# REVIEW PAPER ON APPLICATION OF SOLAR THERMAL COOLING

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**ABSTRACT**

*Solar thermal cooling can be identified as the most promised technology to get cooling from sun. It is a very efficient way of reducing energy consumption and it has reduced green house emissions to a great extent. These systems result in big savings as it reduces the electricity consumption during the peak hours which usually occur during hot sunny days of the summer season. Most commonly used solar cooling system is the lithium bromide absorption chillers. But its high cost of installation acts as an obstacle to its promotion but renewable energy systems have low operation costs and also provide a good performance of energy efficiency.*

*When cooling of rooms is extremely necessary i.e. during the summer season, the solar energy available is the most. But the amount and intensity of sunlight usually depends on the geographical and weather conditions of a country. Experiments show that the annual global solar radiation incident on the horizontal regions is about 2200 kWh/m$^2$ whereas in northern regions of Europe it is half of this value (1100 kWh/m$^2$).Hence, the efficiency of these systems depends on sunlight conditions.*

***Keywords: Absorption Chiller, Cooling, Evacuated Tube Collector, Solar Energy, Thermal.***

## I. INTRODUCTION

Energy is the backbone of human activities. Till today the prime source of energy is the fossil fuel in its solid phase, i.e. wood and coal. But the 20$^{th}$ century industrial revolution and the ever increasing demand of the overgrowing population have lead fossil fuels through a transitional phase.

Solar energy is becoming an important alternative to these fossil fuels and is expected to be utilized on large scale in different fields in the near future. But it has a major limitation. It has to be stored in order to be used during night and overcast periods making it a time dependant source. In order to reduce the green house emissions solar thermal cooling is being used for air conditioning purposes in various parts of the world. Evacuated tube collectors, absorption chillers, a heat storage tank and a cooling storage tank are the basic components of a solar thermal cooling system.

### 1.1 Evacuated tube collectors

The vacuum sealed glass tube absorbs the solar energy in turn heating the special non-toxic heat-transfer fluid present in the copper heat pipe. The water which circulates in the copper manifold heats up because of this heat transfer fluid which rises up in the pipe. The copper manifold is an insulated aluminium header. When the heat transfer fluid cools down, it fall down in the pipe to get reheated and the process repeats.

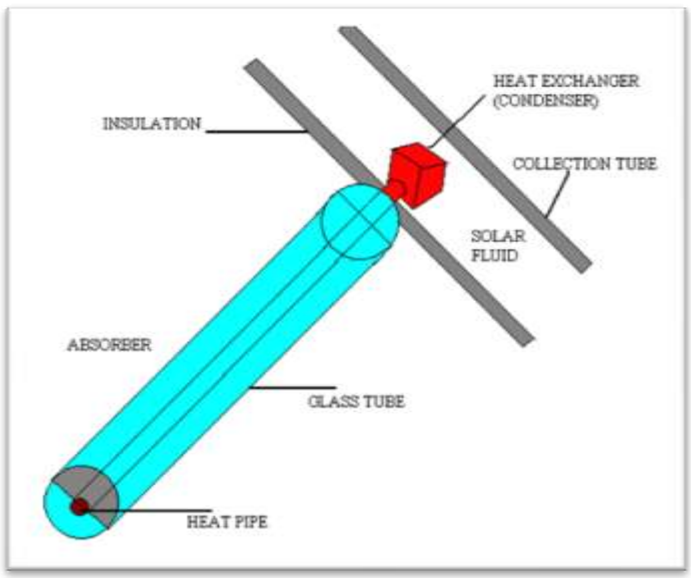


**Fig 1: Evacuated Tube Collector**

Such collectors don't require direct sunlight as it can extract heat from air even during foggy climate. It works perfectly in the morning and in the late afternoon when the sun is not at optimum angle.

### 1.2 Absorption Chiller

An absorption chiller is an arrangement using heat energy to produce chilled water instead of electrical energy that is used in vapor compression cycle. Similar to a compression cycle, absorption cycle removes heat by evaporation of the refrigerant at low pressure. The heat is ejected by condensing the refrigerant at high pressure.

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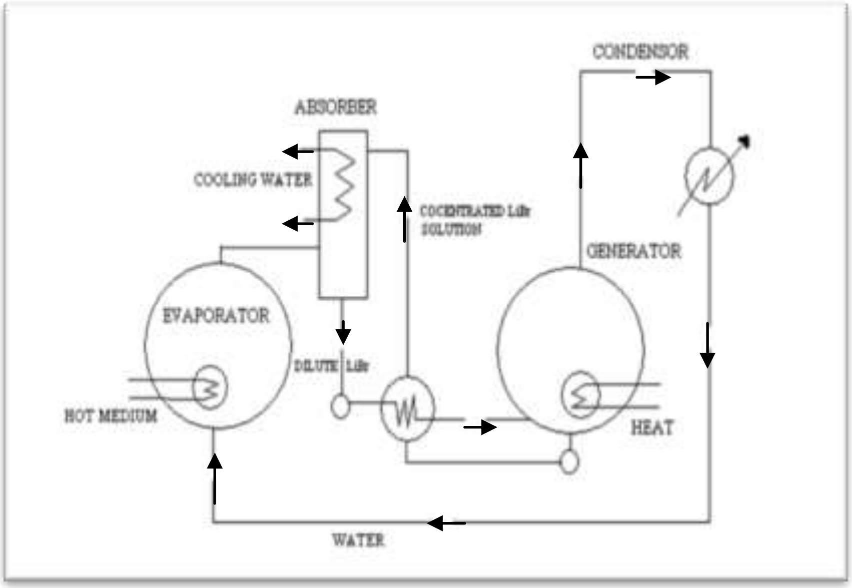
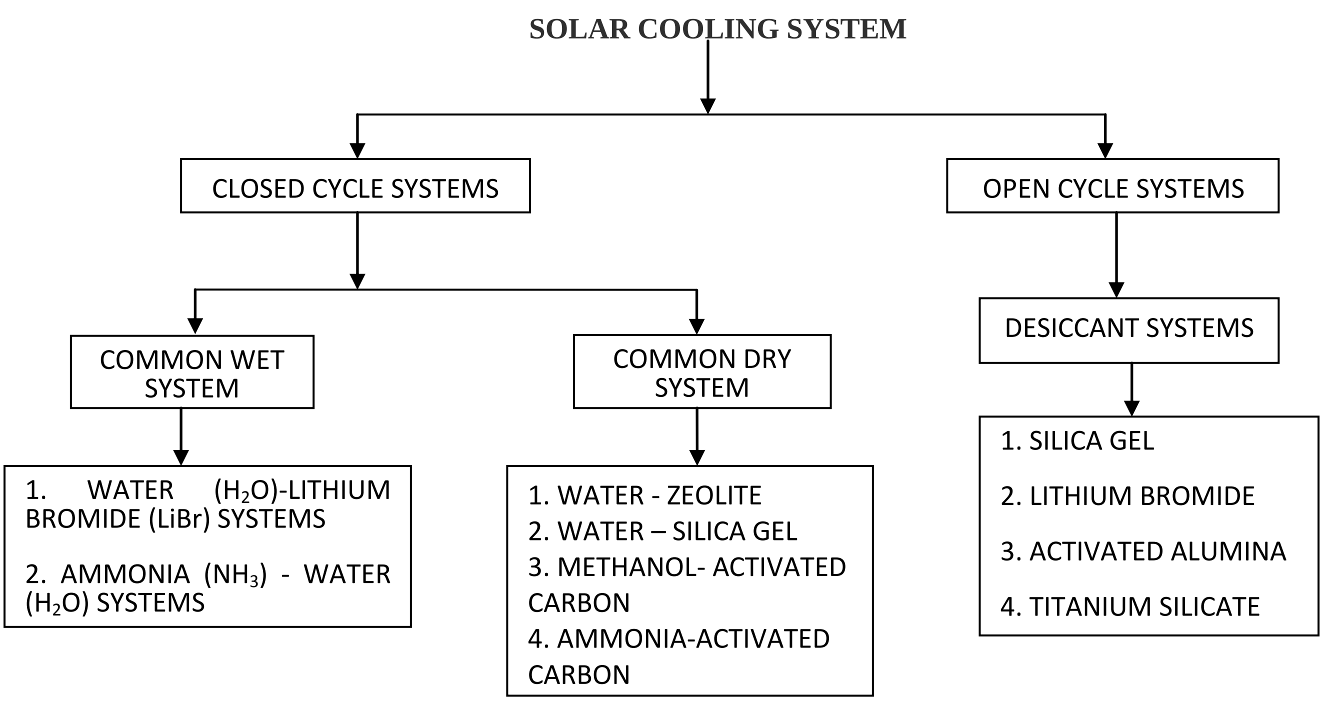



**Fig 2: Absorption Chiller**

The most important difference between an absorption chiller and a vapor compression system is that former makes use of heat to obtain the pressure difference whereas the latter uses a compressor. Absorption chiller is very attractive as it uses heat either solar or waste heat reducing the cost as it needs little work input.

### 1.3 Types of Solar Cooling Systems



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### 1.4 Comparison of the solar cooling systems

| SYSTEM | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| **ABSORPTION** | • Heat supply at low temperature.<br>• Only one moving part i.e. pumps. | • Low evaporation temperature not achieved.<br>• COP is low.<br>• Complicated system. |
| **ADSORPTION** | • Coefficient of Performance is high as compared to other systems.<br>• Low operating temperature achieved. | • High weight<br>• Lower thermal conductivity of the absorbent.<br>• Intermittent system. |
| **DESICCANT** | • Eco-friendly.<br>• Water used as working fluid.<br>• Can be integrated with ventilation and heating system. | • Humid areas cause problem in proper working.<br>• Maintenance needed from time to time because of moving part i.e. rotor wheel. |

## II. REVIEW OF SOME RESEARCHERS

### 2.1 Li Zhong et al [1]

Introduced the China's largest solar thermal cooling system installed in Hainan Island. It covers a huge area of 20.2km$^2$ library of a university campus. Out of the three applicable methods (solar desiccant cooling system, solar absorption cooling system and adsorption cooling system) this project works on the adsorption cooling system. The solar thermal cooling system should always be able to meet just the frequent load and not the peak load i.e. the designed load for the building. A cheap conventional energy system was used to meet the frequent and peak load difference.

In order to avoid the solar irradiation changes affecting the performance of the absorption chiller, the capacity of the hot water storage tank was increased and the capacity of the absorption chiller was comparatively reduced. Large hot water storage ensured that there was enough hot water to prevent frequent starting and stopping of the chiller. As a supplementary source to supply cooling energy a traditional electric driven chiller was used.

#### 2.1.1 Material Specifications:

- U-tube vacuum tubular solar collector.
- Lithium bromide absorption chiller.

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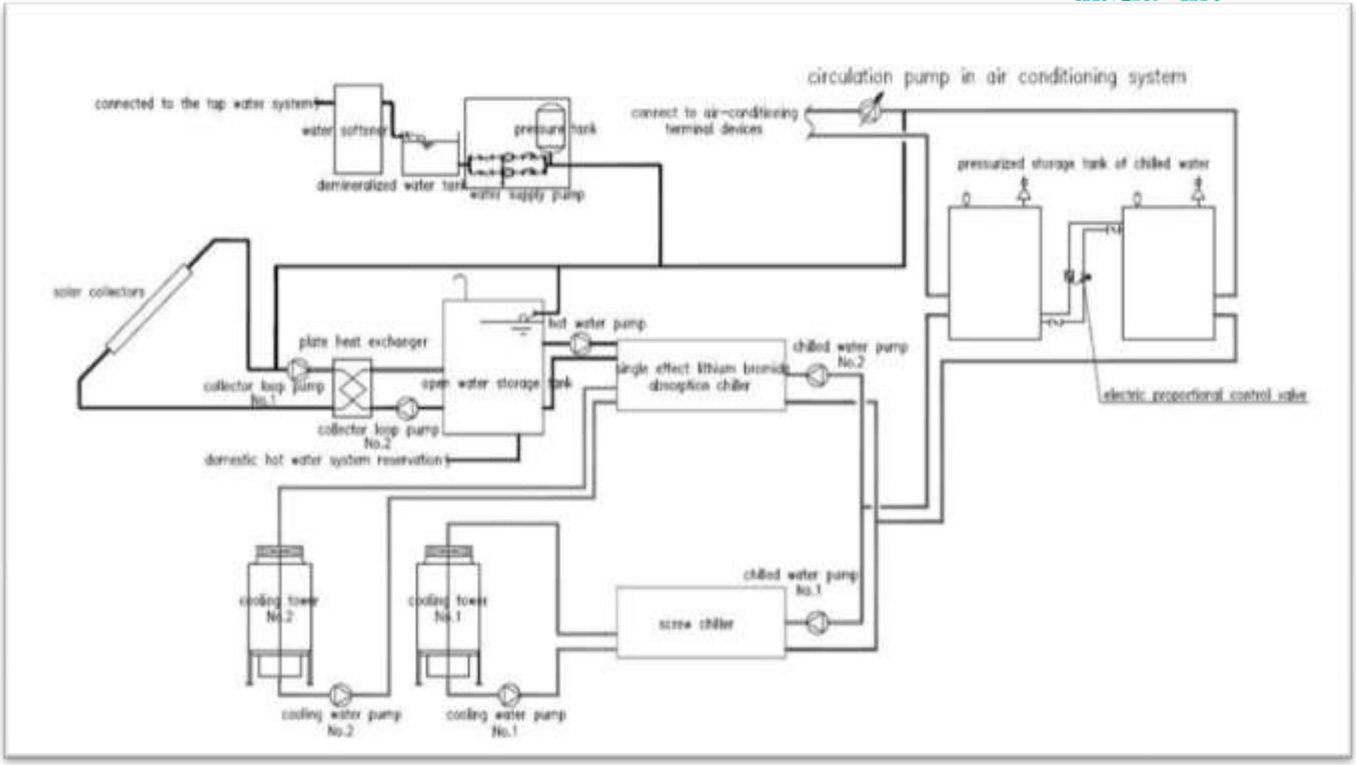


**Fig 3: Flowchart of the solar thermal cooling system**

**2.1.2 Specifications:**

1. Hot water storage tank- 45 cubic meters.
2. Cold water storage tank- 45 cubic meters.
3. No. of collectors- 746 sets accounting for 1492 square meters.
4. Absorption chiller capacity- 316 kW.
5. Electric screw chiller capacity- 1044 kW.
6. 2 pressurized cold storage tanks- 10 cubic meters.

**2.1.3 Experimentation**

- The solar collector works on the principle of temperature difference. When the temperature of the reference collector 5°C higher than the specified temperature, the collector loop pump starts. As soon as the temperature difference reduces to 2°C, the pump stops.
- The absorption chiller starts when hot water storage is at 80°C, cold water storage tank at 14°C and the cooling tower at 19°C.The system operates in following order cooling tower – chilled water pump – hot water pump – absorption chiller, and the sequence of stopping is opposite.
- The absorption chiller stops when hot water storage temperature is 75°C and the temperature of cold water storage is below 10°C. The chilled water is then supplied to the air-conditioning terminal devices.

- As soon as the supply water temperature increases to 12°C, the crew chiller system starts as a supplementary energy source.

A safety valve with a safety pressure of 0.5 MPa is installed in the system in order to drain if the system overheats above 150°C.

### 2.1.4 Results and Discussion

The implementation of this system gave fruitful results as the cooling system proved to be feasible and economical as compared to the conventional air conditioning system.

## 2.2 Peteris Shipkovs et al [2]

This paper presents the idea of using the solar thermal cooling on the northernmost latitudes basically in Latvia, Europe. The country's maximum average summer temperature is 32°C and it receives solar radiation of 1100kWh/year. After the consideration of various factors, an 8kW solar cooling system was installed. The maximum cooling capacity of the system is 11 kW using solar thermal energy. It was also modified as to produce hot water when needed. Considering both factors, solar collectors with low heat loss coefficient and higher optical efficiency (η>0.74) were carefully selected. The annual cold production was 230 kWh per kWp of adsorption chiller nominal power using 560 kW of thermal energy obtained from sunlight alone. Electricity is only used by the fans in the cooling tower. As compared to the conventional air conditioning method it is highly efficient method of air conditioning.

### 2.2.1 Result

- Solar cooling system reduces the energy consumption while increasing the efficiency.
- Solar driven chillers uses only2.9kWh/a or 0.9% of the total electricity consumption.

## 2.3 Xiaoqiang Zhai et al [3]

This paper introduces a mini-type solar absorption cooling system which was installed in the Shanghai Jiao Tong University. The evacuated collectors were spread on the roof of a building over an area of 96 $m^2$ tilted at an angle of 30° and an 8 kW $LiBr/H_2O$ absorption chiller was used. The system was tested in a50 $m^2$ testing room. Also some fan coils were placed in the room for comparison of radiant cooling and electric cooling. An independent fresh air system was installed in the neighboring room for meeting the latent load of the test room. The experimental results obtained from the analysis of the cooling system showed that the average daily efficiency of the solar cooling system is about 0.46 or 46%. The cooling capacity obtained during the continuous 8 hours operation was observed to be 4.5 kW and COP of the chiller was 0.32. Also it was noted that under similar weather conditions, the output of the radiant cooling system was 23.5% higher than that of the fan coils.

### 2.3.1 Result

- The solar cooling system was proved to be more energy efficient than the electric driven air conditioning.

### 2.4 Joshua Fong et al [4]

It is necessary not only to focus purely on reducing energy consumption but also producing minimal amount of carbon. This paper bridges the modern solar cooling technology concept and its future potential for its applications in commercial areas. Two solar cooling techniques were used viz. absorption cooling and desiccant cooling. Analytical comparison methods and detailed modeling was used to check the feasibility of the UK's potential to adopt solar powered cooling according to the weather conditions. By use of computer stimulation methods, comparison of the two cooling systems for their future performance was conducted. The results showed that the desiccant solar cooling system more reliable choice as compared to the absorption cooling system as it has greater cooling efficiency and very low carbon losses. Results from the stimulation software and calculations done manually showed that in the coming years, the cooling effectiveness and the carbon savings would increase for both the solar cooling systems.

#### 2.4.1 Result

- The solar cooling system has thus proved to be effective and more feasible system to reduce the carbon emissions in UK.
- The improvement in the solar collectors (i.e. reducing losses) increases the generation of the hot water which in turn increases the cooling effectiveness for absorption chillers from 16% in 2002 to 42% in 2080.
- The desiccant cooling system is more efficient and achieves higher carbon savings.

### 2.5 Tao He et al [5]

In this paper the researcher has presented the novel solar cooling system which was installed in a building using absorption chillers and evacuated tube collectors to reduce the energy consumptions and reducing the pollution emissions, thus, keeping a good air quality. The heat storage tank stores the heat and provides it to the adsorption chiller driven by a medium at 70~90°C. A 15 $m^3$ heat storage tank and 8 $m^3$ cold storage tanks were used. If the heat storage tank used is too small then the biomass boiler and HM pump has to work continuously decreasing the efficiency whereas if it is too large then it increases the initial cost and heat loss of the system. After the validation tests on the system it was found that the annual average efficiency is 37.6%. Also it was found that the system helped to reduce the primary energy consumption by 66%. Its net present value (NPV) of the life cycle cost is 24%.

#### 2.5.1 Result

- Solar thermal cooling system proves to achieve a significant energy saving effect in public buildings.
- It was estimated that the system would save 13.5 ton of coal which indirectly means reducing $CO_2$ and $SO_2$ emissions by 35.4 ton and 114.8 ton respectively in a year.

## III. CONCLUSIONS

This review paper has focused on the use of solar thermal cooling systems in both domestic and commercial buildings providing an alternative method to reduce the overall energy demand and increasing the carbon savings.

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