ENGINEERING LITERATURE REVIEW

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Introduction

It is evident that the Earth is suffering from an energy crisis. It is a dual-fronted issue, that involves the eminent lack of energy resources and the ongoing climate change dilemma. This crisis is being propelled at a fast rate due to mankind's continued heavy reliance on fossil fuels for many ages. Fossil fuels, such as coal, oil, and gas are substances that are burned to power the electricity generation process at electrical plants. These resources are beneficial to the production of electricity, but they have one major drawback: they are detrimental to the environment. When burned, the CO_2 formed from the chemical reaction rises to the Earth's atmosphere, creating a layer of CO_2. The rising global temperatures is attributed to this layer, as it is being promulgated by the scientific community due to its characteristic of trapping the heat near the surface of the Earth, under the atmosphere. Furthermore, the practice of using fossil fuels has another drawback, that being the limited supply of fossil fuels on Earth. The Earth only has a finite amount of non-renewable energy resources, and with 80 percent of energy generation deriving from fossil fuels, soon Earth will be lacking enough energy to support current consumer demands. Earth will eventually need an alternate source of energy, other than the current fossil fuels. Renewable energy is a great alternative. In the coming years, renewable energy technology will evolve sufficiently to help alleviate the immense fossil fuel dependence the world has grown to have and with fewer fossil fuel emissions, the rapid growth of climate change should see some halting. Renewable energy, unless significantly harnessed through advanced means in the future, is a great current alternative, but not the absolute answer to the energy demands of the world. [1]

Renewable Energy

Untapped renewable energy can be found in our environments every single day. The many forms of energy that people encounter in a day to day setting include thermal, solar/light, sound, mechanical, and chemical. An abundance of three particular energy forms (thermal, solar,

and mechanical) can be tapped into from the daily lives of many. The solar aspect is derived from the Sun itself. It consistently provides both thermal and light energy at an immense rate without any signs of notable degradation in the foreseeable future. Solar energy has been in use, but it is still more of a grand scale technology (electrical grid – connected solar panels need to be large to function efficiently). [2] Mechanical energy, the energy of motion (sum of kinetic and potential energy), is in action all around constantly. Humans generate it when moving and it also occurs at the atomic level, as atoms are constantly in motion. Thermal energy, a form of kinetic energy (energy of moving particles) can be found abundantly in nature and daily human environments. One unique source of it is from daily electronics, ranging from mobile phones to laptops and more. An excess of thermal energy is emitted while these devices are in use, yet this energy is simply allowed to flow through the air without being utilized. [3]

Purpose

Even if one of these forms of excess renewable energy can be harnessed, it could be a major step forward to ultimately reducing electricity demands from generation plants and making consumer use devices even more convenient. Although a permanent solution to the energy crisis is far ahead in the future, modern improvements to renewable energy technology must occur.

In particular, thermal energy, in the form of heat, is constantly found in daily human environments. Sources of thermal energy can be found in moving objects, kitchen cookware and appliances, lights, the Sun, heating systems, electronic devices [3], and organic materials in most living things including plants and animals. This form of energy is the product of reactions; in other words, the leftover, converted energy produced when desired or undesired actions occur. Thermal energy goes quite unwanted, not having any particular use for much else. However,

thermal energy has the potential for use in the generation of electricity, with proper methods and technology being applied. [4]

Thermoelectric Generation

Peltier Effect

The Peltier Effect was developed by a French watchmaker Jean Charles Athanase Peltier in 1834. He discovered that when an electrical current was applied to the system, heating and/or cooling would occur at the junction point of two dissimilar metals. Later on, further research was conducted by a scientist of the name Emil Lenz in 1838, who helped to confirm and support the work and research of Jean Charles Peltier. One of Emil Lenz's contributions to the field of thermoelectrics relates heavily to Peltier's findings. Lenz suggested that the direction of current flow, when applied to the system, would determine the output of the system. This refers to whether the system would output heat or would lose heat. For example, the heat in the junction if removed by the process of adjusting the direction of the current flow, could freeze water and turn it to ice. However, with adjusting the direction in an opposite fashion, the same junction could melt the ice it has just formed. The Peltier Effect dictates that the amount of heat created or lost at a junction is proportional to the electrical current applied to it. This proportion is known to be the Peltier coefficient. [4]

Seebeck Effect

Between the years of 1821 and 1823, Thomas Johaan Seebeck discovered that a circuit, when connected to two dissimilar metals, having different temperatures, would deflect the compass magnet. Originally, he believed it was the temperature difference which had some connection to Earth's magnetic field. However later, Seebeck realized that the circuit with the temperature difference actually generated a "Thermoelectric Force" which held to be responsible

for the magnetic disruption. The temperature difference in a closed circuit actually generates an electrical potential energy, commonly referred to as voltage, the potential difference of charge in a circuit. [4]

The voltage produced by this temperature differential, and the differential between the sides of the junction is in proportion and is known as the Seebeck coefficient. This proportion coefficient is generally referred to as "thermopower." In reality, the coefficient is more so related to the potential of electrical energy, due to its relation to voltage, rather than the power of energy. Sb_2Te_3, Bi_2Te_3, $Bi_{0.9}Sb_{0.1}$, SnTe, Cu-Ni are alloys deemed to be good thermoelectric materials, as researched by Werner Maken in 1910. [4]

In summary, the Seebeck Effect is often related to the generation of electricity, more specifically generating voltage, which increases the electrical potential energy of a system or junction which can provide an electrical current. The Peltier Effect is more so related to the production of a temperature differential of the sides of a system due to the addition of a directional electrical current, with the direction deciding if heat is produced or lost. The following figure visualizes the differences and similarities between the Seebeck Effect and Peltier Effect. [5]

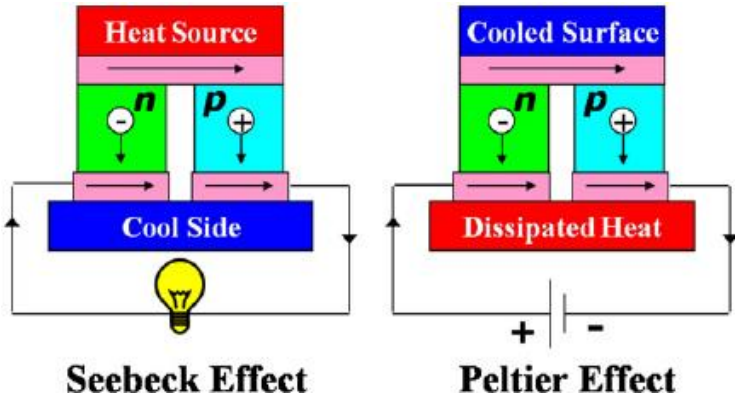

Figure 1. Seebeck Effect and Peltier Effect visualized [5]

Peltier Tile Functionality/Applications

A Peltier Tile, is the common system or apparatus used for Thermoelectrical Generation (TEG) as well as Thermoelectrical Cooling (TEC). The components of one Peltier Module, as well as some of its functions can be visualized through the diagram below. [6]

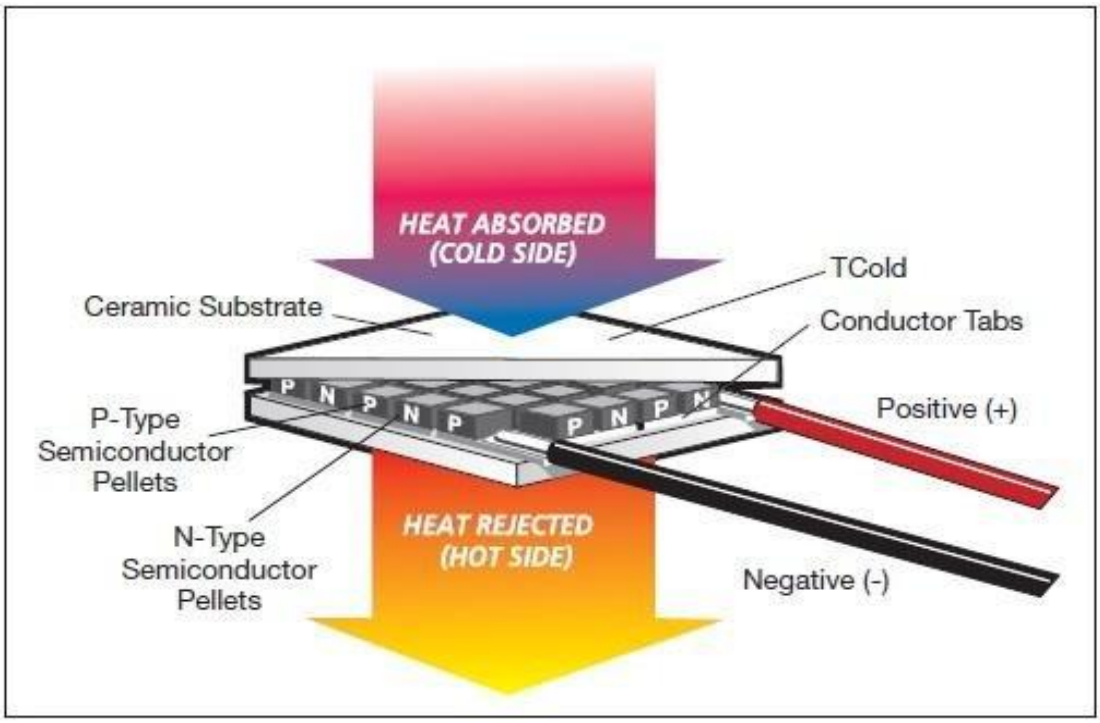

Figure 2. Peltier Tile Deconstructed and Explained Component by Component [6]

Applications of Peltier Tiles, the Peltier Effect, and the Seebeck Effect can be found in many areas. Common applications include refrigeration purposes and cooling technology. It was once believed that thermoelectric technologies such as Peltier Tiles would be replacing heating and cooling agents/mechanisms of our time; however, that has not completely happened. Peltier Tiles can be found in some refrigerators as well as climate control in vehicles, particularly in seating temperature control. Another application is in the space industry. With the use of radioisotopes in spacecraft, which constantly emit heat, TEGs are being installed to generate electricity for long – term space missions, which cannot use the energy of the Sun due to

distance. This form of energy generation is highly effective, particularly to these missions, as the lack of moving parts in the TEGs make for a huge decrease in likelihood that any maintenance will be required, furthering the sustainability of the mission. [4]

Existing Peltier Devices

Power Watch – Matrix Industries

The PowerWatch is a smartwatch that is purely powered through the thermal heat emitted from the human body, particularly the wrist region. After many iterations and design changes, the team at Matrix Industries managed to develop a system which used the Seebeck Effect to generate electricity to power the watch, using only the thermal energy from the user's wrist and a ventilation system to stimulate the temperature differential. [7] It has shown promising results as a startup product, fulfilling many criteria of the modern smartwatches such as: slim profile, attractive, and useful.

Figure 3. Peltier Tile Deconstructed and Explained Component by Component [7]

Hollow Flashlight

The Hollow Flashlight is a first-place Google Science Fair project for 2013, by a 15-year-old girl from Canada named Ann Makosinski, which converts thermal energy from your

hand into electricity to power an LED flashlight. Ann discovered that humans had the potential to emit enough heat for “100 watts’ worth of lightbulbs”. [8] This was designed in response to the challenge to develop a cheap method of producing light, potentially for use in nations with electricity shortages. The apparatus consists of an aluminum cylinder lined with Peltier Tiles, on the exterior, with a hollow interior to provide air flow for the cool side of the Peltier Tile. [9]

Figures 4. Internal View of Makosinski’s Product [8]

Figures 5. External View of Makosinski’s Product [9]

Conclusion

A new source of energy, most preferably renewable, will be needed in the near future for humans due to the immense reliance on the finite fossil fuels. If humans do not find a new alternative source for energy, electricity will ultimately become scarce and expensive. [1] Many advancements have been made, in terms of finding a new alternative renewable energy source. Solar energy is one major field being heavily advanced in, however it retains many drawbacks (costly, inefficient, large-scale). [2] One field has shown some promise, that being the thermal energy field. Effects such as the Peltier and Seebeck have shown the opportunities that come with thermal manipulation which most importantly includes electrical generation. With the use of a Peltier Tile, which consists of two ceramic substrates that allows for an electron gradient between them from a temperature differential, small-scale and potentially large-scale electrical generation can result. [4] There has not been much advancement in this area as of now, barring products like the PowerWatch, [7] however there is much room for it to produce a solution to the future energy crisis.

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