a quarterly magazine on **concentrated solar heat**

SUN FOCUS

CST DEVELOPMENTS AND CASE STUDIES

Volume 3
Issue 1
Jul–Sep 2015

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Empowered lives.
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UNDP–GEF CSH Project
Ministry of New and Renewable Energy
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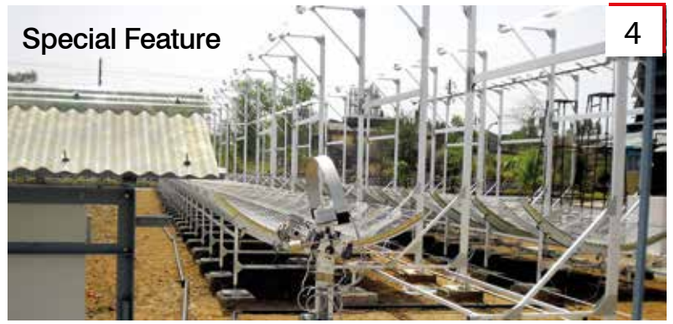
Inside...



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From the editor's desk...

Dear Readers,

I am pleased to inform you that SUN FOCUS has now completed two years successfully and has started its third year with this ninth issue. Previous eight issues of the magazine were planned so as to cover various aspects, such as policy, technology developments, and new applications, of concentrated solar thermal sector in India and latest 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.

The current issue is designed to update its readers about all-round developments in the field of CST while covering a broad range of topics, such as user experience of solar cooking systems, information about National Test Centre activities during last year and new technology developments.

The article Enersun Power Tech Pvt. Ltd introduces their latest CST technology development: Curved Linear Fresnel Reflector technology. The article also discusses two applications of the technology. The second article, by Mr S K Singh, gives an overview of the activities undertaken at National Test Centre facility. There are also two articles dedicated for solar cooking. The first article gives user feedback and opinions on the solar cooking system installed at the Malaviya National Institute of Technology, Jaipur, while the second article discusses possible use of cast iron storage in the mass solar cooking systems. Lastly, there is one article on international developments in CST, introducing Linear Fresnel Reflector technology developed by Industrial Solar GmbH and its two applications in Jordan and South Africa.

I hope you will find this issue interesting and informative as all the previous issues. I look forward to your valuable comments, suggestions, and most importantly 'contributions' for upcoming issues of the magazine.

Sd/-

Tarun Kapoor
Joint Secretary, Ministry of New and Renewable Energy &
National Project Director, UNDP–GEF CSH Project

NOVEL AND INDIGENOUSLY DEVELOPED SOLAR CONCENTRATOR TECHNOLOGY ON CURVED LFR

Deepak Gadhia[1] and Babasaheb G Mukane[2]

A novel and cost-effective technology on Compact Linear Fresnel Reflector (CLFR) has been developed indigenously by Enersun Power Tech Pvt. Ltd, Mumbai. Enersun is a Solar Thermal Energy Company, focussed on providing energy solutions based on a unique, modular technology for solar concentration. The technology has been designed by Professor J B Joshi and Professor S V Panse and has multiple advantages and is named as 'Joshi–Panse Solar Concentrator'.

The technology is based on mass-manufactured components designed for rapid construction, uniform modularity, and unlimited scalability.

Problems Addressed on Existing CSTs

Economical and robust technology to concentrate solar energy is the need of the hour. Technologies for solar collectors in the market today (e.g., Parabolic trough, Parabolic dish, Fresnel reflectors, Scheffler dish, and Solar Tower) require significantly larger land area than aperture area to avoid shadow of one reflector falling on the adjacent one. This is a disadvantage, particularly for process heat applications because land in an industrial area is always at a high premium.

Also, solar concentrators have to be robust to withstand considerable wind load. This entails a major component of their total cost. To reduce cost, they should, therefore, experience substantially reduced wind load, even under stormy conditions.

Also, strips in Fresnel reflectors have to be rotated independently for solar tracking. So their mounting and rotating mechanisms are more involved and costly.

Reflector strips of Joshi–Panse Solar Concentrator

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[2] ***Babasaheb G Mukane, Chief Manager, Enersun Power Tech Pvt. Ltd, Mumbai; Email: baba.mukane@enersunpower.com***

Cost will reduce, if a set of reflector strips is mounted on a single support, and moved together for solar tracking.

The Joshi–Panse Solar Concentrator successfully addresses these problems. Also, there are advantages of reduced heat losses and smaller tracking movement of reflector strips.

Innovations Made in CLFR

Basic Design

Reflector strips are arranged along a single (non-parabolic) curve and each strip has a specific location and orientation and there are gaps between two consecutive strips thus the collector encounters negligible wind load. In spite of the gaps, the collector captures entire solar radiation incident on its aperture. The design is easily scalable. Installation can be done on terrace or ground. The entire support frame is made of aluminium to keep it light-weight and corrosion-free. It is easy to assemble and is extremely stable even during high winds. Fasteners are made of stainless steel. The entire assembly has no welding or painting anywhere. This improves durability and reduces dependence on human skills. Glass mirrors are used as reflectors for a solar collector as they are stable against hostile environmental conditions and abrasion during cleaning. They also have high specular reflectivity. However a curved shape mirror is costly and thus Joshi–Panse Solar Concentrator is so designed so that the reflector is essentially in the form of flat strips. Solar-grade mirror strips (reflectivity >90%) coated with protective layers on the back and sides are used for longer life.

Heat Collection System

A seamless stainless steel pipe with high quality selective coating material acts as receiver. Receiver is stationary and is contained inside a secondary reflector called 'mirror cap' with glass at the bottom and a specially designed and extruded double-walled aluminium structure above, the inner wall of which is an aluminium reflector, which acts as a secondary reflector. The cavity between the two walls is filled with non-conducting material reducing thermal losses.

N-S Tracking System

The tracking is done along N-S with a gear-and-pinion arrangement. The entire array of 120 m^2 aperture is tracked by a pinion shaft slowly rotated by a single weather-proof geared motor of only 0.25 hp. The bearings are made of engineering material and the shaft is made of high-strength MS bar with an integral keyway. This allows for thermal expansion without creating stresses in the structure.

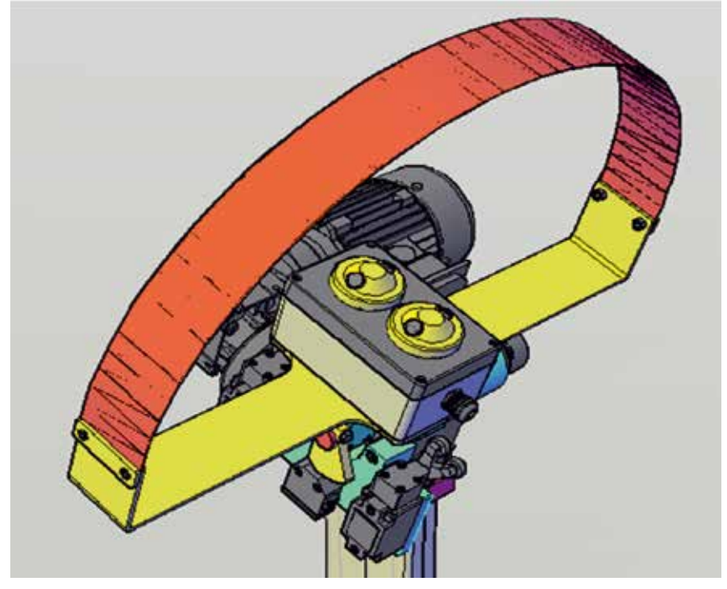
Four light-dependant resistors and a shadow strip together track the sun. A small AC motor coupled with high reduction ratio gearbox rotates the tracker to keep it aligned with incident sun rays. The extent of the rotation is limited by two limit switches and the 'home position' of tracker is marked by precision homing switch.

On a sunny day, the tracker actively tracks the sun, while in an overcast sky, it retreats to passive tracking wherein it is guided by the pre-fed values of the declination angle derived from empirical relations. Sun tracker assembly is rated IP 66, which gives it protection from ingress of dust, heavy downpour, and water jets for cleaning.

Advantages of CLFR

The novel technology of Enersun is (CLFR) has a combination of advantages of both the earlier technologies of Parabolic Trough Concentrator and Linear Fresnel Reflector.

- Enersun collector works on single axis tracking similar to parabolic troughs and Fresnel reflectors. Conventionally, however, solar collectors are arranged with their axes along N–S and tracking along E–W directions. In Enersun's Joshi–Panse Concentrator, the axis is along E–W and tracking is along N–S directions.
- Parabolic troughs use movable receiver pipes whereas Fresnel reflectors use stationary receiver pipes. Stationary receiver pipes do not need flexible joints and thus reduce cost and improve efficiency. CLFR technology uses stationary receiver.
- Parabolic troughs need curved mirrors that can become economical only when mass produced. The market for solar collectors in India has not expanded enough



Innovative: Enersun tracking system

yet to support mass production. The CLFR technology needs reflectors in the form of flat strips which are easily available and be procured in the market off-the-shelf.

- Parabolic troughs are concave curved reflectors thus offer resistance to wind and hence experience a noticeable wind load. Consequently, support structure must be sturdy enough to withstand this load. The CLFR technology comprises a set of flat reflector strips with gaps between adjacent strips. These considerably reduce wind load on the collector making it lighter.
- Conventionally, the strips in Fresnel collector are arranged in one plane. Thus, when rotated to track the sun radiation reflected by one strip, it is partly blocked by the adjacent strip, thereby bringing down collector efficiency. This problem has been addressed in the Joshi–Panse Concentrator by introducing gaps between adjacent strips. The entire incident radiation is captured by the set of strips and concentrated on a single receiver pipe. Thus, there is no compromise in collector efficiency or concentration ratio.
- Every strip in a Fresnel reflector needs to be rotated independently to track the sun hence all the strips are to be mounted separately. This requires a comparatively complex mechanism to rotate them. On the other hand, in Enersun's Joshi–Panse Concentrator, the entire set of strips to be rotated are mounted on a single support and the thus the mechanism to rotate them is comparatively simpler.
- To track the sun, a parabolic trough has to undergo an angular displacement that equals that of the sun in the sky. In case of Enersun's Joshi–Panse Concentrator, the angular displacement of the collector needs to be two-third that of the sun in the sky. Thus, for example in N–S tracking of the collector, the parabolic trough has to move through an angle of about 48° (±23.5° around the latitude angle of the place) during one year whereas the Enersun's Joshi–Panse Concentrator needs to be moved through 32° in one year. Reduced span of angular displacement of the collector implies reduced gap to be maintained between two consecutive rows to avoid shadow of one falling on the other. This improves the 'Land Utilization Factor'. Added advantage is reduced wear and tear of driving mechanism for solar tracking.

Installations

Industrial Process Heating Application at Laxmi Organic Industries Ltd, Mahad, Maharashtra

Enersun has commissioned a system comprising of Joshi–Panse CLF Solar Concentrator of 204 sq. m aperture area covering 306 sq. m of land generating 40,000 Kcal/hr at 0.5 kW/sq. m as DNI.

The total investment of Plant was ₹32 lakh with a payback period of less than five years. Water is the heat transfer fluid, which is heated inside receiver. Pressurized hot water flows into the liquid-gas separator or steam header. The steam generated at desired pressure is used for process heating. The concentrator tracks the sun automatically from 9 a.m. to 4 p.m.

Joshi–Panse solar concentrator at Laxmi Organic Industries Ltd

Enersun's Joshi–Panse Solar Concentrator at Muni Seva Ashram for Cooking

A 34 sq. m Joshi–Panse Enersun CLF Solar Concentrating System has been installed at Muni Seva Ashram for testing and demonstration purpose.

The installation is on its terrace of kitchen of *Athithi Mandir* (Guest House) and the heat generated is in the form of hot water above 100°C that is used for continuous rice cooking. To reduce energy consumption and for ease and hygienic cooking of rice, Prof. Joshi and others have developed an innovative automatic rice-cooking system.

The newly developed rice-cooking system uses hot water instead of steam, thus reducing the energy consumption. The use of hot water is also advantageous from storage point of view and enables cooking in non-solar hours, which is the typical requirement of any mass cooking system.

The most important aspect of the developed technology is automation, which is important for continuous cooking process. The rice is fed into the hopper from where it is fed into the vessel with a screw conveyor. Solar hot water is injected along with rice on one end and on the other end comes out cooked rice. This reduces required manpower and number of cooking vessels. Human touch and intervention is also reduced to minimal making it more hygienic.

Automatic rice-cooking system in operation at Muni Seva Ashram

Two modules of Enersun's Joshi–Panse CLF solar concentrators

The operation of Joshi–Panse CLF solar concentrator and automatic rice cooking system was demonstrated successfully on July 6, 2015 at Muni Seva Ashram after extensive performance testing. It was noted that 75 kg of rice cooked in just 20 minutes. Regional Test Centre of Ministry for New and Renewable Energy at Pune University has recently tested the technology with an efficiency of 52 per cent.

Conclusion

Joshi–Panse Solar Concentrator is a cost effective and efficient solar concentrator useful for industrial applications requiring moderate temperatures (up to 200°C) and for community and institutional cooking. It's a win-win development. India reduces its import of fuels and the users and besides saving fuel also benefit due to ease of cooking. As solar energy is used the quality of air, water, and life improves.

USING SCHEFFLER DISHES WITH CAST IRON HEAT STORAGE FOR MID DAY MEALS

B K Jayasimha

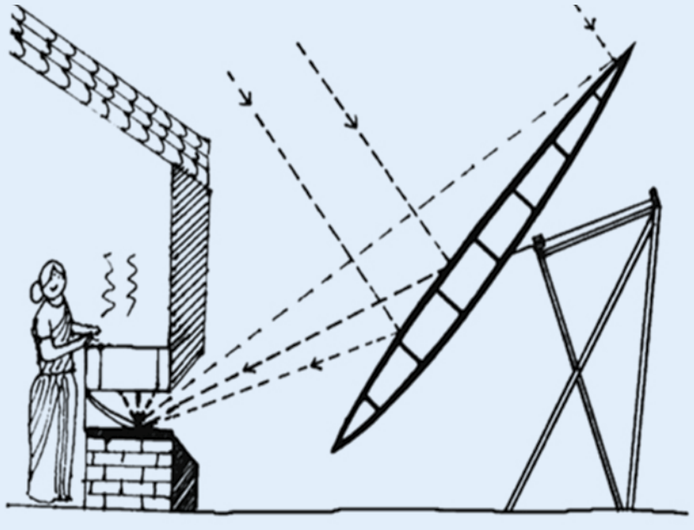
National Programme of Nutritional Support to Primary Education, popularly known as the Mid Day Meal Scheme (MDM), started by the Government of India in 1995, is an attempt to enhance enrollment, retention, and attendance while simultaneously improving nutritional levels among children in school. The main objectives of the scheme (as per the 2006 revision) are: (i) to improve the nutritional status of children from classes one to five in both, government and government aided schools; (ii) to encourage children from disadvantaged backgrounds to attend school regularly and help them concentrate in school activities; and (iii) to provide nutritional support to students in drought-ridden areas throughout summer vacation.

Some research findings on Mid Day Meal Scheme conducted by independent agencies reported that MDM programme is a visible programme and has helped in increasing an attendance and enrollment of children, particularly girls. They also reported that there is an increase in retention, learning ability, and achievement, as well as greater social equity among caste, creed, sex, and gender groups in the schools. Currently serving 10.45 crore children in 11.58 lakh schools, it is the largest such programme in the world.

A huge amount of firewood and other fossil fuels are being consumed to cook food for the children under the MDM scheme. At many places, availability of these fuels is scarce and the cooks also have to face the problem of smoke generation leading to health problems and emitting GHG emissions in the atmosphere.

Solar Solution

World Renewal Spiritual Trust (WRST), a daughter organization of Brahma Kumaris, has been actively involved in the research and demonstration of various renewable energy concepts for more than 18 years. It is one of the pioneer institutes which successfully developed a number of applications in the field of solar energy for institutional use, such as solar steam cooking systems, solar sterilization, and laundry system, as early as the beginning of 1990s. So far, across India, WRST has installed six large steam cooking systems, more than 1.2 MW peak stand-alone solar PV power systems and approx. 50,000 litre/day solar hot water systems at the headquarters. In view of the vast potential of solar intervention in MDM Scheme of India and also considering the challenges coming from using fossil fuels for cooking, a solar cooking scheme is proposed by WRST, as an alternative to currently used solutions.



Schematic of Scheffler dish cooking food inside the kitchen

The Technology

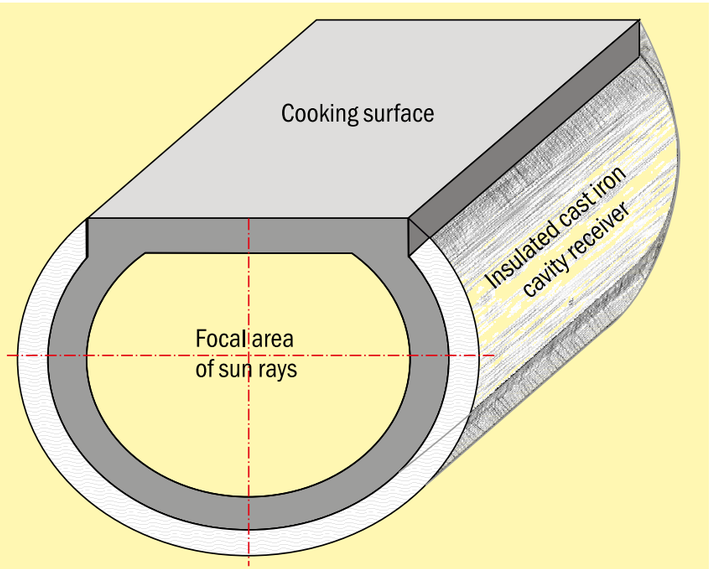
The technology provides an indoor cooking system using direct solar cooking applying 16 m^2 Paraboloid dish with Cast Iron Heat Storage. Concentrated solar rays from the 16 m^2 parabolic reflector (Scheffler) are focussed towards a focal point, an area where a cast iron receiver cum storage is placed. The receiver is designed in such a way that it absorbs the sunlight, stores the thermal energy, and acts as a flat pan for chapattis and all cooking applications. Sunlight is converted into heat energy that is retained for cooking. The thermal storage cum cooking pan allows for cooking during post sun hours and morning hours by using the energy stored during the previous day.

Scheffler reflectors are well proven in the field of cooking, both direct and solar steam cooking. Proposed 16 m^2 reflector has a reflective surface area with daily and seasonal tracking mechanism. Reflector stays along the polar axis, thus keeping the focus point static, which is an indispensable requirement for a cooking application.

A 16 m^2 dish is installed facing south, concentrating sunlight on approximately four metres distance, at a focus area of 400 mm diameter. Cast iron cavity receiver cum storage is placed exactly at the focal point, thus receiving solar energy and its temperature goes up to 400°C. The design of the receiver is shown in the schematic alongside. Small shade and wall shall be built around the receiver, so the cook can stay comfortably in the kitchen while performing his duties.

The receiver is a cast iron cavity cone with flat surface on top to accommodate frying pan and cooking vessels. Approximate weight of the receiver is 350–400 kg and is insulated with LRB mattress and aluminium sheet at the bottom. It is equipped with a flat removable insulated plate to cover the pan during non-cooking hours. As cast iron is a very sturdy material, there is no wear and tear factor and thus, no maintenance is required.

On a typical sunny day, 16 m^2 reflector delivers around 35,000 kcal a day, which is approximately 40 kWh of thermal energy. One parabolic dish of 16 m^2 with thermal storage is sufficient to cook one meal for 250 students. Cooking at school starts around 9:30 a.m. and food is served between 12:30 and 1:30 p.m. In order to have an effective required energy during the three hours of cooking, the cast iron receiver with storage cum cooking pan plays a crucial role. It stores the previous day's energy and provides necessary heat for early morning cooking. As the system is modular, it can be easily expanded to cater to a larger number of students, without the need for steam generation.



Cavity receiver cum heat storage with cooking surface

Advantages of Direct Cooking

The advantage of direct solar cooking over solar steam cooking is that no pressurized steam, piping, or specialized vessels are required. Direct cooking is more efficient and effective. Limitation of solar steam cooking is that no fired items can be prepared. Due to high temperature, the direct cooking rate is relatively fast and it is possible to cook all the traditional dishes, including fried items. Food that can be prepared using the solar dish include rice, *khichadi, pulao, biryani, kheer, dudhpak, basundi,* flavoured milk, pulses, cereals, vegetables, curries, etc. It is also possible to make *puri* and *chapattis*.

In case a school is located in a remote area, where power supply may be often interrupted, direct cooking offers the benefit of operating without power (tracking mechanism can operate with a small PV cell). Steam cooking requires power supply for its operation. Another advantage of direct cooking vs. steam cooking is that it requires very little maintenance and the school staff can be easily trained, as there is no high technology involved.

Operation and Maintenance

The solar cooker works without fuel and hence, there is no danger of explosion or fire. But heat accumulated in the cast iron receiver at the end of cooking can be very intense, so proper precautions have to be observed. The solar dish should be placed at a spot which gets the maximum direct sunlight. Shadow free areas in the courtyard or terrace are the ideal spots. Periodical cleaning of solar dishes is required. Care needs to be taken in terms of children breaking the glass mirrors.

Cost Economics

Cost of total system for 250 students, including reflector and receiver is less than ₹3 lakh, excluding civil work. The system can save approximately ₹150–200 on fuel per day, depending on the type of fuel used. Thus, the payback time is around four years. The system can work for 20 years.

Benefits

- It does not require kerosene, coal, cooking gas, or firewood because it

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works with the heat energy received directly from the sun. As a result, there is no use of matchsticks and lighters and no fuel bills as well.

- It does not create pollution of any kind. Hence, it keeps the atmosphere, the kitchen, and the cooking utensils clean and soot free. It does not emit any smoke or fumes and so it is not a health hazard either.
- Zero-emission, free solar energy replaces firewood, charcoal, or fossil fuels for cooking, the planet remains a beautiful place to live and stays cooler.
- It is the safest cooking device as there is no danger of fire, explosion, cylinder bursts, gas leakage, or electric shock.
- As cooking is done slowly and at a regular moderate temperature, the prepared food is tasty, retains its original flavour, colour, texture, and its nutritious elements too remain intact. The vitamin, protein, and mineral contents of the food are preserved unlike in other mediums of cooking the nutrients are destroyed due to overcooking or high temperatures.
- The solar reflector needs little care and repair work is comparatively inexpensive and quickly done. With little routine care, the cooker gives trouble-free performance for years.
- At an early stage of life, students gain awareness about renewable energy and experience its practical application.

Conclusion

It is suggested that a model district can be adopted to experiment with the proposed solar cooking system, within the existing scheme. A comprehensive techno economical feasibility study needs to be carried out for such a large scheme with the help of experts in this field. Involving capable local NGOs may also help in executing such a scheme.

READERS' RESPONSES

> I am very much thankful to receive the Sun Focus magazine regularly. This magazine has impressed me to install solar power plant.
>
> *M Ganesan, Civil Engineer, Avinashilingam Institute for Home Science & HE for Women, Coimbatore*

> I read recent article of Sun Focus. It's very well compiled and quite informative. I am sure such efforts will provide suitable platform in the spear of Indian Solar Thermal Segment. Congratulations to the entire Editorial Team.
>
> *Nikunj Shukla, SBU Head-Solar Thermal Division, Waaree Energies Limited*

> Interesting and relevant area. The coverage is also good. Should reach not only the solar professionals, but also many other industries and industrialists along with policymakers.
>
> *Shireesh B Kedare*

NATIONAL TEST FACILITY FOR CSTs AT NISE, GURGAON

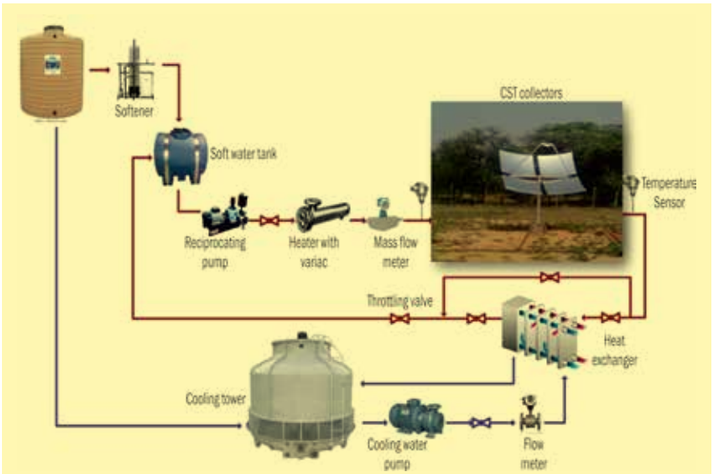
S K Singh[1] and Umakant Sahoo[2]

National Institute of Solar Energy (NISE) has setup state-of-art of test facility for CSTs under UNDP–GEF CSH project on 'Market Development and Promotion of solar Concentrated Based Process Heat Application in India' to develop performance measuring standards, test procedures, and test protocols. The test bed was commissioned in October 2014.

Immobile Test Set-ups

Hot Water/Steam Based Test Set-up

Test facility is capable of testing different models of CSTs over its operating temperature range under clear sky condition for determining its thermal efficiency. The test facility is



Immobile Test set-up for thermal performance of CSTs

Hot water/steam based test set-up for CSTs at NISE

[1] *S K Singh, Director/Scientist 'F', Solar Energy Centre, MNRE; Email: sk_sudhir100@yahoo.co.in*

[2] *Umakant Sahoo, Research Scientist (Solar Thermal), Solar Energy Centre, MNRE; Email: uk.sec.mnre@gmail.com*

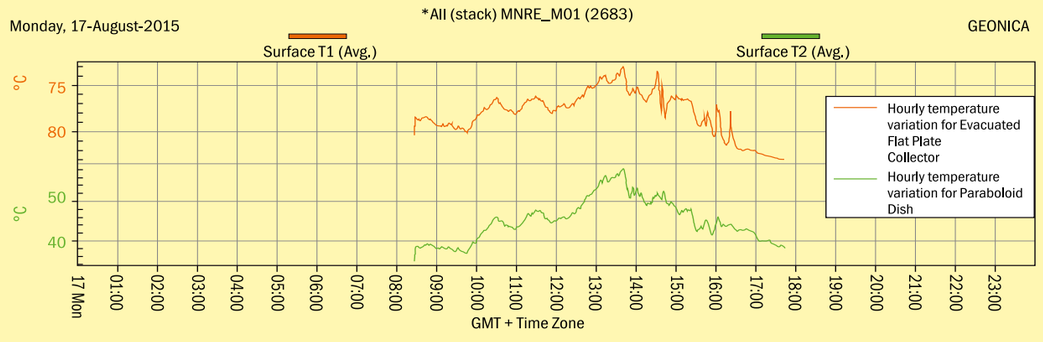
Testing of a CST and evacuated FPC for high temperatures at NISE

hot water/steam based at temperature up to 250°C. The measurements are carried out under quasi steady state conditions. Data points that satisfy the quasi steady state conditions is obtained for at least four inlet temperatures spaced evenly over the operating range of the collector. One inlet temperature shall be selected such that the mean fluid temperature in the receiver lies within ±3°C of the ambient temperature in order to obtain an accurate determination of optical efficiency of the system.

Thermic Fluid Based Test Set-up

Apart from water/steam-based test facility, NISE has also created a thermic fluid-based CSTs test facility to test the thermal performance in the year 2012 as part of project titled 'Development of a Megawatt-Scale Solar Thermal Power Testing, Simulation and Research Facility' in collaboration with IIT Bombay.

Thermic fluid based test set-up for CSTs at NISE



Data logging of various parameters in immobile data logger

This test facility is capable to test all the CSTs using thermic fluid as heat transfer fluid temperature up to 400°C to make test protocol and standardization and comparing the performance of different CSTs. The heat transfer fluid for testing is Therminol VP-1. The CSTs have been tested using heat transfer oil at various temperature conditions up to 400°C at oil flow rates from 5 to 7 kg/s, and pressures up to 10–15 bar. The test facility offers the characterization of CSTs to provide the opportunity for design improvements and selection of concentrators for various applications.

Testing of Other Parameters

NISE has also created the test facility to test other parameters such as:

- Receiver heat loss characterization in Indoor testing condition
- Surface reflectivity test of mirrors/ reflectors
- Absorptivity and emissivity test of receivers.

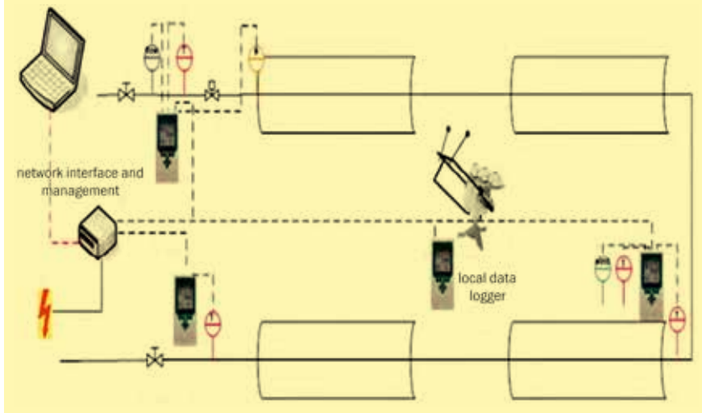
Mobile Test Set-Up

NISE has also created a mobile test facility for characterization testing of CSTs in actual field condition. This mobile test carried out on CSTs in the facility will be surface reflectivity test of reflectors, absorptivity, and emissivity

Heat loss testing of heat receiver

test of receivers, optical, and thermal efficiency test. The test output will help the manufacturer to estimate the performance of the technology in different climatic environment of this country. The various test equipment to measure different parameters of the CSTs are shown in Figure 1.

These test facilities established by NISE are to characterize the CSTs across the country and will prove to be a foundation for emerging CSTs and related applications in the booming solar energy industry.



Mobile test set-up for different CSTs

Mobile solar tracker with irradiation sensors

Ambient temperature and wind sensors

Clamp-on ultrasonic flow meter

Temperature sensors

NIR handheld reflectometer

Mobile data loggers

Figure 1: Mobile test equipment

All manufacturers and new entrepreneurs are welcome to use these facilities.

EXPERIENCES WITH SOLAR STEAM COOKING: A CASE OF STUDENTS' HOSTEL AT MNIT JAIPUR

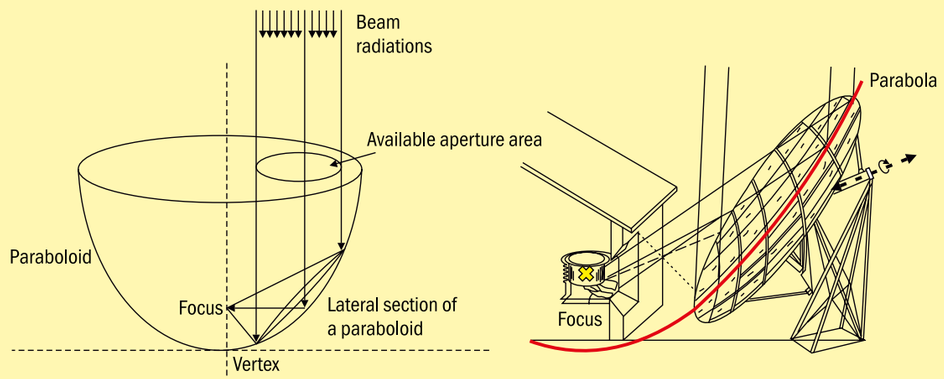
Jyotirmay Mathur[1] and Vashi Mant Sharma[2]

Malaviya National Institute of Technology (MNIT) Jaipur, established in 1963, is one of the prestigious technical institutions in India. It was declared as the Institute of National Importance through the Act of Parliament in 2007. In its mission of making the campus 'green', it has installed many renewable-based systems in the campus. A 300 kW grid connected photovoltaic plant was installed in 2014. Solar water heaters with a total capacity of 60,000 litre/day have been installed which provide hot water in winters in hostels, thereby, benefitting thousands of students. Scheffler concentrator-based steam cooking plant had been installed in the campus in 2013. This has been of the widely used CSTs for cooking purpose. Schematic of Scheffler dish focussing all the sun light on cooking pot kept at focus may be seen below. A bunch of six such dishes (automatically tracked N-S) have been used in the system with circular hollow receivers kept at each of the focal points to generate steam on passing water through them.

The System

With sufficiently high sunshine hours in a year (3,399 hrs in Jaipur), CSTs look promising vis-à-vis clean energy in the Indian context. Steam can be generated using concentrators that can be used for various purposes, such as cooking, sterilization, laundry, process heat, space heating/cooling, power generation, etc. The system can help one reduce the consumption of conventional hydrocarbon-based fuels and electricity and thus, the GHG emissions. Around 170 systems with dish area of about 42,000 sq. m have been estimated to be installed so far in the country. One such system for community cooking has been installed at MNIT Jaipur, which caters to 600 students, twice a day.

The system was installed in 2013 at Gargi Hostel, MNIT Jaipur by a private firm based out of India. The MNRE facilitated the process by providing subsidy and two years of maintenance under UNDP–GEF Support Programme.



Schematic of the Scheffler dish

Solar Steam Cooking System at MNIT Jaipur for 600 students

System Specifications

The system provides steam for cooking *dal*, rice, vegetables, and hot water for doing dishes. The system is installed at the hostel's rooftop. It consists of six Scheffler dishes, each having a reflector area of 16 sq. m and a concentration ratio above 60. The reflectivity of the mirrors is around 90 per cent. Two rows of dishes are placed in parallel, with each row having three dishes in series. A steam storage tank of 400 litre is connected with outlets of two rows. The tank is connected through insulated pipes with the cooking pots, which are downstairs in the mess.

Working, Operation, and Performance

Like any other CST, Scheffler concentrator focusses the incident radiation on a receiver with a smaller area. To keep the focus fixed throughout the day—the most important feature of these systems—the dish has to track the sun in such a way that the focus lies on the axis of rotation. To keep the focus fixed throughout the year, change in the shape of the dish is required on a daily basis, which is known as flexing. The system has automatic tracking for diurnal motion of the sun. The seasonal tracking of the same involves a change in the dish's tilt and flexing (change in shape). The tilt is changed automatically using PLC. However, the flexing needs to be done manually once in a few days.

As the concentrated flux falls on the receiver, the water inside it starts heating up. As steam generation progresses with time, the steam pressure starts building up in the storage tank. In case of zero consumption of steam, pressure keeps increasing with radiation and reaches a peak in the afternoon, and then comes down. In case of steam usage, the tank pressure decreases sharply and again starts building up.

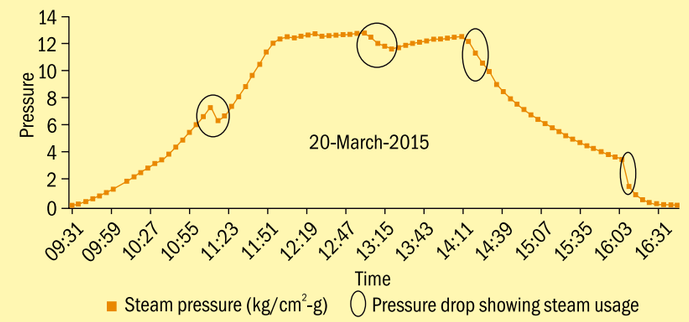
Steam Generation and Consumption Trend on a Typical Day. Pressure (bar) vs. Time of the Day

Steam is generated from the system every day, which is enough to cook *dal*, rice, and vegetables for 600 people, twice a day. The steam generation typically starts taking place around 10:30 a.m. and continues up to 3:30 p.m. The extra steam remaining in the tank is used for washing utensils. In the kitchen, specially designed vessels are being used in which heat transfer from steam to food takes place. In the absence of the sun, conventional LPG-fired burners take care of cooking.

The system was purchased with the subsidy provided by MNRE. According to the hostel management, the system is saving around 20 kg of LPG per day, leading to 5,000 kg annual savings, thereby cutting the greenhouse gas (GHG) emissions by 1.085 tonnes/year.

Online Performance Monitoring

Supported by MNRE under UNDP–GEF Project, steam temperature, pressure, and the amount of generated steam are monitored online. Relevant weather



Variation of steam tank pressure along the day

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Steam Cooking Kitchen

parameters such as solar insulation, air temperature, wind speed, etc., are recorded using censor-based weather station at the system itself. The station is connected with the data logger and equipped with an antenna, using which the values of all parameters can be monitored online for every 15 minutes.

Staff Training

The mess staff has been trained to run the system smoothly. A three-day workshop for mess workers was conducted at the time of installation under the supervision of experts from the manufacturer and institute. The experts in steam cooking technology at the institute regularly visit the system to ensure proper operation. The staff is trained to take all safety measures while working in the solar field. In case of mishaps such as windstorms—quite probable in Jaipur's climate—the trained mess workers can take care of the situation within a few minutes. The dishes are immediately fastened in a position having maximum capacity to bear the wind perturbations for zero/minimal damage.

Issues

Although the system is promising and a game changer in terms of technology, some issues came along that merit immediate attention:

- The system has two-axis tracking mechanism and still needs manual adjustments to allow dish's flexing to counter seasonal motion of sun. This in turn brings error into the system which leads to energy losses
- Due to manual errors, focus sometimes shifts to the outer part of the receiver or even the pipes carrying water/steam. This causes burning of plastic and deformation of the pipes at a few places
- Dishes need to be monitored twice a day and sometimes adjusted for diurnal motion as well, which is supposed to be an automatic process
- Lack of professionalism and understanding in mess management. Sometimes, trained workers are not available on site and new ones are clueless about the system.

Solutions and Recommendations

Fully automatic Scheffler system is the need of the hour. It will not just be a more efficient system, but also something that hardly requires human interventions. Thus, the above issues can significantly be taken care of by using fully automatic tracking. There is work going on regarding the automation of the system at MNIT Jaipur. Fully automatic double-axis tracking of dishes will be a reality in a year or two. Here are some recommendations based on experience for new users:

- Manufacturer should preferably be empanelled by MNRE
- Zero error in system installation is critical as the system has to be oriented and tilted at specific angles that are different for each site. Even a little error in installation can lead to life-long performance issues
- Water softener must always be used before feeding water into the system
- If the climate is such that corrosion is rampant, direct mixing of steam with food for cooking must not happen
- Steam tank and pipes must be cleaned from inside on a regular basis
- Real time online monitoring of weather and system performance is always useful. For example, if radiation levels are normal but steam generation is not happening, it could be a probable indication of deviation of focus from the receiver, in which case, it can damage anything which falls on its way
- Use of weather forecasting tools is always beneficial. If a windstorm is expected to hit the site on a day, system shut down can be scheduled well in advance so that it can be saved from any potential harm
- Training of operator(s) is critical.

Conclusion

In conclusion, it could be said that the system is very promising but the performance and ease of handling can further be enhanced by technological advancements.

LINEAR FRESNEL REFLECTOR TECHNOLOGY FOR INDUSTRIAL PROCESS HEAT APPLICATIONS ABROAD

Christian Zahler,[1] Taobias Schwind,[2] and Farah Gammoh[3]

Industrial Solar GmbH from Freiburg, Germany, the worldwide leading manufacturer of Fresnel process heat collectors and turnkey provider of sustainable energy solutions for industry based on a broad portfolio of renewable technologies, has recently inaugurated two systems that are paving the way to a sustainable future of industry: a solar cooling system for a data centre of Mobile Telecom Networks (MTN), Africa's largest mobile telecommunications company and a direct steam generating solar process heat system for the pharmaceutical company RAM in Jordan.

Linear Fresnel Reflector (LFR)

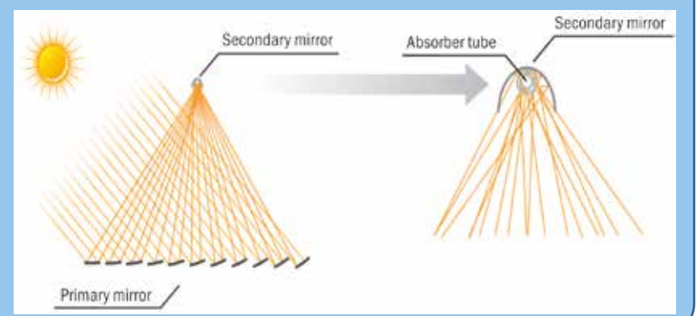
The Fresnel collector consists of modules containing 11 rows of mirrors attached to each other in strings that are driven by electric motors. The length of the strings are designed according to the application being addressed and are economically optimized to minimize the number of motor drives. Pressurized water, steam, or thermal oil can be circulated through the absorber tubes of the collector strings.

Water is a cheap, safe, and harmless heat carrier that has an advantage over other mediums due to its low viscosity allowing cheaper pumps as well as its ability to reach very high temperatures without degrading. Single, double, and triple-effect chillers can be operated either using pressurized water or saturated steam. Most single and double effect absorption chillers are operated using pressurized hot water at temperatures ranging between 140–190°C.

On the other hand, many applications in the food, textile, beverage, and other industries, require saturated steam. Applying direct steam generation in low-medium pressure ranges avoids the use of expensive heat exchangers. Nonetheless, steam systems can become expensive as their pressure and temperatures rise over a certain point. In such cases, water can be substituted with thermal oil allowing operation of the system under no/very low pressure. This in turn also results in a decrease in the piping and peripheries' costs. Industrial Solar's experienced team has been able to offer optimal technical and economic solutions customized to the individual requirements of the customer.

The Linear Fresnel Collector

The Fresnel collector uses uniaxial tracked mirrors to concentrate the solar irradiation onto a vacuum absorber tube which is covered by a secondary reflector that distributes the concentrated solar radiation more homogenously on the absorber tube. A heat carrier is pumped through the absorber tube and heated up to the desired temperature. Individually tracked mirrors together with an intelligent control unit assure very precise temperatures and pressures at the outlet of the collector field.



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[2] *Tobias Schwind, Managing Director, Industrial Solar GmbH, Freiburg, Germany*

[3] *Farah Gammoh, PhD Candidate*

Advantages

- Low susceptibility to high wind loads (mounted near ground)
- High mirror reflectivity (glass mirrors)
- High ground usage factor (no shading)
- Suitable for both rooftop and ground
- Stationary receiver (no need for expensive flexible pipes)
- Modularity
- Long lifetime

Economics

Long term investments, such as investments in buildings or energy systems, prove to have low risks and can at the same time save and eventually even generate money in the long run. To evaluate such investments, it is necessary to examine them over a long period of time. The internal rate of return (IRR) is usually approximate to the economic feasibility of an investment. A typical solar process heat system using the Industrial Solar Fresnel collector ranges between 5–30 per cent, depending on the current energy price, its rate of increase, and the lifetime of the system. The payback times range between 4–10 years. The systems have very low operational costs after that and can generate heat at a price lower than €0.01/kWh, depending on the size of the system. The industry has typical expectations of 3–5 years payback time. Nonetheless, the Fresnel system proves better in terms of return on investment due to its long life span of more than 20 years.

The fossil fuel prices are an important factor in studying the economic feasibility of a system. Many governments have large subsidies on energy and their prices sometimes fall even below the generation cost. Thus, even higher rates of return can be achieved in regions where fossil fuels are less subsidized.

Solar Process Heat and Solar Cooling Systems Powered by Industrial Solar Fresnel Collectors

Industrial Solar GmbH has implemented numerous projects using LFR Technology for various applications, such as industrial process heat and cooling. Case studies of two of the latest installations are given in the following section:

Case Study 1: Solar Cooling of a Data Centre in South Africa

The strongly increasing mobile communication requires a steadily growing IT infrastructure on the part of the telecommunication providers. This results in a high electric power requirement by the servers and network infrastructure, which is generally converted to waste heat. Thus, this infrastructure has huge cooling requirements.

TABLE 1: TECHNICAL DATA OF MTN'S FRESNEL COLLECTOR FIELD	
Installed solar thermal capacity	272 kWth (heat)
Operating temperature	180°C
Heat transfer fluid	Pressurized water
Collector type	Industrial Solar Linear Fresnel LF-11
Collector field layout	2 strings with 11 modules each
Aperture area	484 m²
Annual gross heat production	390 MWhth
Reduction in CO_2 emissions	47,000 kg/a

Figure 1: Industrial Solar GmbH's Fresnel collector field at MTN, Johannesburg, South Africa

Together with its South African partner REACH Renewable (Pty) Ltd, Industrial Solar GmbH has equipped the multinational telecom company Mobile Telecom Networks (MTN) with a solar thermal cooling system to cater to the cooling requirements of the data centre. Table 1 presents the important technical specifications of the project. A Fresnel collector with a thermal peak capacity of 272 kWth was installed on the roof of the company's head office in Johannesburg (Figure 1). The collector powers a double-effect absorption chiller with a cooling capacity of 330 kW (Figure 2). The generated cold is fed into the data centre's cooling system and used, among other purposes, for air conditioning or processor coolers This reduces the use of fossil fuels, CO_2 emissions, and electricity costs, especially in the hot summer months. Links to videos on YouTube: <https://youtu.be/7qqXI0TbF4Y>; <https://youtu.be/mbwiUlb__gg>.

Figure 2: Double-effect absorption chiller integrated with solar collector field

Case study 2: Solar process Steam for a Pharmaceutical Company in Jordan

Pharmaceutical industry is a large pillar of Jordan's economy, and is the second largest exporting industry in the country. It is imperative that each pharmaceutical plant has stringent demands to maintain hygiene integrity; this is mostly done using high quality water steam. Thermal energy at high temperature is also required for mixing and melting processes of certain medical drugs. These demands are usually met through conventionally generated steam using a fossil fuel boiler that feeds a steam network which distributes the steam to the different processes.

In countries that are poor in fossil fuels like Jordan, which imports more than 95 per cent of its energy demand and has started to reduce its subsidies on energy starting 2005, industrial fuel prices threaten the competitiveness of energy intensive processes. Luckily, despite the lack of national fossil energy resources, Jordan is located in a region among the richest in solar energy, having a Direct Normal Irradiance (DNI) greater than 2,500 kWh/m²a in most parts of the country, which make it inevitable to resort to concentrated solar thermal solutions.

Industrial Solar's Fresnel collector field, installed on a total area of 560 m² on RAM Pharma's rooftop, serves as the first solar direct steam generating plant in the entire region (Figure 3). Using intelligent control and without any modification on the current steam generation system, the collector is integrated into the facility to reliably cover a large portion of the steam demand. The system is equipped with a steam drum that acts as a steam buffer before it is injected into the steam network. The steam drum dampens the effect of transients due to solar irradiation, serves storage purposes during solar peak hours, and stabilizes the system during boiler modulation reaction time.

The predicted annual solar yield on site is 860 kWh/m². This will save the company more than 30,000 litre of diesel per year. In the first month of operation, RAM Pharma's fuel demand dropped by 40 per cent. Apart from direct savings in fuel, the collector has a positive side effect as it acts as shading for roof, reducing the cooling demand of the hall underneath it during the hot summer season. The technical specifications of the installation are given in Table 2.

TABLE 2: TECHNICAL DATA OF RAM PHARMACEUTICAL'S FRESNEL COLLECTOR FIELD	
Installed solar thermal capacity	222 kWth (heat)
Operating Pressure	6 bara
Heat transfer fluid	Saturated Steam
Collector type	Industrial Solar Linear Fresnel LF-11
Collector field layout	2 strings with 9 modules each
Aperture area	396 m²
Annual gross heat production	340 MWhth
Reduction in CO_2 emissions	41,000 kg/a

Figure 3: Industrial solar GmbH installation at RAM pharmaceutical company in Sahab, Jordan

Conclusion

Ever since its penetration into the market in year 2008, the Industrial Solar linear Fresnel collector has been successfully installed and operated in various regions in the world. Several more commercial as well as non-commercial solar thermal cooling, process heat, and direct steam generation systems have been successfully commissioned to customers of a wide range, such as the automobile, beverage, and pharmaceutical industries, to name a few. All systems can be remotely controlled and monitored to guarantee smooth operation and ensure the deliverance of the expected power.

Depending on the DNI, current fuel prices and their prospective increase, solar thermal concentrating power systems offer an economically attractive and clean energy alternative to industries currently experiencing the burden of their energy expenses and high carbon footprint. An investment into such systems can yield payback times as short as three years and an internal return on investment as high as 30 per cent. In some countries, such as India, the government offers subsidies for solar thermal applications. Taking that into account together with the high DNI values, Industrial Solar expects to increase its share in the Indian market with its high-end products and long years of experience.

Revised Support and Category of
Demonstration & Replication Projects
under UNDP–GEF CSH project

(Applicable w.e.f 1/8/2015)

The support has been revised keeping in view the increased cost of materials, labour, fossil fuels, etc., and will be available mainly for on-line performance measuring equipment, operation & maintenance, preparation of DPR/ Pre-feasibility reports, submission of fuel saving data, etc.

Category of Demonstration & Replication projects has also been changed in view of all the new technologies coming under Demonstration category (other than 16 sq. m Scheffler) well demonstrated in last few years. Now all the technologies will come under Replication category except those having size 500 sq. m & above which will come under Demonstration category for having detailed performance monitoring.

Category	Type & Applications of CST	Support under CSHP
Demonstration	All types & application with sizes 500 sq. m & above	15% of MNRE benchmark cost to a maximum of ₹ 75 lakh
Replication	All types & application with sizes below 500 sq. m (excluding Scheffler dishes for direct cooking)	15% of MNRE benchmark cost but not less than ₹ 2 lakh for projects of sizes 45 sq. m & above on dish and 64 sq. m & above on other CSTs. For projects below that ₹ 1.5 lakh will be available.
Space cooling where new VAM is installed* (Maximum 5 projects)	All types of CSTs with minimum 30 tonne capacity of VAM	25% of MNRE benchmark cost to a maximum of ₹ 75 lakh
Project in ESCO mode	All types & application of CSTs	10% more of MNRE benchmark cost to a maximum of ₹ 15 lakh in addition to above
For Leh-Ladakh region, being a difficult area, the support for all types of CST based projects (except direct cooking) mat will be provided to the extent of 20% of approved project cost irrespective of size. One special project for Kargil may be supported to the extent of 30% of approved project cost.		

Note: *Installation of 2 nos of Pyranometers; with and without shading ring along with other instruments will be necessary for all demonstration projects of sizes 500 sq. m and above for measuring DNI for the purpose of on-line performance monitoring. For projects below 500 sq. m only flow meter, temperature & pressure sensors and sim-based data logger will be necessary. Five years AMC for projects above 250 sq. m and 3 years for project below that (including 1 year warranty) will also be mandatory. Five years warranty for solar mirrors/reflectors will also be mandatory.*

This support is in addition to MNRE subsidy and will be applicable for new projects, yet to be sanctioned.

GROUP STUDY TOUR TO EUROPE ON CONCENTRATED SOLAR TECHNOLOGIES

United Nations Industrial Development Organization (UNIDO) recently organized a seven-day study tour from August 23–29 to learn European experiences of solar thermal applications in the industrial sector using CSTs. The tour was organized with a special focus on peripherals attached to solar technology integration with the industrial process systems. It was carefully designed with this mandate and the group travelled through three countries in Europe—Austria, Switzerland, and Germany to learn and recognize the points of intervention and innovation from both the consumer and manufacturer side.

The participants in the study tour very well represented the stakeholders involved in the solar thermal sector of India, which included members from central government, state governments, financial institution, academicians, think tanks, and industry representatives. From the central government, Joint Secretary, MNRE Shri Tarun Kapoor attended the study tour along with Director, MNRE Dr R P Goswami. It was loudly recognized by all the participants that such tours are very important in narrowing down areas where minimum action can result in maximum output.

The tour began with an informal group discussion with the Director, Energy and Environment Branch UNIDO, Dr Pradeep Monga on mobilizing efforts in getting global leaders of solar thermal industries to India. He mentioned that India is at the brink of achieving great milestones in the RE sector and these achievements can be fortified with a strong quality control and careful consideration of efficiency in conventional processes and RE technologies.

Director - Energy and Environment, UNIDO and Joint Secretary, MNRE with study tour participants at the UNIDO HQ.

The study tour covered three industrial applications of solar thermal technologies which include meat processing unit, brewery unit, and a cheese producing dairy industry. The technologies covered were flat plate collectors and parabolic trough collectors. It is important to note that all the three industries visited are part of the food processing sector. This careful selection was made as the technology integration process in such industries is very specifically designed such that the stringent food norms of the country are maintained. The group also visited four manufacturers of solar thermal technologies which include flat plate collectors, parabolic trough collectors, and Fresnel systems.

The study group at a cheese factory in Zurich

As witnessed in India, the European countries are also struggling to provide competitive prices of CST systems. Automation/robotics is used by the companies to reduce error rates and the costs. The companies are also investing heavily in research to understand which technology works best for given conditions, such that more customized solutions for different conditions can be created. In addition, leading research institutes of the region, such as the German Aerospace Centre (Deutsches Zentrum für Luft- and Raumfahrt; DLR) were visited, who are also working on system improvement in more controlled settings, through effective public–private partnerships,

Overall, the tour was a great experience to understand the industrial integration for CST technologies and also to understand the motivations behind industries adopting such technologies. The payback period for all the industries was greater than six years with secured funding. Most of the industries were motivated with energy independence and the shifting ideology of greening the industry.

EVENTS UPDATE

Training Programme for Banks/FIs at Pune on July 29, 2015

A training workshop was conducted in association with the Bharathiya Vikas Trust (BVT) at Pune, to sensitize bankers about the concentrated solar technologies, their potential and market in India and indulged them in discussion to devise a lending mechanism that enable swift and large-scale development & implementation of these technologies.The outcome of the workshop was very positive with more than 50 participants representing 22 banks, technology providers, and organizing agencies (MNRE, PwC, and BVT). The training workshop concluded with a site visit to 'Mahindra & Mahindra' Chakan, Pune.

International Conference on Energy Economics and Environment at Greater *Noida August 21–22, 2015*

The first International Conference on Energy Economics and Environment (UPCON–ICEEE 2015) was organized by the Department of Electrical Engineers, Galgotias College of Engineering and Technology during August 21–22, 2015 in Greater Noida, Uttar Pradesh, India. The objective of the Conference was to exchange and share their experience related to Energy, Economics, and Environment. The programme included presentations by professors, various technical academicians, senior officials of Govt/PSUs/PMU of UNDP, and other technical experts.

Partner's Meet at Greater Noida on July 28–29, 2015

United Nations Development Programme (UNDP) organized a two-day project partner's meet from July 28–29, 2015 at Greater Noida to review the progress and action plan of UNDP supported projects for the year 2015, as per Annual Work Plan. The participants were addressed by UNDP Country Director, Mr Jaco Cilliers and Dr Preeti Soni, Assistant Country Director. ACD summarized the proceeding of the two days by emphasizing the importance of the partner's meet in achieving multiple objectives of completing the annual requirements and learning from other projects.

Training Programme on CST at Abu Road on April 17–19, 2015

The first Concentrating Solar Thermal (CST) Technology training programme was conducted by WRST at Abu Road, Rajasthan during April 17–19, 2015 under the banner of UNDP–GEF CSH project. The training was dedicated to Scheffler paraboloid reflector its concept, design, fabrication and installations aspects. The programme gathered 21 participants representing 11 manufacturers, installers, consultants, industrialists, and institutional users from all over India. Sessions were conducted by experts having long time association and practical experience with Scheffler elliptical dishes. The participants showed great interest, expressed by active interaction and high level engagement during sessions and networking time.

FORTHCOMING EVENTS

NATIONAL

Energy Efficiency Summit
September 2–5, 2015 | Hyderabad, India | Website: http://events.hellotrade.com/conferences/energy-efficiencysummit/

RENERGY 2015
September 9–10, 2015 | Chennai, India | Website: http://www.renergyteda.com/

Renewable Energy India
September 23–25, 2015 | Greater Noida, India | Website: http://www.ubmindia.in/renewable_energy/home

2 days Residential Workshop on CSTs for State Nodal Agency's
8-9 October, 2015 | Mount Abu, Rajasthan | UNDP–GEF CSH project

INTERSOLAR India
November 18–20, 2015 | Mumbai, India | Website: https://www.intersolar.in/en/home.html

RenewX
December 17–18, 2015 | Hyderabad, India | Website: http://10times.com/renewx

RE-Invest Conference
February 18–20, 2016 | New Delhi, India | Website: http://www.re-invest.in/

INTERNATIONAL

Renewable Energy World Asia 2015
September 1–3, 2015 | Bangkok, Thailand | Website: www.renewableenergyworld-asia.com

INTERSOLAR South America
September 1–3, 2015 | Sao Paulo, Brazil | Website: http://www.intersolar.net.br/en/home.html

Conference on Small-Scale Concentrating Solar Power in Sardinia
September 25, 2015 | Pula (CA), Italy | Website: http://www.sardegnaricerche.it/en/

GulfSol 2015
September 14–16, 2015 | Dubai, UAE | Website: www.gulfsol.com

Solar Energy UK: Energy Plus
October 13–15, 2015 | Birmingham, UK | Website: http://uk.solarenergyevents.com/energy-plus

SHC (Solar Heating and Cooling) 2015 Conference
December 2-4, 2015 | Istanbul, Turkey | Website: https://www.shc2015.org/home.html

सत्यमेव जयते
Government of India

Make your Establishment
green by reducing the carbon foot print

CONCENTRATING SOLAR TECHNOLOGIES

can meet a significant amount of your steam requirement for
community cooking & process heat applications

SALIENT FEATURES

- Can provide steam/hot oil/ pressurized water at 90-350 C
- Integrated with conventional boiler provides trouble free operations during non-sunshine hours. Systems with heat storage also available
- Gives economic return in 3-5 years besides getting a green tag
- Around 200 systems of various capacities working in country.

FINANCIAL SUPPORT

- 30% of benchmark cost as government subsidy
- Higher subsidy in special category states
- 80% accelerated depreciation to profit making bodies
- 15% of cost limited to Rs. 75 lakhs from UNDP-GEF project for specific activities.

Interested Organizations may contact our Channel Partners (**Clique Solar, Mumbai:** 09665055059/adb@cliquesolar.com; **Leverage Net Solutions, Pune:** 09970319054/ contact@energy-guru.com; **Megawatt Solutions, New Delhi:** 09654451401/ smalik@megawattsolutions.in; **Taylormade Solutions, Ahmedabad:** 09712933390/ dharam@tss-india.com; **Thermax, Pune:** 020-67308880 or 8885/ kdeshpan@thermaxindia.com; **Ultra Conserve, Mumbai:** 09004445530/ vivek@conserve.co.in; **Unison, Bangalore:** 09880022272/ shivanand.nashi@unisun.net;) and **Consultant- PwC, Gurgaon:** 08130322334/ vibhash.garg@in.pwc.com) write to us at following address. For more details, visit our website www.cshindia.in.

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