GENERATION OF SELF-SUSTAINABLE ELECTRICAL ENERGY FOR THE *UNIDAD CENTRAL DEL VALLE DEL CAUCA*, BY THE USE OF PELTIER CELLS

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Abstract: - It is proposed to generate self-sustainable electrical energy taking advantage of the environment's natural conditions in the *Unidad Central del Valle del Cauca* (UCEVA). This, by the use of the so-called Peltier Cells, which have the capacity to generate electricity from a thermal gradient, thanks to the properties of the Seebeck, Peltier, Joule and Thompson effects, for semiconductor materials, being these the main theoretical references in this research project. To carry out this idea, it is proposed to design, build and characterize a floating device initially made up by Peltier Cells. Likewise, it is aimed to place on the lake in the university campus in order to take advantage of both the low temperatures of this water reservoir and the high temperatures generated by direct exposure to sunlight turning those opposite temperatures into a source of energy. That energy will provide a certain area adjacent to the lake not before expanding the studies related to the effects mentioned above and other principles of thermoelectricity.
This research project will open the doors to a relatively new branch of renewable energies, thermoelectricity, both for the UCEVA and for the scientific community in Tuluá and Valle del Cauca.

Keywords: - Peltier Cells; electric current; Peltier effect; Seebeck effect; Renewable energy, Joule effect, Thomson effect, Thermodynamics.

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1 Introduction

During the last decades, a considerable climatic deterioration has been noticed mainly due to the use of fossil fuels for the generation of electric current and other natural activities of the human being. This is greatly increasing the presence of carbon dioxide (CO2) in the air, reaching to register up to 403.3 parts per million in 2016, 3.3 parts per million more than those registered in 2015 and representing the largest increase in the last thirty years [1].

However, research and development of renewable energies has taken a faster, focused and significant course only until the last few years. In such a way that currently there are devices coming from different branches of alternative energies that generate self-sustainable electrical energy able to supply thousands of homes in a very efficient way. Devices such as the well-known Solar Cells, the famous wind turbines [2] and even the development of nanotechnology in the service of solar energy, through the acquisition of a new material called "nanoflakes", these devices have revolutionized and could revolutionize even more the transformation of all types of energy inherent in the ecosystem (kinetic energy, solar energy, etc.) [3] in electricity, and it is thanks to these that even households under scarce economic resources could obtain electric supplies at a low cost and in a safe way, as far as the environment is concerned.

At present, extraordinary projects are being developed that will allow the harnessing of all the potential that the natural resources possess to which we have the possibility to access. Projects such as the already implemented floating solar plants inaugurated in China in 2017, which eliminate several of the disadvantages that had to be placed on solid ground, such as visual pollution affecting tourism or the use of extensive areas that are considered could be dedicated to other activities. These floating solar parks have the possibility to produce up to 30 MW being able to supply electric power up to an amount of 15,000 homes. [4].

The main objective of renewable energies is to create devices generating electricity efficient and profitable enough to replace fossil fuels or alternative energies such as wind, solar and bioenergy, which require a large investment both as for its installation as for its operation and maintenance; which makes it practically unattainable for natural people and hardly applicable in non-industrial environments. This is why this line of research on renewable energies is quite striking, once there are thermoelectric devices that, as Winder et al. states, "they are solid state units that convert the thermal energy of a gradient of temperature into electrical energy" [5]. This, having the capacity to take advantage of the thermal waste of industrial operations or as it is approached in this article: the thermal energy of the ecosystem.

Thermoelectric energy is a branch with extensive research developments; research projects such as the one carried out by Reddy et al. who seeks the development of new chemical compounds at molecular level that present a greater efficiency in the conversion of thermal energy into electrical energy [6]. Or the study carried out by Takahashi et al. where the thermoelectric efficiency of individual FeSb2 crystals is analyzed, accompanied by quasi-ballistic photons dragging electrons of a large effective mass [7]. As well as research projects at larger scales such as the one presented by Hájovský et al. where they visualize the effectiveness of a device formed by Peltier Cells to feed the 12V batteries of certain sensors that read the levels of substances harmful to the human and the environment in the large mines in constant combustion of the Moravian-Silesian Region [8].

In the same way, the article presented by Holanda et al. in which they make use of the Seebeck effect of longitudinal spin to generate a spin current through a temperature gradient over magnetic materials as it is in this case the ferromagnetic metal N81Fe19 (Py). In this, the researchers made a sample of three layers Py/ NiO/NM, with NM being any normal metal which generated a spin current when exposed to a temperature difference that passed through the NiO reaching the NM layer, and at this point the spin current becomes a charge current by using effects such as the Hall Effect [9].

Research projects undertaken by Herranz state that "the industrial applications of thermoelectric modules have been scarce so far" this enhances the research and application that is expected to be done with the peltier modules, applied to a social benefit [10]. And last, but not least, the article presented by Dalola et al. research in which the thermoelectric efficiency of quasi-one-dimensional nanowires made of zinc oxide is analyzed, making use of the Seebeck Effect, of course, to serve as an energy source for low-power portable electronic elements and even for sensor systems. That efficiency turns out to be acceptable to analyze it according to the Seebeck coefficient that it presents when performing the experiments, but this only occurs at lower temperatures better than 350 degrees Kelvin, then it is necessary to consider new compounds that are functional and resistant at high temperatures, as the quasi-one-dimensional metal oxide is [11].

In addition, the Seebeck effect has not only been used for the current electrical generation, but also for the creation of sensors of different types and applications. A clear example of this, it is the research carried out by Michez & Foucaran, where they explain the construction and operation of hot wire anemometer based on the Seebeck Effect. In order to understand this, it is initially necessary to understand the meaning of an anemometer of this style: "a hot wire anemometer usually refers to the use of a small electrically heated element placed within a fluid with the objective of the properties of this means". Taking the above into account, the sensor is based on periodic structures created from quick evaporation techniques on a Polyimide substrate; the anemometer implements both the Joule effect and the Seebeck effect, using the Joule effect to produce a temperature gradient between several junctions within the circuit (Sensor) and the Peltier effect in order to detect these gradients. The above was carried out taking into account important variables such as the Seebeck coefficient, the thermal conductivity of the compound, and the electrical resistivity [12].

This type of renewable energy shos acceptable operations at an individual level, as can be seen in the project presented by Cifuentes where it is posed, analyzed and defended the use of residential wind turbines for the direct power supply of one or several homes. It is also stated that this type of systems has lower initial investments, less time to recover the investment and other benefits that make this a profitable and efficient idea [13]. But they also have the capacity, still unused, to be part of a device and/or mechanism that contains elements of each branch to enhance the electric power supplied, as can be seen in the article by Mosiori where a built device is proposed from important and well-known branches of renewable energies, solar energy and wind energy, highlighting the fact that the combination of several alternative energies within the same device to generate electric current could provide a solution to the deficiencies and cons that each one possesses individually [14]. In addition, devices formed by different electronic elements of renewable energies, can serve as additional feeder and support for the current traditional electrical system. Serving as intermediate microgrids strategically positioned between the power plant and the geographical area they feed, in order to reduce the loss of energy due to the great distance that they must travel or even to deliver additional electrical energy when the power plant's capacity does not meet the needs at a given moment [15]. Serving as a transitional stage while the community and industry adopt the full use of renewable energy.

The cells not only have the capacity to produce electrical energy but also other alternatives such as those proposed by Barrera which focuses on a type of sensor, in which the researcher proposes to develop "a system for condensing water using a Peltier cell", taking advantage of the humidity of the environment to generate as much water as possible (%) of it. For this, it requires a system that can regulate the temperature of the cell so that the condensation is successful and efficient, observing that the fuzzy controller and the neuronal have the largest amount of water extracted [16].

It is because of its potential capacity to take advantage of the environment that Thermoelectric Energy is being the pivot in the research that has been carried out in the UCEVA by the *Sinergia dx* Research Incubator. More specifically because thorugh this and with the use of Peltier Cells a thermodynamic gradient will be leveraged that will be obtained from the ecosystem and by means of it, electric energy will be obtained, a greater temperature difference will deliver a greater potential difference, and this will force a electron diffusion that translates into higher amperage.

The potential difference along with the useful life cycle obtained from the device will be variables that will be expected to optimize in such a way that it can be shared for the self-sustainability of the institution without major long-term costs.

At the UCEVA, there are no projects with respect to renewable energies, and by observing the large amount of research that has been conducted at the national and international level, it is time for the institution to participate through the development of projects such as the one explained in this article.

This will allow the UCEVA to start to be part of the academic institutions that bet on the preservation of the ecosystem and this way we will be in the future in the GreenMetric World University Ranking, where the academic institutions of the planet that have bet most on the preservation of the ecosystem are classified.

The University of Wageningen, the University of Nottingham and the University of California, David are in the top ten of the mentioned ranking, however, no university of South America can be observed [17].

One aspect to highlight is that there are more universities that annually have joined the initiative to conserve the ecosystem through renewable energy. In Chile, the *Pontificia Universidad de Chile* conducted a study with experts and determined that about 58% of Chilean universities consider that it is important to contribute to the reduction of threatening environmental phenomena such as climate change and have adopted some measures such as the use of bicycles, garden cultivation and the implementation of sustainable energy systems. [36].

In Colombia, there are few universities that contribute to the ecosystem, and minimal efforts in the management of solid waste, actions against climate change and environmental education. Interestingly, the *Universidad Nacional de Colombia* has managed to reduce by 70% making ordinary solid waste end up in the Doña Juana landfill. Another university that has contributed to sustainable energy resources is the *Universidad de los Andes,* which has a solar panel that covers 40% of the energy needs of the sports center.

The *Universidad Tecnológica de Pereira* (UTP) has on its campus the largest conservation area of Pereira (Risaralda), the *Universidad de Santander* has one of its major campus reforestation projects with the planting of 700 endemic and fruit trees, and the *Universidad Industrial de Santander* has made a percussion band that uses instruments with different recycling tools, kitchen elements and discarded appliances [18].

Although these universities have carried out large projects to mitigate the environmental impact, in Colombia, only 20% of them (Universidad de los Andes), have bet on renewable energies. Colombia is a power for these energies since it has some ecosystems that only occur in tropical countries.

These energies emerge as a solution to the main environmental problems generated by fossil fuels, which have worsened over the last decades, creating greenhouse gases (GHGs).

The greenhouse effect is because the gases in the atmosphere are transparent to solar radiation. If this phenomenon does not occur, the temperature of the earth would be -18°C, as well as the combustion of fossil fuels realeses a great amount of sulfur and nitrogen oxides that react with the gases in the atmosphere, precipitating in the form of acids (sulfuric and nitric) increasing the acidification of water [19].
The main deposits of fossil fuels are concentrated in very specific areas of the planet. The control and exploitation of them is the cause of wars and social tensions that are seen every day in the media generating this social imbalance. The best solution for so many problems are renewable energies, which allow to show and raise awareness in the community the importance of reducing environmental impact.

1.1 Seebeck effect

German physicist Thomas Johan Seebeck discovered the Seebeck effect in 1821, who accidentally found that an electromagnetic field (EMF) occurs between the two ends of a metal plate when they are at different temperatures. After performing more experiments on this phenomenon, he realized that the mentioned electromagnetic field was generated by a diffusion of electrons from the hottest end towards the coldest end of the bar (an electric current) and this, in turn, was generated by a potential difference (a voltage) [20].

In short, heating one end of a metal bar while cooling the other (a temperature gradient) results in a potential difference that allows the passage of a continuous electrical current.

1.2 Peltier effect

The Seebeck effect turns out to be the reciprocal of the Peltier Effect, the French physicist Jean Charles Peltier discovered this effect in 1834; 13 years after the Seebeck Effect was discovered. This is based on the generation of a temperature gradient between both ends of a semiconductor material after delivering a continuous electric current. Being used generally for the construction refrigeration devices [21].

Martínez et al, states in the document that the heating or cooling is the result of the union of two different metals creating an isothermal interface when passing current through it and that this depends on the type of metal and the temperature of the union [22].

1.3 Joule effect

It is called Joule effect to the heating generated in a semiconductor material when being exposed to an electrical current. The English physicist James Prescott Joule initially studied it in 1841 when measuring the variation of the temperature of a fixed mass of water when submerging in it a wire through which electric current circulated.

By performing diverse experiments with different variations of the electric current induced to the material, Joule discovered that the generated heat can be expressed as follows [23].

$$(1)\ Q=I^2Rt$$

Source: PID temperature controller, neural networks and fuzzy logic to condense water in a Peltier cell (in Spanish "*Controlador de Temperatura PID, Neuronal y Fuzzy para condensar agua en una celda Peltier*").

Where the heat generated (Q) is equal to the current high squared (I^2) multiplied by the electrical resistance of the conductor (R) and the elapsed time (t).

1.4 Thomson effect

The British physicist and mathematician William Thomson discovered this effect in the year 1851, being he who showed an existing relationship between the Seebeck effect and the Peltier effect and thus delivering the third effect of the so-called thermoelectric effect.

This effect affirms that a material has the capacity to absorb or expel heat if it is induced an electrical energy, quite similar to the Joule effect, with the variable that this heat is not equal to the square of the current to which the material is exposed, so a negative result can be generated. This means that the sign will change depending on the direction of the current: heat will be absorbed if the current goes from the coldest end to the hottest end and heat will dissipate in the environment if the current goes from the hottest end to the coldest end [24].

1.5 Fourier's Law

A relevant factor related to the efficiency of the Peltier cell is the thermal conductivity between each of the faces (cold and heat). This conduction of heat is a property of materials, and acts when two bodies at different temperatures are in contact, transmitting heat from the body with higher temperature to lower.

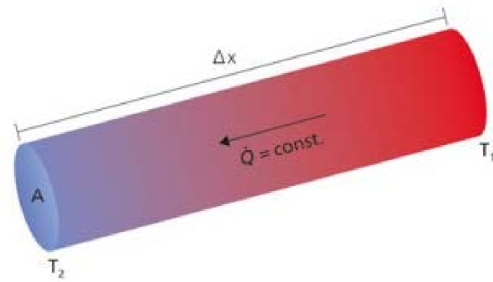

Figure 1: Explanatory diagram of thermal conductivity.[35]

Source: https://www.netzsch-thermal-analysis.com/en/

The Fourier's law that describes the heat flow between the two extremes as a function of a temperature difference, and the thermal resistivity between the two can express this property [25].

$$(2)\ Q\dot{c} = -K\ \Delta T$$

Source: Study and parameterization of a thermoelectric generator.

According to Isodoro Martínez "the flow of heat that crosses the unit of area per unit of time, *Qc*, is proportional to the gradient of the temperature, ΔT, being called thermal conductivity to the coefficient of proportionality, k (or thermal diffusivity to α≡ k/ (ρcp))" [26].

2 Methodology

Initially for the construction of the device it is necessary to obtain all the elements of which the design consists, the main component will be the Peltier Cells, which are the union of two different conductive materials through a semiconductor material. See Figure 2.

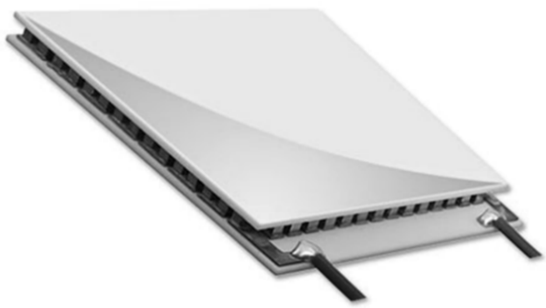

Figure 2: Physical aspect of a Peltier Cell. **Source**: http://www.warsash.com.au [27].

The Peltier Cell is linked through a pair of semiconductors (tellurium and Bismuth) that are electrically and thermally connected in series as shown in Figure 3.

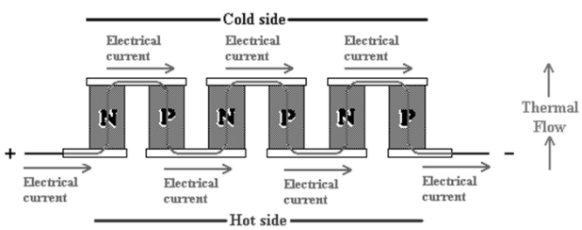

Figure 3: Internal components of a Peltier Cell and distribution.

Source: The Peltier Effect [28].

On the market, Peltier Cells are classified in multiple references depending on for example: the voltage that generates; the serial is preceded by the acronym TEC, which means Thermoelectric Cooler, and this is classified in several families in terms of its composition, TEC1, TEC2, TEA, TEG and TES. The TEC1 family is the most commercial and the easiest acquisition, the TEC2 is connected with a resistance, the TEA is a module with aluminum substrate that exceeds the ceramic pairs in thermal conductivity. The TEG is an electrical component that has been used in the NASA missions as in the "Voyager" that was sent to deep space and has lasted more than 20 years, and also in the "Apollo" that has lasted more than a decade, and the TES is a micro Peltier, which is used for low power/low current applications. For ease of obtaining these materials, it was chosen to work with the TEC1 family of cells [29].

Although the information related to the Peltier Cells is considerably scarce and even more when it focuses on its capacity to generate electrical current, it has been researched in different languages such as Mandarin and English, finding studies and related pages that thanks to them has observed that the cells are classified by means of a dissipation factor (Q). Before choosing the Peltier Cell reference that will be implemented in the device, it is necessary to know what is involved in the already mentioned dissipation factor (Q) in the generation of electric current, for which three different references will be acquired: TEC1-12706, TEC1- 12715 and TEC1-12710.

Reference		Th= 30°C; Qmax (W)
TEC1-12706		51,4
TEC1-12710		85
TEC1-12715		127

Table 1: References of selected Peltier Cells. **Source**: http://www.everredtronics.com

As Table 1 shows, cells of low, medium and high dissipation factor (Q) were chosen, expressed in units of Watts (W), with the objective of characterizing each one by exposing them to a variable temperature gradient and observing which of them turns out to be more efficient in the specific conditions of this project. The dissipation factor is governed by the following equation

$$(3)\ R=\frac{\Delta T}{Q}$$

Source: HOW TO SELECT A HEAT SINK [30].

Where R is the thermal resistivity, which is already stated in the technical specifications of each thermoelectric cell and semiconductor material, and this is equivalent to a variation in temperature divided by the dissipation factor.

In addition, these cells will not only be characterized by their dissipation factor but also by their Seebeck coefficient (α), a constant resulting in the conversion process, since the potential difference delivered by the cell turns out to be proportional to the thermal gradient, but existing a value that minimizes the result. Therefore, it can be taken as a type of thermal resistance inherent to the material, the above can be expressed algebraically as follows:

$$(4)\ V=\alpha\,(Th-Tc)$$

Source: Seebeck and Peltier Effects [31]

Being V the voltage obtained from the cell equal to a Seebeck coefficient (α) multiplied by a temperature difference; finding that with the above equation, we can make an analogy of Ohm's law for voltage:

$$(5)\ V=IR$$

Source: http://fisica.uc.cl/images/Ley_de_Ohm_v3.pdf [36]

Where the voltage is equal to a Current (I) by a resistance (R), hence, the temperature difference (Th-Tc) would be similar to the electric current (I), and the Seebeck coefficient (α) to the Resistance which argues the claim that the Seebeck coefficient is actually a type of resistivity.

When the Peltier Cell has been selected, that is considered as the most indicated according to the data obtained, the following steps will be followed:

• The performance of the device will be optimized when analyzing, choosing and implementing different circuits (in series, in parallel or mixed) integrated by the cells, which enhance the voltage, current and durability of the device, as it was said before. When exposed to thermodynamic conditions simulated in the laboratories of the university campus, making use of a heat sink and carrying the respective control with a galvanometer that allows to determine if the obtained data are acceptable or not.

• It will be analyzed which of the proposed circuits performs better comparing voltage, current and power delivered.

• A floating prototype will be made with the selected circuit, which will be placed on the lake of the UCEVA (See Figure 3)

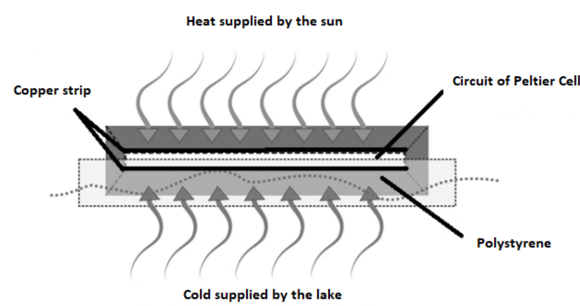

Figure 4: Prototype

Source: The authors.

The device will have the upper face exposed directly to the sun's rays to obtain the high temperatures of these and the lower face will be receiving the cold or the low temperature provided by the lake. The behavior of the prototype will be observed when encountering real and variable situations that will be kept in constant reading using laser thermometers and installed multimeters that store them automatically.

• To enhance the performance of the circuit, the participation of elements, whether electrical or physical, will be found out; implementing those that overcome the research filter, to the floating prototype. The idea then is to analyze the intensity of the final current delivered after the connections and verify if it is greater or less than that found in previous variations.

• The signal obtained will reach an operational amplifier, where it is purified; it will pass to a voltage or current riser from there that will simultaneously serve as a DC to AC current converter, finally passing through a transformer that will leave it ready for being used as power supply to a chosen area of the university campus.

3 Materials

Although the research is at an early stage, several elements are currently being considered with which the final device could count, starting with a material derived from polystyrene that keeps it afloat (float), based on the research carried out by Zhejun Liu *et al*. Solar Still Prototype, where they describe the development and results of a floating desalination device [32].

In addition to being conformed with Peltier Cells, the idea is suggested of adding solar cells to the device in the future, taking advantage of the energetic capacity of the sun or other elements coming from renewable energies. Such as electromagnetic devices as well as physical elements such as lenses that enhance in a considerable way the temperature delivered by the solar rays and thus generating a higher thermal gradient without altering the natural conditions of the lake.

There has also been doubt how to achieve that the temperature is the same in the entire area of the lower and upper face of the circuit independently, since internal variations could limit the effectiveness of the device. For this, it is proposed to make use of materials with good thermal conductivity that placed on each side allow a homogeneity in the temperature of the entire area of the same, however, this material must be resistant to oxidation because they will be exposed to the constant humidity of the water reservoir. Finding then when analyzing articles such as the one published by Viscardi and Di Leo, “Study and Experimental test of Pelier Cells for an energy recovery system in a renewable energy device” that the best material that meets the conditions turns out to be copper [33].

4. Expected outcomes

The main result of this research is to make a durable and efficient floating device consisting of Peltier Cells and other electronic elements that allow to take advantage of the thermodynamic conditions of the ecosystem present in the UCEVA for the generation of self-sustainable electrical energy that can feed a certain area of the same without generating large long-term expenses as it can be caused by constant maintenance.

The device has great electrical potential since, like the aforementioned study conducted by Viscardi and Di Leo, they show that a Peltier Cell with 4 centimeters wide by 4 centimeters long is capable of generating up to 30% of the energy delivered by a Solar Cell of 26.6 centimeters long by 33 centimeters wide. Therefore, numerically speaking 48 Peltier Cells (necessary to cover the area of a Solar Cell) would generate 1440% of the energy delivered by a Solar Cell, a value that could be a little surreal but that developing the series-parallel circuit more suitable this research could deliver quite significant results. This would generate great advances in the area of renewable energies by providing a new, additional and effective alternative to replace in the long term the use of hydrocarbons as fuels [34].

It also seeks to exponentially increase the research activities related to clean energies and environmental care in general in the UCEVA, in order to place the name of the institution on high while helping to reduce environmental deterioration.

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