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Novel Heat Controller for Thermogenerators Working on Uncontrolled Stoves

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This paper describes the development of a thermogenerator designed for uncontrolled firewood household stoves. It was built on BiTe thermoelectric (TE) modules, and it uses a water pot as a cooling device that also serves as a hot water source. An original heat controller was developed; it has low thermal resistance (R) during low-power operation, but its R can be continuously increased according to the stove temperature so that the TE never overheats while its power generation is optimized.

Key words: Thermoelectricity, thermogenerator, heat flux controller, prototype development, household electrification

INTRODUCTION

Thermoelectric (TE) materials have been known for almost two centuries, although to date they have not been massively applied for electricity generation. However, in the last few years, TEs have been considered within the portfolio of new sustainable energies[1–4] due to the entrance onto the open market of independent manufacturers of BiTe modules from the USA such as Tellurex[5] and also Thermonamic from China.[6] Tellurex's TEs are priced at approximately 4000 USD/kW and Thermonamic's at 2500 USD/kW, both cheaper than photovoltaic (PV) panels. In addition, the possibility of using a household heating source (such as a firewood stove) burning for many hours a day allows TEs to obtain net capacity factors (calculated as the total amount of electricity generated annually divided by the product of the annual hours and the nominal power of the module) noticeably higher than PVs, thus potentially offering a less costly option.[7] Nevertheless and despite this favorable outlook, there are issues related to thermal behavior that must be solved in order for TEs to become a feasible technology, since commercial TEs available on the open market cannot withstand the temperatures of gas chimneys[8] or the tops of domestic firewood stoves.[2,8] Up to now, only conceptual prototypes have been proposed, but they do not resolve this major issue.[1,2,9–11]

The Hi-Z prototype[9] uses two TE modules attached to a hot gas chimney and cooled by dissipators with self-powered fans. This solution implies high consumption of about half of what the TEs generate.[10] However, worse than that, this design cannot manage the high temperature range of output gases, ranging from 150°C to 450°C.[8] Of course, it is possible to put a large thermal resistance between the chimney and the hot side of the TE so that it never overheats; however, in this case, the TE generation is greatly penalized when the stove is working at lower temperatures, which is what happens in most cases.

The above-described behavior is key to understanding the real potential of this application. Domestic stoves usually work within a wide range of temperatures, for example, reaching the maximum temperature once a week for baking, but working at much lower temperatures most of the time. Commonly, a stove works at medium temperature during the morning hours for cooking, and after that it is kept at a minimum temperature throughout the whole day except when cooking. This pattern is reinforced during the winter season with longer working hours and higher temperatures with much higher temperatures at night, since the stove is

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