

# Verifying Usage of Thermoelectric Peltier as an Electric Generator for Electric Vehicle

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## Abstract

In this study, an experiment is conducted to verify usage of thermoelectric Peltier as an electric generator for electric vehicles using heat converting to electric conversion. The study successfully shown a production of electric by emphasizing the potential of thermoelectric to generate electric. Experiment has performed and exhibited efficacy in generating voltage and current to facilitate the production of electricity. Nevertheless, there were several restrictions, such as the constrained positioning of the Peltier unit, small-scale testing, and the exclusion of other possible materials' heat conductivity. Besides, the studies are to examine generation in order to generate electric for electric vehicles and improving by mere more research. The goal of the study was to demonstrate sustainable power production systems that uses Peltier modules to utilise thermoelectric conversion and are efficient. The greatest temperature differences and material research on the Peltier semi-conductor are among the suggested enhancements. These recommendations seek to improve the main line of knowledge and advance the efficient and higher production of electric from heat difference conversion to electricity.

## 1. Introduction

When driven by renewable energy sources, plug-in electric cars (PEVs), such as battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (electric cars), significantly reduce greenhouse gas emissions. The necessity to recharge the battery of an electric vehicle, which can cause range anxiety and inconvenience, is a significant worry for owners of these vehicles. Long wait times and restricted access are caused by the current charging infrastructure's inability to keep up with the demand, which is particularly noticeable in rural and lower-income areas. This circumstance emphasizes the need for creative solutions to enhance the EV recharge experience and encourage a wider uptake of electric cars.

For electric vehicles to be widely used, infrastructure for charging them must be both efficient and readily available. Public charging infrastructure becomes vital in areas where private garages are hard to come by, even while choices for charging at home or at work are critical for the early success of the market. Research highlights the necessity of public charging stations in places with high population density. The use of thermoelectric generators (TEGs), which transform thermal energy from vehicle dynamics into electrical energy, is one method that shows promise. The goal of this project is to create a thermoelectric model that can power EV batteries without the need for public charging stations, hence overcoming existing infrastructure constraints.

The availability and efficiency of charging infrastructures are pivotal to the viability and widespread adoption of electric vehicles (EVs) in today's rapidly evolving transportation landscape. A regular charging option found within home or workplace is deemed to be important for the success of PEV in the early market

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phase (Hardman S., 2018). In countries where the availability of private garages is limited, a demand arises for public charging infrastructure, as those with ample access to private garages can depend on personal charging solutions for their daily charging needs (Helmus, J.R., Spoelstra, J.C., 2018). (Funke et al., 2019) also agreed that public charging infrastructure as an alternative to home charging is needed in some densely populated areas. These previous studies highlight the importance of public charging infrastructures for EV customers to utilize.

## 2. Methodology

The overall study flow in a research experiment refers to the sequential actions and procedures used to carry out the study successfully and meet the study's goals. The planning, design, development, gathering of data, analysis, and interpretation steps are included in this project flow. Maintaining ethical concerns, following project scope, and ensuring the study's validity and reliability are crucial throughout the study flow. Depending on the unique research topic, goals, and procedures used, the entire study flow may change. Additionally, researchers should remain flexible in case new information or difficulties arise throughout the course of the experiment. Fig. 1 shows the flowchart for overall study.

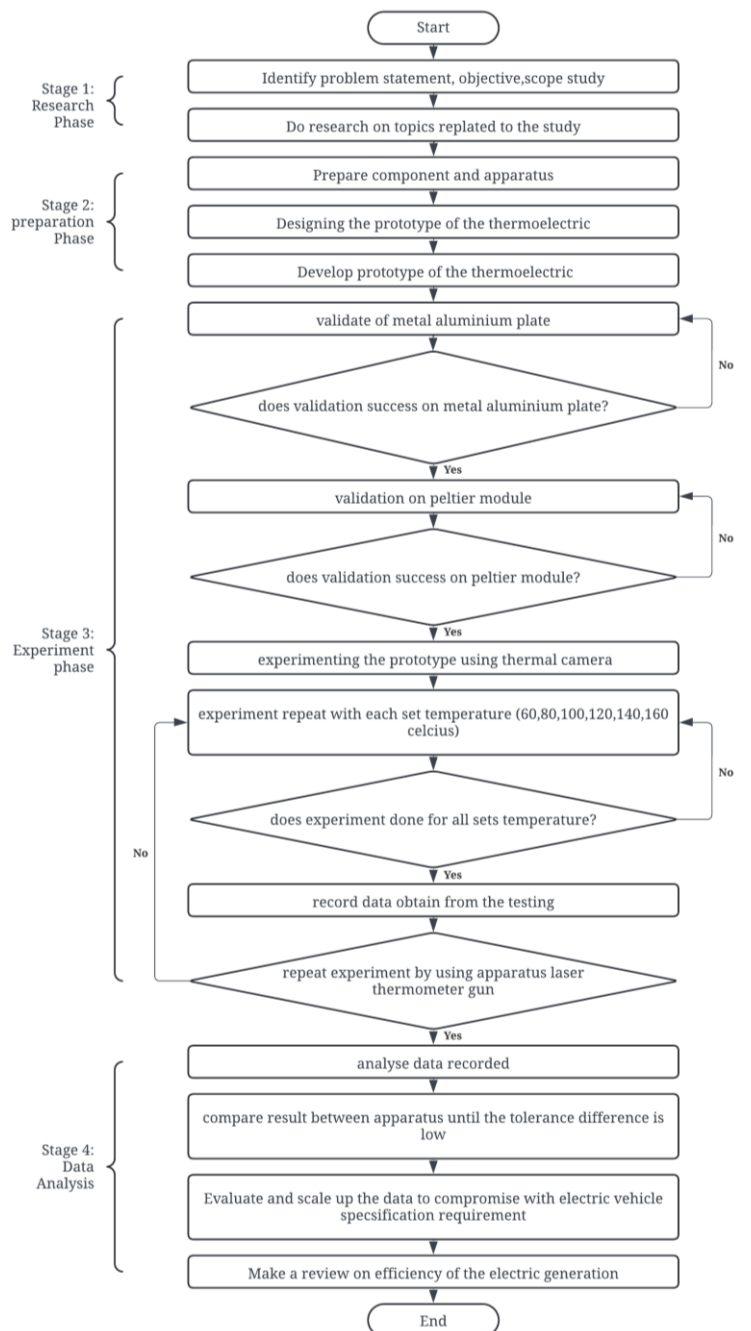


Fig. 1 Project flowchart

## 2.1 Components and Apparatus

The thermoelectric generator circuit will be design in to block diagram to ensure the connectivity is improvised and a few main parts such as Peltier, thermal paste, heatsink block, metal plate, and apparatus such as multimeter, thermal camera and heater will be used to contribute for the building of the prototype.

## 2.2 Procedure Develop Prototype

### Step 1: Placing the Peltier in Configuration (4x4)

The first aspect of the prototype involves arranging the Peltier modules in a specific configuration. The chosen arrangement here is a (4x4) layout, implying a grid of four Peltier modules aligned both horizontally and vertically.

### Step 2: Circuitry Bridge-Joint

Incorporating the circuitry bridge-joint is crucial for ensuring proper electrical connectivity and control over the Peltier modules. This bridge-joint facilitates the flow of electricity and enables precise management of temperature differentials across the system.

### Step 3: Determining the Most Effective Combination

The core objective of this experimentation is to identify the most efficient combination of components and configurations. To achieve this, various setups will be tested and compared. In this context, "effectiveness" might refer to factors such as cooling efficiency, energy consumption, or overall performance.

### Step 4: Placement of Peltier Modules and Aluminum Plates

Within the (4x4) configuration, specific placement of the Peltier modules and aluminum plates is essential. One approach involves positioning each Peltier module onto an individual aluminum plate. The use of aluminum plates helps to dissipate heat efficiently and evenly across the surface.

### Step 5: Application of Thermal Paste

Between the Peltier modules and the aluminum plates, a layer of thermal paste is applied. This thermal interface material is crucial for maximizing heat transfer between the Peltier modules and the aluminum plates. It fills in microscopic imperfections in the surfaces, ensuring optimal thermal conductivity. The placing thermal paste is shown as in Fig. 2.

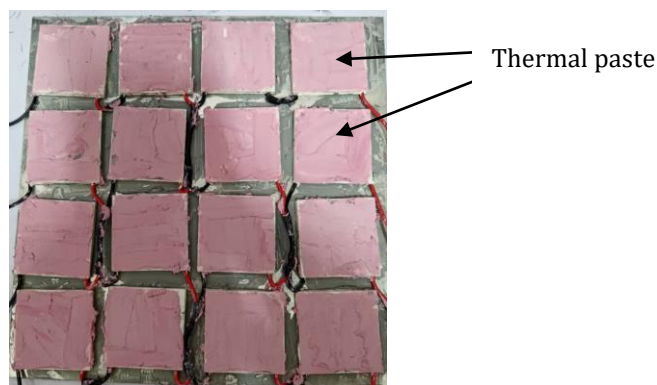


Fig. 2 Applying thermal paste onto Peltier

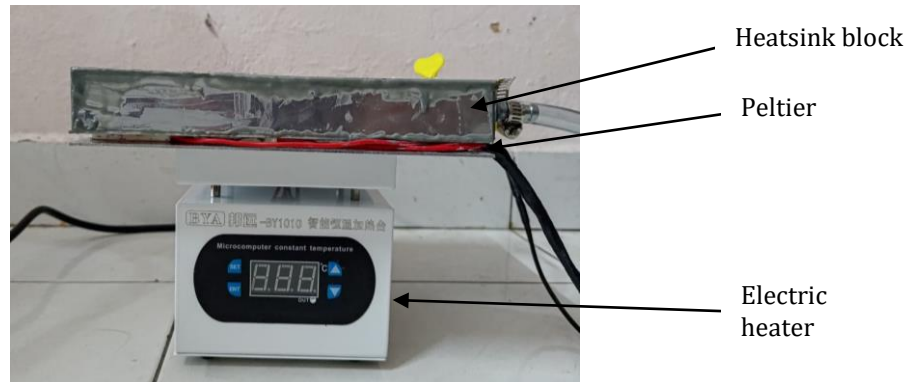
### Step 6: Placement of Heatsink Block

In the ongoing pursuit of optimizing thermal management, the next step involves placing a heatsink block onto the surface of the Peltier module opposite to where heat is being applied. This strategic placement aims to leverage the Peltier effect to achieve higher temperature differentials across the system.

### Step 7: Testing and Analysis

Once the prototype is assembled according to the specified configuration, rigorous testing and analysis are conducted. This phase involves monitoring various parameters such as temperature differentials, power

generates, and efficiency of the power generate. Data collected during testing is then analyzed to determine the effectiveness of different heat different affect.



**Fig. 3** Conducting experiment configuration

### 2.3 Iterative Testing

The system undergoes iterative testing, where temperature setpoints are adjusted incrementally to evaluate their impact on temperature differentials and power generation.

### 2.4 Power Generation for Electric Vehicle

Utilizing insights from meticulous data analysis, the implementation of Peltier units for upscaling to support electric vehicles (EVs) involves extrapolating findings to accommodate the typical 360 Wh battery size, as summarized by (Frisby, 2023). This upscale model seeks to determine the optimal number of Peltier units required for efficient charging while considering factors such as energy efficiency, temperature differentials, and power generation capabilities. Integration into the charging infrastructure requires careful consideration of placement and system design to maximize efficiency and reliability. Real-world validation ensures the model's feasibility and effectiveness, with scalability and future advancements in technology incorporated for long-term sustainability and adaptability in the evolving landscape of electric transportation.

$$\frac{\text{power}(\text{experiment})}{60(16)} \tag{1}$$

$$\frac{360Wh}{\text{Watt from 1 unit of peltier generator}} \tag{2}$$

$$\frac{360W \div 60}{\text{Watt from 1 unit of peltier generator}}$$

### 2.5 Calculations Efficiency

Based on journal from (Habeeb M., 2015) the efficiency can be calculated by using formula and the temperature data that get form the experiment become the variable for  $T_H$  and  $T_c$ . Power ( $Z$ ) need to be calculated which is found out using the following formula:

$$Z = \left[ \frac{S_H - S_c}{\sqrt{\rho_H K_H} - \sqrt{\rho_c K_c}} \right]^2 \tag{3}$$

$$M = \left[ 1 + \frac{Z}{2} (T_H - T_c) \right]^{\frac{1}{2}} \tag{4}$$

$$\eta = \left( \frac{T_H - T_C}{T_C} \right) \left[ \frac{M - 1}{M + \frac{T_C}{T_H}} \right] \tag{5}$$

By obtaining both power value from experiment and calculation, the study can evaluate the performance of the thermoelectric system. The results provide important data on the efficiency of the system in generating power and help determined the optimal condition of the Peltier This knowledge is essential for developing effective for determined usage of thermoelectric Peltier as an electric generator for electric vehicle.

### 3. Result and Discussion

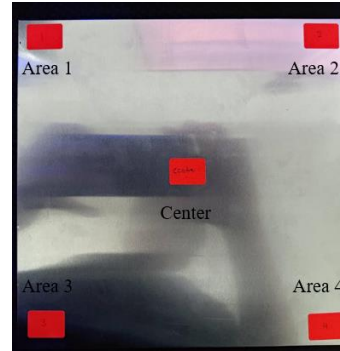
The preliminary results that have been acquired within the experiment conduct will be discussed in detail such as of the equipment choose to use and the implement of method used, and the analysis of the output voltage, current and power that has been achieved with preliminary experiment. The circuit was developed with the idea from literature review from (thankakan,2021). the Peltier generator, the output voltage, output current and output power were produced with the presence temperature difference.

#### 3.1 Validation of Metal Aluminium Plate

In order to validate the efficiency of the aluminum metal plate, a heater will be utilized as a heat source. The metal plate will act as a distributor, and the heat will be dispersed across five designated areas: the center, top left (area 1), top right (area 2), bottom left (area 3), and bottom right (area 4). The heat distribution will be assessed by setting the manipulated variable as time, with a total of four set time intervals. The control variables include the initial heat temperature set by the heater, and the responding variable is the temperature measured in each area when the specified time intervals are reached. This validation process aims to evaluate the uniformity and effectiveness of heat distribution across the metal plate as in Fig. 4.



**Fig. 4** Reading temperature using thermal camera onto aluminum plate



**Fig. 5** Allocation on each side of the mark area at aluminum plate

Fig. 5 displays the aluminum metal plate, segmented into five distinct locations on its surface. This division allows for the examination of heat distribution across the entire metal plate. The specified locations aid in comprehending the thermal distribution conditions, providing insights into how heat is dispersed throughout the plate.

**Table 1** Data recorded on heat flow to designated area on the aluminum plate

Time	Temperature on Center (°C)	Temperature on Area 1 (°C)	Temperature on Area 2 (°C)	Temperature on Area 3 (°C)	Temperature on Area 4 (°C)
0 Minute	25.9	25.4	25.3	26.3	26.2
1 Minute	27.5	26.6	27.1	27.0	27.3
2 Minute	34.9	28.8	28.8	29.3	28.7

Table 1 shown as time progresses, there is an overall increase in temperature across all areas, indicating the impact of the heater. The center area consistently shows the highest temperature, which is expected as it is the central point where heat is applied. Area 3 and Area 4 exhibit slightly higher temperatures compared to Area 1 and Area 2. The temperature distribution seems to be influenced by the heating process, with variations becoming more evident as time passes. These observations provide insights into the evolving thermal conditions across different areas of the metal plate over the specified time intervals.

### 3.2 Validation on Peltier Module (Thermoelectric Generator)



**Fig. 6** Conducting evaluate experiment on the Peltier module

In Fig. 6, the SP1848 thermoelectric generator module is utilized as the electric generator to produce both output voltage and current. The selection of the SP1848 module for this experiment is deliberate, aiming to investigate and analyze the generated output in terms of voltage and current. This specific Peltier module serves as the core component in the thermoelectric generator system, playing a crucial role in the overall experiment focused on researching its output characteristics.



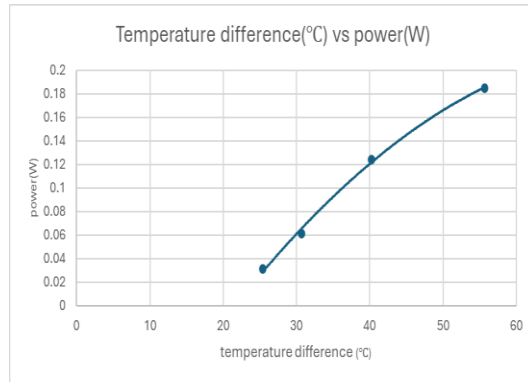
**Fig. 7** Voltage reading on a unit Peltier



**Fig. 8** Current reading on a unit Peltier

**Table 2** Data reading on the Peltier module generating current and voltage

Temperature(°C)	Voltage (V)	Current(mA)	Power=IV (W)
25.4	0.43	71.8	0.031
30.7	0.58	104.8	0.061
40.2	0.83	149.1	0.124
55.7	1.00	185.4	0.185



**Fig. 9** Graph relationship between Temperature difference ( °C) vs power(W)

The observed data from voltage and current reading in Fig. 7 and Fig. 8, the SP1848 thermoelectric generator module indicates a direct correlation between temperature and electrical output shown in graph temperature vs power in Fig. 9. As the module's temperature increases, both voltage and current exhibit proportional increments, resulting in a notable rise in power output. This aligns with the anticipated behavior of thermoelectric generators, where temperature differentials play a crucial role in electricity generation. The observed trends underscore the module's sensitivity to temperature variations and highlight an optimal operating temperature range for maximizing electrical output. These insights contribute to a comprehensive understanding of the thermoelectric generator's performance characteristics and offer valuable guidance for refining system efficiency and temperature control strategies.

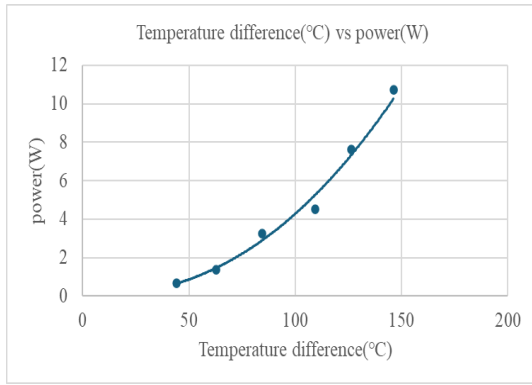
### 3.3 Experimenting Result



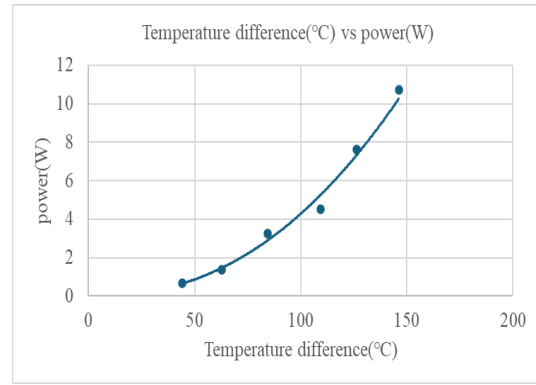
**Fig. 10** Conducting experiment

**Table 3** Data measurements for using thermal camera and laser thermometer gun

Temperature applied to the Peltier module (°C)	using thermal camera			using laser thermometer gun			Current (A)	Voltage (V)	Power (W)
	Temperature on cold side (°C)	Temperature on hot side (°C)	Temperature difference (°C)	Temperature on cold side (°C)	Temperature on cold side (°C)	Temperature difference (°C)			
60	15.8	57.9	42.1	15.0	59.2	44.2	0.38	1.76	0.67
80	14.9	77.5	62.6	16.7	79.6	62.9	0.52	2.65	1.38
100	12.0	97.1	85.1	14.4	98.9	84.5	0.8	4.05	3.24
120	9.1	120.0	110.9	12.9	122.2	109.3	0.95	4.75	4.51
140	11.1	138.9	127.8	13.4	139.9	126.5	1.22	6.23	7.60
160	7.6	158.6	151.0	13.2	159.4	146.2	1.50	7.15	10.7



**Fig. 11** Temperature difference ( °C) vs power(W) for thermal camera



**Fig. 12** Temperature difference ( °C) vs power(W) for laser thermometer gun

The observed data during conducting experiment in Fig. 10 give a set of data as in Table 3 to configure a graph to show the correlation between temperature vs power for both apparatuses. The graph depicts a trend where the power output increases as the temperature difference between the hot and cold sides of the TEG increases. However, the power output generation rate remains relatively low, as indicated by Fig. 11 and Fig. 12. This observation aligns with the fundamental theory behind thermoelectric generators (TEGs). TEGs operate based on the Seebeck effect, which states that a temperature difference across a conductor generates a voltage difference and, consequently, an increase in current. Therefore, the power generated is directly related to the thermal difference, denoted as  $\Delta T$ . The effectiveness of TEGs in converting thermal energy into electrical energy is dependent on this temperature gradient, but practical limitations and material inefficiencies often result in lower-than-expected power outputs. These figures illustrate that while an increase in temperature difference enhances power output, achieving high power generation efficiency remains a challenge due to the inherent properties of the materials used in TEGs and the need for significant temperature differentials to produce substantial electrical power.

Additionally, this relationship highlights the efficiency of the TEG in converting thermal energy into electrical energy. As the temperature difference increases, the voltage output rises steadily, demonstrating the potential for higher power generation under larger temperature differentials. This underscores the importance of maximizing the temperature difference to enhance the performance and efficiency of thermoelectric generators in practical applications. The consistent data points in the graph reinforce the reliability and predictability of the TEG's performance, which is essential for its integration into various energy-harvesting and power generation systems.

### 3.4 Implementation on Real Scale to Electric Vehicle

This involves adapting the findings to work with typical EV battery capacities around 360 Wh, as discussed by (Frisby, 2023). The goal is to develop a model that determines the ideal number of Peltier units needed for efficient charging, considering factors like energy use, temperature differences, and power generation.

Wh from 1 unit of Peltier generator:

$$\frac{10.73}{16} = 0.6706W$$

Numbers unit of Peltier needed to support electric vehicles:

$$\frac{360Wh}{0.6706W} = 60W$$

$$\frac{60W}{0.6706W}$$

$$89.47$$

$$\approx 90$$

\* 90 units peltier needed to support electric vehicle

### 3.5 The efficiency of the thermoelectric generation

Power (Z) need to be calculated which is found out using the following formula:

From the experimentation we found on 160°C (laser thermometer gun):

$$T_H = 159.4 \text{ }^\circ\text{C} @ 432.55\text{K}$$

$$T_C = 13.2 \text{ }^\circ\text{C} @ 286.35\text{K}$$

$$Z = \left[ \frac{-228 \text{ } \mu\text{V/K} - (185 \text{ } \mu\text{V/K})}{\sqrt{(12.6 \text{ } \mu \Omega\text{m}) (1.8 \text{ W/mK})} - \sqrt{(12.6 \text{ } \mu \Omega\text{m}) (1.3\text{W/mK})}} \right]^2$$

$$Z = 2119\text{K}^{-1}$$

$$M = \left[ 1 + \frac{2119\text{K}^{-1}}{2} (432.55\text{K} - 286.35\text{K}) \right]^{\frac{1}{2}}$$

$$M = 393.573$$

$$\eta = \left( \frac{432.55\text{K} - 286.35\text{K}}{286.35\text{K}} \right) \left[ \frac{393.573 - 1}{393.573 + \frac{286.35\text{k}}{432.55\text{K}}} \right]$$

$$\eta = 0.51\%$$

From efficiency percentage which 0.51% shows that thermoelectric still not able to support usage due to reliability and efficiency is too low. The thermoelectric required more focus to achieving high efficiency due to low power output. Costing in build or designing Peltier as a generator to supply power is not reliable. Even though the has given high temperatures different, still lacking on power generates.

The upscale quantity of units of Peltier module just to generate power to supply electric vehicles is inevitable due to such quantities needed is too costing rather than improving the electric car charging reliability. This can be proven that thermoelectric system still did not in highly efficient compared to other renewable energy generators.

### 4. Conclusion

This study investigated the utilization of thermoelectric energy harnessing, specifically using Peltier generator modules for electric vehicles. The first objective, to experimentally verify power generation performance from thermoelectric conversion, was achieved through the development of a prototype. This prototype used a bridge joint configuration to minimize internal resistance and applied heat spreaders like heatsink blocks to enhance the thermal gradient, thereby maximizing power output.

The second objective analyzed the efficiency and sustainability of a power generation system using Peltier modules. The performance evaluation of a 4 x 4 Peltier module configuration provided valuable insights into the voltage and current output, demonstrating the potential for Peltier modules in power generation for electric vehicles.

In conclusion, the study successfully shows that Peltier modules can be used as power generators, contributing to the knowledge base of sustainable energy. However, the high cost and low efficiency of using multiple Peltier modules make this approach impractical for electric vehicles. While thermoelectric conversion using Peltier modules is feasible, the low efficiency observed in the experiments indicates that this method is not advisable for practical applications in its current form. Further research and development are needed to improve the efficiency and cost-effectiveness of thermoelectric energy harnessing for it to be viable in electric vehicle applications.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

The author attests to having sole responsibility for the following: planning and designing the study, data collection, analysis and interpretation of the outcomes, and paper writing.

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