THE CONVERSION OF THERMAL WASTE INTO GREEN ENERGY

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Abstract. *In the process of producing electricity, most of the primary energy is lost in the form of thermal waste; this is an inevitable consequence of the laws of thermodynamics. Even the use of a small fraction of this thermal waste is a valuable resource of green energy. This project investigates the recovery of usual thermal waste using cheap Peltier and Seebeck modules for thermoelectric conversion.*

Key words: *green energy, thermoelectric conversion, Peltier, Seebeck*

INTRODUCTION

Thermal waste. Industrial and household processes generate a large quantity of heat which cannot be used due to its relatively low temperatures (40^0C – 200^0C). In 2012, global energy production was 153 PWh[1], and at least a third of it was wasted as thermal waste. Thus, recovering only a few percents out of thermal waste generated in industrial and household processes would represent an extremely valuable source of green energy.

Thermal engines are too complex and costly to to put these heat sources to use; therefore, a precious energetic resource is lost. Thus, a simpler and more direct way is required for the conversion of thermal energy into electric energy.

MATERIAL AND METHOD

1. Thermoelectric conversion

Thermal energy can be converted directly into electric energy by using the Seebeck effect: the heat transfer into an electric conductor will engage charge carriers, resulting in electromotive force.

Two junctions **A** and **B** between different conduction materials **a** and **b** will generate electromotive force between ends **C** and **D** if the two junctions are maintained at different temperatures (Figure 1).

In an open circuit, the electromotive force generated is proportional with the difference of temperature between the two junctions:

$$E = \propto (T_1 - T_2)$$

α being the Seebeck differential coefficient for the two materials. The Seebeck coefficient for metals is around 10 μV/K, therefore the voltages generated are used only for measuring the temperature in thermocouples. The most widely used is thermocouple K (junction with chromel alumel alloys). This provides 41 μV/K and can function between -200^0C and $+1260^0$C[2] (Figure 2). In order to obtain higher voltages, tens or hundreds of thermocouples can be connected in series, forming thermopiles.

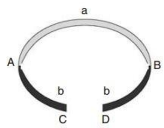

Figure 1. The junctions between different points

Figure 2. Thermocouple

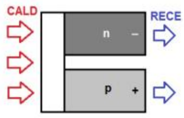

Figure 3. Semiconductors

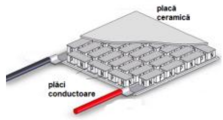

Figure 4. Seebeck module

In semiconductors, the Seebeck effect can generate much higher voltages, hundreds of μV/K. The majority carriers are engaged by the heat flow. Thus, electromotive force is obtained, the polarity of which is indicated in Figure 3.

Tens or hundreds of serial elements form Seebeck modules, which can provide tens of mV/K (Figure 4).

In our experimental investigations we used modules TEG-40-40-19/200, produced by Eureca (Germany). These generate 54 mV/K[3].

If current runs through a circuit made up of junctions between different materials, a heat flow will appear between the two junctions. This is the Peltier effect. Thus, one of the junctions adsorbs the heat generated at the other junction.

The Peltier effect can be used for cooling components or spaces. Peltier modules with semiconductors are built similarly with Seebek modules, but they are cheaper, as they are optimized for cooling and not for generating thermoelectric force.

Peltier modules can be used for generating thermoelectric force, but their performance is inferior to the Seebek module performance.

In our research we used Peltier modules TEC1-12705A (China).

2. Thermoelectric generators

We built several thermoelectric generators, using Peltier modules (the only ones that are available on the Romanian market) as well as Seebeck modules.

The heat sources we focused on were green energy and the usual ones in a household:

- Domestic hot water
- Thermal waters
- Roof and facades of buildings
- The sun

Besides Seebeck and Peltier modules, we only used recovered components and materials for building the generators:

- LEDs (from old devices)
- Metallic boxes (from packages)
- Expanded polystyrene (from packages)
- Cables and connectors (from old devices)
- Glass board (from a faulty scanner)
- Parabolic antenna (reconditioned)
- Tripod (from a dismantled telescope)
- Ventilators (from old devices)

RESULTS AND DISCUSSIONS

1. Hot water thermoelectric generator

Geothermal water, the hot and cold water in households and farms can become the hot and cold sources for generating electrical energy.

The hot water thermoelectric generator is made up of four serial Peltier modules placed between two metallic boxes filled with hot and cold water, respectively. The metallic boxes are placed into a larger box made of expanded polystyrene, for thermal insulation (Figure 5).

The thermogenerator can fuel small electrical devices (LED lamp, ventilator, radio, phone) for around 15 minutes, until the temperature in the two metallic boxes becomes the same.

The resulting lukewarm water can be used in the household.

- **A variant in continuous flow, placed before the chamber for mixing the warm and cold water in a tap and also on the thermal water heating system can provide electrical energy for free, with no moving parts and with no maintenance costs!**

2. Central heating system for apartments

Millions of homes are heated with the type of heating system.

Our proposal is to turn the heating systems for apartments into thermoelectric systems!

Thermoelectric modules will be placed in the combustion chamber (4) of the thermal power station, and they will generate electrical power while the water is being heated. With a 10% yield, 2 kW electrical power can be generated, which will be enough for all the necessities of a home.

Model

We built a model of a central heating system for apartments which shows the operating principle (Figure 6). The gas burner (primus) heats the water in a metallic container. A thermoelectric generator is placed between the burner and the container. This can generate 5 V / 1A for 10 hours and it can be used for generating electrical power in emergencies or in isolated places.

Figure 5. The hot water thermoelectric generator

Figure 6. The model of a central heating system

3. Thermoelectric solar generators

Thermoelectric generators are a viable alternative for photovoltaic panels:

- more robust;
- higher power density (1 W/cm^2);
- generate warm water simultaneously with electrical power.

We built a solar generator with Fresnel lens and thermoelectric module (Figure 7). Fresnel lenses are cheap and compact, concentrating sunlight on the thermoelectric module. The heat generated can be used for heating water.

4. Solar thermoelectric generator-1

The sun is a huge energetic resource which is still not exploited enough.

Solar-1 is a simple solar thermoelectric generator made from a piece of black anodized aluminium sheet. This is heated by the sun and transfers heat to five serial Peltier modules.

In order to prevent heat loss, the darkened part of the sheet is isolated with a layer of expanded polystyrene. The cooling is made by a large aluminium radiator, placed in the shaded part. In order to intensify the heating, the equipment was put in a glass enclosure, thus obtaining a greenhouse effect (Figure 8). In order to increase the quantity of solar energy collected, we built a pliable collector made of cardboard covered by reflective foil (Figure 9). The cooling process can be intensified by cold water spraying through a wick passed through the fins of the aluminium radiator. The generator provides 10 V in open circuit and a short-circuit intensity of 280 mA. The maximum power supplied in the exterior circuit is 1.3 W. Thermoelectric conversion of solar energy is a viable alternative to photovoltaic conversion – thermoelements are more robust, with a lifespan of decades and producing hot water at the same time.

➢ **Any roof or façade of a building can thus become a source of electrical energy, with no moving pieces and no maintenance costs!**

5. Solar thermoelectric generator-2

The effective power of thermoelectric conversion increases when the difference of temperature between the hot and cold water sources increases.

In order to increase the effective power of the conversion, we built a solar generator with parabolic concentrator (Figure 10).

The parabolic concentrator is made of a dilapidated parabolic dish which we covered with reflective foil. The maximum temperature reached in the centre is 211^0C, so we used a Seebeck module capable of withstanding temperatures up to 250^0C.

The cooling is ensured by a ventilated aluminium radiator. The ventilator is powered by the radiator itself. The cooling can be intensified by cold water spraying through a wick passed through the fins of the aluminium radiator.

The generator circuit voltage is 5 V, the short-circuit current of 3.2 A and the maximum power generated of 8 W.

➢ **Thermoelectric generators are a viable alternative for converting solar energy into electrical power, being more robust than photovoltaic panels!**

Figure 7. Solar generator with Fresnel lens and thermoelectric module

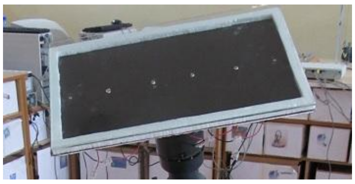

Figure 8. Solar thermoelectric generator

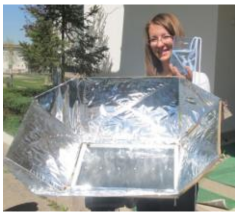

Figure 9. Pliable collector made of cardboard covered by reflective

Figure 10. Solar generator with parabolic concentrator

CONCLUSIONS

- The devices we built prove that Seebeck and Peltier modules can be used successfully for the use of energetic waste in households, greenhouses, etc.
- Thermoelectric generators can exploit heat flows with small temperature differences, they do not have moving pieces, they do not require maintenance and their life spans over decades.
- Seebeck modules have proven to be very efficient (9% conversion efficiency for a difference of temperature of 150^0C).
- Peltier modules have lower efficiency (2%), but they can exploit successfully resources with temperature differences of only a few tens of degrees Celsius.
- The heat wasted from geothermal water, domestic hot water and the central heating system in the apartment can be used for converting thermal energy into green energy useful in households, greenhouses, farms, etc, especially when electric power from the network is not available.
- Solar radiation can be converted into electrical power with the use of thermoelectric generators, which are a more robust alternative than photovoltaic panels. Any rooftop of façade of a building can thus become a source of electrical energy!
- All materials and components used for building the generators, except for Peltier and Seebeck modules, came from discarded materials, in order to put the wastes to use and to protect the environment!

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