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A review of solar powered absorption systems

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ABSTRACT

For the last two centuries, fossil fuel has been considered and utilized as the main source of energy. However; the negative impacts of burning fossil fuel on the environment have forced the energy research continuity to seriously consider renewable sources of energy. Solar energy, in particular, has been the main focus in this regard because it is a source of clean energy and naturally available. Solar energy applications include solar photovoltaic and solar thermal. Solar thermal systems are used to power absorption refrigeration and air-conditioning systems. This study presents a review of recent published work in the field of solar powered absorption systems which utilize pairs of working fluid. The focus in this study is on solar powered absorption refrigeration systems, diffusion absorption systems, ejector based absorption systems, compression absorption systems and cogeneration/trigeneration absorption systems. The thermodynamic properties of most common working fluids as well as use of ternary mixtures in solar powered absorption systems have been reviewed in this study. The review indicates that along with aqua-ammonia and LiBr–water, there are certain other working fluids that have theoretically shown good performance such as lithium nitrate–ammonia, sodium thiocyanate–ammonia, TFE–TEGDME, methanol–TEDGME, monomethylamine–water and LiCl–water. It is also found that, for diffusion absorption systems, TFE–TEGDME working pair have theoretically shown good performance. The review also indicates that the ternary mixture of LiBr:CHO_2K–water have shown good performance compared to other ternary mixtures.

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1. Introduction

The technological advancement and economic growth of any country rest on the availability of utilizable form of energy in that country. The quantity of available energy also reflects its quality of life. So far, fossil fuel is considered and utilized as the prominent source of generating utilizable form of energy [1]. However, concerns are growing on daily basis over the negative effects on the environment that are caused by burning of fossil fuels that includes global warming and green-house gas effect on the ozone. Thus serious efforts are being made to explore alternatives that could reduce the fossil fuels burning. So far renewable energy represents the best alternative to reduce the burning of fossil fuels. Renewable energy refers to the form of energy that either do not get depleted or has the natural ability to renew itself. Renewable energy sources include biomass, geothermal, hydropower, wave, wind, solar and tidal energy sources. Among all of these naturally available and environmentally friendly sources, solar energy stands top on the list of renewable energy sources. The main reason behind the enormous potential of solar energy is its cleanliness and natural availability. It has also been calculated that the total solar radiation transmitted to the earth is about 1.74×10^{17} W [2] while the overall energy consumption of the world is about 1.84×10^{13} W [3]. Thus solar energy presents an enormous potential renewable energy source.

It is not possible to completely replace the conventional source of energy by renewable energy. However, a major portion of the consumption sector energy requirements can be met with the utilization of renewable energy. Hence, this will contribute to the reduction of fossil fuel consumption. So the recent focus is on utilizing renewable energy sources to meet the energy requirements for the consumption sector. Within the consumption sector in the gulf region, air-conditioning and refrigeration presents one of the highly energy consuming field. This can be acknowledged by the fact that as per the statistic of 2010 [4], about 52% of the electrical energy produced in the KSA is consumed by the residential sector whereas more than 70% of this residential energy consumption goes to the comfort conditioning as shown in Fig. 1.

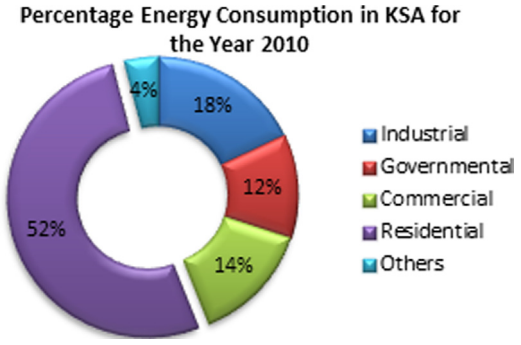

Fig. 1. Pie-Chart for the energy consumption in KSA.

Thus, more than 36% of electrical energy produced in the KSA is consumed by the air-conditioning sector.

Furthermore, the energy requirements for air-conditioning sector are also increasing each year [5]. Hence, utilization of renewable energy sources is being given a serious consideration to meet the power requirements of the air-conditioning sector. In this regard, solar energy is considered as the most appropriate option among other renewable energy sources since its peak coincides with the peak demand of air-conditioning [6].

Solar electrical and thermal powered refrigeration systems can be used to produce cooling [7]. The first is a photo-voltaic based solar energy system, in which solar energy is initially converted into electrical energy and then utilized for producing the refrigeration much like conventional methods. The second one utilizes solar thermal energy to power the generator of an absorption refrigeration system. Kim and Ferreira [8] made a comparison between the two systems both from the point of view of energy efficiency and economic feasibility. The comparison indicated that solar electric refrigeration systems using Photovoltaic appear to be more expensive than solar thermal systems. Otanicar et al. [9] showed that a very small portion (less than 35%) of the incident solar radiation is converted into electrical energy using photovoltaic cells while solar thermal systems can utilize more than 95% of the incident solar radiation. Due to these advantages of solar thermal systems over solar photovoltaic systems, recently more research has been carried out in the field of solar thermal cooling systems [10]. Therefore, the current study presents an intensive review on the recent developments in the field of solar powered absorption systems.

2. Solar powered absorption refrigeration systems

The absorption refrigeration system operates on the principles of absorption cycle rather than the compression cycle. This absorption cycle eliminates the need of a compressor by replacing it with an absorber and a generator [11]. In the case of a compression cycle, the refrigerant pressurization is required which is performed by the compressor in the vapor phase. However, in case of an absorption cycle, the refrigerant pressurization is not performed in the vapor phase. Rather the refrigerant is first absorbed in an absorbing material and is then pressurized in the absorbed liquid phase. The pressurized absorption mixture is then reheated in the generator to regenerate the pressurized refrigerant vapor. The advantage of the absorption system over the compression system is that very little or no electrical power is required to pressurize the refrigerant compared to conventional compression system which requires considerably large amount of electrical power [12]. However, such absorption systems require heat input to regenerate the refrigerant vapor. Such heat is provided by solar thermal collectors in case of solar powered absorption refrigeration systems [13].