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An experimental comparison of two receiver geometries for domestic thermal processes, suitable for high solar radiation African regions

Musa Rukaaya [a], Oyirwoth P. Abedigamba [a,b,*], Ashmore Mawire [b,1], Willy Okullo [a]

[a] Department of Physics, Kyambogo University, P.O Box 1, Kyambogo, Uganda
[b] Material Science, Innovation and Modelling (MaSIM) Research Focus Area, Department of Physics, North-West University (Mafikeng Campus), Private Bag X2046, Mmabatho 2735, South Africa

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ABSTRACT

The study presents an experimental evaluation of two receiver configurations (zigzag and circular) integrated with a packed-bed TES system for domestic thermal processes, particularly cooking and drying. The research addresses a critical gap by examining how receiver geometry influences thermal performance in packed-bed TES systems, offering a potential solution to Africa's energy storage challenges. The zigzag design achieves a higher average thermal efficiency of 8.30 ± 0.4 % compared to 6.52 ± 0.3 % for the circular design. It also obtained a higher maximum stored energy of 0.91 ± 0.005 MJ than the circular receiver, which reached 0.74 ± 0.004 MJ, over a 4-hour charging period under identical operating conditions. Notably, we performed experiments in a controlled environment and performance on local conditions will be assessed through outdoor testing. Additionally, we fabricated the receivers using locally sourced materials (copper and aluminum), making the technology more accessible and affordable, thus supporting a transition from non-renewable biomass fuel (firewood and charcoal) towards cleaner and more sustainable cooking solutions.

Introduction

Thermal energy storage (TES) systems play a crucial role in bridging the gap between energy supply and demand, particularly in regions with limited access to energy [1]. In Africa, where energy poverty is a significant challenge, TES systems can help to stabilize the grid and provide a reliable energy supply [2]. TES can be categorized as sensible, latent, and thermo-chemical energy storage systems [3–5]. Thermochemical systems result from reversible chemical reactions, where energy is absorbed and released as molecular bonds of a material break and reform [6]. Sensible heat storage relies on the temperature change of the storage material [4], whereas latent heat is based on the energy absorbed or released when a material undergoes a phase transition from solid to liquid and vice versa [7]. However, thermochemical storage materials are rarely applied as TES due to their complex nature and high costs [8]. In most

* Corresponding author.
E-mail address: oyigamba@kyu.ac.ug (O.P. Abedigamba).

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