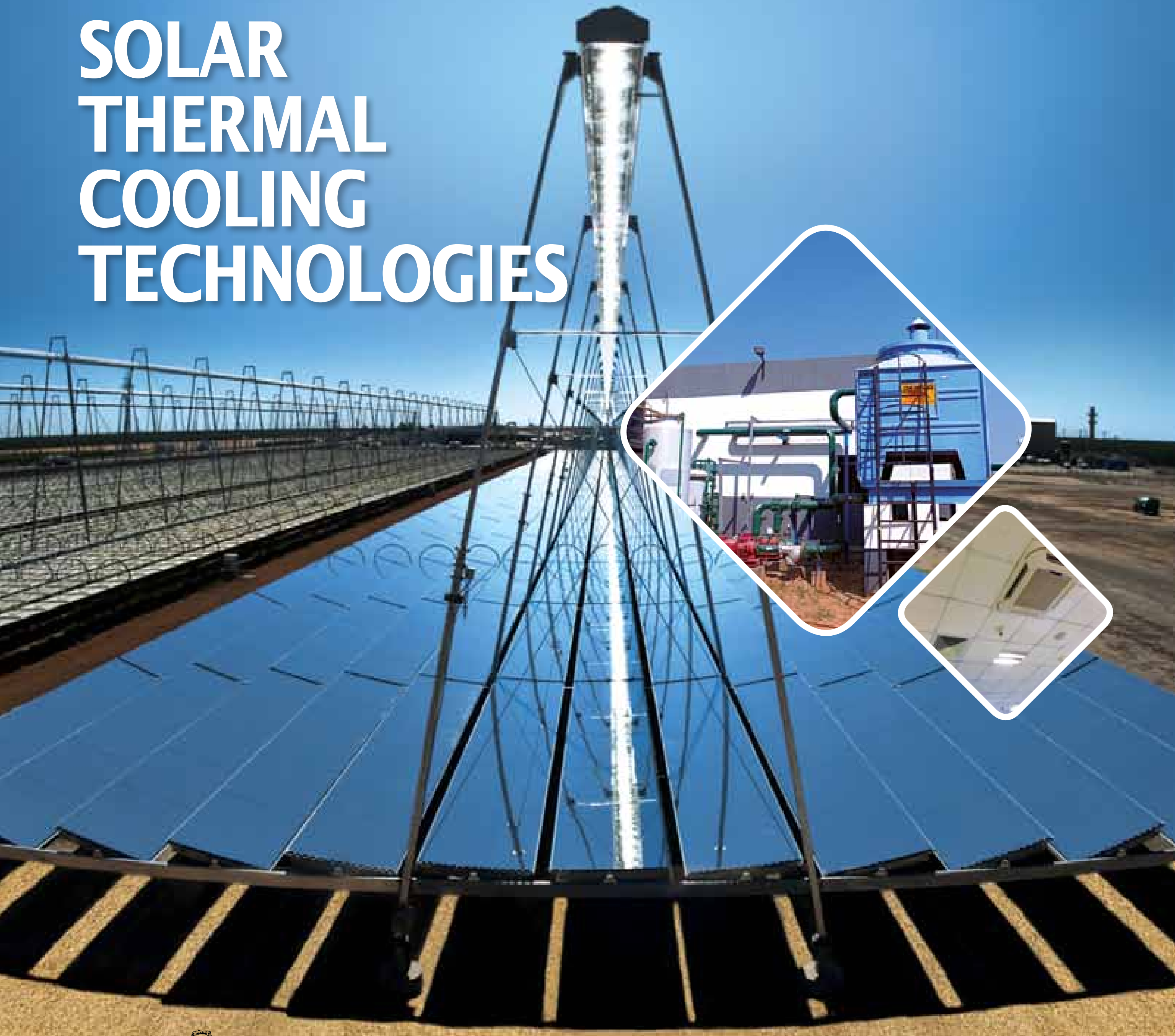
a quarterly magazine on **concentrated solar heat**

SUN FOCUS

Issue 4 | April–June 2014

SOLAR THERMAL COOLING TECHNOLOGIES



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Resilient nations.

UNDP-GEF Project on CSH

Ministry of New and Renewable Energy
Government of India

Financial Support Available for CST-Based Systems

MNRE

- 30% of system benchmark cost as capital subsidy in general category states. Higher subsidy (60% of cost) in special category states, including hilly states, islands, and border districts, except to commercial establishments.

UNDP-GEF Project

- 15% of system benchmark cost to a maximum of Rs 75 lakh for demonstration projects of 250 sq. m and above for online performance monitoring, O&M expenses, feasibility report/DPR, etc. For dual axis tracker dishes, the support is for project of 150 sq.m and above
- Rs 5-10 lakh for replication projects of 250 sq. m and above for providing performance/fuel saving data, O&M expenses, etc.
- Rs 2 lakh for projects below 250 sq. m but not less than 64 sq. m for Scheffler dishes and 45 sq.m for other concentrators mainly for meeting part O&M expenses
- Additional 10% of cost to a maximum of Rs 15 lakh for projects done in ESCo mode
- 20% of the system cost to a maximum of Rs 15 lakh for 5-year-old systems for repair/renovation, subject to the condition that an equal amount is spent by the beneficiary
- In addition, 80% accelerated depriciation benefit is available to profit making bodies in the first year

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Readers may send their views on the **SUN FOCUS** Magazine at *arpita.dasgupta@teri.res.in*. Your feedback is valuable for inspiring the quality of the magazine.

SUN FOCUS

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INside...

Readers' Responses

We appreciate the thought behind Sun Focus. The CST industry requires credibility and the end users need to be educated. The magazine is fulfilling both these objectives well by including articles that focus on performance and information that spreads awareness. It will add towards the growth of the CST industry.

Abhishek Bhatewara, Director, Clique Solar

The magazine has been interesting. I wish you all continued success in disseminating news about solar thermal technologies. "

Dr S P Viswanathan,
President, Empereal-KGDS Renewable Energy Pvt. Ltd

It is excellent.

Mr Niranjan Khatri, General Manager Environment, ITC Ltd

We appreciate and enjoy the news updates and technical content on CST development in India and abroad. One comment from our side is about the lack of sharing the examples of CST applications installed and run by the World Renewal Spiritual Trust (WRST) in number of Brahma Kumaris' Ashrams in India. The WRST has a long standing and broad experience in the field of the paraboloid reflectors in various CST applications. We wonder if there would be an opportunity to share those experiences with the audience of the SUN FOCUS.

Aneta Loj, India One Solar Thermal Power Plant
World Renewal Spiritual Trust

Feedback Form

Name			
Organization			
Did *Sun Focus* add value to your area of function and your projects?	Yes	No	
Which issue of *Sun Focus* did you find the most interesting?	1st issue	2nd issue	3rd issue
From where did you come to hear of *Sun Focus*?			
What other information on concentrated solar technologies would you want us to cover in the forthcoming issues?			
Any suggestions for improvement			

Your feedback is valuable for improving the quality of the magazine.
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From the editor's desk...

Dear Readers,

I am happy to bring to you the fourth issue of Sun Focus. In due course, Sun Focus has become a knowledge publication for various stakeholders, which is evident from the encouraging responses we are receiving from readers.

This issue focuses on solar cooling and refrigeration technologies. Cooling applications go hand-in-hand with solar energy, however, so far technical challenges have restricted the use of solar energy for this purpose. You will find innovative technologies and applications using solar energy for cooling applications in this issue. The issue covers both technology assessment and case studies.

It is heartening to see the number of successful application of solar cooling technology. The projects are however being installed at places where electricity cost is high or people are using diesel/ LPG to run the Vapour Absorption Machine (VAM) for cooling. Though a number of such plants have been installed in the country but progress is slow and needs to be accelerated.

With this issue, Sun Focus will complete its first cycle of four issues. We look forward to extending coverage and providing more relevant content in the forthcoming issues of Sun Focus.

I encourage all readers to put forward their suggestions and views towards the advancement of Sun Focus magazine.

Sd/-
Tarun Kapoor
Joint Secretary, Ministry of New and Renewable Energy

STATUS AND SCOPE OF SOLAR COOLING IN INDIA

Dr A K Singhal

Space cooling and refrigeration are highly energy-intensive processes. Cooling demands in various sectors are maximum mainly during day time when solar energy is also prevalent; this is more so in the hot summer season. Most parts of India get abundant sunshine throughout the year. Solar cooling/refrigeration is, therefore, the most relevant application for our country, especially in view of the rapidly increasing demand for energy and shortage of electric power. It is estimated that cooling consumes about 35,000 MW of electricity for various end-uses. Part of this is from conventional power plants in areas where electricity is easily available and the rest is being generated through DG sets which consume a significant amount of highly subsidized diesel leading to noise and air pollution, besides heavy CO_2 emissions. Apart from this, in rural areas, where such options are not available, 30–40% of agricultural produce is being destroyed due to lack of proper post harvest cooling facilities. Thus, resorting to solar cooling not only mitigates energy shortage and environmental pollution, but also contributes to the reduction of food spoilage.

The applications of cooling include domestic refrigeration, comfort/ space cooling in various sectors, industrial refrigeration and process cooling, cold storages with deep freezing, vaccine storages in PHCs, etc. The capacity range of systems varies from a few Watts to thousands of kiloWatts. Solar cooling/air-conditioning systems have the potential to catering to all the above sectors. However, this is an emerging technology and faces many growth barriers, which are different from other heating and cooling technologies.

Cooling Technologies

Two types of cooling machines are generally available in the market; one that works on electricity, i.e, Vapour Compression Machine (VCM) and the other that works on thermal heating Vapour Absorption Machine (VAM).

Vapour Compression Machines

They work on conventional electricity, are very common, and are commercially available in the capacity range of 1 ton and above. These machines are generally called Air-Conditioners (ACs—split or window) are being used in all establishments, be it residential, institutional or commercial. These machines are compact because of their high co-efficient of performance. In these machines, the refrigerant—in the form of vapour/liquid—is compressed/expanded to obtain required temperature for a particular application.

Vapour Absorption Machines

They are being used at places where waste heat is available or conventional electricity is either not available all the time or is expensive. These machines are generally available in the capacity range of 30 ton and above, and are being preferred in large establishments depending on the availability of waste heat or other factors. The VAMs occupy a large space because of their low co-efficient of performance (COP). To increase their COP, the machines have been developed with double effect and triple effect absorption cycles which require higher degree of heat to operate at that efficiency. In these machines the refrigerant in the form of liquid is mixed up in the absorbent which is separated out using thermal heat in the form of vapour which is further condensed and expanded to get the desired temperature for a particular application.

The refrigerant used in these machines depends on the requirement of temperature for a particular application. For example, for space cooling the temperature requirement is around 18–26 °C, so Freon/ R22 which does not have a very low freezing temperature is being used in VCMs while LiBr-Water combination is generally being used in VAMs.

Solar Concentrator installed being used at Turbo Energy Ltd, Chennai, for space cooling

Vapour Absorption Machine being used for cooling

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For applications where the temperature requirement are less to store perishable food products, generally between -20 °C and 4 °C, ammonia is being used as the refrigerant whose freezing temperature is much below the required temperature for cooling. A few other technologies have also been developed but these have their own limitations.

Solid sorption "dry" cooling technology

In these systems, solid sorbents with different sorbent-refrigerant pairs—Silica Gel–Water, Carbon-Ammonia, etc.—have been considered globally. Some demonstration systems have been also built and are in operation. Silica gel–water systems are available abroad commercially, even though to a limited extent. These systems are especially feasible for small capacity and mobile/ portable systems. These are also expected to have better part load efficiencies compared to conventional "wet" systems.

Other technologies

Other solar energy based technologies include Vapour Jet (Ejector) Cooling Systems, Open Cycle Desiccant Cooling Systems, and Solar PV operated Vapour Compression Systems. While sporadic efforts have been made to build and test these systems, there are no major headways to bring them to demonstration / commercial levels.

Solar Cooling Systems

Both commercially available machines —VCM & VAM—can run on solar energy; VCM on solar photovoltaics connected with an inverter to convert DC power to AC power and VAM on solar thermal collectors with the type of collectors decided on the basis of type of VAM used (single/ double/ triple effect). Solar cooling systems both working on solar photovoltaic and on thermal collectors have been developed and installed in the field. These systems, however, because of the added cost of solar field, are still expensive at places where electricity is cheap and is available through out the requirement without any problem. These are also not viable at places where waste heat or other fossil fuel are available at very low cost. For the past few years, solar cooling systems are getting attention due to the following:

i. Increasing cost of electricity and its non availability on a 24X7 hour basis at many places
ii. Decreasing cost of solar electricity through photovoltaic which has come down to around Rs 8/- per unit from the earlier price of Rs 18/- per unit about 3 years back
iii. Increasing cost of diesel/ LPG, difficulty in their procurement and storage, and pollution caused by their use.

Between both the cooling technologies, VAMs operating on solar thermal technologies are finding good acceptance in the country. There are many places where people either do not have electricity available all the time or it is very expensive. At such places they are forced to use diesel to run DGs Sets for running the ACs or run boilers on diesel/ LPG to generate steam/ pressurized hot water for feeding into the VAMs to generate cooling. Solar thermal systems connected to the boilers make sense and are a viable solution. Solar systems based on concentrating technologies (CSTs) are getting better recognition compared to flat plate based systems due to the fact that they can provide heat at higher temperature and pressure to operate VAMs at higher efficiency. Also, CSTs require lesser space as compared to flat plat technologies. A typical system of 30 ton capacity for commercial complexes and institutions require about 250–300 sq. m. of CST area depending on the type of technology used which may cost around Rs 60–70 lakh. This system should be able to save 18,000–22,000 litre of diesel per year depending on the solar radiation available at the place of installation. It should be able to recover its cost in 5–6 years at the current price of diesel at the rate of Rs 55 per litre. The payback time may be reduced to 3–4 years with 30% subsidy available from the government. It will further reduce the payback if depreciation benefit to the extent of 80% is availed in the First year itself by profit-making organizations which is available on all renewable energy technologies.

Standalone solar cooling systems

These systems with intermittent heat storage has also been developed by M/s Thermax Ltd, Pune, under a public–private partnership with MNRE. The system of 30-ton capacity using indigenously made concentrating parabolic troughs and triple-effect VAM has been developed and demonstrated at the Solar Energy Centre, MNRE, for the purpose of air-conditioning of office complexes. It is a standalone system for day time use and can take care of intermittent

Parabolic Trough Concentrators being used for Space Cooling at Honeywell Automation Ltd, Hyderabad

CST-based systems installed in India for space cooling					
Place	**Capacity in TR & type of VAM**	**Type & size of solar field**	**Solar heat fed to VAM**	**Year of installation & Manufacturer**	**Solar Cost (Rs in lakhs)**
NPCIL, Kota, Rajasthan	100 TR with triple effect VAM	100 nos of PTC, 641 m^2	Pressurized water at 17 bar and 200 °C	2013 (Thermax)	245
Honeywell Tech. Hyderabad	100 TR with triple effect VAM	128 nos of PTC, 821 m^2	Pressurized hot water at 17 bar and 165 °C	2013 (Thermax)	213
NTPC, Noida, UP	50 TR with 2-day storage and double effect VAM	2 nos of Arun 160, 338 m^2	Steam at 15 bar and 170 °C	2012 (Clique Solar)	250
Turbo Energy Ltd. Chennai	50 TR with double effect VAM	2 nos of Arun 160, 338 m^2	Pressurized water at 15 bar and 180 °C	2011 (Clique Solar)	80
Civil Hospital, Thane	212 TR (160 TR with VAM and 52 desiccant cooling) double effect VAM	150 nos of Scheffler Dishes, 2040 m^2	Steam at 7 bar and 150 °C	2011 (Sharda Inv.)	399
Mahindra Vehicles, Chakan, Pune	120 TR with double effect VAM	70 nos of Scheffler Dishes, 1120 m^2	Steam at 8.5 bar and 167 °C	2010 (Thermax)	125
Magneti Mareli, Manesar, Haryana	30 TR	20 nos of Scheffler Dishes, 320 m^2	Pressurized water at 7 bar and 130 °C	2010 (Thermax)	104
Cancer Hospital, Muni Seva Ashram, Goraj, Gujarat	100 TR with double effect VAM	96 nos. Scheffler Dishes, 1250m^2	Steam at 8.5 Bar & 167 °C	2008 (Gadhia Solar)	100

clouds through small heat 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 and are in operation at SEC.

Available Support from Government for Solar Cooling Systems

A total of 30% subsidy to all categories of beneficiaries with additional benefit of 80% accelerated depreciation to profit-making bodies is available from the MNRE for installations. Higher subsidy for special category states is available. In addition, up to 15% support is available from UNDP-GEF project for systems sizing 250 sq. m. and above for specific activities.

Scope of Solar Cooling Installations in the Near Future

Keeping in view the present status and cost of electricity/diesel and other fossil fuels fuel and also the available solar technologies, there seems to be a vast potential of solar cooling as per following:

- Space cooling at places where DG sets or VAMs are being used. Retrofitting of CSTs with existing boilers are a viable option
- Standalone solar cooling systems with intermittent heat storage for institutions and other establishments working during day time
- Integrated hybrid solar systems both for heating and cooling to work in all seasons.

If all efforts are put to tap above potential, 5 million sq. m. of solar collectors area with 25,000 TR (tons of refrigeration) is possible to achieve by 2022 for solar cooling. ■

STANDALONE SOLAR AIR CONDITIONING SYSTEMS DEVELOPED UNDER PUBLIC–PRIVATE PARTNERSHIP

Dr R R Sonde[1], S V Kulkarni[2], R R Desai[3]

It is interesting to note that the country today faces a greater demand for non-electricity applications, i.e., where the primary energy source could have been applied in a more efficient way than use of electricity-driven applications. However, a major focus has been on the development of solar-to-power applications rather than other forms of solar energy utilization, such as direct solar cooling. It is estimated that 29% of total energy generated is used for heated ventilation and air-conditioning (HVAC), especially in the service and commercial sector. Use of solar energy for HVAC applications in a distributed mode is perhaps the most potent application of solar, after the solar photo voltaic power application.

Use of highly efficient Vapour Absorption Machines (VAMs) — using single, double, and even triple effect — coupled with medium temperature high efficiency low-cost single axis tracking parabolic trough based solar collectors have made the solar direct air-conditioning system a hugely appropriate technology for use in India. Thermax Ltd is a globally recognized player in VAMs; this coupled with indigenously built medium temperature solar collectors will ensure that the entire system is an indigenous effort. This development does not demand the use of any semi-conductors and neither is it dependent on high technology silicon VAMs being privy of only few global players.

Virtual Power Generation by Using Solar Cooling System

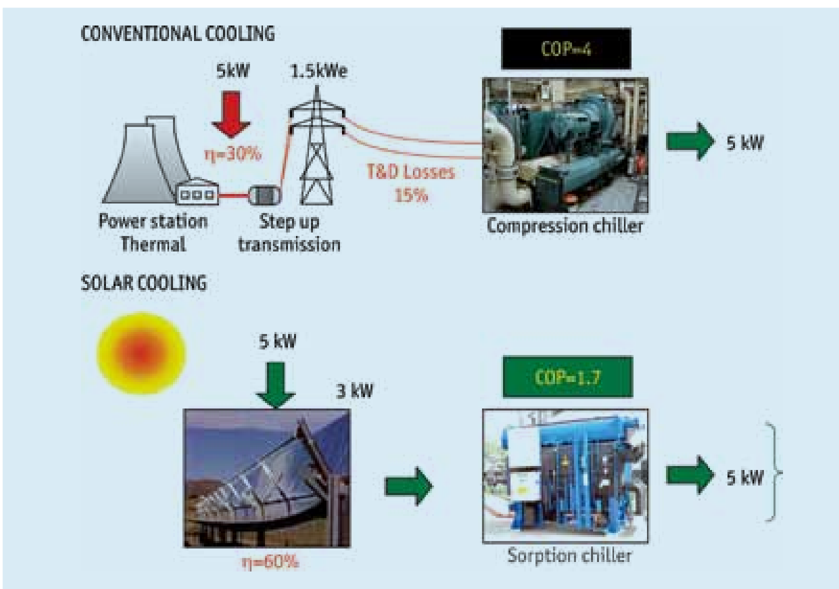
A solar cooling system consists of solar collectors and vapour sorption machines. The heat generated in the solar collectors drives the sorption machine to produce chilling for HVAC systems. Vapour sorption machines are popular in industries where waste heat is available, and there is need for process cooling and comfort cooling. Conventional Vapour Compression Chillers are driven by electricity. To generate 5 kW of cooling, 1.5 kWe electricity is required along with 5 kW equivalent fuel. Solar heat if used with sorption machine can produce this cooling. Thus, every 5 kW of cooling produced saves 1.5 kWe of electricity. This saving of electricity is equal to generating of electricity; hence, solar cooling produces virtual power.

Demonstration Projects under PPP Mode

Thermax, along with the Solar Energy Centre (SEC), MNRE, has created a world class facility for demonstrating these technologies for various applications.

Large-scale HVAC system for commercial complexes and large offices

These include large-scale air conditioning systems using rooftop-mounted parabolic troughs and triple-effect VAMs being built at a scale of 100 kW and more. These systems are typically water-cooled centralized air-conditioning with chilled water circulated through air handling units. Since space is at a premium, getting maximum cooling from minimum area is important. Integration of the



Virtual Power Generation using solar cooling system

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Parabolic Troughs coupled with Triple-effect Vapour Absorption Machine (100 kW Cooling Capacity)

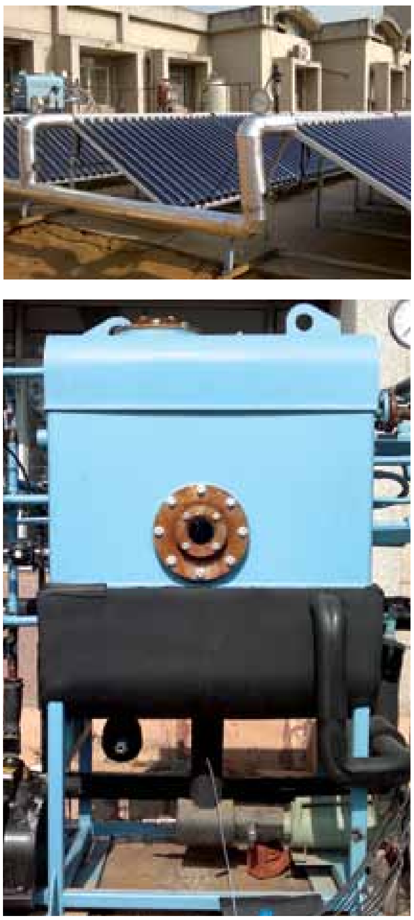
triple-effect chiller with medium temperature solar collectors achieved 30% reduction in space along with 20% extra cooling as compared to other solutions. This solution also has relevance to industries that have process cooling requirements.

Medium to small-scale HVAC system for small offices and mini commercial establishments

These include medium- to small-scale air conditioning requirements of commercial establishments and small offices using rooftop-mounted parabolic troughs and double-effect VAMs being built at a 5–15 kW scale. These systems are typically air-cooled with a split design of an Indoor Fan Coil Unit and an Outdoor Condenser Unit.

Parabolic Troughs coupled with Air Cooled Double-effect Vapour Absorption Machine (15 kW Cooling Capacity)

In this case, cooling capacities are small as space is again at a premium and water cooling is not preferred. Air-cooled double-effect vapour absorption chillers developed by Thermax and integrated with medium temperature solar collectors provide the most optimum solar energy driven cooling solution in this capacity range.



Non-imaging concentrators coupled to Solid Adsorption Based Machine (5 kW Cooling Capacity)

HVAC Systems for Colder Climates

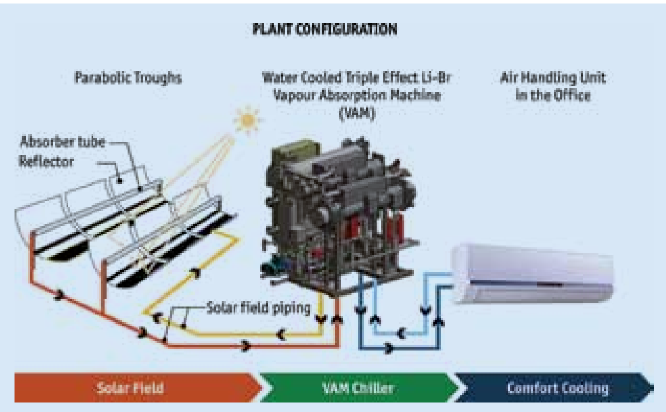
Thermax has demonstrated a very unique concept of using a very low grade hot water, say 60–70 °C and developing a heating-cum-cooling solution using advanced solid adsorption based compact systems. Their systems are especially useful in cold regions, such as in Europe, with high heating requirements. Solar cooling represents a virtual power generation solution since it replaces grid power consumption (See Figure 1). It also presents itself as a distributed power generation model wherein specific cooling-related load is generated at the point of use reducing the load on the grid. It supports grid stability and actually makes available such grid power saved from cooling for other uses during the most crucial part of the day when peak power deficits are witnessed. With the use of a higher efficiency system and lower space requirement, direct solar cooling solutions precisely meet the need of our country. It will be pertinent here to mention that proliferation of this concept is must to bring this technology to ideal economic viability.

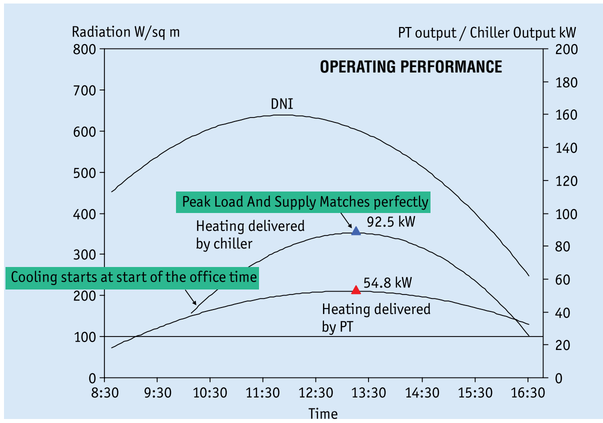
A Possible Approach

A direct solar cooling initiative by the MNRE, successfully demonstrated at the Solar Energy Centre (SEC), needs to be now taken to the next level. This will enable sustainability and viability of the concept across different locations under varying climatic conditions. Such a thrust will result in acceptance of the concept and facilitate mass multiplications of such systems. This would then naturally lead economy of scale manufacturing of various components within the country, which will have multiple-level benefits to the country. The importance thus lies in building indigenous capabilities, skill sets, and know-how multipliers that will create a virtuous cycle in this vital field. In order to ensure quick proliferation and deployment of these solutions, initially CAPEX support should be provided at both the Solar Field as well as the VAM collectively as a solar cooling system. The need for CAPEX support would diminish once the solution is fine-tuned and proven as per needs of different geographies. Thereafter, other support measures such as feed-in tariff can be introduced for cooling energy harnessed from solar energy. A mechanism for measuring solar-based cooling for which a pre-defined feed-in tariff has already passed is at the design stage. This can be implemented as is done for solar grid connected power plants.

Configuration and Performance of Demonstration Projects

PTC based 100 Kw system using triple effect Vapour Absorption Machine

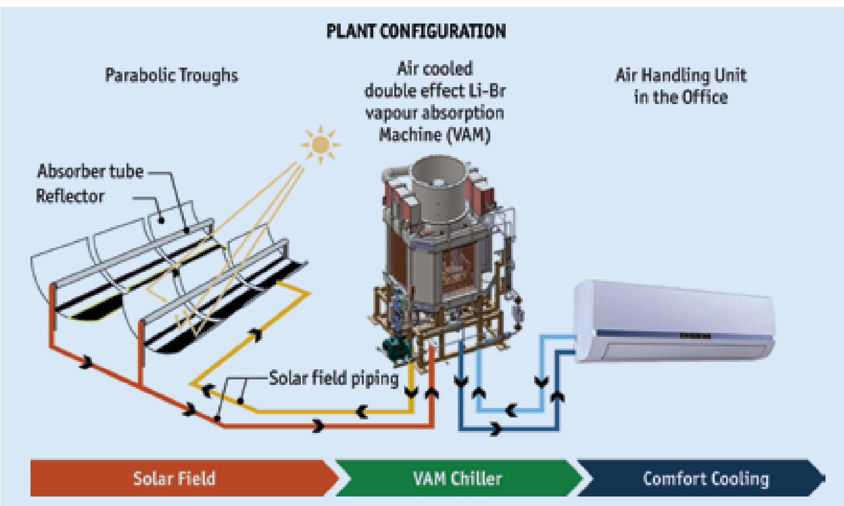




Specification

Chilled water In/Out : 12–7 °C ▪ Hot Water In/Out : 210–200 °C ▪ COP: 1.7 ▪ Collector Area: 288 sq. m.

PTC based 15/5 kW system using air cooled double effect Vapour Absorption Machine



Specification: 15 kW

Chilled water In/Out: 15–10 °C
Hot Water In/Out: 180–170 °C
COP: 1.0
Collector Area: 72 sq. m.

Specification: 5 kW

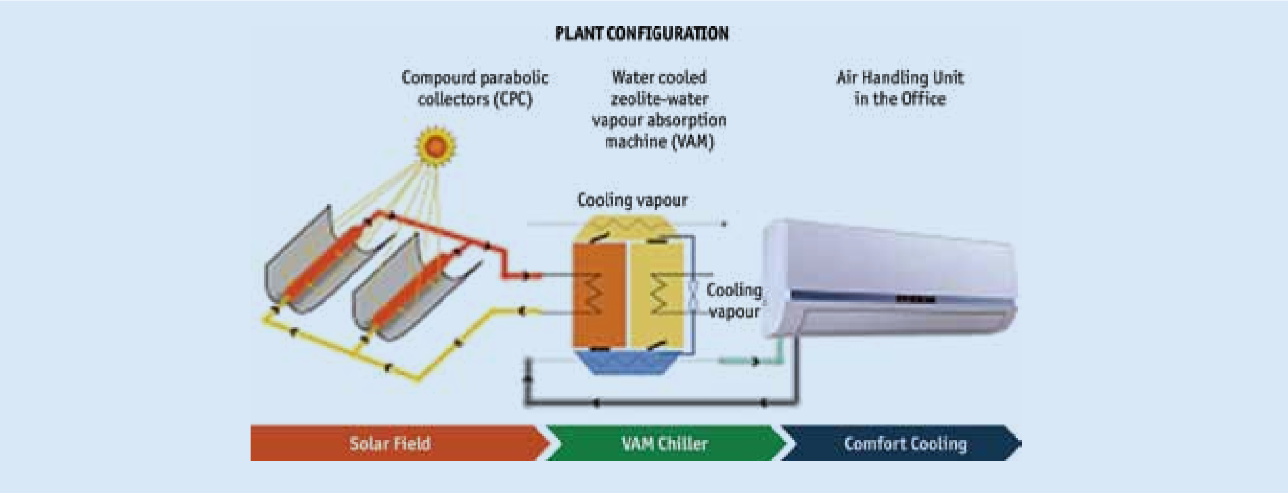
Chilled water In/Out: 15 –10 °C
Hot Water In/Out: 180–170 °C
COP: 1.0
Collector Area: 24 sq. m.

Configuration of 15/5 kW unit

Performance Details

CHW in Temp	CHW out Temp	HW in Temp	HW out Temp	Air in Temp	Capacity	COP
°C	°C	°C	°C	°C	kW	
15.7	10.7	175.8	161.5	31.2	4.9	1.0
14.1	08.8	174.8	166.9	33.3	4.3	1.2
14.0	08.7	175.8	167.2	34.4	4.3	1.2
15.2	09.8	177.6	163.0	31.3	5.0	1.1
15.9	10.4	175.4	160.7	32.5	5.2	1.1

CPC based 5 Kw Solid Vapour Absorption Machine



Configuration of adsorption unit

Specification: 5 kW

Chilled water In/Out : 15 / 10 °C ▪ Hot Water in/Out : 80/70 °C ▪ COP : 0.4 ▪ Collector area : 61 Sq m

Performance Details

CHW Temp in	CHW Temp out	HW Temp in	HW Temp out	Cooling water	Capacity	COP
°C	°C	°C	°C	°C	kW	
15.1	8.4	97.3	87.0	30.4	5.8	0.4
15.2	8.5	94.6	84.2	30.7	5.8	0.4
14.7	9.0	98.4	87.4	31.3	5.0	0.3
15.0	9.6	85.4	74.9	32.3	4.9	0.3
15.3	9.3	82.4	71.9	29.9	5.2	0.4

Concluding Remarks

With the world's first-of-a-kind development model built under a public–private partnership model by Thermax Ltd and SEC India, it would be possible to put in place the right kind of technology backed with appropriate policy measures. Solar-based cooling is thus the appropriate solution for both developed and emerging economies. ■

SOLAR–BIOMASS HYBRID COLD STORAGE SYSTEM FOR RURAL APPLICATION

S K Singh

Background

India is the second largest country in the world producing a variety of fruits and vegetables. Till recent times, the fruit and vegetable industry was mostly concentrated in rural areas, which was catering to the requirement of urban areas as well. A revolution in this industry started with the processing of fruits and marketing of fruit pulps in the indigenous and international markets. Horticulture provides 6.5% of GDP, 13% of employment, and accounts for more than 9% of Indian exports with only 9% crop acreage. Cold storage facilities for India's agricultural produce are falling short by more than 10 million tonnes of storage capacity. Recent regional economic growth and changes in dietary patterns have made both the production and consumption of fruits and vegetables increasingly important. The fruit and vegetable sector has a vital role in farm income enhancement, poverty alleviation, food security, and sustainable agriculture in Asia, especially in developing countries such as India. This sector however suffers greatly from post-harvest losses. Some studies suggest that about 30–40% of fruits and vegetables are lost or abandoned after leaving the farm gate. Huge post-harvest losses result in diminished returns for producers. Storage losses of fruits in India are high owing to temperature and humidity condition. This necessity evolved a new concept of storing these items at below or just above sub-zero temperatures known as Cold Storage.

It is a known fact that agriculture is the backbone of the rural economy and rural income is mainly dependent on agricultural produce. A large amount of biomass is produced both

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in agriculture and forest sectors and this includes vegetables, corns, straw, cotton gin thrash, rice husk, olive pits, tree pruning, saw dust, and wood chips. India is also blessed with good solar resource availability almost all over the country. Considering the fact that electricity, lighting, irrigation, and cold storage infrastructural facilities are crucial problems of rural areas, a solution to combat these issues can be explored by using two of the most abundantly available natural resources, namely biomass and solar. Thus, a hydrid cold storage system based on a biomass gasifier efficiently using biomass for heat and power generation, and solar thermal collectors was conceptualized.

Project at a Glance

Keeping in view the importance and need for cold storage and sustainable development of rural areas in India, the Solar Energy Centre (SEC), Gurgaon, a technical Institution under Ministry of New and Renewable Energy (MNRE), in collaboration with Thermax (cold storage component) and TERI (gasifier component), implemented a demonstration-cum-performance evaluation project at the SEC campus. It involved design, development, fabrication, and field trial of a solar–biomass hybrid absorption cooling system operating on thermal energy to produce cooling. The hybrid system was also designed to generate electricity keeping in view the demand for electricity in rural areas. Detailed computer modelling was carried out to optimize system design before going to field-level implementation. The research initiative was funded later by the MNRE under the aegis of the Asia Pacific Partnership on Clean Development and Climate.

System Components

- Biomass gasifier (capacity: 50 kWe)
- Gas-engine generator (capacity: 50 kWe)
- Waste Heat Recovery Unit
- Solar Dish (4 Scheffler dishes of 16 sq. m. area each)
- Chiller (15 kW)
- Cold storage Chamber (capacity: 20 T of vegetable storage)

Specifications

Cooling Capacity: 15 kW
Cold Storage Temperature: 0–5 °C
Gas Engine Capacity: 50 kWe
Biomass Consumption: 70 kg/hr
Heat source for VAM
During solar hours: Solar and producer gas engine exhaust
During non-solar hours: Producer gas engine exhaust/auxiliary firing

Outcome

TERI's biomass gasifier is coupled with Thermax's newly developed Vapour Absorption Machine (VAM) of 15 kW cooling capacity and concentrating solar parabolic dishes. This system can provide clean power and cold storage facility for about 25 tons of fruits and vegetables. Since the cold storage can be cooled to temperatures as low as 0 °C, it is able to a store a wide variety of fruits, vegetables, and horticultural produce. The biomass gasifier produces 50 kWe electricity producing exhaust heat at 400 °C. About 70% of this waste heat can be recovered to generate hot water at 135 °C for the VAM of 15 kW capacity system for cold storage. Four Scheffler dishes with aperture area of 16 m² each have been integrated to provide thermal energy for operation of the chiller during sunny hours of the day. The gasifier will not run at its peak-rated capacity during day time in view of the non-requirement of the lighting load in the village; therefore, solar dishes will compensate the requirement of heat for rated output of cold storage. Simultaneously, during non-sunny hours, i.e., at night, the gasifier will run at its peak-rated capacity to meet the electricity requirement of the villagers. Running the gasifier engine at full rated capacity will produce 50 kW of exhaust which would be sufficient to meet the requirement of VAM. In case, non-availability of sunshine as well as sufficient electrical load to meet the heat requirement of VAM, special arrangements have been made to utilize the producer gas in the heat recovery unit to meet the balance amount of heat required for VAM. The hybrid system has thus been designed to provide electricity from locally available biomass to a few villages along with a cold storage plant in a remote location. The solar–biomass hybrid cold storage system for rural application has been commissioned. Performance evaluation of all the independent units such as biomass gasifier, solar dishes, VAM and cold storage unit, and the integrated system have also been carried out. The system has been operational since 2013.

SEC, TERI, and Thermax have gained considerable experience in the operation of the proposed cold storages. During the installation and commissioning of the first of its kind prototype, considerable efforts have been dedicated to promoting such systems and interacting with stakeholders involved. Knowledge of system integration in such systems is critical and necessary for their successful operation. Successful implementation of the solar biomass hybrid cold storage system can open avenues for its replication in other parts of India and thus help in saving valuable agricultural produce and also in achieving rural electrification. ■

AN INTERNATIONAL SCENARIO OF A FEW SOLAR THERMAL COOLING SYSTEMS

Shirish Garud

Air conditioning is the dominating energy-consuming service in buildings in many countries. In fact, in many regions of the world, the demand for cooling and dehumidification of indoor air is growing due to increasing comfort expectations and increasing cooling loads. Conventional cooling technologies exhibit several clear disadvantages:

- Energy consumption is high
- Cause high electricity peak loads
- In general, they employ refrigerants, with considerable global warming potential

Solar Cooling System at Charlestown Square, Australia

The utilization of solar energy to work heat-driven cooling machines is a way to address these problems. These systems use solar heat to drive a heat-drive chiller or dehumidifier, such as ab- or adsorption chillers, and desiccant evaporative cooling systems. A well-designed solar-assisted air-conditioning system produces cooling with considerably less electricity demand than conventional air-conditioning systems. Furthermore, the working fluids used in sorption chillers and desiccant rotors will not contribute to global warming, contrary to most working fluids in conventional compression chillers.

Solar cooling system installations have increased substantially in the last decade and there are a number of installations with successful working records, especially in Europe. Recently, in last 3–4 years, a lot of R&D activity has taken place for performance and efficiency improvement of solar cooling systems. The focus of this R&D work is to develop new and more efficient cooling technologies, new applications such as solar-based refrigeration and overall optimization of the system design of solar thermal cooling systems. Germany, Australia, and USA are the leading countries in this on-going effort. Some of the major solar cooling or refrigeration installations at the international level have been showcased here.

Solar Cooling System at Charlestown Square, Australia

The Charlestown Square Solar Thermal Cooling System is a 230 kWr absorption cooling system that provides chilled water to a shopping centre in Charlestown (near Newcastle), NSW. The solar field consists of 12 PolyTrough 1200 concentrating trough collectors that are manufactured, supplied, and installed by NEP Solar. The total aperture area is 350 m² which is installed on the roof of the shopping mall, supplies 180 °C pressurized hot water to a BROAD double-effect absorption chiller based on Li-Br cycle. The system is operational since 2011. Being one of the few installations based on medium temperature heat and double-effect chiller, the commissioning activity and initial performance of the system were monitored carefully.

Two major lessons learnt can be summed up as: one, solar cooling system designs (solar collector field and storage tank) can be optimized using the transient modelling approach; and two, proper system design, integration, and controls are critical for efficient operation of the system.

Solar Thermal-based Cold Storage, Germany

The research project 'AgroKühl' was initiated by Fraunhofer Institute of Solar Energy aimed at the development of

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an integrated solar thermal driven cold storage room for agricultural produce. The pilot project was implemented by a consortium of partners from industry and science. The pilot project has been installed at Kramer GmbH which is located in Umkirch near Freiburg. The company is a specialist for shopfitting, cold room construction and insulation technology. The system is based on the CLFR-type solar collector field supplied by Industrial solar and absorption chiller based on Ammonia-water cycle supplied by Kälte Grohmann GmbH & Co. KG. A total of 100 m³ volume was chilled using the system.

Specifications

Solar Collector Field: 88 m^2
Absorption Chiller: 12 kW
Cooling Capacity: 52 kWh

The solar collector field size was deliberately oversized considering the local weather conditions. The preliminary performance results of the system were very promising and overall COP of the system was observed to be about 1.2. It was observed that the direct cooling option was more efficient than the use of storage. The scope for further optimization of the system was also identified by better control strategy and integration.

Solar Cooling System for Football Stadium at Doha, Qatar

The heat generated by the CLFR Solar Collector Field designed and supplied by Industrial Solar is used to power a 1 MW absorption chiller, which provides air-conditioning for a 500-seat showcase football stadium constructed by ES-Group/London and designed by Arup Associates in connection to Qatar's bid for the World Cup 2022. In this first solar-cooled stadium, the air is circulated around the stadium to keep players and spectators comfortable. And, because the sun's energy is used to power the entire stadium, it is genuinely carbon zero. The project was commissioned in 2010 and has been successfully working since then.

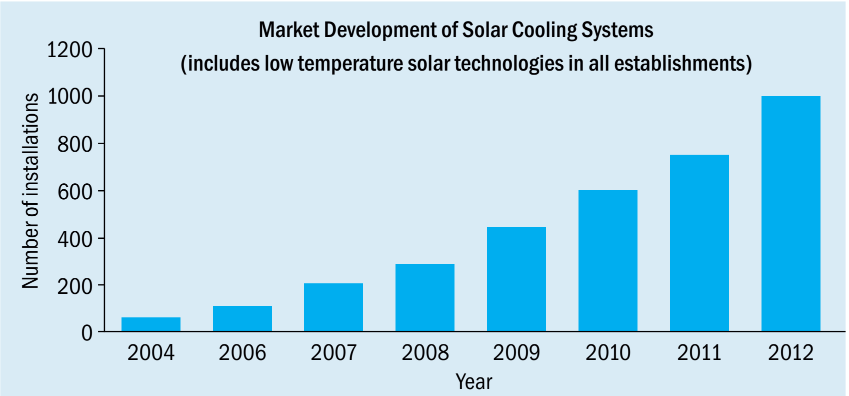
Specifications

Solar Collector Field: 1,400 m^2
Chiller: Double Effect
Absorption-based Chiller
Cooling Capacity: 1 MW

Concluding Thoughts

Solar-assisted air-conditioning system studies are very important. Experience shows that many problems of real operation rise at the system level rather than at the level of components. The evaluation of successful design strategies and successful system layouts in different climates will be very important. In general, the projects aim to develop an energy-efficient technology and do not discuss the price of the system or the energetic advantages compared to other competing technologies such as solar PV-based compression systems. For further market development of solar-assisted air conditioning systems, these themes should be better integrated into the research projects or in subsequent studies. Also, the number of relevant projects where solar collectors are developed is lower. The main reason is that availability of solar collectors, at the applicable temperature range needed to drive absorption or adsorption chillers, are available on the market. Many manufacturers offer many different products, including flat plate collectors, evacuated tube collectors, single axis tracking concentrators, and double axis tracking concentrators. Related to the application in solar-assisted air conditioning systems, the primary need is further reduction of costs in order to increase the overall competitiveness of the entire system. Considering this, further R&D can focus on the following:

- Further R&D on smaller size systems (less than 25 TR) that are reliable and can operate at low temperatures. This enables the use of non-tracking concentrators and ease of heat storage.
- Research on integrated hybrid systems which work on both compression cycle and heat-driven cycle.
- Interesting new options have come up for the liquid desiccant cycles. One effect is the possibility of using the concentrated desiccant as energy storage for air conditioning. Another is that it is possible to cool the absorber and thereby to increase the potential for dehumidification remarkably. Such a process could also be combined with the solid desiccant cycle in order to increase its dehumidification potential and COP. ■



Source: Based on Global Status Report, REN21 *(2013) and Mungier and Jakob,* Keeping Cool with the Sun *(2011).*

SOLAR COOLING SYSTEMS AT MAHINDRA & MAHINDRA, PUNE: A CASE STUDY

Dr Anagha Pathak[1], Sunil Datar[2]

Introduction

Mahindra & Mahindra Limited (M&M) is an Indian multinational automobile-manufacturing corporation and the largest seller of tractors across the world. It was ranked as the 10th most trusted brand in India by The Brand Trust Report, *India Study 2014* and 21st in the list of top companies of India in *Fortune India 500* in 2011.

The Chakan facility of Mahindra is its largest, most effective and sustainable facility spread over 700 acres in the outskirts of Pune, with a phased investment of INR 5,000 crore. What sets this plant apart is the fact that it has been designed with sustainability on its mind, especially in terms of CO_2 reduction and frugal use of energy. In order to further this goal, Mahindra embarked on a journey testing solar and renewable solutions that fit in perfectly with its industrial process heat and cooling requirements.

Objective

One of the processes identified was the Paint Shop Process which requires cold water at a very low temperature of 7 °C. This is to maintain temperature of the Cathodic Electro Deposition bath. The existing system consists of Electrical Chillers (a 160 TR Chiller with another standby). But, continuous operation of the Paint Shop processes led to high electricity cost. Additionally, LPG is also used and vaporized using Electrical Heaters. Over a period of time, these caused carbon emissions and a serious financial burden on the company. What was needed thus was a renewable solution that could cut energy costs and reduce CO_2 and other harmful emissions.

Customized Integrated Solar and Heat Recovery Project for Paint Shop

At the Paint Shops that need high levels of heating and cooling — 3.6 mm/kcal per hour and 416 TR — the challenge before energy managers was to integrate renewable energy and conventional systems and reduce overall energy intensity of fossil fuel. An exclusive solar option was unviable. Studying the energy patterns of the paint booth that used a conventional LPG-fired hot water generator for heating and electrical chillers for cooling, the team harnessed solar energy and waste heat, and put together the various components that would eventually be integrated.

A Brief System Description: The Solution

Now, Mahindra's facility in Chakan is running an innovative solar energy cum waste heat recovery based solution that has drastically reduced the use of fossil fuels and CO_2 emissions. The combined heating and cooling system integrates 70 Solar Dishes and an array of equipment — Waste Heat Recovery Units, Vapour Absorption Machines and Heat Pump, Heat Exchanger, and a Hot Water Generator.

Solar Field

Hot water at 130 °C is generated using solar thermal energy. This system consists of Solar Parabolic Concentrators, Receivers, hot water supply and return headers, an Automatic Tracking System, and valves and controls.

The Parabolic Concentrators concentrate the sun's heat and generate hot water. A battery of

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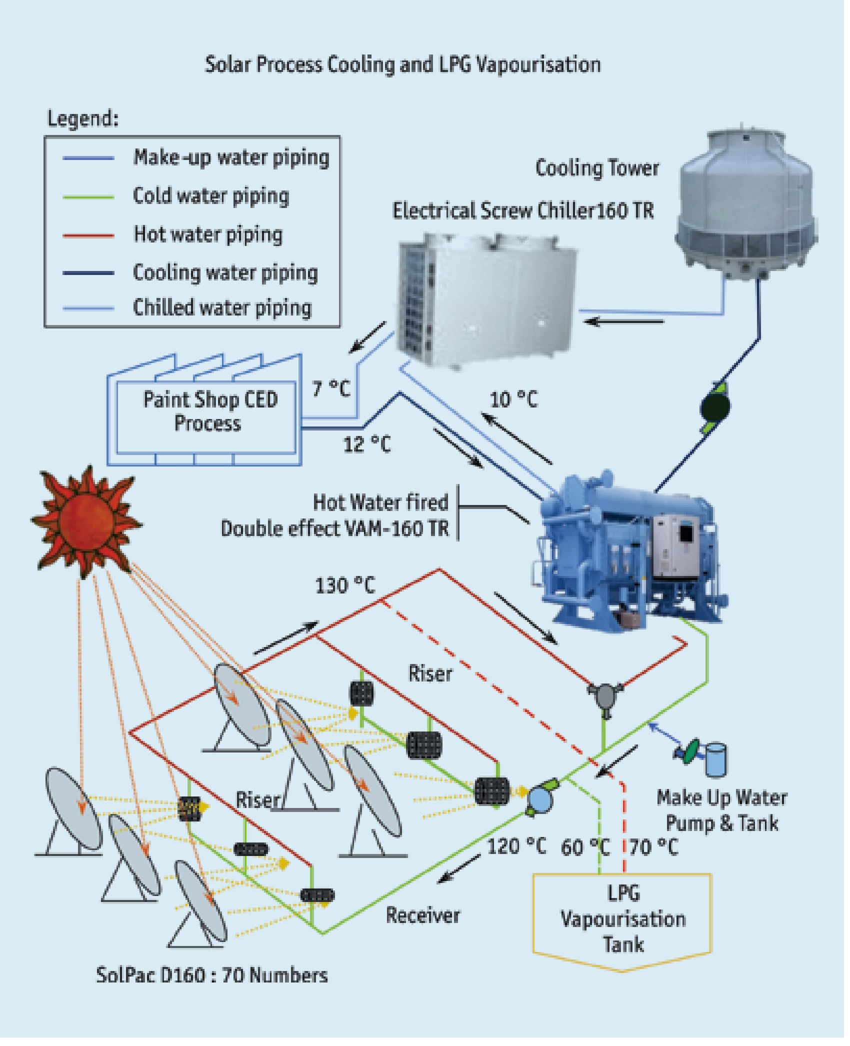
receivers is connected to the hot water supply and return headers. This hot water circuit is pressurized through N_2 blanketing in the expansion tank. The hot water at 130 °C is pumped from the expansion tank to the energy efficient, environment friendly, double-effect Vapour Absorption Machine (VAM). The hot water returns at 120 °C from the VAM to the solar concentrators. The VAM supplies chilled water at 10.3 °C to the Electrical Chiller whose outlet at 7 °C is circulated through PHE to the Paint Process. Thus way chilled water is used for Paint Shop chilling requirement where chilled water is heated to 12 °C and returned to the VAM. The balance chilling load (10.3 °C – 7 °C) is met with electrical chillers. These chillers also cater to the chilling requirement during the initial hours of the day, when maximum solar radiation is not available.

System Performance

Months	Energy generation /day (kcal)
January	1,908,340
February	1,553,160
March	1,509,300
April	1,280,540
May	1,046,620
June, July, August	Rainy/Monsoon Season
September	475,58
October	1,359,660
November	1,756,980
December	1,875,660



LPG Vapouriser

Electrical Heaters are used to vapourise LPG constantly in the plant. An array of 30 preset electrical heaters are on a permanent standby, with 6 heaters running at any point of time, in order to heat water that vapourises the LPG. This contributed to enormous electrical consumption, which was mitigated by harnessing low-grade heat during the monsoon season for the vapourisation process. This has helped the system harness energy for an extended time during the year, which goes on to prove the expertise of the system engineers who designed the process to maximize solar usage in the plant. This integrated system offers the advantage of optimizing the use of electricity and maximizing the use of clean, renewable solar thermal energy, while meeting the required chilling load. ■

CUSTOMER'S FEEDBACK

Solar Heat is being used for two different processes for effectively maximizing use of high grade and low grade solar heat throughout the year. Solar Process Cooling in Paint Shop Process and for LPG Vaporization with CO_2 mitigation of 1,40,000 kg/p.a.

Electricity savings: 200000 kWh/p.a.

Monetary benefits: INR 15 lakhs/p.a.

FORTHCOMING EVENTS

Chilesol 2014

27–28 May 2014

Santiago de Chile, Chile

The year 2014 will witness CSP Today LATAM and PV Insider LATAM combined to create the inaugural CHILESOL conference giving attendees the perfect mix of joint networking opportunities and specialist CSP and PV technology knowledge in one of the hottest solar markets in the world. Participants will be able to meet with mining companies and national utilities and learn how to develop cost-competitive projects that win PPAs, find out from local and international banks how to ensure financing to move your project from environmental permit to construction, learn from regulators and transmission companies how to gain permission to connect your plant to the grid in less time, hear from industry insiders in Peru, Uruguay and Brazil to get an overview of the further opportunities for solar in the region, and understand the critical aspects of building in the Atacama desert — as manpower shortage and seismic nature of the land — to optimize construction.

SolarTech India 2014

22–23 July 2014

Gurgaon, India

The conference addresses the current and future opportunities and issues the Indian solar market.

Over 20 leading EPCs and developers active in the Indian solar energy market will share their extensive experience in planning, building and operating medium and large solar plants in the country. Along with the developers leading PV, CSP and solar-thermal and inverters technology companies will present their latest.

As solar projects in India still struggle to raise debt finance the conference will in 2014 also focus on bankability and debt financing and insurance options for solar projects in India by Indian and international banks, non-bank financial companies (NBFCs) and infrastructure funds. Speakers will present both risks and mitigation strategies from lender's perspective and structuring debt finance from borrower's view.

Over two days of sales conversations, meetings with customers, suppliers and new contacts, top insights from seasoned industry experts and - above all - high-level networking, the event will bring together top solar energy technology companies, project finance providers, developers and installers and allow your company to market itself towards high-profile audiences across the entire supply chain.

Gleisdorf Solar 2014

25–27 June 2014

Gleisdorf, Austria

Organized by the AEE Institute for Sustainable Technologies (AEE INTEC), Gleisdorf Solar 2014 is the eleventh International Conference on Solar Heating and Cooling. It is going to be held from 25 to 27 June 2014. The event has grown in reputation during the last years and now attracts considerable interest from all over the world. Approximately, 300 participants from at least 20 nations are expected to attend the conference in 2014. The events will take off on its first day with a technical tour. On 26 and 27 June, leading experts are going to present recent results from research, development, and demonstration projects. The conference languages are English and German with simultaneous translation. The presentations will be followed by a technical and poster exhibition.

IEA Solar Heating & Cooling Programme (IEA SHC) 2014

13–15 October 2014

Beijing, China

SHC 2014, the third international conference on solar heating and cooling for buildings and industry, offers a broad discussion platform for researchers, technical experts, marketing specialists and policy makers. The host country China offers the opportunity to get first-hand impressions from the by far biggest solar thermal market. The international solar thermal community will present their work and exchange views and ideas. In addition to key technical topics, the conference will also address market and policy issues from an international perspective.

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Salient Features

- ✓ Can provide steam/hot oil/ pressurized water at 90-350 C
- ✓ A smallest system of 100 sq. m. reflector area requiring double the land space can save 5000 to 10,000 liters of fuel oil per year during day time
- ✓ Is integrated with conventional boiler to have trouble free operations during non-sunshine hours
- ✓ A number of technologies suitable for various applications are available
- ✓ Pays back the cost in 3-5 years depending on sunshine, application& fuel being used
- ✓ Over 150 systems of various capacities working in country


Solar Energy Centre, Gurgaon, for space cooling


Chittlay Dairy, Maharashtra, for milk pasteurization


Brahmakumaris, Mount Abu, for community cooking


Hindustan Vidyut, Faridabad, for process heat

30% subsidy to all category of beneficiaries with additional benefit of 80% accelerated depreciation to profit making bodies available from Ministry for installations. Higher subsidy for special category states. In addition,up to 15% support is available from UNDP-GEF project for systems sizing 250 sq. m. & above for specific activities.

Interested beneficiaries may contact our Channel Partners (Thermax, Pune: 020-67308885/ 6708889; Clique Solar, Mumbai: 022-28609011; Taylormade Solutions, Ahmadabad: 079-40035875/ 40040888; Megawatt Solutions, Delhi: 09654451401; Unison, Bangalore: 080- 22289663/ 22355239; Forbes, Pune: 020-27145595/39858555; Arier Natura, Bangalore: 080-23417353/ 7754/0784; Essential Equipment, Dhule: 02562- 223164; Leverage Net Solutions, Pune: 020- 30560130) or write to us at following address indicating the heat requirement, fuel being used, space availability etc:

NATIONAL PROJECT MANAGER
UNDP-GEF Project on Concentrated Solar Heat
Ministry of New & Renewable Energy
Block 3, CGO Complex, Lodhi Road, New Delhi-110003.
Telefax: 011- 32314365 /24363638, E-mail: singhalak@nic.in / pankaj.kumar74@nic.in.

Toll Free Helpline No. 1800 2 33 44 77 could also be accessed during Monday to Friday Between 9.30 am to 6.30 pm & on Saturday: 9.30 am to 1.30 pm