes, such as walls, roofs and floors, and can also be integrated into building equipment such as air cooling systems, air heating systems, and ventilation systems.

Latest research by Key Laboratory of Enhanced Heat Transfer and Energy Conservation, China suggests that expanded perlite (EP) is composited with salt hydrate mixture of $CaCl_2.6H_2O$ to develop a nonflammable thermal storage material for building use. This composite material were made into PCM boards embedded in bricks to form PCM bricks. Their result indicates that when applied as roof of a test room, the PCM brick decreases the indoor peak temperature and causes hysteresis in the indoor temperature

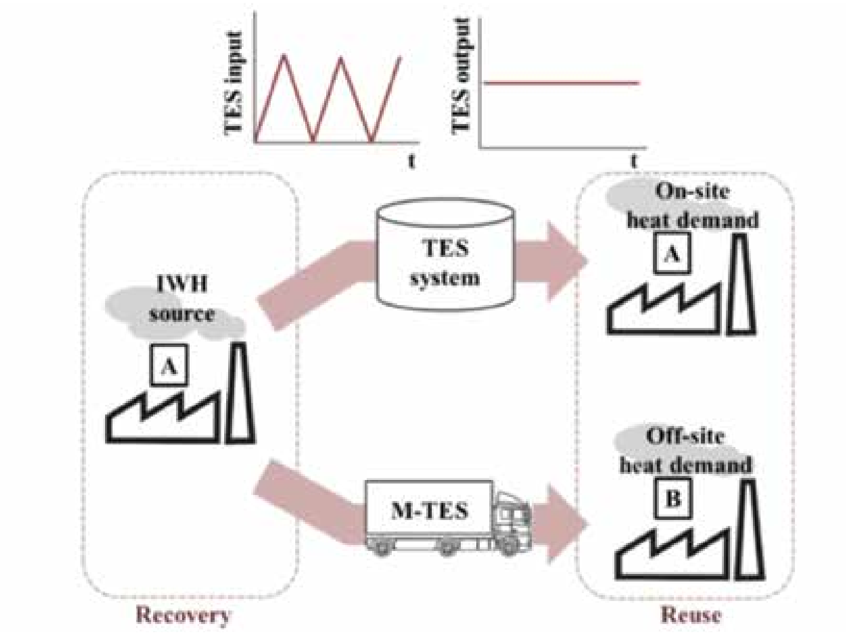

Figure 3: Schematic diagram of onsite and offsite reuse of waste heat in industry

rise, compared with the foam insulation brick. The nonflammability along with good thermal storage and insulation properties make the $CaCl_2 \cdot 6H_2O$/EP composite PCM show great promises for use in building energy conservation. Similarly, in the case of space heating systems, CST can be used to warm the space with building material-integrated TSS for extended hours of operation.

Heat transfer fluid with greater operating temperature range

Recent trends in this sector have focused on the usage of nanofluids in heat transfer materials. Common heat transfer fluids such as water and oil have limited heat transfer capabilities due to their low thermal conductivity properties. In contrast, thermal conductivities of metals are up to three times higher than the fluids. Therefore, researchers are trying to combine these two substances to produce a heat transfer medium that behaves like a fluid but has a thermal conductivity close to that of a metal. Nanofluids are engineered suspensions of nanometer-sized solid particles in a base fluid. Various types of nano-particles such as metallic, nonmetallic, or polymeric particles are possible to form nanofluids. CST industry can adapt outcomes of this research which will help in improving the performance output of a system.

Anti-Soiling coating

The continuous cleaning and maintenance of the CST reflectors is a crucial factor in maintaining their high effectiveness. Throughout the year, this process becomes very costly, time-consuming, and unsustainable. Also the majority of installation sites were chosen to be in water-scarce region owing to good solar radiation. As per data, to properly clean a CST system 0.25 l/m^2 of distilled water is required every week. Thus, the need for a better method of CSP reflector protection is a must which can be achieved through anti-soiling coating.

To resolve this issue, research is being conducted with an objective to determine the optimum material to use for anti-soiling protective coating and study a deposition technique. Titanium dioxide represents a promising material so far to be used as an anti-soiling protective material coating for CSP reflector and is soon expected to be available in the market.

Conclusion

Plenty of good research is being conducted by various organizations and universities for the betterment of this technology. When these lab-scale research will be available commercially, the CST sector will be able to deliver much better solution to the industrial community to fight against climate change.

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FLT TECHNOLOGY: ULTRA HIGH TEMPERATURE CHEMISTRY

Rajesh Jain, CEO, High Temperature Solar Technologies

Background

Scholars are increasingly pursuing ultra-high temperature chemistry and applications centred around new materials, nanomaterial, and gas conversion. High temperature furnaces (from 1000°C to 2500°C) along with lasers and plasmas (above 5000°C) are the primary heat source in the laboratory for such research. Scale-up to study for commercial viability of such experiments is a challenge in terms of expenses, time, and effort. Commercial viability has been envisaged if such temperatures and power densities can be provided using concentrated solar. A classic example of such attempts is the field tests being carried out to mitigate greenhouse gases using metal oxide thermochemical cycles and dry reforming of methane and carbon dioxide. For the last six years, High Temperature Solar Technologies (HTST) has been working on providing solutions to challenges encountered by scholars and academia, pursuing such high temperature chemistry to produce intermediaries. HTST has invented a new family of solar concentrators called as Fresnel Lens Tunnel (FLT) technology that can provide temperatures of above 2000° C.

Overall arrangement of FLT technology

Methodology

The exponential drop in the cost of photovoltaic panels and photovoltaic (PV) electricity has rendered 'industrial solar thermal technologies' riddled with challenges. Under such constrains there can be two scenarios. First scenario can be the development of ultra-low cost solar thermal application. The second scenario can be developing applications that cannot be provided easily using PV electricity. HTST has pursued the second scenario. We asked ourselves one question: How easy or difficult, will it be to use solar energy to thermally crack greenhouse gases (GHGs), and provide about 50 kW power at ultra-high heat rates to a graphite nozzle having a diameter of 200 mm and length of about 200 mm and heat it to 2500°C in a controlled environment?

Close-up of capsule loading and removal mechanism

Alumina samples treated under high temperature

We have invented a method of converging foci, generated by multiple lenses. Such convergence of multiple foci leads to generation of ultrahigh temperatures with extremely high flux densities in a comparatively small area, leading to greatly reduced re-radiation (T^4) losses.

We manufactured a 1 kW proof of concept and demonstrated temperatures of above 2200°C with heat rates of more than 300°C/s. These trials were conducted in October 2018, when the solar DNI was around 800 Watts/m^2. Our Pyrometer maxed-out at 2200°C. We have also demonstrated conveying of shaped solids and gases through such temperatures in controlled environment.

This manufactured 1 kW furnace, "Works-Like" laboratory proof of concept. The science and technology have been validated and de-risked. This new technology prototype built has functionality demonstrated the challenges overcome though testing has been carried out over a limited range of operating conditions.

These tests can be done on a scaled version if scalable funding/commercialization funding is available. We have designed a 7 kW setup to be used as experimental solar furnaces and a 50 kW setup for pilot plants. Future industrial setups in the range of 125 kW to 500 kW have been envisaged.

Overview of Technology

We have converged multiple foci that are generated by multiple lenses. The invented new family of solar concentrators can provide temperatures above 2500°C at heat rates of about 300°C/s, with power/heat capacities ranging from 7 kW (experimental solar furnaces) to 50 kW (setups for pilot-plants). Future setups for commercial production have been envisaged in the range of 125 kW to 500 kW. We have manufactured a 1 kW 'proof of concept' and have attained temperatures of above 2200°C. As mentioned above, our pyrometer maxes out at this temperature. We have also invented and demonstrated a method of conveying shaped solids and gasses (in controlled environment) through such temperatures. A modified market circuitry components like isolation and direction control valves to handle high temperatures has also been achieved.

The technology has three major subsystems

- Optical system
  - » This consist of set of mirrors and lenses organized in circular fashion around the focal point in such a manner that they will always focus reflected sunrays on small focus area where objects to be heated are kept.
- Mechanism for capsule loading and removal
  - » This mechanism has been developed to handle the capsule of carbide or silica which can be exposed to high temperature. The unique automatic loading system is designed to handle the loading and removal of test samples without direct human assistance.

- Tracking and control mechanism
  - » This mechanism controls orientation and tracking of the mirror and lenses assembly.

Applications

1. We have invented a method of separating thermally dissociated ions at such high temperatures (Magneto-Hydro-Dynamic Electrolysis, Indian Patent Granted).
2. We also worked towards envisaging possibilities to generate temperatures for steam thermolysis to be made an exothermic reaction by modifying the FTL technology for solar pumped lasers. These include highly customizable reactor for predefined shaped solids with provision for gas injection and extraction, with multiple steps heating. And mass transfer of shaped solid provided for enhancing throughputs.
3. Tungsten carbide circuitry capable of withstanding temperatures of about 3500 °C has been also developed.

Market

World over, field experiments of such high temperature solar chemistry are pursued by a handful of premier research institutes and are centred around mitigating greenhouse gasses. Usually such field experiments are funded by the government and such projects run for two to five years and cost millions of dollars, sometimes even involving building a new solar concentrator and receivers with conveying systems.

We propose to reduce the time and costs associated with such 'field experiments' by providing 'commercial' experimental solar setups 'optimized' with mass transfer and conveying of shaped solids and gasses in controlled environment. We seek traction for our invention and our thought process, to make 'field experiments' economically accessible, to chemists and engineers at large, in academia and industry. Fractional ownership of setups will be major contributors to such efforts. We envisage the equipment to be locally designed and manufactured by engaging the services of contract manufacturers.

Competition

We are not aware of any other identity offering optimized' solar concentrators for field experiments with capabilities that we offer in terms of temperature, heat rates, power density, mass transfer and scalability.

SOLAR PAYBACK ASCERTAINS INDIA AS POTENTIAL SOLAR PROCESS HEAT MARKET

Jaideep N Malaviya, Project Manager, info@stfi.org.in

The Solar Thermal Federation of India (STFI) and the Indo-German Chamber of Commerce (IGCC) have teamed up for the international 'Solar Payback' project, which aims to increase the use of solar heat for industrial processes (SHIP). It was started in January 2017. This project is part of the International Climate Initiative (IKI), supported by the German Federal Environment Ministry funded by the International Climate Initiative, and is implemented in India, South Africa, Mexico, and Brazil. It is coordinated by the German Solar Association (BSW-Solar) and 11 partner organizations.

The study on Indian market was recently concluded and reveals that much of the process heating in industries use only low to medium temperatures up to 200°C. Considering the heat demand in selected industry segments, the report identified dairy processing, food processing and beverages, automotive components, textiles, chemicals, and pharmaceuticals as relevant industry sectors to use industrial solar heat. Although flat plate collectors were used for industrial heating until 2012, but concentrated technologies offer better potential.

India's import dependence on fuel oil is on an average 75%. Industrial sector accounts for almost 40% of total energy consumed in the country largely through fossil fuels. Close to 16 million of tonnes fuel oil is consumed annually in India for medium-high industrial heating applications, that is, up to 200°C. It is anticipated that up to 25% of this can be

Figure 1: *SHIP system at Vidya Dairy for process heating*

(Photo credit: Solarpayback India)

conserved through energy efficiency measures or adopting renewable energy sources like solar thermal. Although the Direct Normal Incidence (DNI) in India is not amongst the highest in the world but the available radiation for almost 300 days in most of the industrial regions of the country offers potential to exploit SHIP. Figure 2 shows the DNI map of India.

For every 3 million m^2 of installed area, the annual diesel saved will be 20 million litres on continuous basis and abate worth 55,000 tonnes of CO_2 annually. The dairy processing itself can fulfil this target considering India is the world's largest producer of milk and dairy products. This is especially true in states with high irradiation, such as in the north-western and central states, which can be supplied on a decentralized level.

The study further suggests aggressive target be set as a part of the National Solar Mission if India needs to reduce its dependence on import of fuel oil. One suggested policy measure is a certain percentage of renewable heat obligation in the identified industries, which will act as a driver and accelerate the SHIP projects.

Dairy Processing—Potential Segment to Initiate Acceleration

At 176.4 million tonnes annually, India is a leading producer of milk and milk products globally. There are over 1200 large, medium, and small dairy industries. Milk processing in India constitutes around 35% of

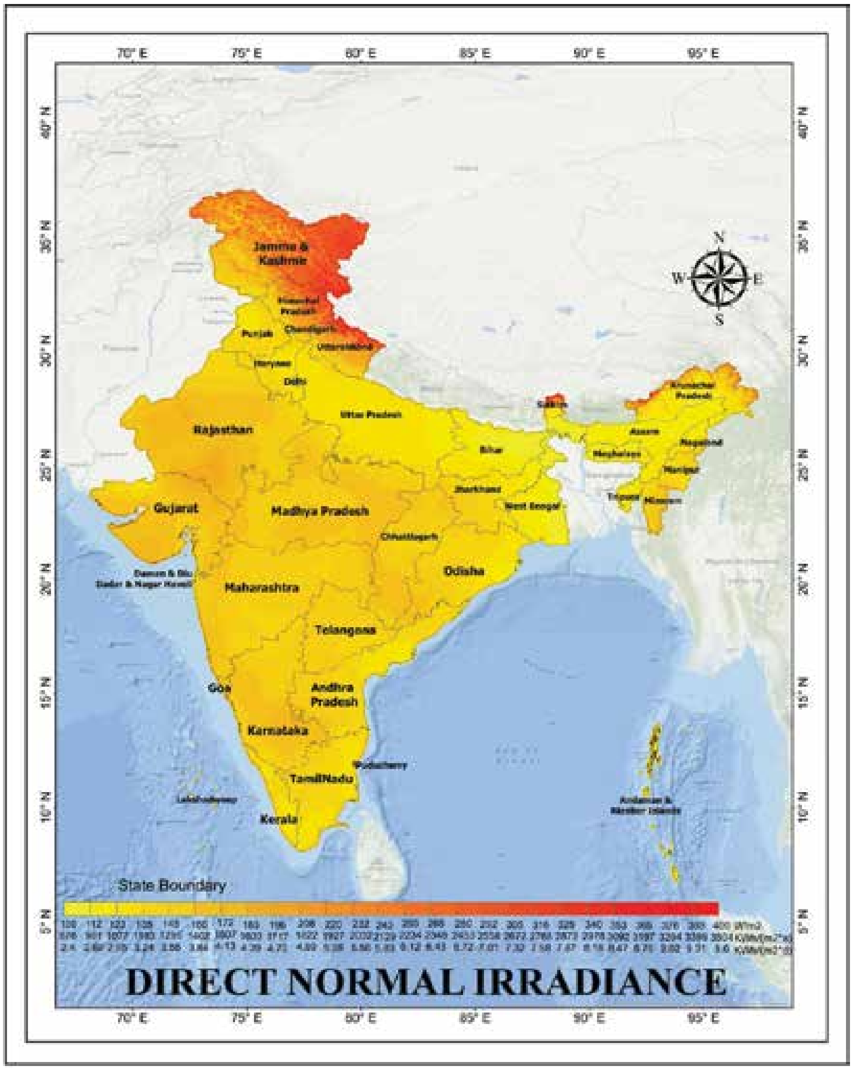

Figure 2: Direct Normal Irradiance Map of India

Source: National Institute of Wind Energy total milk production. Energy plays a major role in processing milk and milk products. Nearly 30% of overall manufacturing cost is spent on purchase of furnace oil, electricity, which is substantial. Typical dairy plants derive about 70% of their energy requirements in the form of thermal energy and the remaining 30% is consumed in the form of electricity. The applications include washing and cleaning, sterilization, pasteurizing, cooling, evaporation, spray-drying chemical process, and other minor applications. Their heat demand is as shown in Figure 3.

Most of the applications require heat under 200°C, hence solar thermal can best supplement the heating demand. The dairy processing can play a sample model to showcase the success of SHIP. The government has already announced to increase the milk production from 53.5 million tonnes to 108 million tonnes by 2025 and processing will play a major part. Thus, solar heating will have attracive business.

India has an already established industry of solar thermal companies and suppliers that have installed more than 35,000 m^2 of plants for SHIP. As per the latest Solarpayback survey, India now ranks the fourth fastest growing market in the world as shown in Table 1.

Capital cost reduction and cheaper storage will need to be addressed as future strategy in order to make SHIP commercially attractive. To overcome the challenge of high capital investment 'Make in India' can perhaps lessen the burden.

Solar Payback Project illustrates market niches and applications in identified industries and provides a methodology as a basic tool to facilitate the economic calculation of SHIP projects. The report can be downloaded at: https://www.solar-payback.com/solar-heat-for-industry-in-india/

India: Process-wise heat demand and share of energy consumption in the dairy industry

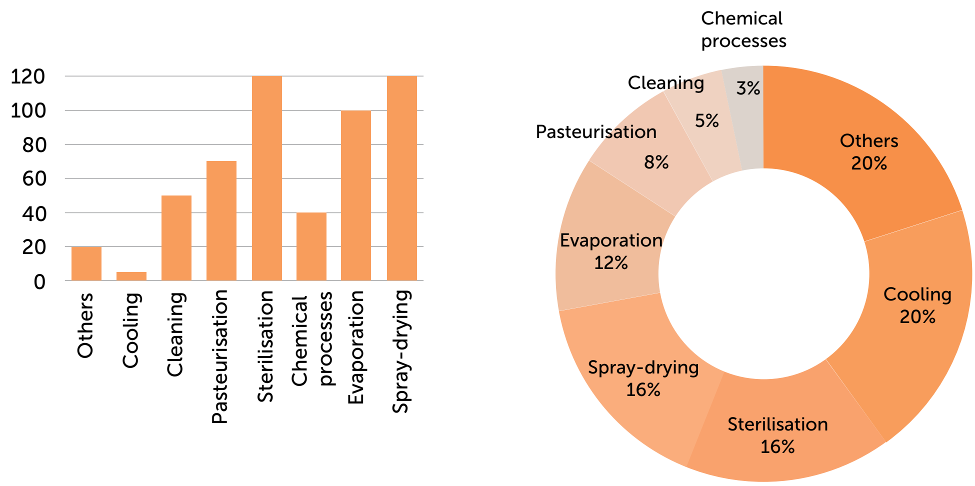

***Figure 3:** Process-wise heat demand and share of energy consumption in dairy processing*

Photo credit: Solarpayback India

Table 1: Countries ranked by the number of SHIP installations put up in 2019.

Country	No. of systems put up in 2018	Collector area added in 2018 [m^2]	No. of systems put up in 2019	Collector area added in 2019 [m^2]	Average system size in both years [m2 per system]
China	15	28,813	26	76,182	2561
Mexico	51	6898	26	4040	142
Germany	9	1589	11	1470	153
India	5	2264	7	3152	451
Spain	3	1218	3	386	267

The average size of these systems can vary significantly. Source: Solar Payback SHIP Supplier Surveys 2018 and 2019

FORTHCOMING EVENTS

NATIONAL

World Solar Congress
February 18, 2021 | Mumbai India

International Conference on Mathematical Modeling, Computational Intelligence Techniques and Renewable Energy
February 6–8, 2021 | Gandhinagar, India

INTERNATIONAL

2021 Renewable Energy Summit
January 12–14, 2021 | Wisconsin, USA

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.

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.