Thermoelectric use in various renewable alternative energy source

S Jumini*, R S Iswari and P Marwoto

1Department of Physics Education, Universitas Sains Al-Qur’an Jawa Tengah In Wonosobo, Indonesia
2Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Indonesia

*Corresponding author: srijumini@unsiq.ac.id

Abstract. Energy and environmental conservation problems are increasing every day. The use of electricity began to experience shortages by about 1.6 billion people. The use of fuel oil (BBM) in road transportation requires a larger number along with the number of means of transportation. On the other hand, there is an inefficient use of energy for some equipment used by humans. Gasoline and electric vehicles generally use inefficient internal combustion engines. About 25% of the combustion results are used for vehicle operations, and 40% is lost to waste heat that is wasted. Waste heat is also wasted on household appliances. Global warming and environmental pollution due to the use of inefficient energy are also increasing. Research by experts on thermoelectrics shows good results in overcoming inefficient use of energy and can provide solutions to energy problems and environmental conservation. Its use is flexible, because it does not require complicated mechanical structures, and is also environmentally friendly. This paper provides a review that reviews the use of thermoelectric in various equipment that produces waste heat energy that has not been utilized optimally.

1. Introduction

The use of world energy resources will always increase with the increase in the world's population. Electric energy supply is also beginning to be limited, even though this is very important for social and economic growth [1], [2]. According to data from the Energy Information Administration (EIA) that the use of electricity has increased every year, around 35% in 2018 and 36% in 2019 [3]. Meanwhile, the use of fuel oil increases almost every day from 94 million barrels in 2014 to 100 million barrels in 2018 [4]. The use of fuel oil demand has increased with the increasing number of means of transportation both land, sea, and air, especially the use of land vehicles.

The use of vehicles as a means of transportation is increasing every year, both nationally and internationally. The most growth of vehicles in Indonesia is motorcycle speed vehicles. According to the Indonesian Statistics Agency, the growth of motorcycles every year has increased by around 8% [5]. Data on vehicle usage in Indonesia according to the 2019 Statistics Agency can be seen in table 1.

The growth of these vehicles has fueled demand for fuel which also increased dramatically. One side of the energy and environmental problems is increasingly growing. One of the world's problems in the field of energy and environmental conservation is the need for fuel oil for road transportation [6]. The world's main energy sources in the economic and social systems still use mining fuels such as coal, petroleum, and natural gas [7]. At present fossil fuels supply about 80% of the total energy needed by
world economic and social activities [8]. But this non-renewable energy will eventually run out and will pose a threat to the lives of the next generation. Besides the impact of air pollution and the environment is very disturbing for health. This condition demands to always reduce the use of fossil fuels, and reduce the environmental impact of air pollution.

Table 1. Motorized Vehicle Data

| Transportation type | 2015       | 2016       | 2017       | 2018       |
|---------------------|------------|------------|------------|------------|
| Passenger car       | 13480973   | 14580666   | 15423968   | 16440987   |
| Bus car             | 2420917    | 2486898    | 2509258    | 2538182    |
| Freight cars        | 6611028    | 7063433    | 7289910    | 7778544    |
| Motorcycle          | 98881267   | 105150082  | 111988683  | 120101047  |
| Amount              | 121394185  | 129281079  | 137211818  | 146858759  |

Problems of energy and environmental conservation also occur in the use of electricity. The use of electricity is still considered difficult by some people [9], [1], [3]. Especially in rural and rural areas. Access to electricity has not been fully felt. Only a few high-income people can enjoy electrical energy facilities for various household needs. Medium for low-income people only limited to meeting basic electricity needs such as light. For charging cell phones or other electronic devices that have not been fully met. Electricity needs will also continue to increase along with the increasing population, especially Indonesia as a developing country.

Problems in the field of energy and environmental conservation are also carried out by experts and researchers with the effort to create electricity through the use of biomass that can be used for household operational needs. Utilization of waste heat from wood-burning stoves or often called CLIP (Combustion Latérale Inversée Performance) stoves has produced around 500kPa, sufficient to be used for household electrical operations, such as lighting, radios, cell phone charging, and other electronic devices [9]. Heat energy can be generated from vehicles both electric and oil fuel, wood stoves and electric stoves, geothermal, nuclear, solar, bonfires (wood), road asphalt, the human body. Thermal energy is very much available in nature. The solar energy that causes heat reflection on roads, buildings, and other objects can be used as an energy source. Electronic devices such as cellphones, televisions, computers also produce heat that can be recovered by using thermoelectrics [10].

The use of thermoelectrics gives the breadth to utilize thermal energy from nature. To paraphrase the words of Tesla "Electricity is everywhere with an unlimited amount, it can be used to drive the engine without being dependent on fossil fuels" [3]. This inspires that creating energy sources can be done with the availability of heat energy in nature which is very broad. The use of thermoelectric to convert natural heat energy into electrical energy also provides solutions to the problem of environmental conservation in a sustainable and environmentally friendly manner. For this reason, this paper will analyze the use of thermoelectrics from various research results.

2. Methods

To get quality articles to need to see articles from quality sources. The article is taken from Elsevier's database, springer, tandfonline with thermoelectric keywords, and alternative energy. In getting 800 articles. Then the articles are selected from Scopus-indexed journals with a maximum quartile of Q3 and a minimum impact factor of 0.5. as the main article search source. Publication time is limited to the last 15 years from 2005 to 2020, this is to see the research trends that are developing. Articles were seen relating to the theme and filtered back 52 articles left behind.
3. Results and Discussion

Alternative solutions to energy and environmental conservation problems continue to be made. Thermoelectric has provided a new perspective to create a renewable and sustainable source of electricity and environmentally friendly [11]. The thermoelectric effect is the conversion of heat energy to electrical energy, it can also be electrical energy to heat energy [12]. A thermoelectric generator (TEG) is active equipment that functions to convert heat energy into electrical energy [13]. Thermoelectric generators convert small portions of heat into electrical energy, figure 1 [9].

![Figure 1. Basic principles of TEG power generation](image)

Thermoelectric generators convert small portions of heat into electrical energy, figure 1 [9].

![Figure 2. Seebeck cell structure](image)

Thermal components are connected in parallel and electrical components in series. Two ceramic plates are used to cover both sides as shown in Figure 2. When the semiconductor cells are heated, the n-type component is negatively charged, and the p component is positively charged so that an electric current flows as shown in Figure 3. Temperature difference from the Seebeck effect:

\[ \Delta T = T_{panas} - T_{dingin} \]

Temperature difference from the Seebeck effect:

\[ \Delta T = T_{panas} - T_{dingin} \]  

This temperature difference produces a voltage of,

\[ V_{out} = N \propto \Delta T \]  

The character of the Seebeck effect is indicated by the coefficient of the Seebeck effect, which is the magnitude \( \propto = \frac{V}{\Delta T} \).

Another advantage of thermoelectric, in the use of thermoelectric devices, can be combined with other systems or planted on other plants such as solar energy systems, vehicle internal systems, can be planted on other plants such as humans, asphalt walls, stove furnaces, computers, electronic devices and other systems that produce hot [21]. There are three kinds of materials for thermoelectrics, namely bismuth telluride (Be2Te3), tin telluride (PbTe), and silicon-germanium for refrigeration [22]. If thermoelectric is to be used for a long time, then the material used is bismuth telluride (Be2Te3) [12].
To improve the thermoelectric quality, TE (Seebeck cell) modules have been developed. To increase the electrical conductivity the nanoinkclusion metal phase is used as a dopant [23].

The power generated from the system by utilizing thermoelectric can be maximized by installing maximum power point tracking (MPPT) [6]. Tracking the maximum power point (MPPT) began to be used to maximize the output power on the engine of an oil-fueled or hybrid vehicle [24]. The waste heat utilization system using a thermoelectric integrated with the MPPT consists of 1) a heat exchanger mounted on the catalyst converter of the exhaust gas system capturing waste heat when the engine is operating; 2) thermal energy is passed on to the TEG system, to produce electricity; 3) power conditioning is enabled for maximum power transfer. Installation of MPPT controls is feasible for practical implementation, and MPPT effectiveness is measured by comparing experimental results using direct connections. Thermoelectric generator system can connect 120 TEG devices in series. The recovered power generated by more than 600w which accounts for about 50% of the consumption of automated electronic power. Cuk converter for power conditioning can minimize interference with TEG and battery. MPPT was successfully carried out with an increase in power of up to 14.5% and 22.6% [25]. The implementation of TE with MPP can be seen in the results in Figure 4 [20]. Renewable alternative energy includes the following:

3.1. TE in wood stove waste
Open fire furnaces have low efficiency. Imperfect fire stoves have high emissions. Air pollution from smoke produced can disrupt the respiratory tract. A clean and efficient cooking stove is needed to reduce fuel consumption and reduce indoor air pollution. Combining TE generators with alternative cooking stoves for the supply of electrical energy. By developing the energy-saving multi-function stove "Combustion Latérale Inversée Performante" (CLIP), figure 5 [1].

The process of using thermoelectric in a wood-burning stove system is as follows, a) Testing the TE model by experimenting in a laboratory with gas heaters to stimulate the stove. b) Arrangement of generators, thermal and mechanical parts. c) Switching electrical regulators that change the unstable voltage of the TE module to a stable output voltage. d) Saving result of energy in a power bank. e) Result of the experiments is compared with the results of a theoretical analysis using TE and heat transfer equations.

3.2. TE on the Human Body
The making of alternative energy has started on the utilization of heat produced by humans and can be used alone. Thermoelectric is integrated into the human body, so it can be used to convert waste heat energy from human activities into electrical energy. The use of the internet of things (IoT) gets more attention because it provides a lot of convenience in the use of technology in everyday life. Similarly, in the utilization of battery resources for electronic devices used by humans. The battery is considered inefficient in its use, in addition to its size which is still large and heavy, it must also be frequently charged. The utilization of energy in the body is an alternative inefficiency of battery power [1]. The energy possessed by humans is generally used to move and generate heat. Thermoelectric is used to utilize this heat [26]. The power generated from the utilization of human body heat depends on the type, position, and size, as well as utilization efficiency. In addition to the power generated, the utilization of heat energy must be comfortable to use and not limit the levels of the natural function of the body's organs, not large and heavy, does not hinder the body's movements or metabolism [27].
efficiency of the body is only around 15-30% [28], and most of the energy of the human body is expended in the form of heat. Body heat can be a source of sustainable energy. Human body heat around 37 ° C. Total heat loss from the entire human body is approximately 60-180W depending on body activity [27]. The TE system in the body can be shown for example in figure 6.

3.3. TE on Asphalt Road

Asphalt roads absorb very high solar energy around 700C, storing a large amount of heat energy [28]. Environmental conditions such as weather conditions, air temperature and humidity, sun exposure, rainfall, hot asphalt road conditions, and wind movements greatly affect the temperature on the asphalt road [29]. The thermoelectric used to harness the heat in this system is placed through the aluminum sheet, this is to avoid road losses.

3.4. TE in Solar Energy Radiation

The utilization of solar thermal power is a way to increase the power requirements for electronic equipment. Solar energy has a very large potential [29] About 1.2 × 105 TW solar radiation is received by the surface of the earth and can be used to provide solutions to the world's energy problems. Power of solar Solar is used in the form of heat power through heat collectors or into electricity through photovoltaic panels [30]. Photovoltaic (PV) systems are widely used because they almost do not pollute the environment and are cost-effective because the devices are simple. However, PV cells show poor efficiency due to the loss of about 80% of heat energy both solar and reflected radiation [31]. This system has been developed for many years to produce electricity from solar energy to the fullest. To make the most efficient use of solar energy, Thermoelectric (TE) is used.

3.5. TE in waste Automatic

Rising oil prices and energy conservation, along with the increasing number of vehicles for transportation. In addition to vehicles with fossil fuels, leaving smoke that is very disturbing to the environment and breathing. That's why one of them was created hybrid vehicles powered by electric energy, and began to demand a lot. But the limitations of electrical energy, eventually also became an obstacle to the development of this hybrid vehicle. All oil-fueled or electric vehicles adopt inefficient internal combustion of engines. Both use an inefficient internal combustion engine, even though the Internal Combustion Engine Vehicles (ICEVs) underwent many developments and modified for more than one hundred and twenty-five years. From ICEV only 25% of its energy is used for vehicle operations, and 40% of heat is wasted, not utilize [6]. Visible flow of energy from the vehicle's internal combustion. Nearly half the heat energy is wasted. One side of the need for electrical energy for household appliances is still in need of supplies.

4. Conclusion

Discussion of the utilization of waste heat energy using thermoelectric generators (TEG) can be concluded that: Thermoelectrics have demonstrated their ability to convert waste heat energy into renewable electrical energy to overcome global energy problems and environmental conservation. Utilization of TEG in the formation of renewable electrical energy still needs to be done in the future.

References
[1] Ando Junior O H, Maran A L O and Henao N C 2017 Renew. Sustain. Energy Rev. 91 76
[2] Engenharia E D 2010 Sérgio André Machado Bastos Pulseira para Geração de Energia (Universidadi do Minho)
[3] Jaziri N, Bougahonoura A, Müller J, Mezghani B, Tounsi F and Ismail M 2019 A comprehensive
review of Thermoelectric Generators: Technologies and common applications (Energy Reports)

[4] U. E. I. Administration 2018 Short-Term Energy Outlook (STEO)

[5] Herawati S 2019 J. Pendidik. Vokasi 9 21

[6] Zhang X, Chau K T and Chan C C 2008 J. Asian Electr. Veh. 6 119

[7] Allouhi A 2019 Sol. Energy Mater. Sol. Cells 200 109954

[8] Shittu S, Li G, Akhlaghi Y G, Ma X, Zhao X and Ayodele E 2019 Renew. Sustain. Energy Rev. 109 24

[9] Champier D, Bédécarrats J P, Kouksou T, Rivaletto M, Strub F and Pignolet P 2011 Energy 36 1518

[10] Sun Z, Xie K and Anderman L H 2018 Internet High. Educ. 36 41

[11] Domínguez-Adame F, Martín-González M, Sánchez D and Cantarero A 2019 Phys. E Low-Dimensional Syst. Nanostructures 113 213

[12] Zhang X, Bu Z, Lin S, Chen Z, Li W and Pei Y 2020 Joule 1 18

[13] Proto M, Bibbo A, Cerny D, Vala M, Kasik D, Peter V L, Conforto S, Schmid and Penhaker M 2018 Sensors 18 1

[14] Champier D, Bedecarrats J P, Rivaletto M and Strub F 2010 Energy 35 935

[15] Krishna R 2020 Mater. Today. 45 1828

[16] Weera S, Lee H S and Attar A 2020 Energy Convers. Manag. 205 112427

[17] Zhu Y, Zhuang F, Wang J, Chen J and Shi Z 2019 Neural Networks 119 214

[18] Goupil C 2011 Thermodynamics of Thermoelectricity Intech Europe (Europe, Intech: Rijeka)

[19] Selvam C, Manikandan S, Krishna N V, Lamba R, Kaushik S C and Mahian O 2020 Int. Commun. Heat Mass Transf. 114 104561

[20] Yu C and Chau K T 2009 Energy Convers. Manag. 50 1506

[21] Kiyota Y, Kawamoto T and Mori T 2020 Synth. Met. 259 116217

[22] Nozariasbmarz A 2020 Appl. Energy 258 114069

[23] Luo D, Wang R, Yu W and Zhou W 2020 Renew. Energy 154 542

[24] Eakburanawat B I J 2006 Appl Energy 83 687

[25] Cottona S 2019 Energy Convers. Manag. 198 111832

[26] Suarez F Ó M, Nozariasbmarz A and Vashaee D 2016 Energy Env. Sci 9 209

[27] Riemer 2011 J. Neuroeng. Rehabil. 8 1

[28] W D A 2005 Biomechanics and motor control of human movement. 3 ed. (Hoboken (NJ): John Wiley and Sons)

[29] Verbelen Y, De Winne S, Blondeel N, Peeters A, Braeken A and Touhafi A 2017 World Acad. Sci. Eng. Technol. Int. J. Electr. Comput. Energ. Electron. Commun. Eng. 11 279

[30] Dey M A K A, Bajpai O P, Sikder A K and Chattopadhyay S 2016 Sustain. Energy Rev. 53 653

[31] Culebras C M, Igual-Muñoz A M, Rodríguez-Fernández C, Gómez-Gómez M I and Gómez A C 2017 Interfaces 9 9 20826