Short communication

Revolutionizing Concentrated Solar Power: Progress in Thermal Energy Storage Fluids

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Abstract

Enhancing the performance of Concentrated Solar Power (CSP) plants is closely linked to advancements in thermal energy storage (TES) systems. This communication reviews recent breakthroughs in TES fluid technology, focusing on quaternary nitrate-based molten salts and the potential of nanoparticle enhancements. The discussion also highlights key challenges and future research paths.

Keywords: CSP, thermal energy

1. Introduction

CSP plants provide a renewable energy solution with potential for consistent power output. However, their efficiency and cost-effectiveness depend heavily on the capabilities of TES systems. Developing advanced TES fluids is critical to improve energy storage and heat transfer in CSP applications [1-34].

2. Advances in TES Fluid Composition

Quaternary nitrate mixtures have emerged as promising candidates due to their high thermal stability and superior thermophysical properties. Research by Kwasi-Effah et al. (2023) has demonstrated these fluids' ability to outperform conventional binary and ternary mixtures in terms of thermal conductivity and energy density.

3. Nanoparticle Integration for Enhanced Performance

Recent studies have explored the addition of nanoparticles such as Al_2O_3 to TES fluids to further enhance their thermal conductivity [29]. These enhancements allow CSP systems to operate at higher temperatures, improving both heat retention and overall energy efficiency.

4. Economic and Sustainability Considerations

While advanced TES fluids show clear performance benefits, their economic and environmental impact must be assessed for widespread adoption. The integration of sustainable practices is crucial, as outlined by the UN Sustainable Development Goals (SDGs), which emphasize balancing technological progress with environmental stewardship.

5. Challenges and Future Research Directions

Despite significant progress, challenges persist, particularly related to the cost of nanoparticle-enhanced fluids and their long-term operational stability. Addressing these issues through

innovative material development and cost-reduction strategies is essential. Collaborative research that bridges material science, engineering, and sustainability will be vital to overcoming these barriers.

Conclusion

The evolution of TES fluids, with the adoption of quaternary nitrate mixtures and nanoparticle technologies, offers exciting prospects for the future of CSP plants. Continued advancements will be pivotal for reducing costs and aligning these technologies with global sustainability frameworks, ensuring a brighter future for renewable energy.

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