JoFRISE 4 (1) (2026)
Journal of Frontier Research in Science and Engineering
https://journal.riau-edutech.com/index.php/jofrise
Publisher :
Andester Riau Edutech
Pusat Inovasi Pendidikan dan Teknologi
ISSN : 3032-0348

# Design and Development of a Portable Mini Water Heater Using Battery Power for Mountain Climbers

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Submiited: 28/02/2026
Review: 24/03/2026
Accepted: 26/03/2026
Published: 30/03/2026
Vol. 4
No. 1



**Abstract-** Mountain climbing activities require adequate preparation, particularly in ensuring access to warm water for hydration and preventing hypothermia in cold environments. Conventional heating systems such as gas stoves present limitations, including safety risks, fuel dependency, and additional weight. This study aims to design and develop a portable mini water heater powered by a rechargeable lithium-ion battery as a safer and more practical alternative for mountain climbers. The research employed a Research and Development (R&D) approach using the ADDIE model, including analysis, design, development, implementation, and evaluation stages. The device utilizes a Positive Temperature Coefficient (PTC) heating element connected to a 14.8 V lithium-ion battery with a capacity of 9800 mAh. Experimental results show that the device can increase water temperature from 30°C to 45°C within 50 minutes, demonstrating stable heating performance. The system offers advantages in portability, safety, and environmental friendliness. However, heating efficiency remains moderate. This innovation has strong potential for further development to improve heating speed and energy efficiency.

**Keywords:** *Footstep energy harvesting; Faraday's law; electromagnetic induction; renewable energy prototype; mechanical-to-electrical energy conversion.*

## 1 Introduction

Mountain climbing has become increasingly popular as both a recreational and physical activity, attracting individuals seeking adventure, endurance challenges, and connection with nature. However, such activities are conducted in extreme environmental conditions, particularly at higher altitudes where temperature significantly decreases. According to Barry and Chorley (2009), temperature drops approximately 6.5°C for every 1000 meters increase in altitude, resulting in harsh cold environments at elevations above 2500 meters. In such conditions, maintaining body temperature becomes crucial to prevent hypothermia, a potentially life-threatening condition (Epstein & Moran, 2019). Warm water plays a vital role not only for hydration but also for maintaining core body temperature and preparing food during expeditions.

Currently, mountain climbers predominantly rely on portable gas stoves for heating water. Although effective, these systems present several disadvantages. Gas canisters are relatively heavy and occupy significant space in backpacks, reducing mobility efficiency. Furthermore, gas-based systems pose safety risks such as leakage and explosion hazards, especially in enclosed shelters or during improper handling. A documented case by Díaz Fernández et al. (2022) highlights the dangers associated with gas leakage leading to explosions in mountainous shelters. Additionally, the dependency on fuel availability limits long-term expeditions, particularly in remote areas where resupply is not possible. In response to these challenges, there has been growing interest in developing alternative portable heating technologies that are safer, lighter, and more sustainable. Recent advancements in energy systems suggest that battery-powered devices offer promising solutions. Portable water heaters utilizing renewable energy sources, including battery storage

**How to Cite**
Brilian, D. N., Supiawan, B., & Azhar. (2026). Design and Development of a Portable Mini Water Heater Using Battery Power for Mountain Climbers. Journal of Frontier Research in Science and Engineering (JoFRISE). 4 (1), 25-30

and solar energy, have been explored to reduce reliance on fossil fuels (Patel et al., 2021). These systems provide advantages such as zero emissions, ease of operation, and compatibility with modern energy storage technologies. However, designing such devices requires careful consideration of several critical factors, including heating capacity, energy efficiency, device weight, and environmental durability (Amala et al., 2025).

Thermodynamics plays a fundamental role in understanding the operation of water heating systems. Heat transfer mechanisms, including conduction, convection, and radiation, govern the efficiency of energy transfer from the heating element to the water. In portable heating devices, conduction is the primary mechanism, where heat is transferred through direct contact between the heating element and the container. Efficient heat transfer ensures minimal energy loss and faster heating performance. Additionally, thermal insulation is crucial to reduce heat dissipation to the surrounding environment, particularly in cold outdoor conditions. Electrical energy serves as the primary source of power in battery-based heating systems. The conversion of electrical energy into thermal energy occurs through resistive heating elements. According to Chapman (2012), electrical energy is generated through the movement of electric charges and can be converted into various forms, including heat. The efficiency of this conversion process depends on factors such as electrical resistance, current flow, and material properties of the heating element. The relationship between voltage, current, and resistance determines the power output, which directly influences the heating rate (Sedra et al., 2020).

One of the key components in modern portable heating devices is the lithium-ion battery. Lithium-ion batteries are widely used due to their high energy density, lightweight characteristics, and long cycle life (Tarascon & Armand, 2001). These batteries can store significant amounts of energy in compact sizes, making them ideal for portable applications. However, their performance is influenced by environmental conditions, particularly temperature. Low temperatures can reduce battery efficiency and output capacity, which is a critical consideration for mountain climbing applications (Andrea, 2010). Therefore, integrating efficient battery management systems (BMS) is essential to ensure stable performance and safety. Another important technological component is the Positive Temperature Coefficient (PTC) heating element. PTC heaters are self-regulating devices that increase their resistance as temperature rises, preventing overheating and improving safety. This characteristic eliminates the need for additional temperature control systems, making PTC heaters suitable for portable applications. Their ability to maintain a stable temperature enhances energy efficiency and prolongs device lifespan (Febi & Sianturi, 2025).

Despite these technological advancements, several challenges remain in developing portable battery-powered water heaters. One of the primary challenges is balancing heating efficiency with energy consumption. Heating water requires a significant amount of energy due to its high specific heat capacity. As a result, increasing heating speed often leads to higher energy consumption, which can quickly deplete battery capacity. Therefore, optimizing system design to achieve efficient heat transfer while minimizing energy loss is crucial. The system typically consists of several key components: a lithium-ion battery as the power source, a PTC heating element as the heat generator, a thermally insulated container for water storage, a switch for operation control, and a charging system. When the device is activated, electrical energy flows from the battery to the heating element, which converts it into thermal energy. This heat is then transferred to the water, gradually increasing its temperature. The insulated container helps retain heat and improve efficiency by minimizing losses (Liyanty et al., 2025).

This study aims to develop a portable mini water heater using battery power specifically designed for mountain climbers. The device focuses on providing a practical, safe, and environmentally friendly solution for heating water in outdoor environments. Unlike conventional gas-based systems, this device eliminates combustion-related risks and reduces environmental impact. Additionally, its compact design enhances portability, making it suitable for use in challenging terrains. The significance of this research lies not only in technological innovation but also in its contribution to outdoor safety and sustainability. By integrating principles of thermodynamics, electrical engineering, and energy storage, this study demonstrates the potential of interdisciplinary approaches in solving real-world problems. Furthermore, the development of such devices aligns with global efforts to promote clean energy technologies and reduce reliance on fossil fuels.

In conclusion, the need for safe, efficient, and portable water heating solutions in mountain climbing activities has driven the development of battery-powered heating devices. While challenges related to energy efficiency and heating performance remain, advancements in battery technology and heating elements provide promising opportunities for further improvement. This research contributes to the ongoing exploration of sustainable and practical solutions for outdoor applications, paving the way for future innovations in portable energy systems.

## 2 Research Methodology

This study employed a Research and Development (R&D) approach to design, construct, and evaluate a portable mini water heater powered by a lithium-ion battery. The R&D method was selected because it enables systematic product development, starting from problem identification to product testing and refinement. The development process followed the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation.

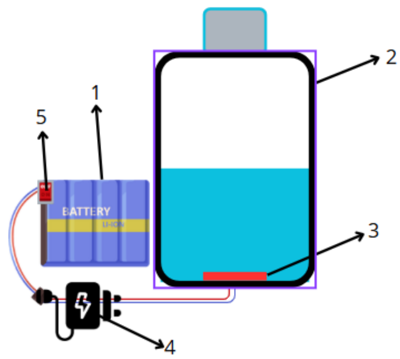


**Figure 2.** Product Design

### 2.1 Analysis Stage

In this stage, the primary problem identified was the lack of safe, lightweight, and practical heating tools for mountain climbers. Existing solutions, such as gas stoves, present safety risks and logistical challenges. Literature studies were conducted on thermodynamics, battery systems, and heating elements, particularly focusing on lithium-ion batteries and PTC heating technology.

### 2.2 Design Stage

The design phase involved creating a conceptual model of the device. The system consists of several key components:

- Lithium-ion battery (14.8 V, 9800 mAh) as the energy source
- PTC heating element (12 V, 80°C)
- Stainless steel insulated bottle as a water container
- Switch system for operation control
- 12 V adapter for battery charging

The design prioritized portability, safety, and energy efficiency. Thermal insulation was integrated to reduce heat loss to the environment.

### 2.3 Development Stage

During this phase, the device was assembled using the selected materials. The heating element was installed inside the bottle, and electrical connections were made between the battery, switch, and heater. Adhesives such as epoxy and hot glue were used to seal openings and ensure waterproofing.

### 2.4 Implementation Stage

The device was tested in a laboratory setting at the Physics Education Laboratory, Universitas Riau. The testing process included:

1. Functional testing of each component (heater, battery, switch, adapter)
2. Temperature measurement using a thermometer
3. Time tracking using a stopwatch

The heating process was monitored over 50 minutes, with temperature recorded every 10 minutes.

### 2.5 Evaluation Stage

The evaluation focused on analyzing heating performance, energy stability, and system reliability. If any component failed to function properly, revisions were made to improve performance. Data analysis involved comparing temperature changes over time to determine heating efficiency.

## 3 Results and Discussion

*Results*


**Figure 2**. The Result of Making Tools

The experimental results demonstrate that the portable water heater operates effectively in increasing water temperature over time. The recorded data are presented below:

**Table 1.** Temperature Change Data Collection

| Initial Water Temperature (C) | Time (minutes) | Temperature (°C) |
|---|---|---|
| 30 | 0 | 30 |
| 30 | 10 | 33 |
| 30 | 20 | 36 |
| 30 | 30 | 39 |
| 30 | 40 | 42 |
| 30 | 50 | 45 |

*Discussion*

The results indicate a gradual and consistent increase in temperature, demonstrating stable performance of the heating system. The water temperature increased from 30°C to 45°C within 50 minutes, representing a total increase of 15°C. This confirms that the PTC heating element successfully converts electrical energy into thermal energy.

The linear trend of the graph suggests that the heating process is relatively stable without significant fluctuations. This stability can be attributed to the self-regulating nature of the PTC heater, which prevents overheating and maintains a constant power output. Additionally, the lithium-ion battery provides a steady supply of electrical energy throughout the experiment.

However, the heating rate can be categorized as moderate. Several factors contribute to this limitation:

1. Limited Power Output
   The device is designed to prioritize energy efficiency, which results in lower heating power.
2. High Specific Heat Capacity of Water
   Water requires a significant amount of energy to increase temperature, slowing the heating process.
3. Heat Loss to Environment
   Despite insulation, some heat is lost through conduction and radiation, especially in open environments.
4. Battery Constraints
   The system must balance heating performance with battery life, limiting maximum power usage.

## 4 Conclusion

This study successfully designed and developed a portable mini water heater powered by a lithium-ion battery for mountain climbing applications. The device utilizes a PTC heating element to convert electrical energy into thermal energy, enabling safe and controlled heating without the need for combustion-based systems. Experimental results demonstrate that the device is capable of increasing water temperature from 30°C to 45°C within 50 minutes, indicating stable and consistent performance. The use of a PTC heater ensures safety through self-regulation, preventing overheating and improving system reliability. Additionally, the lithium-ion battery provides efficient energy storage, supporting portable and independent operation in outdoor environments.

One of the key advantages of this system is its portability and safety, making it highly suitable for mountain climbers who require lightweight and reliable equipment. Unlike gas-based heating systems, this device eliminates risks associated with fuel leakage and fire hazards. Furthermore, it contributes to environmental sustainability by producing zero emissions. However, the heating efficiency remains moderate, as the system is designed to balance energy consumption and battery capacity. The device is more suitable for producing warm water rather than boiling water. Future development should focus on improving heating speed, optimizing energy efficiency, and enhancing thermal insulation. In conclusion, this portable water heater represents a practical and innovative solution for outdoor heating needs. With further optimization, it has strong potential for broader applications in camping, emergency situations, and remote environments.

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