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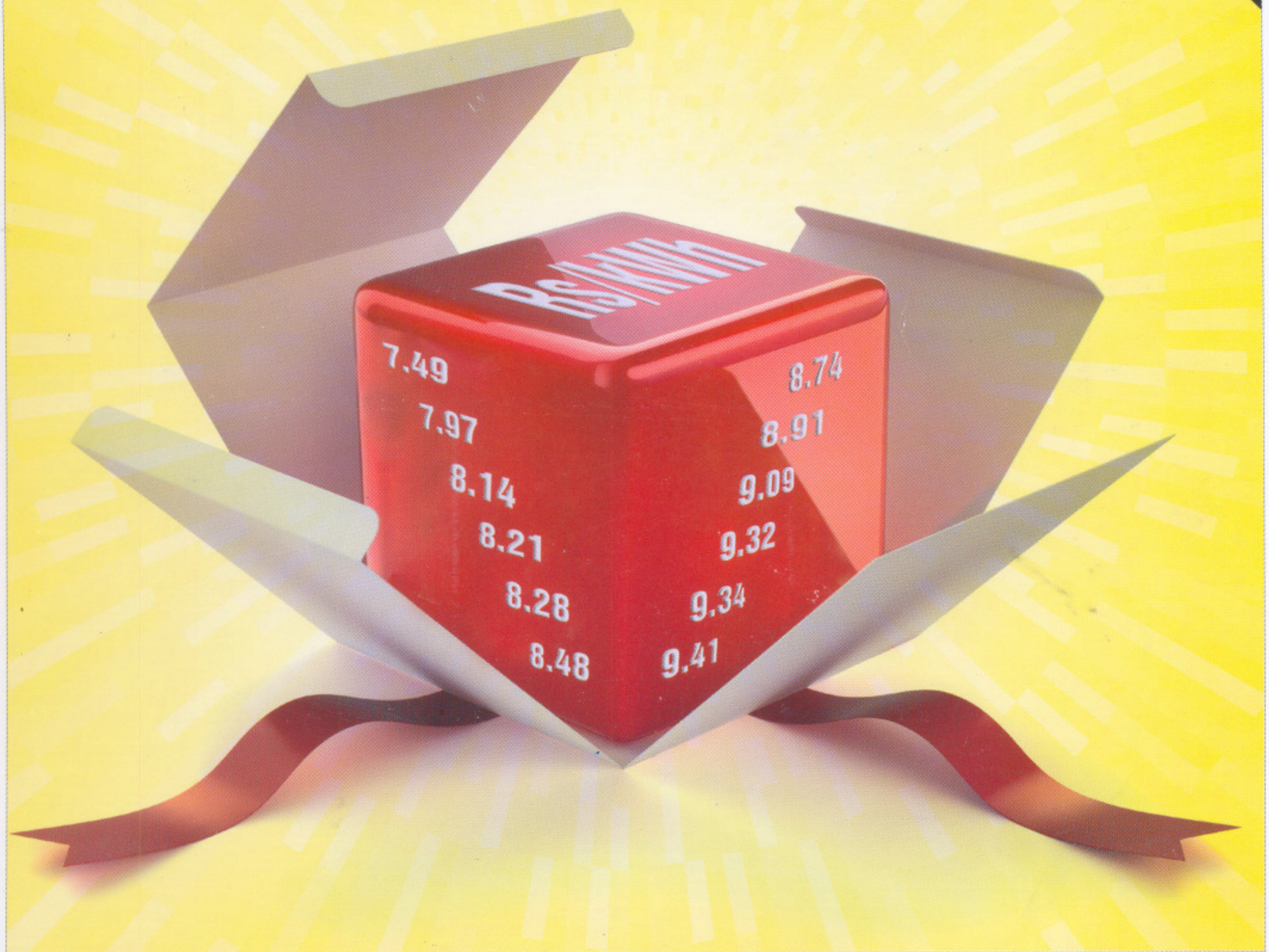

Solar Thermal Applications

Technologies for industrial process heating and cooling

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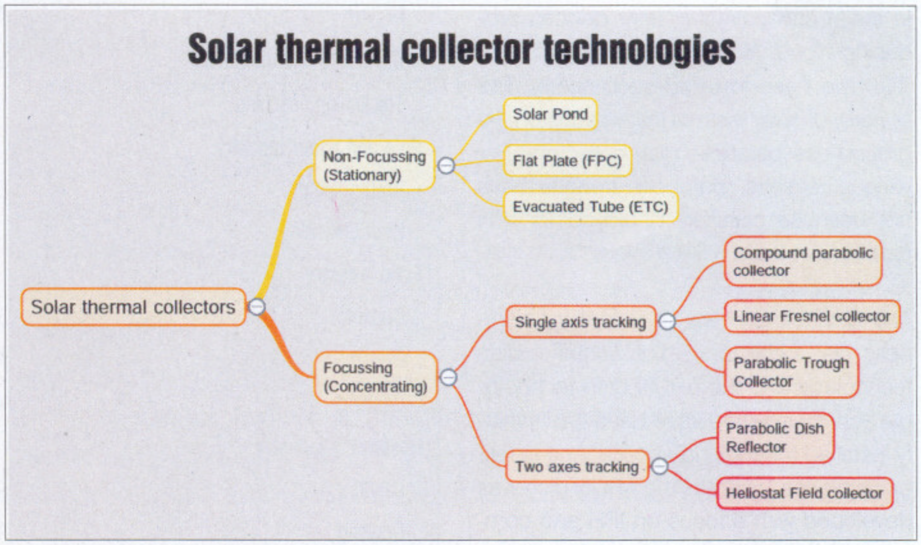


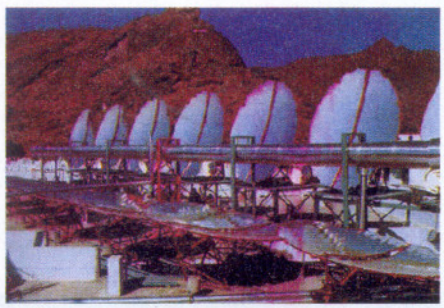
Industrial process heat (IPH) applications below 250 °C contribute to about 20 per cent of India's total oil consumption (almost 80 per cent of which is imported). Cooling and air conditioning is another energy-intensive process. Due to the limited supply of fossil fuel, its rising costs and pollution problems, and the ever-increasing power shortage, there is a need to make use of renewable energy sources to meet this IPH and comfort cooling energy demand. According to a McKinsey study, the power deficit in India could be as high as 25 per cent by 2017.

About 5-7 kWh per square metre of the total solar radiation (on non-tracking horizontal surface) is available in India for 300-330 days a year. Also, many cooling loads have a high coincidence with the availability of solar irradiation.

In India, concentrating solar devices, which produce the higher temperatures required for IPH and cooling applications, have been successfully deployed. This article discusses the various technologies available in this space and their on-the-ground performance along with relevant case studies. It also presents the basic parameters for evaluating the economic viability of investing in a solar energy system.

Solar thermal system applications

Comfort cooling applications: Solar cooling systems use thermal energy from solar radiation captured through solar concentrators to power thermally driven cooling machines. As many cooling loads, such as air conditioners, have a high coincidence with the availability of solar irradiation, the combination of solar thermal and cooling obviously has a high potential to replace conventional cooling machines. Cooling and air conditioning are one of the most energy-intensive processes among the various power consuming applications. Any technology that can save energy in cooling and air-conditioning applications



can help reduce the country's power shortage burden to a great extent.

Community cooking applications: Several religious places and schools/colleges across the country provide meals to devotees and students respectively. Many of them have community cooking facilities, which utilise high-cost fuels like liquefied petroleum gas. Solar energy can be used to substitute these fuels. An analysis of the per-meal intake and corresponding thermal energy requirement for cooking is presented in the table below.

Solar thermal technologies

There are various types of solar collectors. Flat plate and evacuated tube collectors are mainly used for low temperature applications. The area required by these is large as compared to concentrated collectors. A range of technologies can be used to concentrate and collect sunlight and convert it into medium to high temperature heat energy.

In India, concentrating solar devices producing higher temperatures (80 °C to 250 °C) have been installed successfully. The majority of solar thermal installations on the ground use parabolic dish collectors. For various reasons, parabolic troughs have not been successfully deployed for IPH purposes in India.

Two technologies are prevalent for parabolic dish collectors – the Scheffler dish technology and the ARUN dish technology. Scheffler dishes have been traditionally installed for cooking applications at religious places, whereas the ARUN dish was developed with a focus on IPH and comfort cooling applications.

Industrial applications

Industry/Process	Working fluid	Temperature range (°C)
Pharmaceutical industry		
Sterilisation	Steam	80-120
Drying	Air, steam	120-230
Syrup preparation	Water	80-130
Textile industry		
Mercerising	Water, steam	Up to 100
Drying	Steam	60-135
Finishing	Steam	60-150
Chemical industry		
Drying	Air	60-125
Dissolving and distillation	Steam	85-170
Thickening, leaching	Steam	85-170
Pulp and paper industry		
Kraft pulping	Steam	185
Kraft bleaching	Steam	140
Food industry		
Cooking	Steam	120-185
Drying	Air, steam	120-230
Canning	Water, steam	80-130
Hospitality industry		
Laundry	Steam	150-180
Cooking	Air, steam	120-140
Cleaning and bathing	Water, steam	50-60

Case studies

Some examples of large solar thermal system installations for IPH and cooling purposes are as follows:

Solar cooling: The first cooling system assisted by an ARUN solar concentrator has been installed on Turbo Energy Limited's premises in Paiyanoor near Chennai. It saves an equivalent of 18,000-20,000 litres of high speed diesel per annum.

Solar boilers: ITC Maurya has successfully installed and operated two ARUN solar concentrator dishes for meeting its thermal energy needs for laundry, cooking, bathing, etc. This installation saves ITC an equivalent of 40,000-42,000 litres of fossil fuel (furnace oil) per annum, which equates to an annual reduction in CO_2 emissions of 110-130 tonnes.

Thermal energy requirement for cooking

Food item	Per-meal intake	Thermal energy required for cooking	Cooking temperature required
Rice, dal, vegetables	Rice 100 gm, dal 50 gm, vegetable 50 gm (dry weight)	85-90 kCal per meal	120 °C
Chapattis	25 gm per chapatti, 2 chapattis per meal	~50 kCal per chapatti, or 100 kCal per meal	~280 °C
Hot water, milk, etc.	200 ml equivalent	50 kCal per day	~100 °C

Dairy industry

A solar dish is operational at Mahananda Dairy for hot water generation for milk pasteurisation. The system pressure and temperature are 18 bar and 180 °C respectively. Due to a mismatch in the working hours of the plant and the availability of sunlight, an insulated pressurised water storage tank with a capacity of 5,000 litres has been provided for non-solar hours'

Comparison between two parabolic dish collector technologies		
Parameter	**ARUN-160**	**Scheffler dish**
Aperture area	169 sq. metres per dish	169 sq. metres per dish
Tracking system	Double axis, both axes automatic	East-west: automatic and north-south manually adjusted
Maximum delivery temperature; pressure		
Thermic fluid/oil	Up to 400 °C, 15 bar (g)	Up to 150 °C, 0.5 bar (g)
Steam	Up to 252 °C, 40 bar (g)	Up to 150 °C, 4 bar (g)
Thermal output (same aperture area)	ARUN delivers 2.5 to 4 times heat per sq. metre to that of Scheffler	
Equal thermal output at 100-120 °C	1 dish of ARUN-160	25-30 dishes of Scheffler
Equal thermal output at 120-150 °C	1 dish of ARUN-160	30-40 dishes of Scheffler
Equal thermal output at 225 °C (thermic fluid/steam system)	1 dish of ARUN-160	100-125 dishes of Scheffler
Energy output	Promised quality and quantity can be delivered for almost full day	Promised quality and quantity can be delivered for about 5 hours per day
Energy generated at 150 °C (on clear sunny day)	3.75-4.25 kWh per m^2 per day	1.5-1.75 kWh per m^2 per day
Operation at peak capacity	About 8 hours per day equivalent	About 5 hours per day equivalent
Footprint area required for installation	5 metres x 5 metres for 1 dish (dish column and integration area)	10 metres x 25 metres for 10 dish (dishes, focus and integration area)
Structure of the dish	Sturdy structure that can sustain in windy conditions	Structure is very light; hence, focus gets disturbed frequently in windy conditions
Efficiency	55 to 65 per cent	20 to 40 per cent
	Efficiency does not drop significantly at lower insolations or in hazy atmosphere	Efficiency drops significantly at lower insolations or in hazy atmosphere

operation. Pressurised water was selected as the medium of heat transfer and storage as it has high specific heat, no fire hazards, no possibility of accelerated oxidisation overnight (as in the case of tarring of thermic oil), compatibility with food products and low operational costs.

Economic viability

Apart from drawing energy from a free power source, solar systems require very little maintenance. The majority of the lifetime cost, therefore, is made up of equipment and installation costs. The basic parameters that should be considered while evaluating the investment returns in any solar energy system are as follows:

- Cost of the solar energy system
- Subsidies
- Financing options
- Value of energy generated
- Non-financial factors that influence the economics.

Other than the standard investment rate of return, net present value and the payback period calculations that are mostly used in evaluating investment opportunities, some sector-specific economic indicators must be considered. These are as follows:

- Cost per kCal of energy delivered over the lifetime
- Energy per unit area occupied
- Energy gain ratio

Conclusion

Due to the limited supplies, high costs and pollution problems associated with fossil fuels, there is an urgent need to make use of renewable sources of energy to meet the thermal energy and cooling requirements in industries. The use of an appropriate solar technology for such applications can have a positive impact on the country's energy and environmental scenario. ■