



“SOLAR REFRIGERATION SYSTEM USING PELTIER MODULES”

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Abstract: Traditional vapor compression refrigeration systems account for approximately 15% of global electrical energy demand and rely on refrigerants that contribute significantly to ozone depletion and global warming [1],[2]. This research investigates the design and performance of a sustainable alternative: a solar-powered thermoelectric refrigerator utilizing the Peltier effect. The system integrates 12V DC thermoelectric modules with a photovoltaic array and battery storage, eliminating the need for moving parts or chemical refrigerants [3],[4]. Experimental results demonstrate that optimized systems can achieve a Coefficient of Performance as high as 3.74 at a current of 1.4A when the cold side temperature reaches 0°C [5]. Performance tests on a 2.6-liter cooling chamber showed a rapid temperature reduction from an ambient 22.48°C to 15.15°C within 136 seconds [3]. Furthermore, the integration of dual-axis solar tracking can enhance the COP by 44% to 75% compared to fixed-panel systems [6]. The results highlight that while thermoelectric coolers typically have lower COPs than conventional systems, they offer a 44–63% reduction in power consumption for small-scale applications and a potential lifespan of up to 40 years [3],[7]. These characteristics make solar-powered Peltier refrigeration an ideal solution for portable medical storage and food preservation in remote, off-grid, and humanitarian contexts [8],[9].

Keywords: Peltier Effect, Thermoelectric Cooling, Solar Photovoltaic, Coefficient of Performance, Sustainable Refrigeration, Portable Cooling, Renewable Energy, Heat Dissipation

INTRODUCTION

Conventional refrigeration systems rely heavily on vapor compression technology, which accounts for approximately 15% of global electrical energy demand [1]. These systems utilize refrigerants such as CFCs and HCFCs that contribute to ozone depletion and global warming [2], [3]. Solar-powered thermoelectric refrigeration offers a sustainable alternative by utilizing the Peltier effect, where electrical energy is converted directly into a temperature gradient without the need for moving parts or harmful chemical refrigerants [1], [4]. This technology is particularly vital for remote areas where electricity is scarce, providing a portable and maintenance-free solution for food preservation and medical storage [5], [6].

LITERATURE REVIEW

Research in thermoelectric cooling has focused on improving the typically low Coefficient of Performance compared to vapor compression cycles [1].

Performance Benchmarks: Studies have shown COPs ranging from 0.1 in basic setups to 0.66 in portable models, with highly optimized systems reaching COPs of 3.74 through advanced heat dissipation techniques like curved fins [5], [7], [8].

Solar Integration: Researchers such as Chaudhary et al. and Durgakar et al. have demonstrated that 12V DC solar-powered boxes can effectively reduce internal temperatures below ambient levels [7].

Optimization: The use of dual-axis solar tracking systems has been found to enhance solar energy capture, leading to a COP improvement of 44–75% compared to fixed panels [9].

Design Variations: Comparisons between single-stage and multistage TE modules indicate that while single-stage modules achieve significant temperature differences more easily, their COP remains lower for domestic applications [7].

METHODOLOGY

The development of a solar Peltier refrigerator involves the integration of photovoltaic systems with thermoelectric modules.

Power Supply: Solar PV panels (e.g., 660W or smaller portable units) capture solar radiation, which is regulated by a solar charge controller to charge 12V batteries [6], [8].



Thermoelectric Cooling: The heart of the system is the Peltier module (typically 40x40 mm). When DC current is applied, heat is absorbed on the cold side and rejected on the hot side [4], [8].

Heat Management: To maintain efficiency, the hot side must be cooled using aluminum heat sinks and high-speed DC fans to prevent heat backflow [4], [5].

Insulation: The cooling chamber, often constructed from aluminum or insulated plastic with capacities ranging from 2.6L to 5L, is sealed to minimize thermal gain from the environment [4], [10], [11].

RESULTS

Experimental evaluations of SPTR systems have yielded promising data:

Temperature Drop: In a 2.6L chamber, temperatures dropped from an ambient 22.48°C to 15.15°C within 136 seconds [4]. Other designs successfully maintained internal temperatures at approximately 10°C [11].

Energy Efficiency: Solar-powered units demonstrated a 44–63% reduction in power consumption compared to conventional refrigerators of similar capacity [4].

COP Stability: The COP is highest when the temperature difference (ΔT) between the hot and cold sides is minimized; for instance, a maximum COP of 3.74 was recorded at a current of 1.4A when the cold side reached 0°C [8].

DISCUSSION

The performance of SPTR is highly sensitive to solar irradiance and the efficiency of heat rejection [9], [12]. While the COP of Peltier modules is lower than vapor compression systems, their environmental benefits—being refrigerant-free and noise-free—make them superior for specific niche applications [1].

A critical factor identified is the relationship between input energy and COP; as input energy decreases, the COP tends to increase until it stabilizes [8]. Furthermore, the lack of moving parts translates to a significantly longer lifespan, potentially reaching up to 40 years, with very low maintenance costs [5]. This makes the system economically viable for humanitarian contexts and remote medical clinics [11], [13].

CONCLUSION

Solar refrigeration utilizing Peltier modules is a viable, eco-friendly solution to the environmental and energy challenges posed by traditional refrigeration. Although currently limited by lower COP values, advancements in heat sink design and solar tracking significantly enhance their effectiveness. Future development should focus on optimizing thermoelectric materials to achieve higher cooling capacities, making SPTR a mainstream alternative for portable and decentralized cooling needs globally [1], [9].

REFERENCES

- [1]. Chavan, S. S., Avhad, S. P., & Chavan, S. R., ***"Solar Based Thermoelectric Refrigerator Using Peltier Module"***, *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, 2022. ([IJRASET][1])
- [2]. Rajshekhar Manohar, S., Mallikarjun, R. N., Sidharam, G. A., & Vyankatesh, G. P., ***"Analysis of Solar Refrigeration System Using Thermo Electric Cooling (TEC) Module"***, *International Journal of Innovations in Engineering Research and Technology*, 2021. ([IJIERT][2])
- [3]. Elnaggar, A. E. M., Sharaf, S., Abdel Rehim, Z. S., et al., ***"Optimizing COP by RSM and MATLAB Model of Mini Refrigerator Based on Thermoelectric Units Driven by Solar Photovoltaic"***, *Scientific Reports*, 2024. ([Nature][3])
- [4]. Dey, B., Rai, B., Bari, K. K., Raja, M. T., & Khan, M. M., ***"An Analysis of Solar-Powered Refrigerators Using Peltier Modules"***, *International Journal of Innovative Science and Research Technology*, 2025. ([IJISRT][4])
- [5]. ***"Experimental Investigation and Analysis of Cooling Performance of Solar Thermoelectric Refrigerator"***, *Solar Energy Journal (ScienceDirect)*, 2023. ([ScienceDirect][5])
- [6]. Kaiprath, J., & Kishor Kumar, V. V., ***"A Review on Solar Photovoltaic-Powered Thermoelectric Coolers, Performance Enhancements, and Recent Advances"***, *International Journal of Air-Conditioning and Refrigeration*, 2023. ([Springer][6])



- [7]. Gupta, S., ***"Enhancing the Performance of Solar Refrigeration System"***, *International Journal of Science and Research (IJSR)*, 2014. ([Int. Journal of Science & Research][7])
- [8]. Augustine Babu, K., & Godson Asirvatham, ***"Nanofluid Augmented Cooling of Solar Thermoelectric Refrigerator – An Experimental Study"***, *International Journal of Engineering Research & Technology (IJERT)*, 2016. ([IJERT][8])
- [9]. Puspita, N. P., Yusfi, M., & Rasyid, R., ***"Eco-Friendly Solar Refrigerator: Peltier Cooling, Remote Monitoring for Sustainable and Efficient Energy Consumption"***, *Jurnal Ilmu Fisika*, 2025. ([Jurnal Ilmu Fisika][9])
- [10]. Goud, S., Shoiab, B., Hassain, I., Muzamil, M., & Vishal, K., ***"Solar Refrigeration System Using Peltier Modules"***, *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, 2025. ([ijarsct.co.in][10])
1. https://www.ijraset.com/research-paper/solar-based-thermoelectric-refrigerator-peltier-module?utm_source=chatgpt.com "Solar Based Thermoelectric Refrigerator Using Peltier Module"
 2. https://repo.ijert.org/index.php/ijert/article/view/1197?utm_source=chatgpt.com "ANALYSIS OF SOLAR REFRIGERATION SYSTEM USING THERMO ELECTRIC COOLING (TEC) MODULE | International Journal of Innovations in Engineering Research and Technology"
 3. https://www.nature.com/articles/s41598-024-72500-1?utm_source=chatgpt.com "Optimizing COP by RSM and MATLAB model of mini refrigerator based on thermoelectric units driven by solar photovoltaic | Scientific Reports"
 4. https://www.ijisrt.com/an-analysis-of-solarpowered-refrigerators-using-peltier-modules?utm_source=chatgpt.com "An analysis of solarpowered refrigerators using peltier modules| International Journal of Innovative Science and Research Technology"
 5. https://www.sciencedirect.com/science/article/pii/S0038092X2300525X?utm_source=chatgpt.com "Experimental investigation and analysis of cooling performance of solar thermoelectric refrigerator - ScienceDirect"
 6. https://link.springer.com/article/10.1007/s44189-023-00022-y?utm_source=chatgpt.com "A review on solar photovoltaic-powered thermoelectric coolers, performance enhancements, and recent advances | International Journal of Air-Conditioning and Refrigeration | Springer Nature Link"
 7. https://www.ijsr.net/getabstract.php?paperid=2014865&utm_source=chatgpt.com "Enhancing the Performance of Solar Refrigeration System"
 8. https://www.ijert.org/nanofluid-augmented-cooling-of-solar-thermoelectric-refrigerator-an-experimental-study?utm_source=chatgpt.com "Nanofluid Augmented Cooling of Solar Thermoelectric Refrigerator – An Experimental Study – IJERT".
 9. https://jif.fmipa.unand.ac.id/index.php/jif/article/view/691?utm_source=chatgpt.com "Eco-Friendly Solar Refrigerator: Peltier Cooling, Remote Monitoring for Sustainable and Efficient Energy Consumption | JURNAL ILMU FISIKA | UNIVERSITAS ANDALAS".
 10. https://ijarsct.co.in/Paper30578.pdf?utm_source=chatgpt.com "IJARSCT Internationa".