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Review

# A review on heat sink for thermo-electric power generation: Classifications and parameters affecting performance

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ABSTRACT

In recent years, there have been growing interests in key areas related to global warming resulting from environmental emissions, and the diminishing sources of fossil fuel. The increased interest has led to significant research efforts towards finding novel technologies in clean energy production. Consequently, the merits of a thermo-electric generator (TEG) have promised a revival of alternative means of producing green energy. It is, however, impractical to account for the cost of thermal energy input to the TEG which is in the form of final waste heat. This is because the technology presents critical limitations in determining its cost efficiency nor its economic disadvantages. This paper reviews the principles of thermo-electric power production, as well the materials use, performance achieved, and application areas. The paper also takes a particular deliberation on TEG heat sinks geometries and categories. The review emphasizes more on the TEG performance while considering a number of heat sink parameters related to its performance.


**Contents**



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## 1. Introduction

With the rapid development of technologies and industrialization, energy demand will keep increasing. The modern economy relies largely on fossil fuels. This dependence is further fueled by the advancement in the industrial sector and the adoption of new technologies. However, fossil fuels have unique limitations since their reserves are increasingly depleting. In addition, there are a number of environmental issues related to fossil fuels production and use, at both local and global scales. Furthermore, a significant portion of energy from fossil fuels is wasted during the transformation process and use. Owing to the issues related to fossil fuels, energy experts around the world have expressed concerns about the future of energy generation. Thermo-electric generator (TEG) has shown to offer a dependable and simpler way of thermo-electric energy conversion. Other advantages of TEG module include lack of moving parts, environmental safety, and silent operation. This generator can also be controlled in a seamless and accurate manner. Researchers have shown increased interest using thermo-electric technology in improving waste recovery efficiency over the last three decades. This has been made possible using a variety of heat-producing processes [1–5]. According to the Web of Science database, annual publications in thermo-electric technology increased in the last 15 years from 500 to a high of 2000 [6]. Fig. 1 shows the published research on TEs (thermo-electric generator and cooler) as a function of date from Web of Science. The search subjects are thermo-electric (TE), thermo-electric and structure (TE + structure) and thermo-electric and electron microscopy (TE + EM).

However, low efficiency in conversion has remained to be a primary challenge facing thermo-electric power production [7–9]. At present, researchers are making intensive effort to improve the efficiency of thermo-electric materials. Table 1 shows studies that have been conducted on many types of thermo-electric materials, most of them during the last five years. At the same time, by the use of efficient heat sink, researchers can improve TEG performance since effective dissipation of heat will keep temperature differences at high levels. Thus, TEG performance can be maintained to operate at an optimum level. For this reason, this paper takes a review of the classification of the heat sink and their application with TEG.

## 2. Recovery of waste heat

There are various reasons for developing more efficient processes. These include the need to cut down on the budget, fossil resources conservation, restricted legal framework, and scarcity of renewable resources. In the fields of energy research, political and economic actors, the topic of the significance of energy efficiency

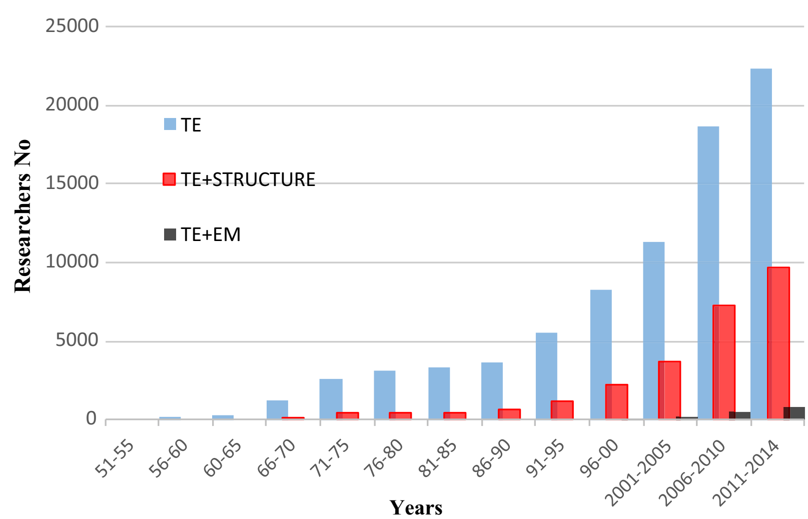


**Fig. 1.** Number of published research on TEGs with search subjects being thermo-electric (TE), thermo-electric and structure (TE + structure) and thermo-electric and electron microscopy (TE + EM).

**Table 1**
The conducted studies on many types of thermos-electric materials.

| Isotropic | Anisotropic layered | With phase transitions | Pseudo-cubic structures | Superionic structures | With high band degeneracy | With Low lattice thermal conductivity |
|---|---|---|---|---|---|---|
| PbTe [10–13] | $Bi/Sb_2Te_3$ [14,15] | GeTe [16,17] | $CuGaTe_2$ [18,19] | $Zn_4 Sb_3$ [20,21] | Half-Heusler [22–24] | Skutterudites [25,26] |
| PbSe[27] | $In_4 Se_3$ [28] | SnSe [29] | $GuInTe_2$ [30] | $Cu_2 Se$ [31,32] | | Stannites [33,34] |
| PbS[35,36] | $Ca_3 Co_4 O_9$ [37,38] | $Cu_2 Se$ [31,32] | | $Cu_2S$ [39] | | Zintl phases [40,41] |
| SnTe[42] | BiCuSeO [43] | $Cu_2 S$ [39] | | $AgBiSe_2$ [44–46] | | Clathrates [47,48] |
| $Mg_2 Si–Mg_2Sn$ [49] | SnSe[29] | $Ag_2 Se$ [50] | | | | |
| SiGe[51,52] | | $AgBiSe_2$ [44–46] | | | | |