"A study on Solar Vapor absorption refrigeration opportunities in tropical wet and dry climate of Indore city"

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ABSTRACT

Vapor absorption solar refrigeration opportunities as a commercial alternative in tropical wet and dry climate region of Indore (22.7°N 75.9°E) city as a model is analyzed. Earth's average temperature has risen by 1.4°F over the past century, and is projected to rise another 2 to 11.5°F over the next hundred years. Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather. Thus realizing the seriousness of the situation an attempt is made to propose the options to stop the use of greenhouse gases used by commercial refrigeration systems by adapting vapor absorption refrigeration systems using solar energy. Energy efficiency of the same is discussed.

Keyword,*Solar Refrigeration, Indore, Vapor Absorption Refrigeration*

Introduction – solar refrigeration opportunities

Current commercial refrigeration systems using Hydro fluorocarbons (HFCs) as a refrigerant have serious implication on environment. The paper enlightens a commercial substitute of the current system which uses HFCs as a refrigerant through the use of solar vapor absorption refrigeration system as an opportunity to protect environment by potent danger of Hydro fluorocarbons. Considering that cooling demand increases with the intensity of solar radiation, solar refrigeration has been considered as a logical solution. Indore (22.7°N 75.9°E) city having annual average Solar Radiation of about 5.63 (kWh/m^2/day) can be potentially used for solar electrical and solar thermal refrigeration systems.

2. Solar electric refrigeration

A solar electric refrigeration system consists mainly of photovoltaic panels and an electrical refrigeration device. Solar cells are basically semiconductors whose efficiency and cost vary widely depending on the material and the manufacturing methods they are made from. Most of the solar cells commercially available in the market are made from silicon as the ones shown in Fig. 1.

In Eq. (1), efficiency of a solar panel is defined by the ratio of power W (kW) to the product of solar panel surface area As (m^2) and the direct irradiation of solar beams I_p (kW/m^2).
I_p= 1 kW/m^2 is commonly used for the calculation of nominal efficiency.

$$\eta_{(solar\text{-}power)} = \frac{W}{Ip \times As} = \frac{W}{Qs} \quad (1)$$

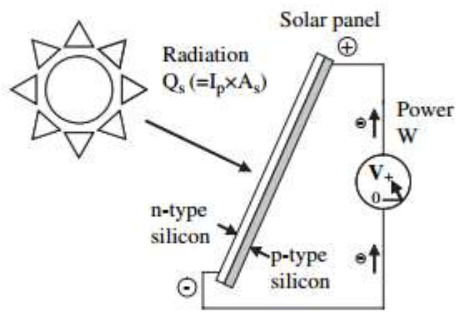


Fig. 1 – Schematic diagram of a solar photovoltaic panel.

The biggest advantage of using solar panels for refrigeration is the simple construction and high overall efficiency when combined with a conventional vapor compression system. A schematic diagram of such a system is given in Fig. 2. In Fig. 2, the work W is consumed by the mechanical compressor to produce the cooling power Q_e. Refrigeration machine efficiency is defined as the cooling power Q_e divided by the work input W:

$$\eta_{(solar\text{-}power)} = \frac{Qe}{W} \quad (2)$$

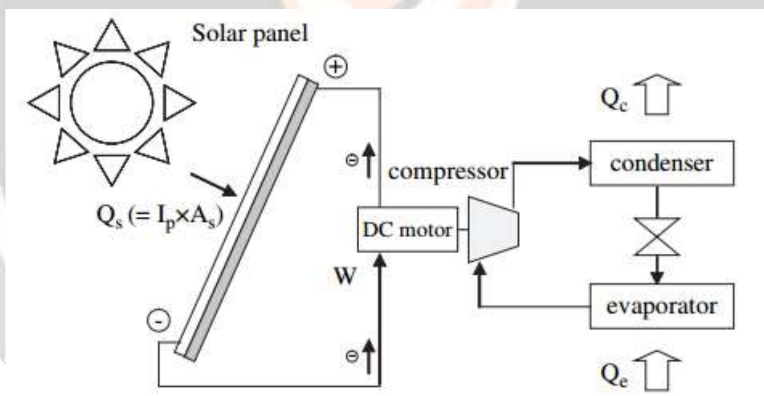


Fig. 2 – Schematic diagram of a solar electric compression air-conditioner

The biggest disadvantage in reference to the perspective of the paper is the use of HFCs in solar electric refrigeration system. Although the electricity consumption part is prohibited by the use of solar energy which in turn prevent the emission of CO_2 if the electricity is generated from thermal power plants by combustion of fuels.

3. Solar thermal refrigeration

Solar thermal systems use solar heat rather than solar electricity to produce refrigeration effect. Flat-plate solar collectors are the most common type, which consists of a metallic absorber and an insulated casing topped with glass plate(s). Evacuated collectors have less heat loss and perform better at high temperatures. Evacuated collectors are typically made in a glass tube design, i.e. a metallic absorber inserted in an evacuated glass tube, to withstand the pressure difference between the vacuum and the atmosphere. Fig. 3 shows schematic diagrams of these two collectors.

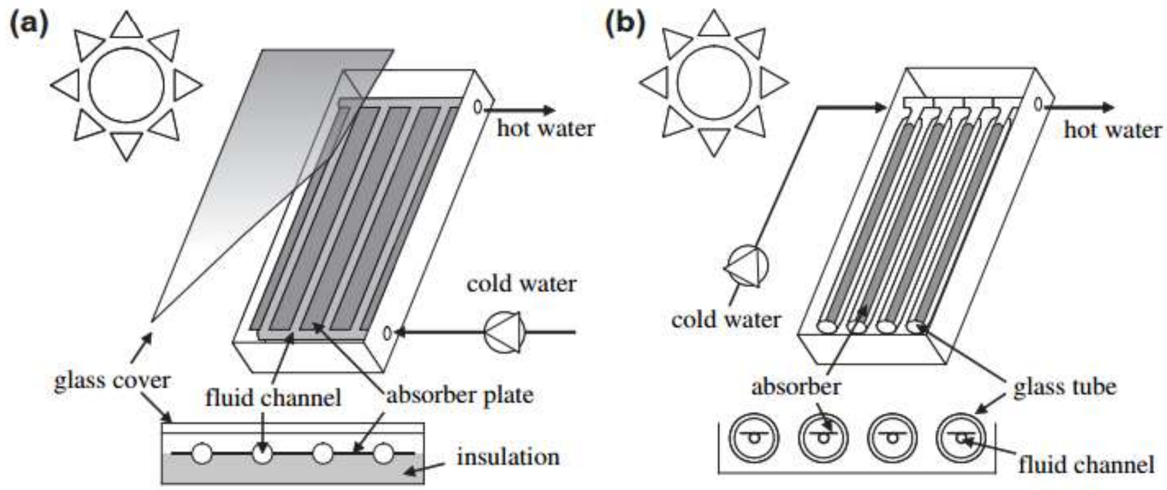


Fig. 3 – Schematic diagrams of non-concentrating solar collectors. (a) Flat-plate type and (b) evacuated tube type.

A solar collector provides heat to the ‘‘heat engine’’ or ‘‘thermal compressor’’ in a heat-driven refrigeration machine. The efficiency of a solar collector is primarily determined by its working temperature. At a higher working temperature, the collector loses more heat to ambient and delivers less heat. On the other hand, the heat engine or thermal compressor generally works more efficiently with a higher temperature. A solar thermal system is designed in consideration of these two opposing trends.

3.1 Vapor absorption solar refrigeration

Absorption refrigeration uses physical or chemical attraction between a pair of substances to produce refrigeration effect. An absorption system has a unique capability of transforming thermal energy directly into cooling power. Among the pair of substances, the substance with lower boiling temperature is called absorbate and the other is called absorbent. The absorbate plays the role of refrigerant. Fig. 4 shows a schematic diagram of a closed absorption system. The component where absorption takes place is denoted as absorber and the one where desorption takes place is denoted as generator. The generator receives heat Q_g from the solar collector to regenerate the sorbent that has absorbed the refrigerant in the absorber. The refrigerant vapor generated in this process condenses in the condenser rejecting the condensation heat Q_c to ambient. The regenerated absorbent from the generator is sent back to the absorber, where the absorbent absorbs the refrigerant vapor from the evaporator rejecting the absorption heat Q_a to ambient. In the evaporator, the liquefied refrigerant from the condenser evaporates removing the heat Q_e from the cooling load. Current absorption technology can provide various absorption machines with COPs ranging from 0.3 to 1.2. Choice of an absorption cooling machine is primarily dependent on the performance of the solar collector to be used. For solar collectors capable of efficiently working at around 150˚C, double-effect LiBr–water chillers with COPs around 1.2 are available for air conditioning. For refrigeration, ammonia–water GAX chillers with COPs around 0.8 can be considered. Heat transfer medium can be either a liquid with a high boiling temperature or steam. A high performance evacuated tube or a concentrating type collector can be considered.

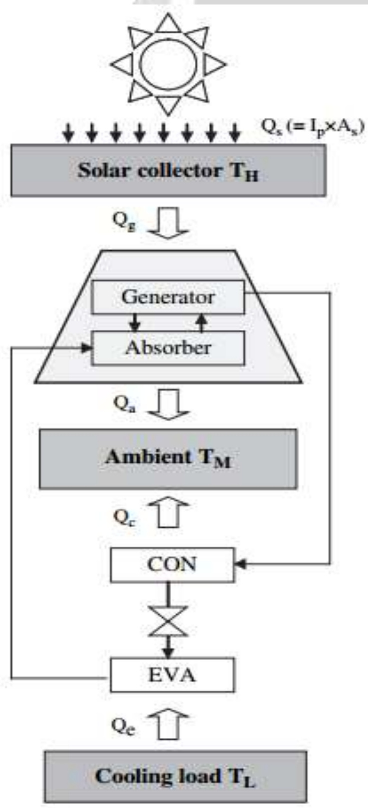
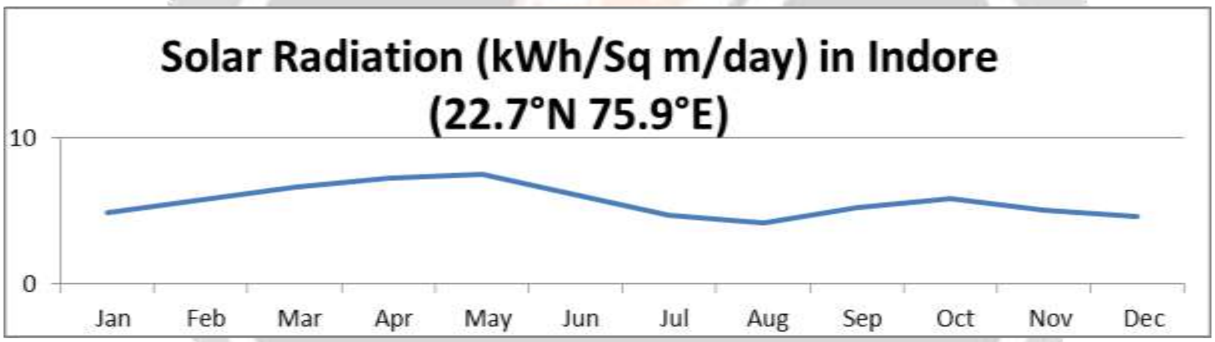


Fig. 4 – Solar absorption refrigeration system.

Solar Radiation in Indore (22.7°N 75.9°E)	
Annual Average: 5.63 (kWh/m^2/day)	
Monthly	**Average**
Jan	4.84
Feb	5.77
Mar	6.65
Apr	7.27
May	7.48
Jun	6.09
Jul	4.66
Aug	4.18
Sep	5.24
Oct	5.84
Nov	5.03
Dec	4.59

Table-1 Variation of Solar Radiation in Indore



Plot-1 Variation of Solar Radiation in Indore

Table 2 – Efficiency analysis of solar absorption refrigeration studies			
Single-effect LiBr–water chillers			
Application	**Q_e [kW]**	**A_s [m^2]**	**$\eta_{heat-cool}$ [–][d]**
Space cooling	**4**	**36[a]**	**0.11**
Space cooling	**210**	**1577[b]**	**0.31**
Space cooling	**90**	**316[a]**	**0.26–0.36**
Space cooling	**35**	**49.9[a]**	**0.34**
Prototype chiller	**10**		**0.37**
Prototype chiller	**16**		**0.4**

Double-effect LiBr–water chillers			
Application	**Q_e [kW]**	**A_s [m^2]**	**$\eta_{heat\text{-}cool}$ [–][d]**
Fuel-fired solar-assisted prototype Cooling/steam (144 C) generation	**140**	**180[c]**	**0.5–0.6**
Diffusion–absorption prototype	**<2.5**		**0.1–0.25**
Wine cooling	**10**	**100[a]**	**0.27**
Space cooling	**15**		**0.27**

[a] Flat-plate collectors.

[b] Evacuated tube collectors (no. of tubes).

[c] Trough collectors (aperture area).

[d] Where not given, a collector efficiency of 0.50 has been assumed.

4. Conclusion

A variety of options are available to convert solar energy into refrigeration effect. The solar electrical system having a disadvantage of the use of HFCs as a refrigerant though cutting the carbon emission generate via combustion of fuel if the electricity is generated from thermal power plants through the use of solar energy. The solar VAR system completely eliminates the use of ozone depleting agents though having efficiency and cost constraints. In Indore *(22.7°N 75.9°E)* having annual average Solar Radiation of about 5.63 (kWh/m^2/day) it is feasible to adapt solar Vapor absorption refrigeration system in commercial use though the initial installation cost and cost per kilowatt cooling is very high. But in future it is expected that continuous improvement in technology along with large scale production of equipment's for solar aided refrigeration along with the subsidies provided by the government of India make it popular for commercial use.

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