Design and Evaluation of a Solar-Powered Absorption Chiller for Off-Grid Refrigeration in Rural Tanzania

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Access to reliable refrigeration remains a major challenge in many developing regions due to the absence of electricity distribution networks. This issue affects critical aspects of daily life, especially the preservation of food and medicine. According to a 2011 FAO report, approximately 37% of food in Sub-Saharan Africa is lost post-harvest, largely because of insufficient refrigeration infrastructure.

This study proposes the design of a solar-powered absorption chiller tailored for the village of Kipili, located on the shores of Lake Tanganyika in Tanzania. Kipili has no access to an electrical grid, and fishing is a primary source of income and nutrition, making cold storage an essential need. The proposed system operates using thermal energy generated by solar collectors and is based on a water-ammonia working pair, suitable for achieving low temperatures required for fish preservation.

The chiller is designed to maintain a cold room at -25 °C, with an internal volume of 20 m^3. A detailed energy and mass balance was performed to determine the system requirements. The thermal power needed to operate the cycle is 11.8 kW, while the mechanical power required by the pump is only 0.1 kW, supplied by photovoltaic panels. To address solar intermittency, thermal energy storage and a small battery system are included, reducing dependence on expensive and maintenance-intensive battery banks. Based on average solar radiation data for Kipili, the estimated area of solar collectors required is 175 m^2. This configuration allows for continuous operation of the refrigeration unit while maintaining sustainability and technical simplicity. The use of solar thermal energy makes the system particularly suitable for remote areas with high solar availability and limited infrastructure.

While Solar Cooling technologies are still relatively underutilized, they offer great potential for both developing and industrialized countries. In off-grid communities, they can enhance food security and health outcomes. In more developed regions, they present a low-emission alternative to conventional cooling technologies, which, according to a 2018 IEA report, contribute to 10% of global electricity consumption and 4% of CO_2 emissions. This work demonstrates how Solar Cooling can bridge critical gaps in infrastructure while supporting broader climate and sustainability goals.

Keywords: *absorption chiller; thermal solar energy; mass and thermal energy transport.*