Concentrated Solar Technologies in India

India is full of sun energy. Technologies developed on use of this energy can help saving the fossil fuels in industrial, commercial and institutional establishments for various applications. A huge amount of fossil fuels especially the electricity and fuel oil are being consumed for thermal applications e.g. water /air heating, community cooking, process heat, space cooling etc. At most places the heat requirement in the form of steam/pressurized hot water/ air or oil is between 90 to 350 C. Industrial sector is the major sector which require such heat for various processes as mentioned below:

Industry	Process
✓ Food processing & Dairy	Chilling/cold storage, cooking, extraction, baking, pasteurization, sterilization, bleaching, drying etc.
✓ Breweries	Boiling, mashing, cold conditioning, fermentation etc
✓ Rubber	Heating, digestion, vulcanizing
✓ Pulp & paper	Pulping, digestion & washing, bleaching, evaporation & drying,
✓ Tobacco	Steam conditioning, drying & softening
✓ Electroplating	Post plating treatment, water heating, drying etc
✓ Pharmaceutical	Distillation, drying, evaporation, fermentation, injection & molding
✓ Textiles(Spinning & weaving, Finishing)	Preparing warps, sizing, de-sizing, scouring, bleaching, mercerizing, dyeing, drying & finishing
✓ Chemicals & Fertilizers	Distillation, effluent treatment, primary reforming, ammonia synthesis, CO2 removal, methanation, steam stripping
✓ Refining	Desalting, cooking, thermal cracking, cleaning, wastewater treatment
✓ Ceramic tile & pottery	Beneficiation, drying, presenter thermal processing, glazing
✓ Desalination	Multiple effect distillation, multi stage flash distillation
✓ Plaster of Paris, Steel re-rolling, Cement, Mining	Augmenting steam to boilers, boiler feed water heating

Solar water heating is already an established technology and is in promotion at large scale for providing hot water for various applications. This technology is, however, limited to temperatures below 90C. Concentrating solar technologies (CSTs) are now emerging fast in the country which can provide high temperatures in the range of 100 to 450 C or more even. These technologies basically focus the sunlight at receiver to achieve higher temperatures for various applications. Since these technologies can focus the direct radiation coming from the Sun, they need to be tracked alongwith the Sun. The technologies can be based on single axis (E-W) tracking as well as dual axis (E-W & N-S) tracking. Depending on their tracking arrangement, they can be put in the category of medium or high temperature applications.

Technology Status

Most of the CSTs have been developed and demonstrated in USA and Spain mainly for the purpose of power generation. Popular technologies for this purpose have been the Parabolic trough concentrators and Central tower receiver. Paraboloid dish and Linear Fresnel Reflector technologies have also been demonstrated at few places. These technologies, have, however, been hardly used for process heat, cooking or cooling applications. A couple of other technologies like Non-imaging concentrators and Heat pipes have also been developed abroad which find good applications for process heat and cooling applications in India .

In India mainly 3 types of concentrating solar technologies are presently in promotion. These are i) Manually tracked dish solar cookers to cook food for 10-40 people, ii) Fixed focus E-W automatically tracked elliptical dishes (Scheffler) for direct indoor cooking for about 50-100 people & for steam generation for the purpose of community cooking, laundry, space cooling etc. of any capacity (Figure-1) and iii) Dual axis fully tracked Fresnel dishes (Arun) for all such applications (Figure-2). These technologies are in implementation for last few years with support from MNRE. A few other technologies e.g dual axis tracked paraboloid dishes, linear Fresnel reflectors, non-imaging concentrators have also been developed and are at demonstration stage.

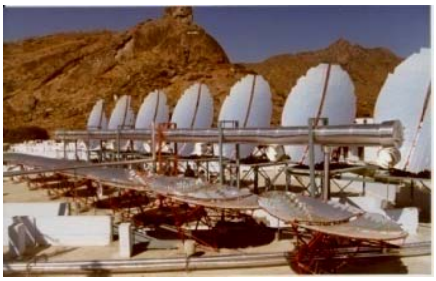

Fig. 1: Solar Steam Cooking at Mount Abu

Fig. 2: Arun dishes at ITC, Maurya, Delhi

Present Applications

CSTs have been found to be quite suitable for cooking food for hundreds and thousands of people in community kitchens especially at religious places and institutional canteens. The world's largest system is functioning at Shirdi for cooking food for 20,000 people/day. The system comprising of 73 nos. of fixed focus single axis automatically tracked elliptical dishes each of 16 sq. m. area generates about 3500 kg steam/ day. It was commissioned in July, 2009 and has been cooking food for pilgrims twice a day. A saving of around 263 kg of LPG/ day (18-20 cylinders) has been reported by the Shirdi Sansthan on a clear sunny day. Many more such systems at religious Ashrams, boarding schools and industrial canteens have been installed and functioning.

These systems are also being installed in industries and commercial establishments e.g hotels and hospitals for process heat and laundry applications. One such system installed at Hindusthan Vidyut Products Ltd, Faridabad, Haryana, comprising of 20 parabolic dishes of 16 sq. m. each is able to deliver around 1 million kcal of heat per day for the purpose of vulcanizing of Cables which is being done by dipping the cable-core in water for 18 to 24 hrs in a heated tank with the temperature maintained up to 85˚C. The system connected to their furnace oil fired boiler heats the oil to 125˚C for 6 hours during the day , thereby, saving a significant amount of fuel oil by the company. A few such systems for process heat applications are functioning in the country. A system installed at Ahmednagar, Maharshtra for laundry application is also working satisfactorily for last many years.

CST based systems alongwith vapour absorption machines have also been demonstrated for air conditioning. These have been installed at places where power cuts are high, electricity is expensive and the establishments are using fuel oil for generating cooling. Among some of systems installed is a 212 TR system (a combination of 160 TR with VAM and 52 TR through liquid desiccant) at Civil Hospital, Thane comprising of 184 no. of Scheffler dishes, each of 13.5 sq. m. area. Being at coastal area, the combined VAM & desiccant system makes it cost effective as the desiccant system first takes care of dehumidification of the moist air which then is cooled using vapour absorption machine (VAM). The system has been integrated with a biomass boiler using briquettes so as to make it run on 24x7 hour basis. 100 TR air conditioning plant at Muni Seva Ashram, Vadodara; 92 TR at TVS, Suzuki factory near Chennai, 30 TR plant at Magnetic Mareli, Gurgaon, 50 TR at NTPC, Noida and 100 TR at Mahindera & Mahindera, Pune are some more such examples of solar cooling.

Installations & Fuel savings

A total of about 144 steam generating systems have been installed so far in the country with a cumulative figure of 28,000 sq. m. of dish area. Another 23 system with 8100 sq. m. of CST area are at execution stage. This includes very small systems of 2 to 3 dishes also which could be 30% of the total number. Most of these have been installed mainly at places where steam generated through conventional boilers is already being used for cooking application. Installed in hybrid mode, these systems could save a significant amount of fuel oil at such places. A 100 sq. m. system can save 5,000-10,000 liters of diesel/ 600-1200 LPG cylinders per year depending on the type of technology used and DNI availability. Assuming 80% functionality (As per preliminary report received from Consultant hired under UNDP-GEF project), it is estimated that about 18 lakh liters of fuel oil equivalent would have been saved per year from the CST installations in the country besides reducing around 8500 tonnes of GHG emission per year in the atmosphere. There are 16 manufacturers/suppliers of such systems whose list is available at MNRE website www.mnre.gov.in. Industry-wise list of installations are given in following **Table**. Major installations have been in those states where steam cooking is already being done using LPG/Oil fired boilers or vapour absorption machines are being used for space cooling due to high power cuts or otherwise. These states include Karnataka, Maharashtra, Tamilnadu & Gujarat.

Table : Status on installation of CST based systems

Sr. No	Industry	Installed in last 5 years (2008-2013)		Total installed so far		Under execution	
		No.	Sq. m.	No.	Sq. m.	No.	Sq. m.
1.	Thermax, Pune	15	4246	15	4246	9	2847
2.	Flareum, Mumbai	40	6118	60	8875	3	1808
3.	Unisun, Bangalore	12	3294	20	3600	1	1280
4.	Clique, Mumbai	15	2470	15	2470	2	137
5.	Taylormade, A'bad	6	1092	6	1092	4	960
6.	Aireer Natura, Bangalore	2	112	3	320	1	224
7.	MWS, Delhi	1	90	1	90	-	-
8.	Bhagwati, Gurgaon	2	77	2	77	1	96
9.	K Energy, Jodhpur	3	192	3	192	-	-
10.	KG Design, Coimbatore	2	2800	2	2800	-	-
11.	Maharishi, Noida	1	316	1	316	-	-
12.	Sharda Invention, Nasik	10	2800	15	3000	-	-
13.	Akson solar, Pune	1	64	1	64	-	
14.	Bergen Solar, Gurgaon	1	20	1	20	2	740
	Total	**110***	**23,600**	**144***	**27972**	**23**	**8092**

* Includes very small systems of 2/3 dishes also which could be about 30% of the total number. The largest system at one place is with 184 dishes of 13.6 sq. m. each at Civil Hospital, Thane. Around 70% of above systems are on community cooking and rest on process heat & cooling applications. 15- 20% may be without any financial support from MNRE.

Salient features & Anticipated Heat delivery from CSTs

CSTs performance depend on various factors which include availability of DNI in a particular region, efficiency of the technology and various other climatic and other factors. To make people aware of the salient features of CSTs with anticipated heat delivery from them, Ministry has placed such information on its website as per below:

Salient features

Technology	Temp. range	Weight	Other features	Suitability of technology	For Retrofitted system as per MNRE specifications	
					Installed cost ** in Plains/ sq. m. (apprx.)	Payback* range with 30% subsidy
Fixed receiver elliptical dish (Single Axis tracked)	Up to 150C	400 Kg. for 16 sq.m. dish & 850 kg for 32 sq. m. dish	North South adjustment of each dish has to be done manually using levers once in 3-4 days.	Suitable for systems with smaller no. of dishes (say for up to 20 nos.). 32 sq. m. dishes could be useful for high temperature & oil based systems	Rs. 16,000	3.5 -6 years
Same with dual axis tracking	Up to 180C	-do-	Such adjustments are done automatically using photo sensors & motors	Suitable for any size of system.	Rs. 18,000	3.5 -6 years
PTC (Non-evacuated heat receiver)	Up to 180C	40 Kg./ sq. m. of PTC	-	Could be effective if space available in N-S is more due to reduced heat losses/ end effects	Rs. 16,000	3.5 -6 years
PTC (Evacuated heat receiver)	250C & above	-do-	-		Rs. 18,000	3.5 -6 years
LFR (Single Axis tracked)	250C & above	-	-		Rs. 18,000	3.5 -6 years
Arun (Dual Axis tracked)	Up to 350C	13 ton for 100 sq. m. & 20 ton for 169 sq. m. dish	Installed on pillar with foot print of 1-2 sq. m. All piping could be underground. Space between pillars could be used for other use like parking etc	Suitable for ground installations. Smaller dishes may be installed at terrace.	Rs. 20,000	3- 5 years
Dish (Dual Axis tracked)	Up to 350C	5 ton for 90 sq. m. & 2 ton for 43 sq. m. dish		Could be installed on terrace also apart from ground	Rs. 20,000	3- 5 years

** Variation is due to varying DNI in different regions. 5% of the cost is taken as O&M cost while calculating the payback period. 80% depreciation benefit to profit making bodies will reduce the payback by 25% or so. This will also be reduced by 30-40 % or so in special category states where subsidy is 60%.*

*** For newer systems, the cost towards boiler, utensils for cooking and VAM and its accessories for air-conditioning etc may be extra by 15 to 30% respectively. In high altitude areas and difficult terrain, the cost may further increase by 20 to 25%. The payback period for newer systems will, therefore, be somewhat more as compared to that mentioned above*

Note : Land/ swept area required for installation of CST based system is generally double the reflector/ collector area of the system

Anticipated Heat delivery

Sr. No	Region	Indicative average DNI/ sq. m. / day* (In kWh)	Sunshine days	Fixed focus elliptical dish^ / Non evacuated heat receiver PTC		Evacuated heat receiver PTC/ LFTR		Fresnel reflector/ Paraboloid based dish	
				Efficiency at 150C**	Heat delivery***/ sq. m/ year (in lakhs of Kcal)	Efficiency at 150C**	Heat delivery***/ sq. m/ year (in lakhs of Kcal)	Efficiency at 150C**	Heat delivery***/ sq. m/ year (in lakhs of Kcal)
1.	Leh Ladakh	6.5	320	35%	6.26	40%	7.15	60%	10.73
2.	Gujarat Rajasthan & western M.P.	6.0	300	40%	6.20	45%	6.97	65%	10.10
3.	North- West including Himalayas	4.5	250	35%	3.39	40%	3.87	60%	5.81
4.	North – East & eastern part of Orissa & A. P.	4.0	250	40%	3.44	45%	3.87	65%	5.59
6.	Southern & Central	5.0	280	40%	4.82	45%	5.42	65%	7.83

^ Average effective aperture area of 16 sq. m. fixed focus elliptical dish for receiving normal radiation during whole year is to be taken as 11 sq.m. The heat delivery from a 16 sq. m. elliptical dish in a year in different regions will, therefore, be 11 multiplied by figures given in above table.

Also dual axis automatic tracked elliptical dishes may have higher heat delivery by say 5% in comparison to single axis tracked dishes due to avoided errors in manual N-S adjustments.

* Can vary by +/- 10% at a particular location in the region

** Its average annualized efficiency and is linked with ambient temperature and wind conditions of particular region. It reduces in the regions having lower ambient temperature and high wind velocity. It also reduces marginally for CSTs working at higher temperatures due to higher heat losses, thereby reducing the heat delivery. Temperature range which can be achieved by various CSTs, their salient features, installed cost & payback period are given below.

*** Heat delivery will

i) increase if the fluid temperature goes down due to less heat losses. Likewise it will also decrease if working temperature is raised high say upto 350C or so especially in case of Fresnel reflector /Paraboloid dishes which are designed for such temperatures.
ii) decrease by 10% or more if the mirrors are not of solar grade quality.

Further Developments

Under public-private partnership with an industry, a 30 ton solar air conditioning system using indigenously made concentrating parabolic troughs and triple effect vapour absorption machine (Figure-3) has been developed and demonstrated at Solar Energy Centre, MNRE. It is a stand-alone system for day time use and can take care of intermittent clouds through small storage. The system has been found to be useful for offices and institutions working during day time when solar radiation is also available. Smaller systems with air cooled condensers have also been developed & in operation at SEC.

Fig. 3: 100kw solar cooling system at SEC, Gurgaon

A State of Art paraboloid dish of 90 square meter aperture area (Figure-4) has also been developed in public private partnership mode and has been successfully demonstrated at Solar Energy Center of MNRE. The dish concentrates the incoming radiation onto a highly efficient cavity receiver which heats the working fluid upto 400deg C for either direct applications or indirect applications via heat exchangers. The dish is designed to track the sun in two axis automatically to follow the sun without any manual intervention. The system has one of highest efficiencies and is expected to address most shortfalls of existing systems.

Fig.4 : State of Art Paraboloid dish

Fig. 5: Dual axis tracked Scheffler dishes with heat storage

To avoid manual errors in N-S adjustments of Scheffler dishes for keeping the focus at center of the receiver, dual axis automatically tracked dishes have been developed by Brahmakumaries at Mount Abu with required storage of heat in a metallic block for use in non sunshine hours (Figure- 5). The heat stored could be utilized for various applications during evenings & nights by sending water to the metallic block which coverts it to steam/ hot water.

East West automatically tracked linear Fresnel reflector technology has also been developed and demonstrated by KG Design (P) Ltd at their factory for steam generation. Based on this technology a 1400 sq. m. area plant has been installed at Ramanathapuram, Tamilnadu for the purpose of desalination of sea water using steam generated from the plant.

Potential & Constraints

There is huge potential of CSTs in various sectors where heat generated at high temperatures from such technologies could be utilized for the purpose of community cooking in kitchens, laundry in hospitals & hotels, process heat in industries and also for space cooling applications; thereby, reducing the use of conventional fuels and GHG emissions in the atmosphere. Major constraints in large scale promotion of CSTs in the country are, however, lack of awareness about the technologies & their benefits, non-lack of information on successful projects through case studies & video films Import of high quality reflectors, non-availability of evacuated tube receivers for CSTs & fool proof technology packages for industries, space constraints for installations, don-availability of performance data on CSTs with varying DNI, no test standards & set ups for measuring performance of CSTs and low returns on investments as compared to SWHs. To address these issues and accelerate the use of CSTs, a UNDP-GEF project on ‘Market Development of CSTs for industrial process heat applications’ is in operation by the Ministry which will continue till March 2017.

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