# White paper on Solar Thermal Technologies

## By A.Vaidyanathan

India receives solar radiation equivalent to more than 5,000 Trillion KWh/year, which is substantially more than its total annual energy requirement. This energy could be utilized for photovoltaic applications and also harnessed for Solar Thermal technologies.

Solar thermal technologies have found ready acceptance for Water heating applications in various sectors such as domestic, commercial and industrial use. This is the most popular and widely application of solar thermal technologies.

A few Solar based cooling systems have been set up by some of the leading corporates in the country. However this has not become popular due to high cost, and limited number of players offering products/ solutions in this high technology area.

Among solar photovoltaic technologies, there are some devices/ systems such as solar lanterns, solar home systems, solar street lights, solar pumps, solar power packs, roof top SPV systems etc which could be useful both in rural and urban areas for the purpose of reducing burden on conventional fuel**(1)**

**Global background for Solar systems:**

The global renewables market has been growing steadily. The investments in 2011 grew at about 17% to reach a total of about $257 Bn. One of the highlights for the year was that Solar power out grew Wind Power in investments. Over the last 6 years, Solar PV operating capacity has increased by an average of 58% annually followed by CSP, that grew at 37%. In terms of capacity Solar PV saw a growth of about 30GW of operating capacity being added in 2011, increasing the total global capacity to about 70 GW.

Solar heating capacity increased by an estimated 27% in 2011 to reach approximately 232 GWth. Most solar thermal is used for water heating, but solar space heating and cooling are gaining ground particularly in Europe.

Solar thermal technologies contribute significantly to hot water production in several countries and increasingly also to cooling. IN 2010, the world added an estimated 44.3 GWth of solar heat capacity nearly all of which was glazed systems.

Solar cooling installations has increased substantially in the past five years. The most advanced markets are Germany, Spain and Austria. Globally the market share for systems that provide both water and space heating is about 4% and rising**.(2)**

Solar thermal energy has the potential to cover 50% of the total Energy demand. To reach this goal existing technologies have to expand and new technologies should be developed for new sectors like apartment buildings and the industrial applications (upto 250 deg. C) and solar cooling.

In Europe the final energy demand for heating and cooling (49%) is higher than the electricity (20%) or transport ( 31%) -EREC 2006. In the past, the heating sector has been traditionally neglected in the energy policy debate. Now it is becoming increasingly relevant that the renewable heating and cooling (RES-H/C) must play a major role in reaching the European policy goals

Use of modern renewable energy technologies for heating and cooling is still limiated relative to their potential for meeting global demand. But, interest is on the rise and countries (particularly in the EU) are starting to enact supporting policies to track the share of heat derived from renewable sources. For example, renewable energy met 10.4% of Germany's heating demand (mostly from biomass) **(3)**

**Solar Heating – India:**

For domestic market Flat plate type Solar water heaters is a popular technology, while for low temperature applications Evacuated Tube Collectors. The usage of Solar heating for temperatures above 100 deg.C is rather limited in the country. Industrial applications that demand temperatures up to 250 deg. C could be developed with solar heating.

Another application under promotion by Indian Government is Solar steam generating systems based on fixed receiver E-W automatically tracked technology and the other being fully tracked receiver technology (Arun). Indian Government has funded several projects for harnessing Solar heat for industrial applications including 'heat based cooling'**. (4)**

India is expected to increase its share of manufacturing to 25% of GDP from current 16%. This would all for substantive increase in creation of industries in the Tier2 / 3 cities as well as areas that are currently semi urban or rural. These industries would have various application that require heat upto 250 deg.C. A comprehensive understanding of the relevant solar heating technologies and road map for utilization of these will go a long way in reducing the load on grid power, while further new solar technologies / companies to offer these and employment opportunities in these sectors.

**Solar Cooling:**

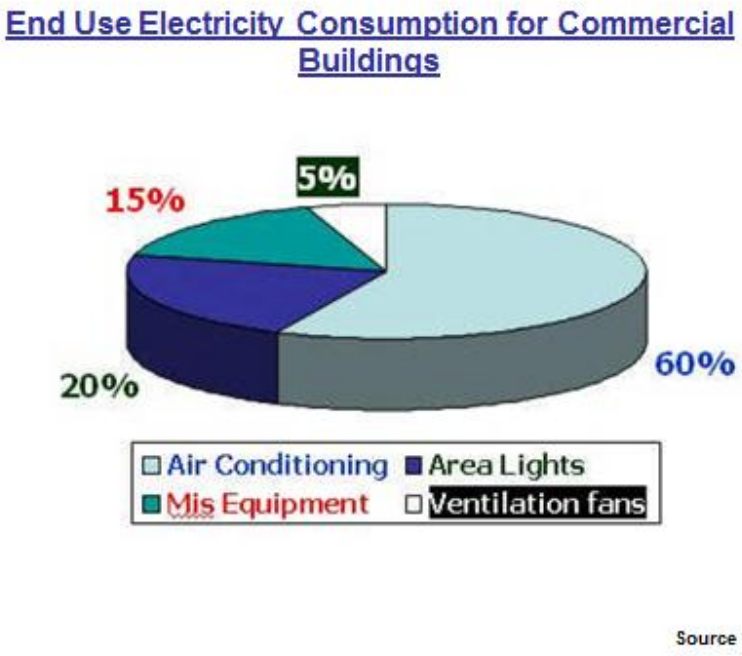
Solar cooling refers to utilization of solar radiation for various applications under 'Air conditioning & refrigeration'. It is relevant and obvious that the air-conditioning / refrigeration load increase when the ambient temperatures are higher. As a tropical country, India experiences summers and extended summers where in almost the entire country experiences temperatures of >35 deg.C.

The importance of renewable energy technologies, including solar cooling technologies could be appreciated more if we evaluate the environmental impact of air-conditioning.

**Environmental impacts of air conditioning:**

Commercial buildings is one of the largest consumers of electricity. The domestic and commercial sector in India accounts for about 30% of its electricity use. A typically air conditioned building uses about 50 to 60% of the total energy for this purpose. CII –GBC's estimates are as shown below:




Source : IGBC

Developed countries spend about than 50% of the total energy consumption goes for Buildings heating and cooling. In Europe the final energy demand for heating and cooling (49%) is higher than the electricity (20%) or transport ( 31%) EREC 2006. **(5)** In U.S alone air conditioning is a $ 10Bn industry that uses over 4.3quads (4.54 billion GJ) of primary energy, almost all of which comes from non renewable sources**.(6)**

As a developing country, India has less than 20% of its buildings air conditioned. However, with rapid urbanization and development of commercial buildings, growth of newer sectors, the neatly all the new buildings (in cities) are air conditioned.

Effect of conventional air conditioners on CHG emissions:

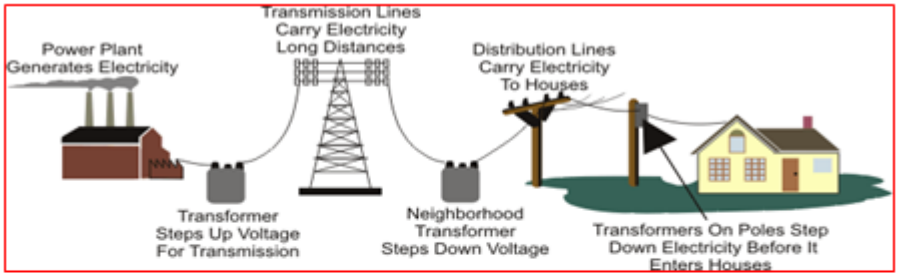
1. Direct emissions: Leaking of refrigerants into the atmosphere. Refrigerants have a high GWP and ODP. **(7)**

| Refrigerant | ODP | GWP |
|---|---|---|
| R -22 | 0.05 | 1700 |
| R -134a | 0 | 1300 |
| R -401 a | 0.37 | 1100 |
| | | |

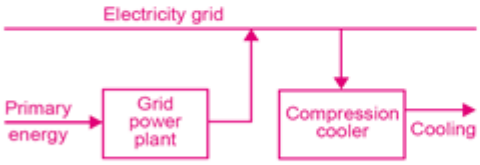
2. Indirect emissions: High energy consumption which releases CO2 in the atmosphere again contributes to global warming. This effect is much larger (about 11-12% of GHG emissions is due to HVAC electricity generation) than that of direct effect (3 to 4%)

As regards the electricity generation, the standard vapour compression cooling system turns an inefficient user of total resources, when considering power plant loss, Generator loss, T&D loss and end equipment loss **(8)**




**Electrical compression cooling system**




Power plant loss : 70 %
Generator Loss : 5 %
T &D Loss : 30 %
End Equipment loss: 10 %

25 kWh – 7.5 kWh --- 6.75 kWh --- 4.75 kWh – 4.25 kWh

**Source – Site Factor : 0.17**

In addition to the poor utilization of natural resources, the other resource required for electricity generation is water. The water requirement for generation of 1 kWh ofelectricity generation is as below: **(9)**

| Power Plant | Water consumed (litres) |
|---|---|
| Nuclear Power plant | 205 |
| Thermal Power plant | 150 |
| | |

Source: Environment Canada

While the environmental impact of air conditioning has been extremely well documented, it is perceived as a necessity. The usage of air conditioning has got into the life style of urban population. While positive effects in terms of thermal comfort, increased productivity, increased equipment life, better utilization of applied resources in an air-conditioned office can be counted as the positives, the negative effect of space cooling necessitate rethink into various related aspects as Adaptive comfort for tropical environment, evaluation of technologies based on renewable sources.

The requirement and the challenges pose an unique opportunity for India. By harnessing solar potential and the society's requirement of cooling solutions, India could channelize its resources to become a technology leader in this segment.

India could exploit opportunities for Solar cooling through:

1. Solar thermal systems based Cooling Solutions
2. Leveraging on established technologies

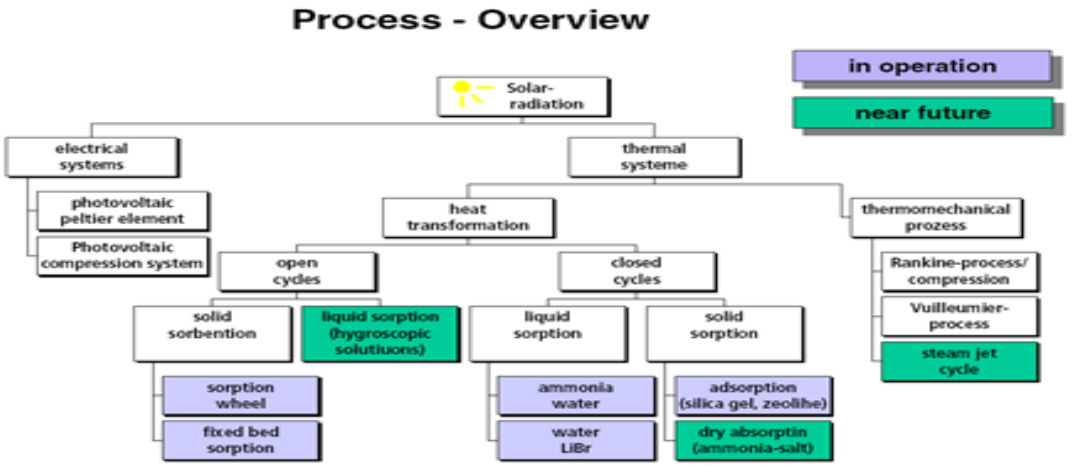
**Solar Cooling technologies:**

The technologies that could be developed fall under two broad categories: **(10)**

Solar (PV) based Electrical systems: This renewable electricity could be used for Pelitier effect based cooling systems, that could be used in refrigeration and air conditioning for different applications.

Solar Thermal systems, lend themselves to both Open cycles and Closed cycle technologies.

Under open cycles, Sorption wheels or fixed bed sorption technoloiges could be developed. Under closed cycle both liquid sorption and solid sorption technologies are available. In liquid sorption cooling technoloiges based on Ammonia & water or Lithium Bromide & water are being commercially offered. In solid sorption, new technoloiges based on adsorption (silica gel , zeolite) is being tried. Another exciting possibility under solid sorption is dry absorption (ammonia-salt)

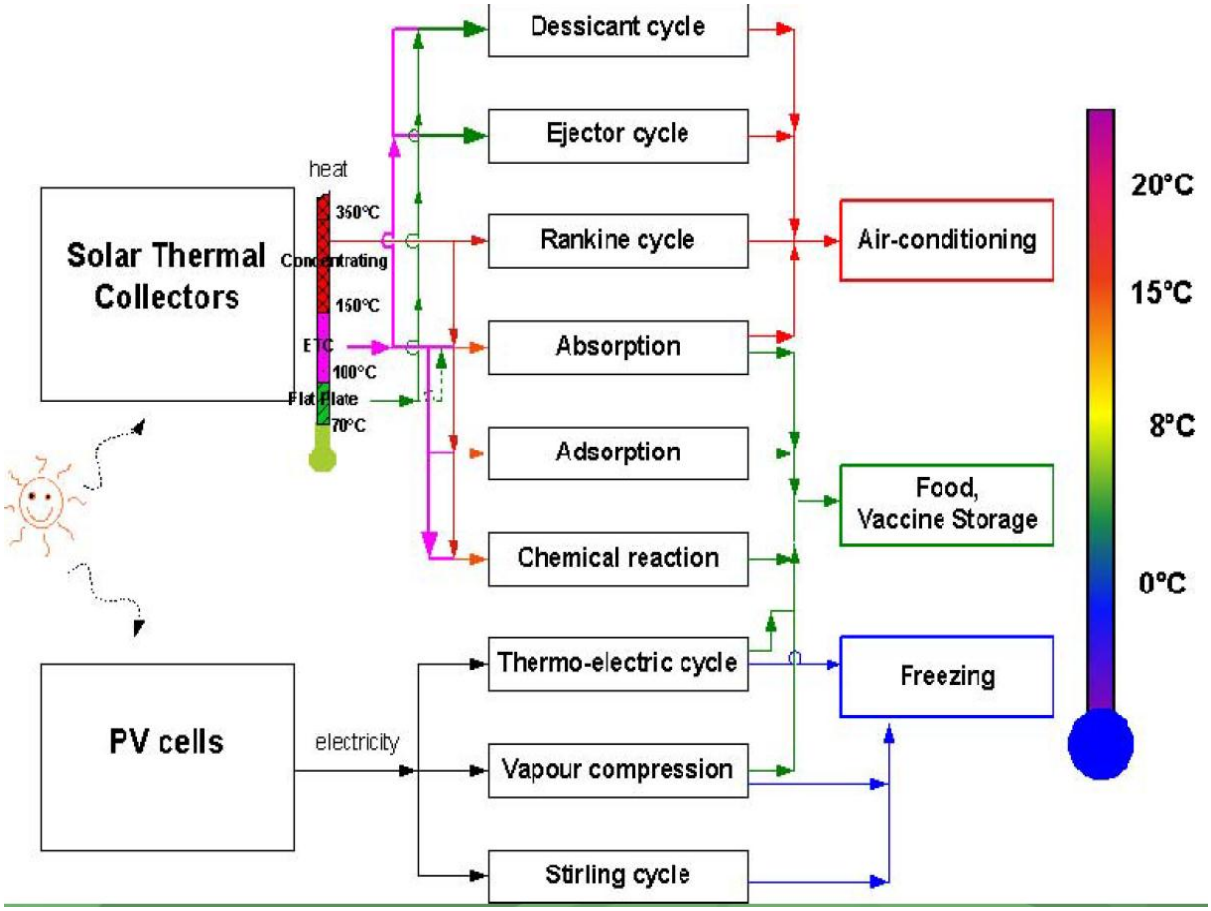



*Source : Fraunhofer Institut für Solare Energiesysteme*

In India Vapour absorption Machines are reasonably popular. Indian solar cooling market has a few successfully established cases of hybrid cooling solutions for office spaces. These have used Solar & VAM together as a hybrid solution. Indian Government through MNRE has funded academic and commercial establishments for developing products based on these technologies. **(4)**

The sketch below shows various opportunities:




*Renewable Energy based Cooling Systems – Dr. Saravanan, Anna University, Chennai*

Thermo electric cooling technology is less efficient as the theoretical maximum Carnot efficiency is about 35% **(11)**. However the technology lends itself to small construct and usability with solar PV technologies. This technology has been successfully used for leveraging the windows area of a building to create cooling in the inside space.(12)

A detailed analysis and review of various above technologies could throw new light on the extent to which India could explore such evolving technologies along with Solar technology development .

**Leveraging on established technologies:**

The evolution of technologies and adaptation of these by Indian industry has been guided by thermal comfort standards of America and Europe. These have rigid guidelines for temperature and relative humidity control that has necessitated mechanical refrigeration & air conditioning systems to become a necessity.

India has been the fountainhead of 'evaporative cooling' technology. History has recorded that it knew to make Indian ice cream (Kulfi) without the support of mechanical refrigeration. The palaces and homes built during the medival time bear witness to leveraging and use of evaporative cooling technologies.

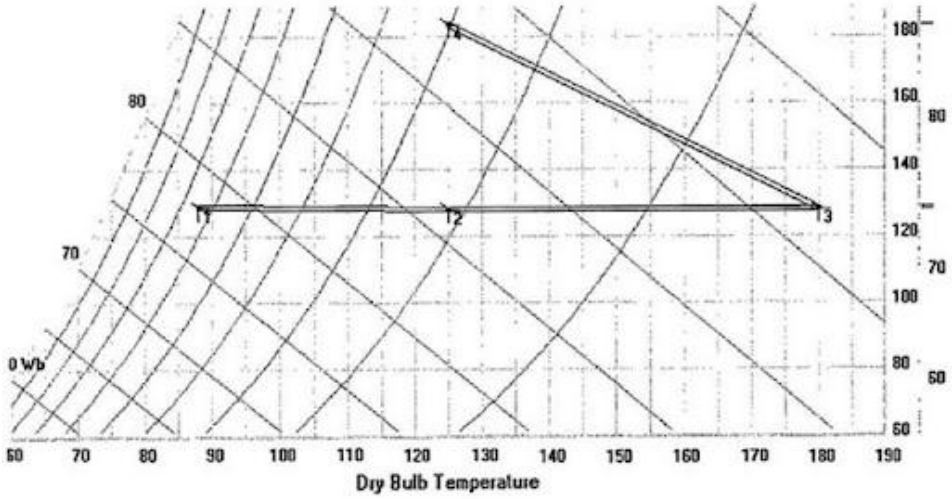
Interestingly, even now, while India sells about 3million air conditioners (window & split air conditioners), the market for Air coolers / Evaporative coolers is about 10 Million per year.

According to World Bank Technical paper and report, India is one of the largest Evaporative air conditioners market. **(13)**

Indian companies have done some pioneering work in both Indirect Evaporative Air conditioners too. These technologies (Evaporative / Indirect evaporative) work best during times when cooling is required the most, namely, during the day time when ambient temperatures are high. These technologies in combination with other technologies offer interesting possibilities for technology development.

Evaporative cooling reduces the DBT, in increases absolute humidity. This is shown as line 13-14 in the psychrometric chart below.

Indirect evaporative cooling sensibly cools the air without any increase in absolute humidity. This brings down the temperatures to lower than possible by evaporative cooling. This process is shown as lines 13 -11 in the psychrometric chart below.




Indirect Evaporative plus Desiccant offers exciting possibilities of developing new range of air conditioners. National Renewable Energy Laboratory, Colarado ( NREL) is working on technologies to develop and demonstrate these.**(14).** National Research Council, Canada is working on evaluating 'Evaporative Cooling (both direct & indirect) along with Desiccant wheel for use in residential buildings. **(15)**.

Along with contemporary research, a lot of papers are presented with reference to leveraging Solar energy for cooling systems for industrial refrigeration and air-conditoning applications.**(16)** . While one addresses Desiccant technology for moisture removal, re-activation temperature could be achieved with solar radiation **(17).** Investigations are also on to use liquid desiccants for solar cooling technologies (18)

Successful development and deployment of these technologies in India will enormously aid development of eco-friendly and energy efficient cooling and refrigeration technologies in India. Further, these are likely to present an interesting opportunity of India taking leadership in integrating some of these technologies for the tropical countries, developing countries and eventually even the developed countries such as Australia, South West, America.

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