


Chapter 6

Energy Performance Modelling and Optimization of Nanofluid Cooling Systems in Renewable Energy Applications

Dhirendra Patel

 <http://orcid.org/0000-0003-3308-168X>

Amity University, Greater Noida, India

M. L. Kumar

Amity University, Greater Noida, India

Ankesh Kumar

Amity University, Greater Noida, India

ABSTRACT

This chapter presents a comprehensive treatment of energy performance modelling and optimization for nanofluid-based cooling systems used in renewable energy applications. It covers the physical principles of nanofluids, effective-property models, convective heat transfer correlations, numerical and reduced-order modelling approaches, experimental considerations, and optimization strategies (design of experiments, response surface methodology, evolutionary algorithms, and multi-objective techniques). Case studies — including solar photovoltaic (PV) cooling, concentrated solar power (CSP) receivers, and thermal energy storage augmen-

DOI: 10.4018/979-8-3373-6023-2.ch006

tation. practical modelling workflows, key results, and trade-offs. Figures, tables, and sample graphs are included to guide researchers and engineers in developing, validating, and optimizing nanofluid cooling solutions.

1. INTRODUCTION

Nanofluids, suspensions of nanoparticles in conventional fluids, have emerged as advanced heat transfer media in renewable energy applications. Their use improves thermal conductivity, heat transfer coefficients, and energy efficiency in solar collectors, PV panels, and thermal energy storage systems. Energy demand is rapidly increasing worldwide due to industrialization, urbanization, and improved living standards. At the same time, the depletion of fossil fuel reserves and environmental concerns such as greenhouse gas emissions have accelerated the global transition toward renewable energy technologies. Solar, wind, biomass, and geothermal systems are playing a vital role in achieving sustainable energy targets (Choi, 1995). However, renewable systems often face efficiency and reliability challenges.

Worldwide energy systems are undergoing a rapid transformation driven by the twin imperatives of climate mitigation and rising energy demand. Renewable technologies — especially solar photovoltaics (PV) and concentrated solar power (CSP), are central to that transition, but their real-world performance is limited by thermal management issues. For instance, PV modules lose electrical conversion efficiency as cell temperature rises, and CSP systems require heat transfer fluids that remain stable and efficient at high operating temperatures. Improving heat-transfer performance in these systems therefore directly increases energy yield, reduces operating costs, and prolongs component lifetime. The development of advanced working fluids is a promising route to meeting these needs (Xuan & Li, 2000).

Renewable energy systems (solar thermal collectors, photovoltaic panels, concentrated solar power, and thermal storage systems) often suffer performance limitations from elevated temperatures and suboptimal heat transfer. Advanced cooling strategies improve energy conversion efficiency and system longevity. Nanofluids—colloidal suspensions of nanoparticles (metals, metal oxides, carbon-based) in base fluids (water, ethylene glycol, propylene glycol, oils) offer enhanced thermal properties compared to conventional fluids (Das et al., 2003; Chen et al., 2005). This chapter focuses on modeling and optimizing nanofluid cooling systems to maximize energy performance in renewable energy applications as shown in figure 1.1 Growth of nanofluid publications in renewable energy applications and Growth of nanofluid publications in renewable energy applications.

24 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage: www.igi-global.com/chapter/energy-performance-modelling-and-optimization-of-nanofluid-cooling-systems-in-renewable-energy-applications/410724

Related Content

Green Finance for Sustainable Global Growth: Costs and Benefits of Green Buildings Compared With Conventional Buildings

Elizabeth Motunrayo Ojo-Fafore, Clinton Aigbavboa, Wellington Thwala and Pretty Remaru (2021). *Research Anthology on Environmental and Societal Well-Being Considerations in Buildings and Architecture* (pp. 373-393).

www.irma-international.org/chapter/green-finance-for-sustainable-global-growth/284829

LEED Certification and Sustainable Building Practices: A Comprehensive Guide to Efficient and Sustainable Facilities

Nour Elhouda Hallas (2024). *Design Strategies for Efficient and Sustainable Building Facilities* (pp. 124-161).

www.irma-international.org/chapter/leed-certification-and-sustainable-building-practices/353134

Social Life-Cycle Assessment for Building Materials

Liz Kutschke (2020). *Examining the Environmental Impacts of Materials and Buildings* (pp. 217-250).

www.irma-international.org/chapter/social-life-cycle-assessment-for-building-materials/250569

Cronocaos: An Alternative Approach to "Preservation"

Belen Butragueno, Javier Francisco Raposo and María Asunción Salgado (2019). *Conservation, Restoration, and Analysis of Architectural and Archaeological Heritage* (pp. 108-125).

www.irma-international.org/chapter/cronocaos/216067

A Review of the Accuracy of Force- and Deformation-Based Methods in Determining the Seismic Capacity of Rehabilitated RC School Buildings

Orkun Gorgulu and Beyza Taskin (2019). *Architecture and Design: Breakthroughs in Research and Practice* (pp. 1090-1113).

www.irma-international.org/chapter/a-review-of-the-accuracy-of-force--and-deformation-based-methods-in-determining-the-seismic-capacity-of-rehabilitated-rc-school-buildings/216014