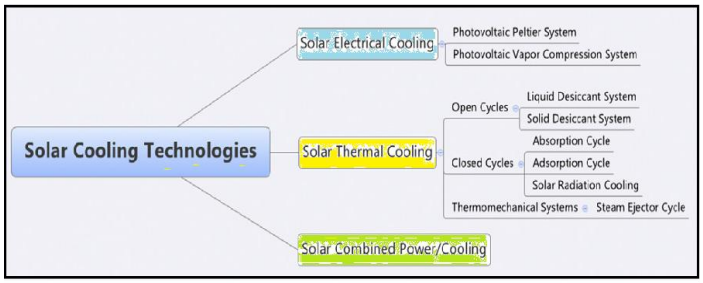

Figure 1: Various Solar cooling technologies

IV. SOLAR ELECTRICAL COOLING

In this cooling technology, solar energy is used to produce Direct Current (DC) electrical energy with the Thermo-electric Module. PV based electricity production has been highly accepted in many countries and thus, the DC electricity generated needs associated devices like inverter, battery and Vapour Compression AC system [6]. This will lead to lower grid demand but the production of Freon still persists with solar electrical cooling as it produces the high grade electrical energy to be used in the archaic vapour compression AC unit. Peltier cooling technology has the ability to cater low cooling demands, but is highly advantageous when coupled to the back side of PV for cooling the cell, so that the cell temperature can be reduced, which otherwise can lower down the cell efficiency and accelerate cell degradation [16].

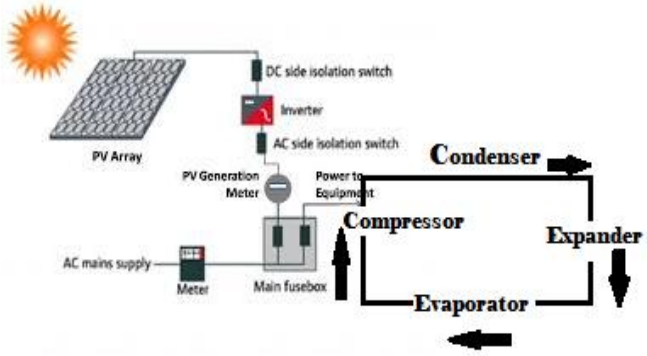

Figure 2: PV assisted Vapour Compressor AC unit

V. SOLAR THERMAL COOLING

Solar thermal Cooling are preferable to solar electrical cooling as the formal can collect solar heat with solar thermal collectors up to an efficiency of about 80% with state of the art thermal collectors [17] whereas the later technology direct convert solar energy into electricity with an efficiency of up to 35%, rest goes as waste in form of heat energy[6] along with the release due to leakage of CFCs and HCFCs which are ozone depleting gases [3][19][22].

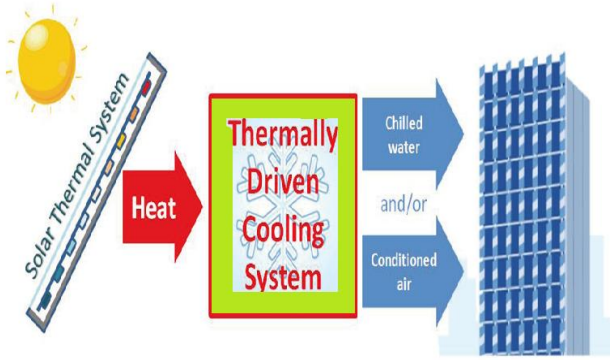

Figure 3: Solar thermal cooling technology

Dessicant systems are used to induce or reduce the moisture content of the supplying air depending on the vapour pressure difference between air and solution. In dehumidification process, the dessicant absorbs moisture and gets diluted and inefficient for further use, which leads to the requirement of regeneration to a useful level of concentration. Absorbents that can work satisfactorily in solar energy range are Tri-Ethylene Glycol and LiCl-H_2O [18][19]. The main constriction for widespread implementation of dessicant system is the need to maintain the constant dessicant mixing ratio by controlling its temperature and concentration which in turn maintains the equilibrium vapour pressure of the solution [15][19].

Solar assisted vapour absorption system is highly popular for its multiple advantages like higher COP than its counterpart cooling methodologies. Most of the researchers suggested solar assisted VARS and performed numerical modeling for deploying the system at various location of the world based on their different solar irradiations influenced by the latitude and longitude. These papers suggested the use of LiBr-water as the best working pair as this pair does not need rectifier and analyser as Lithium bromide is non-volatile and water can easily vaporize with solar heat received from solar thermal collectors (Evacuated Tube Collector being mostly used for vaporizing water) [3][20]-[23]. Researchers conducted modeling and simulation to determine the viability of the system and deduced that further researches can alleviate the cost and elevate the efficiency of the components involved in the system [20]. Associated net TEWI (Kg of CO_2) production with solar VARS is lower than 4.5 % as that of Vapour Compression System (R134a) [3]. When Carbon taxation is impended as per the Clean Development Mechanism (CDM) and the present cost of VARS being reduced, then have a huge potential to compete with the conventional AC techniques.

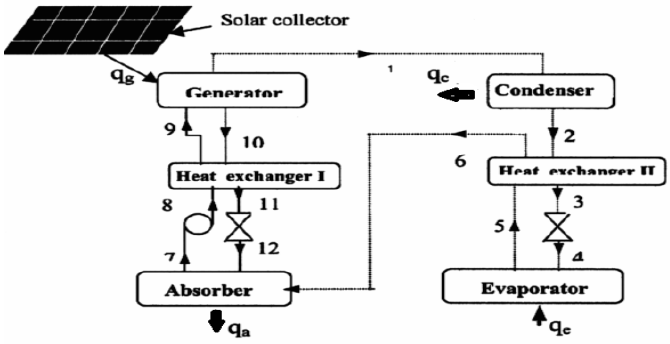

Figure 4: Schematic diagram of Solar VARS

Adsorption technology have been widely used for various applications, differs from the absorption technique as it's a surface phenomenon whereas absorption is a volumetric phenomenon. Adsorption cooling has been used now-a-days in vehicle cooling [4] due to its vibration free and corrosive resistant properties when powered by high temperature vehicle exhaust unlike absorption which vibrate for its absorbent and corrode above 200^0C [6]

In the thermo-mechanical solar cooling system, the thermal energy is converted to the mechanical energy. Then the mechanical energy is utilized to produce the refrigeration effect. When the steam ejector cycle is integrated with a parabolic solar collector, then it's a solar operated steam ejector cycle. The steam produced by the solar collector is passing through the steam ejector. Steam ejector replaces electrically driven compressor of conventional AC systems but the cycle is operated in VCRS cycle only [24].

VI. Solar Combined Cooling

Hybrid solar air conditioner which couples the use of Photovoltaic/thermal collector along with Vapour compression system has been a state of the art technique. By the experimental investigation, it has been observed that the efficiency and indoor comfort condition improves in hybrid AC as compared to conventional standalone Vapour compression AC system and in some condition, COP is more than unity. When desiccant is incorporated in an AC, then it takes care of the moisture part and it reduces the load of an AC significantly in hot and humid parts [25]. In hybrid system, Sun acts as an additional heat source to assist the energy needed to drive the cooling process of a conventional air conditioning system which in turn reduces the electrical consumption required to run the compressor.

The difference between the standalone and hybrid system is the technique by which gas is changed back in to a liquid so that it may be used again. Usual air conditioning system uses a compressor to increase the pressure of the gas, forcing it to become a liquid again through the use of the condenser coil while in Solar hybrid Air Conditioning System, it uses solar heat from the sun to superheat the refrigerant which enables the refrigerant to begin changing state at the top 2/3rd's of the condenser coil.

The improvement in effectiveness of heat exchanger of solar thermal collector may further reduce the dependency and share of electrical compressor which, in turn will lower down the operating cost of the system [Centre of Energy and Environment setup, MNIT].

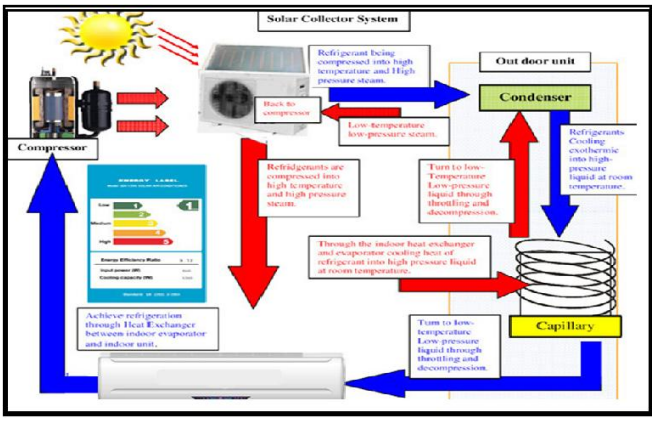

Figure 5: Solar Hybrid cooling

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VII. Conclusion

Solar cooling has been regarded as a very promising application for solar thermal energy in countries with high insolation and high cooling loads. This solution has been demonstrated in different configurations and applications, but currently it's not that prevalent in Indian market. A lot of research needs to be done on cost reduction, system quality improvement, energy performance enhancement, and better building and process integration to make it easily adoptable by common people [20]-[23]. With these objectives in mind, R&D should aim at improving thermally driven cooling components and enhancing system performance, integration and reducing material costs of each component present in VARS. In Europe, solar thermal assisted cooling systems are getting widespread over the last two decades [27]. A few years ago, market development and commercialization started in the residential sector in Mediterranean countries (e.g. Spain, Hong Kong) [28] and in the office building sector in Asia (India, Singapore, China) [29]. The analysis of the first commercial market development phase highlights a substantial potential to accelerate this development with further R&D work.

Solar thermal driven air-conditioning and refrigeration systems have high capital costs due to multiple system components, i.e. cooling equipment, solar collectors and heat storage appliances, and have not been cost-competitive with conventional electrically-driven cooling systems. But the best part of it is that it employ refrigerants with no ozone depleting potential and no, or very small, global warming potential. Most systems use water as refrigerant.

So far, mainly pilot plants and a few commercial plants have been in operation, limited know-how is one of the major barriers for widespread installation of solar air-conditioning and refrigeration systems. Only a small number of professionals are well informed on both solar thermal and air-conditioning in buildings. Due to this limited experience with solar cooling-refrigeration systems, steps are taken to encourage the dissemination of existing know-how and improve system quality. Places in north-western part like Rajasthan and Gujarat has high solar intensity which makes it a worthy option for solar powered devices and systems [29]. The awareness of global warming has been intensified in recent times and has reinvigorated the quest for alternative energy sources that are independent of fossil fuels and contribute less to global warming [26].

VIII. ABBREVIATIONS

COP	Coefficient of Performance
CFC	Chloro Fluoro Carbon
DC	Direct Current
HVAC	Heating, Ventilation and Air Conditioning
TEWI	Total Equivalent Warming Impact
VARS	Vapour Absorption Refrigeration System
VCRS	Vapour Compression Refrigeration System

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