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Solar sorption refrigeration in Africa

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ABSTRACT

Solar sorption refrigeration technologies are regarded as a promising way to meet the growing refrigeration needs in Africa, for thermal comfort, foods and crops, vaccines and medicines conservation. Sorption technologies projects and studies have been reported in Africa since the late 1970s. This paper describes the most representative reported research activities and projects in various African climatic conditions. An emphasis is put on demonstrative plants involving absorption, adsorption or desiccant cooling applications. From this overview, it appears that a lot of achievements have been made, though applications are mainly focused on small-size cold boxes for foods and vaccines preservation; no direct building air conditioning based on adsorption or absorption has been reported. Mediterranean countries seems to offer the best weather conditions for solar sorption refrigeration applications and plenty of related activities could be identified in these countries. A more adequate design for each of other climatic zones in Africa may then be relevant. As anywhere, the high cost of these technologies remains the main the biggest brake to their diffusion in Africa.

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Abbreviations: AdSR, adsorption refrigerator; ANN, artificial neural network; COP, coefficient of performance; ID, inner diameter; NGO, non-governmental organisation; PVPR, photovoltaic powered refrigerator; OD, outer diameter; SAbIM, solar absorption ice maker; SAdIM, solar adsorption ice maker; SR, sorption refrigerator

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1. Introduction

On the road to development, the African continent, especially Sub-Saharan Africa, is delayed by a major problem of extremely low energy services accessibility and a poor level of energy consumption. While in Northern Africa, access to electricity is higher than 90%, the electrical plants of the whole fifty sub-Saharan countries, except South Africa, are equivalent to that of Argentina (generation capacity: 28 GW) [1,2] and hardly the fifth of the population in this area has access to electricity. Moreover, in the areas of this region, where an electrical grid exists, there is frequently power outage in the year, mostly in dry or hot seasons. At the same time, thermal comfort needs are growing in the sub-Saharan African countries, including the use of air conditioning due to the economic development that creates a higher living and working standards. As stated above, in most of the sub-Saharan countries, power outage is severe in hot seasons, exactly when thermal comfort is needed since the cooling load and the solar insolation availability are concomitant. Furthermore, the fraction of the produced electricity devoted to air conditioning may be very high (60% in Ouagadougou, Burkina Faso; 32% of the electrical energy consumed by the domestic sector in Egypt [3,4]). The need of refrigeration – cold production either for chilling, cooling or air conditioning – in sub-Saharan region is not only for air conditioning but also for food preservation, including in the countryside, where more than 70% of the population actually lives. Food preservation is not only a health issue but also an economic one because a big part of the harvest including dairy products is lost in African rural areas due to lack of refrigeration systems. The same applies for drugs and vaccines conservation.

However, the abundance of energy resources (solar, coal, oil, gas, uranium (nuclear), hydroelectric power potential, wind, biomass), which are only lightly exploited for the moment, can make scandal. Africa has exceptional insolation conditions (between 16 and 30 $MJ\,m^{-2}\,day^{-1}$ of solar insolation) and its refrigeration needs can be largely satisfied by solar-assisted refrigeration applications, if the latter become economically viable.

Two main solar refrigeration technologies are available: the photovoltaic powered refrigeration technologies and the solar thermal powered refrigeration technologies (Fig. 1).

In Africa, the encountered photovoltaic powered refrigeration technology uses photovoltaic panels (PV) to supply electricity to a conventional vapour compression refrigeration cycle. Assuming an efficiency of 10–15% for PV panels and a coefficient of performance (COP) of 3 for the vapour compression refrigeration cycle, the overall or solar COP of a PV powered refrigerator (PVPR) is about 0.30–0.45. Compared to refrigerators that utilise fuels (kerosene), they have the advantages of having their energy source on site and of being environmental friendly. PVPRs have been mainly promoted in Africa by international health promotion organisations, such as the World Health Organisation (WHO), which use PVPRs to keep vaccines and drugs cold [5]. The high specific value of the latter products explains the commercial success of PVPRs in spite of various limits, the first of which is the high price of the complete system. In fact, some limits of this application have been pointed by Iloje and Enibe [5], who have prospected solar cooling for Africa – both PV and sorption machines – in a report published in 1995. PVPRs are relatively expensive and currently, a PV manufacture could hardly be identified in Africa (only few PV manufactories could be identified in South Africa).

In the usual applications of solar thermal powered refrigeration, solar thermal collectors (flat-type collectors, evacuated tubes, parabolic troughs) supply heat to a sorption machine (adsorption or absorption). Sorption refrigerators (SRs) are easier to be produced in Africa because they require widely held skills in many Africans countries [5]. SR has no or very few moving parts, thus no or very little maintenance is required; therefore, sorption refrigeration is a reliable technology in Africa where a lot of projects failed because of lack of maintenance. Since there is no moving part, no additional electricity supply is required and there is no operating cost. SRs are environmentally friendly and no harmful refrigerant is used. They are cheaper than PVPRs (Fig. 2) [6,7] although a quick look on the prices suggested for various commercial small power SRs suggests that this actually remains a challenge. The SR technology exhibits however some disadvantages. They are very bulky for a small refrigeration power, which makes transportation difficult [5]. In addition, their performance are depends not only on the solar insolation, they are also highly sensitive to the ambient conditions (temperature and eventually wind). Furthermore, solar SRs show low solar COPs (typically about 0.1).

In this paper, an overview of solar sorption refrigeration applications and research activities in Africa is addressed in order to highlight the potential of this technology in Africa and barriers that have to be overcome.

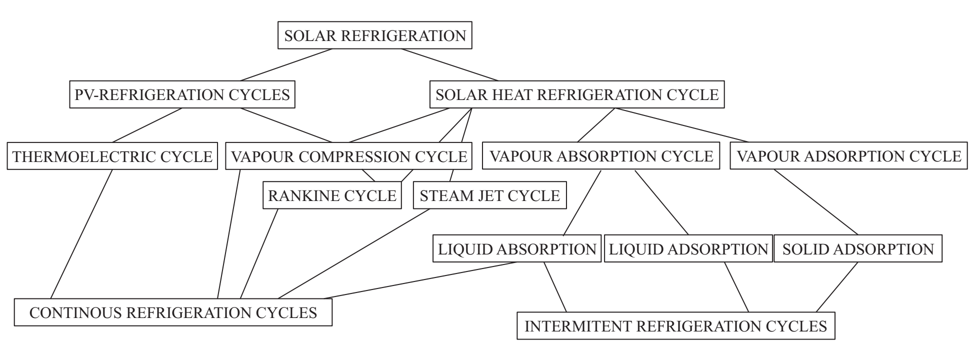

Fig. 1. Classification of solar refrigeration cycles [27].