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Planetary Thermodynamics

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This work is a result of all the love I have received.

Would be impossible to mention all the people who helped me make it possible, so I thank all the people who have ever offered me a kind word throughout my life. I thank to all the teachers who encouraged my critical thinking, especially my first teacher: my father. Only my family knows the pain of his absence, and I thank my family for the support I received over the years.

Abstract

The Climate Crisis generates a lot of distress around the world and even as the scientific consensus thinks that the use of fossil fuel is the culprit - it's still hard to imagine a world without the use of oil. The current understanding is that carbon dioxide (CO2) increases the Greenhouse Effect that in turn generates the Global Warming. This thesis opposes this current notion of the Climate Change and blames the air conditioning systems.

The rationale behind this change of perspective will be explained in the beginning and then a new experiment to prove the hypothesis will be proposed. Finally, future work will be suggested involving a new refrigeration system.

Key-words: Global Warming, Climate Crisis ,Greenhouse Effect, Air Conditioning, Geothermal Refrigerator

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Introduction

The Climate Change is one of the main study fields over the last decades; causing great concern both within and outside the scientific community. It was first discovered the relationship between burning fossil fuel that increases the Greenhouse Effect - process that was called Global Warming. However, it was later discovered that the planet was not warming in a uniform manner, sometimes with even with colder winters in some regions. For this reason, this phenomena was renamed to *Climate Change* or *Climate Crisis*.

The disparity between climate scientists' predictions and reality has been noticed by society over the past few years. This generates social anxiety and paralysis, as we do not know the best route to solve the problem. Weather forecasts' uncertainty hinders agriculture and other sectors of the economy. The Climate Change has also already caused deaths and put lives at risk due to problems such as floods, inundations, droughts, and other catastrophic events.

This thesis aims to provide a better understanding of the thermodynamics of Earth's atmosphere, as well as to suggest technologies to stabilize the climate and mitigate possible future extreme weather events. Initially, the focus is on understanding the mistaken attribution of fossil fuel combustion as the main driver of the climate catastrophes occurring around the world. Next, tools will be presented to eliminate extreme weather events and, consequently, achieve greater climate stability. Finally, possible future work and areas of study will be presented to deepen the understanding of global climate functioning.

1 Air-conditioning Systems

Thermodynamics has gained a lot of attention since the Industrial Revolution, because this field contributes to the creation and improvement of different thermal machines, notably steam engines. Every piece of technology around us has had contribution from thermodynamics for its creation. For this reason, even as society thinks that the Climate Change is a consequence of those technologies, we don't want to stop using it.

There is a natural transfer of energy between warmer to colder bodies - this phenomena is known as heat. The heat transfer can occur by three different manners: radiation, convection and conduction. If two or more bodies don't exchange more heat, we consider that they are in thermal equilibrium. The heat exchange between substances can affect properties besides the temperature, such as pressure or volume. Thermodynamics studies these sort of interactions (MAXWELL, 1908).

Heat flows between bodies with higher temperature to the ones with lower - this is known as The Second Law of Thermodynamics. For this reason, machines like air-conditioning and refrigerators that tries to make heat flow in the opposite direction has a cost. These machines sometimes are called: inverse cycle thermal machines. They were theorize first by Sadi Carnot in the attempt to calculate the maximum efficiency of thermal machines. However, they ended up being actually used without the due attention with the rise of atmospheric entropy (CARNOT, 1824).

Sadi Carnot compared thermal machines to a waterfall - the top of the waterfall is the Heat Source and the bottom is the Cooling Source. This analogy helps with understanding the absurdity of trying to make heat flows its opposite way. It is possible with small amounts of energy, however if you analyze the whole system, heat will always flow its natural course the same way that the water of the waterfall will fall. On reality, there is not a great thermal insulation between the Heat and Cooling sources, which makes air-conditioning systems spend a lot of energy (Figure 1).

On other words, air conditioning greatly influences the entropy of the atmosphere. Entropy was defined by Rudolf Clausius as the infinitesimal change in heat divided by instantaneous temperature. Sometimes it is known as the measurament of chaos in a system, so if the aim is climate stabilization, it's essential to be aware of machines that greatly increases this property (CLAUSIUS, 1867).

The air-conditioning system simply throws heat from a room to the outside, and in this process, some of the electric energy is converted in more thermal energy. Since heat flows its natural course, some of this thermal energy promptly returns to the room. Besides, since warmer air tends to rise due to its lower density, air-conditioning negatively

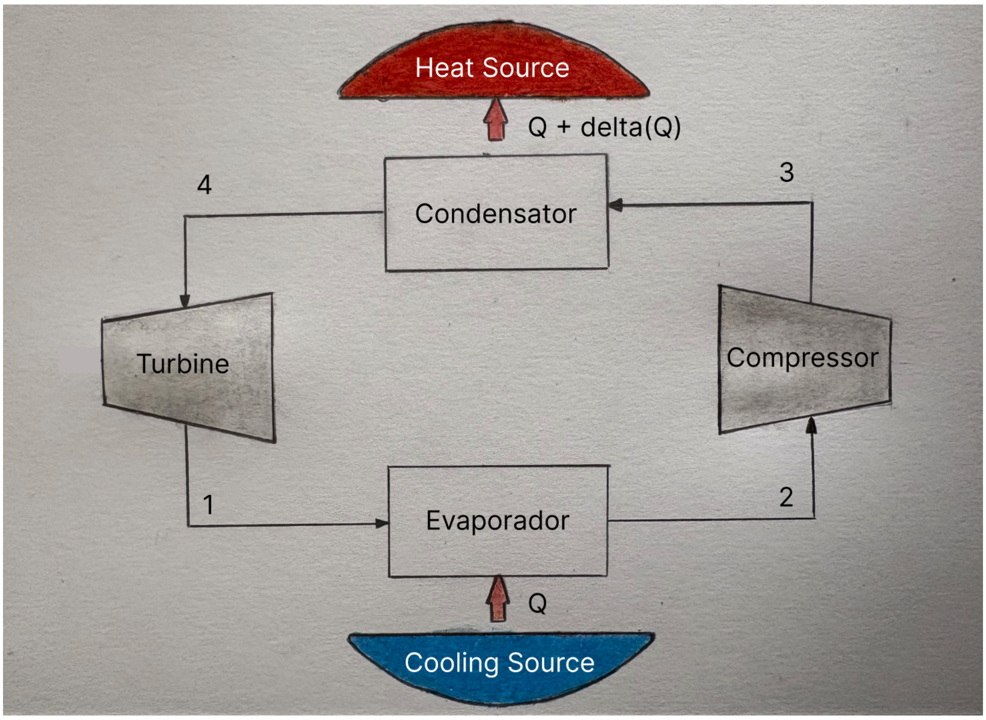

Figure 1 – Carnot's inverse cycle thermal machine - would be an ideal refrigerator, but it is impossible on practise.

affects upper floors in buildings. The lower floor neighbors' air-conditioning throws its heat to the outside, which tends to go upwards to the upper neighbors' flat. We are waisting energy using air-conditioning systems as refrigerator method (Figure 2).

A second analogy to air-conditioning systems is: removing water from a broken ship with a bucket. It does not solve the problem and it wastes a lot of energy. Air-conditioning systems are refrigerators with open doors: they might soothe the problem for the person in front of it, but for the overall system its efficiency is negative. **Besides, Global Warming is a public problem and its solution must also be in the public infrastructure.**

Carnot's thesis "Reflections on the Motive Power of Fire" considered the thermal machines as insulated from the environment, which is a comprehensive mistake since at the time there were no inverse cycle thermal machines in use. However, if we analyze the current urban systems with millions of these machines, we start to better understand the Climate Crisis.

When we analyze the system on a global scale, the air-conditioning use creates more thermal energy and increases the local atmospheric entropy. This generates a high pressure zone that is sometimes called Urban Heat Island (Figure 3). Air-conditioning is not a room refrigerator, it is a **world heater**. The higher pressure on the urban heat islands expels clouds and decreases the likelihood of raining, since warmer temperatures requires more water for precipitation. In this manner, when it rains the amount of water is higher, increasing the risk of rainstorms, floods and hurricanes.

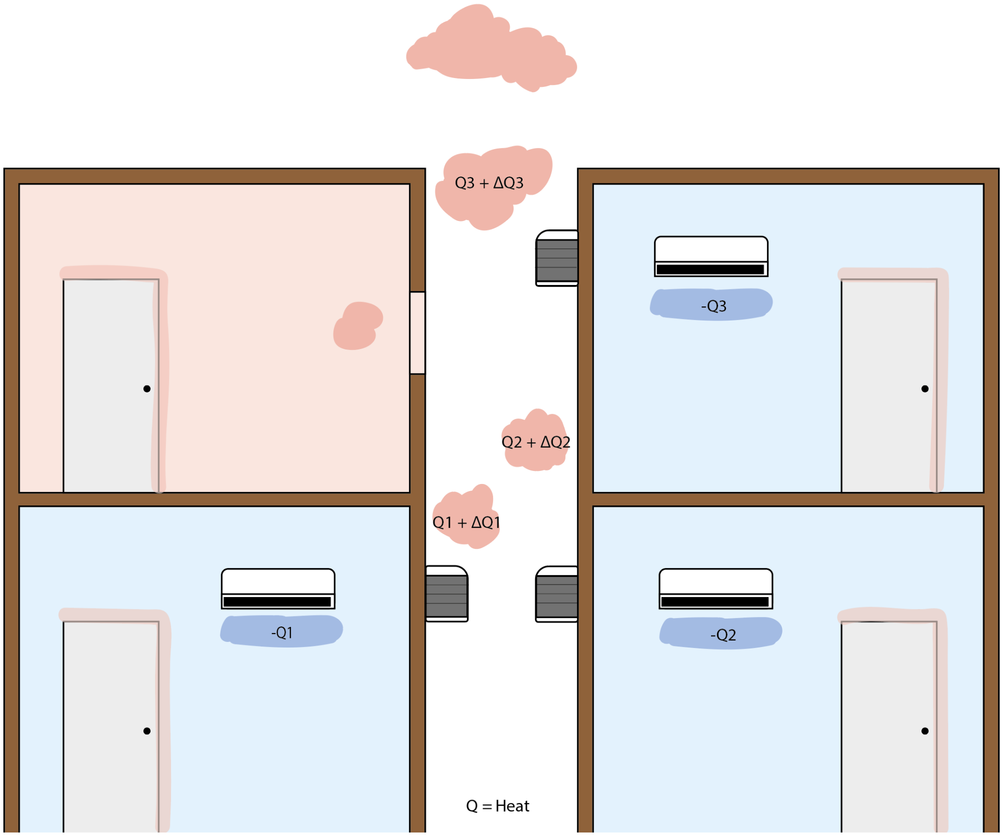

Figure 2 – Air-conditioning system functioning - Increase of heat that flows back into the room and neighbors' homes.

It is an error to consider the atmosphere as a thermal reservoir as it is taught in engineering courses. It is true that it has a lot od thermal capacity when compared to daily life objects. However, society has hundreds of millions of air-conditioning systems working, which have the capacity to affect world's atmosphere. Besides, most of them are concentrated in urban areas. As a last argument, The air-conditioning systems loses efficiency when it is too warm, so when people most need a refrigerator system, it will consume more energy.

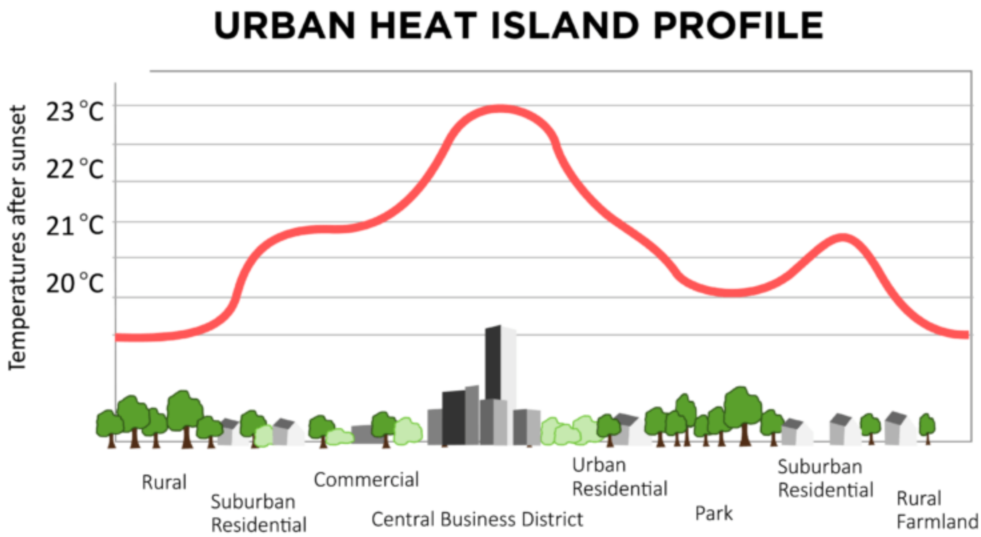

Figure 3 – Urban Heat Island due to the use of air-conditioning systems and fossil fuel burning.

Fonte: https://www.metlink.org/fieldwork-resource/urban-heat-island-introduction/, accessed on July 2025

2 Greenhouse Effect

The Greenhouse Effect is the process of infrared rays reabsortion by the Earth's atmosphere. It is essential for life, because otherwise the planet would be much colder: around -18°C (NASA, 1998). The problem with the current way of studying this phenomenon is that we are trying to dissect the contribution of the various components of the atmosphere and study them separately.

What we call Greenhouse Effect is the resistance generated by the solar radiation pressure in opposition to the radiation reflected by the planet's surface. We know that the radiation emitted by a star decreases with the square of the distance; so the maximum temperature that Earth can reach depends much more on the intensity of solar radiation received than on the composition of the atmosphere itself. This is because a planet's position relative to its star not only affects the amount of energy received but also influences the rate at which it loses heat to outer space. Since there is no perfect vacuum, the temperature of outer space around a planet is also directly influenced by its distance from its star (PENZIAS; WILSON, 1978).

In other words, even as the Greenhouse Effect affects global climate a lot, there is a limit to its effect. The Greenhouse Effect acts like a blanket, trapping heat and preventing it from escaping into space, but it does not create more heat. There is a maximum temperature that Earth can reach, which is influenced by the position of the Earth relative to the Sun and the intensity of radiation sent by it. These two factors change only on cosmic time scales, so it is possible to stabilize the planet's climate in the long term.

The poles receive less solar radiation and, due to the ice also reflect some of it, enhancing the cooling effect of the area. This creates a constant flow of heat between the Equator and the poles. At all times, the planet reflects part of the heat as light energy into outer space. That is why when Voyager took its last photo, the planet could be seen as the "Pale Blue Dot", if Earth did not radiate energy to outer space all the time, our planet could not be seen (Figure 4).

This is obviously a simplified view of the issue, as ice intensifies the degree of reflection of solar rays and can reach a critical point that generates Ice Ages. Another reason why it does not make sense to dissect the degree of greenhouse effect of each atmospheric component is that depending on the concentration, its effect can reverse. Very cloudy days and/or with a lot of atmospheric smoke cause more solar rays to be reflected by the atmosphere than reabsorbed by the Greenhouse Effect, that is, the same components can affect the climate differently under various circumstances.

Figure 4 – Earth's photograph taken from Voyager 1

Fonte: NASA/JPL-Caltech

Besides, due to the rotation of the planet, there is a difference between day and night on opposite sides of the Earth, and this difference also influences terrestrial winds. During the night, the planet loses thermal energy more intensely to outer space, which ends up bringing winds from the warmer areas to these regions due to the natural flow of heat.

The most famous greenhouse gas is carbon dioxide, which is produced mainly by the burning of fossil fuels such as oil or coal. However, there are other gases that have this property, such as methane - which generates a lot of discussion in terms of the effect of livestock farming on climate change. Plants absorb carbon dioxide to produce organic matter and many evolved during the Carboniferous period when CO2 concentration was much higher. For this reason, emissions of this gas will only enhance the growth effect of plants if humanity does not continue with abusive deforestation practices.

Dispite less discussed, water vapor has greenhouse properties that work as a feedback effect (BRIAN; ISAAC, 2005). This name was given because the warmer it is, the more water vapor can be retained without saturation or precipitation in the form of rain. Thus, in urban heat islands, it is possible to retain a large amount of water without rain; and this water vapor will enhance the thermal sensation in the environment due to its greenhouse effect capacity.

However, even if all fossil fuels were consumed, the Earth's temperature would still be at a pleasant level for life, as has occurred in other geological periods. The minimum and maximum temperature that a planet can reach depends mainly on the distance it is from the star it orbits and the type of star. Therefore, Venus will always be too hot for life as we know it, and Mars does not receive enough solar energy to sustain it - unless some nuclear power plant is built, which seems unlikely in the near future. The focus of environmental scientists should therefore be on controlling atmospheric entropy levels: first by stopping the use of air conditioners and then by creating geothermal cooling systems.

Besides, it is a mistake to think that the increase in temperature on Earth will directly cause an increase in ocean levels. The increase in temperature will influence the water cycle forming more storms that can increase rivers and lakes, which can be directed to arid regions using geothermal cooling.

2.1 Urban Heat Islands and Rio Grande do Sul Floods

The urban heat islands formed by the cities of the Southeast have a high concentration of air conditioners, making it difficult for water vapor to saturate. The atmosphere in the metropolitan areas ends up having a large concentration of water on hot days, which does not precipitate easily due to the intensive use of air conditioning and a large amount of fossil fuel burning - many cars in a small space. Remembering what has already been explained earlier that water has a feedback effect in relation to the greenhouse effect, except on very cloudy days.

The air with high water saturation follows the natural flow of heat, meaning it moves towards the South Pole where it encounters a cold front that forces its saturation, resulting in the floods and inundations being experienced in the Southern Region of Brazil. The disasters seen in the Southern Region can recur if there is no change in how the Southeast region cools itself. However, if geothermal cooling begins to be used on a large scale, not only could these tragedies be avoided, but we could also see positive effects regarding combating desertification in the northeastern hinterland. The opposing problems between the Northeast and South of the country are both connected to the high atmospheric entropy of metropolitan regions.

3 Geothermal Refrigeration

For the goal of real cooling and providing thermal comfort to the population, it is necessary to follow the Laws of Nature: specifically transferring thermal energy from an environment to a colder thermal reservoir. In practice, outer space is the only cold source when analyzing planetary thermodynamics. The interior of planets has high temperatures due to the effect of gravitational pressure (SIMON; GLATZEL, 1929), and we receive thermal energy from the Sun during the day - part of which is retained in the atmosphere by the Greenhouse Effect. However, since the planet continuously loses thermal energy to space, there is always a cold source underground (Table 1). In other words, at a certain depth in the soil, the temperature tends to be lower than at the surface during the day.

Table 1 – Soil Temperature vs Depth

Fonte: https://renouvelable-habitat.fr/en/soil-temperature-at-2m-depth

Depth(m)	Temperature(°C)
0.5	10 – 15
1	12 – 15
2	13 – 16
3	14 – 16
4	15 – 17
5	15 – 18
10	18 – 25
300	25 – 30
1000	30 – 50

Geothermal refrigeration is naturally more efficient than an air conditioner because it follows the natural flow of heat. There are various ways to design a geothermal refrigerator, but the principle of all is the same: bury some fluid a few meters below the ground and use a pumping system connected to some thermal radiator. Using water as a fluid is the most natural option due to its excellent thermal capacity and the fact that it is abundant on Earth.

The temperature of the soil varies according to the latitude on the planet, type of soil, season of the year, and time of day, among many other factors. Therefore, the depth of the wells for geothermal refrigeration is a data that must be obtained experimentally, and I cannot estimate in this thesis the amount of heat that can be extracted from the environment using this technology.

However, another advantage of geothermal refrigeration, compared to air conditioners, is the fact that it can be used outdoors. Since this technology truly has the power to cool an environment - by following the natural flow of heat - the effect of its use is beneficial throughout the neighborhood. Unlike air conditioners, which worsen the thermal quality in neighboring spaces.

It is common knowledge that trees positively affect the local climate, cooling it down, and in many cases, making the thermal sensation feel a few degrees lower than in the same city in a less green area. However, this difference is often attributed to the fact that trees provide shade, rather than the main reason, which is that they can draw water stored underground at a temperature much lower than that of the atmosphere at the moment. The goal of geothermal refrigeration is to create the same cooling effect that tree cover generates, but without having to wait for the tree to grow. In addition to the fact that many environments that need cooling cannot have trees on site.

In order to calculate the planetary thermodynamics, it is necessary to divide between organic and inorganic, because living beings have their own metabolism that influences the global climate. And life is not distributed equally across the planet; there is much more metabolism within the Amazon than compared to the Sahara Desert. Similarly, thermal machines are not evenly distributed across the planet; urban centers like São Paulo have much more machinery using energy than a village in Africa. All these parameters still need to be studied in more depth, and it should also be kept in mind that there is a barrier of winds between the Earth's hemispheres, and therefore distinct measures may be necessary between them.

The most usual construction of geothermal refrigerators consists of burying pipes with water or other refrigerant fluids, as shown in (Figure 5). However, I believe this is an inefficient project compared to creating impermeable wells connected to a pumping system that will create an "urban circulatory system," as shown in (Figure 6). The reason is simple: the less earth you need to remove for construction, the cheaper it becomes, and the amount of water stored determines the cooling power of that geothermal refrigerator. This is a closed system, meaning that the water added to the well will not leave the system except in case of leaks and damage. The well is then connected by pipes to multiple thermal radiators so that heat can be exchanged with the environment.

This technology is not only beneficial for urban centers, as it has the potential to revolutionize agriculture. In addition to being able to create greenhouses with controlled climate, it is possible to combat desertification through the production of organic matter and seedling cultivation. Therefore, geothermal refrigeration greenhouses act in multiple ways against desertification and can be the key to converting unproductive lands into economically autonomous regions. However, for use in closed environments, it may be necessary to use fans attached to the radiators for better efficiency in thermal exchanges. In (Figure 7), I exemplify an outdoor radiator use, and in (Figure 8), it is an example for a closed environment.

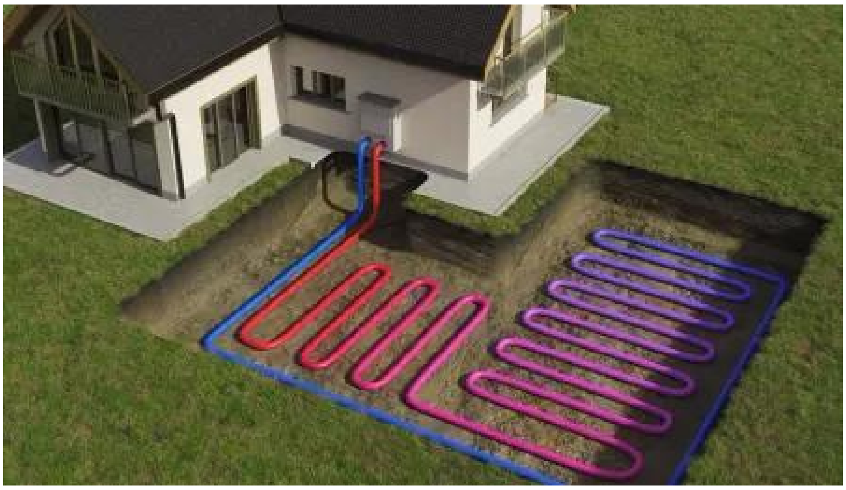

Figure 5 – Scheme of a geothermal refrigerator with pipes buried in the ground

Fonte: https://pt.solar-energia.net/energia-renovavel/energia-geotermica, accessed on June 2025

3.1 Experiment

This thesis is written in a purely theoretical form, and it is necessary to create an experiment to confirm it, always making it clear that scientific development must be empirical and collaborative. The proposed experiment is to choose a metropolitan region with high air conditioner usage and create the first geothermal refrigerator in the area. Once the refrigerator is operational, it is necessary not to use air conditioners and utilize meteorological monitoring systems to verify if the cooling effect aligns with the theory. It is important to remember that it is still not possible to predict how many systems will need to be built to stabilize the Earth's atmosphere, even if this theory proves valid.

As previously mentioned, the ideal depth for the wells - which should be around 2m - varies depending on various factors such as latitude, season of the year, and type of soil. However, since the amount of heat generated in urban areas would decrease with the end of air conditioners, another beneficial effect is that this would be reflected in the temperature of the underground over time, meaning that this system becomes more efficient at removing heat as the years go by.

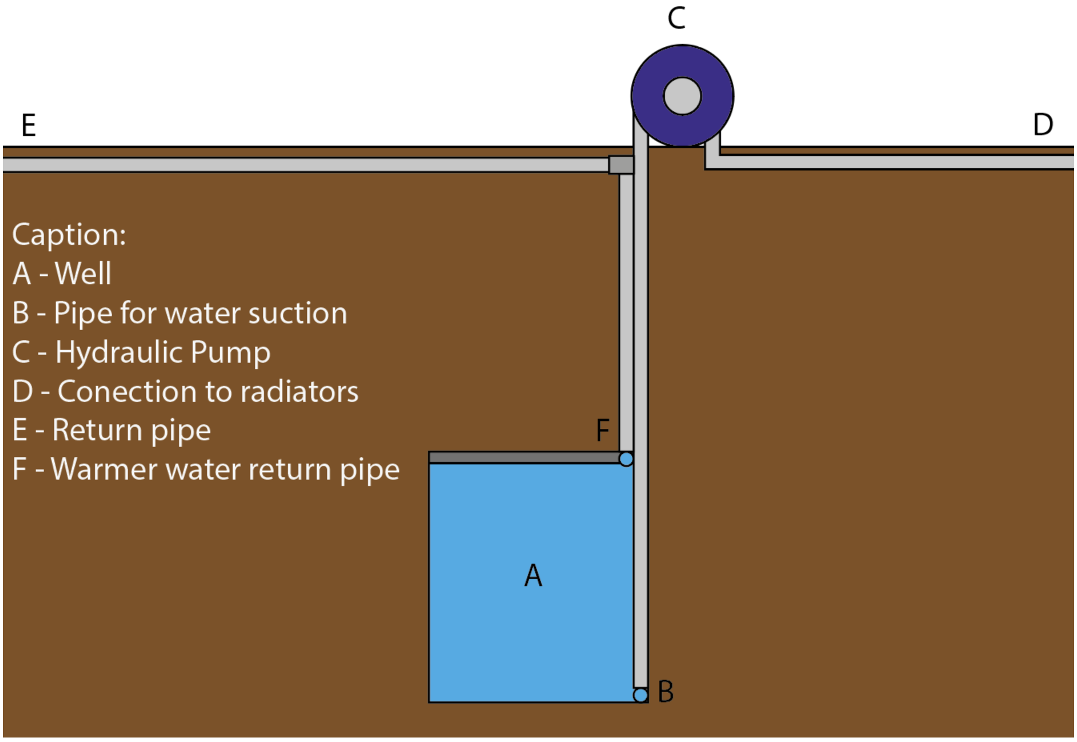

Figure 6 – Suggestion of a geothermal refrigerator with wells and radiators

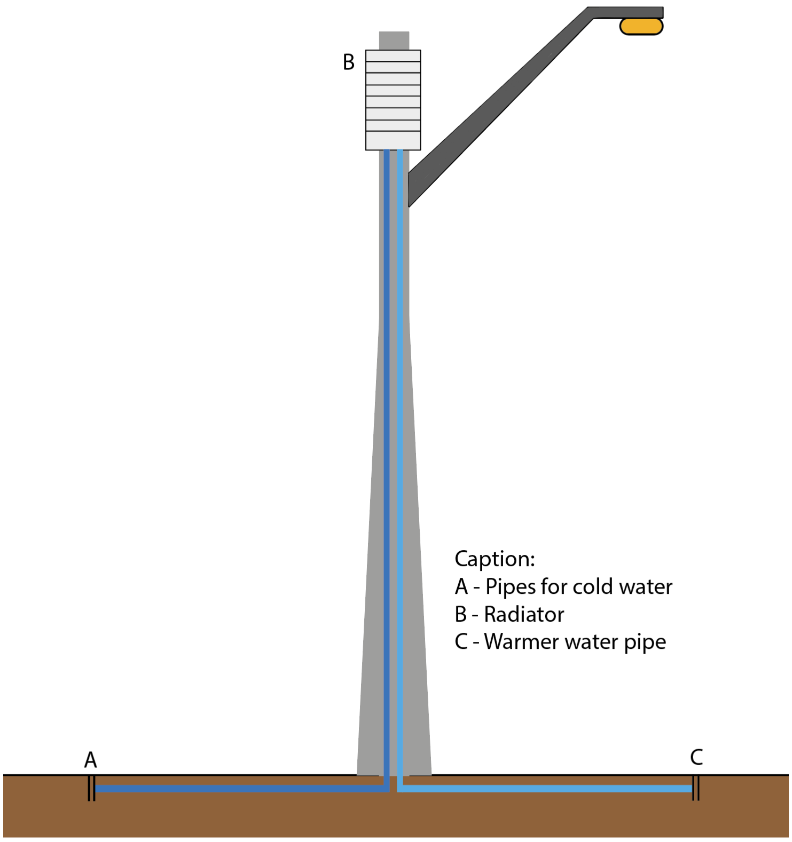

Figure 7 – Scheme of construction of an outdoor radiator - ex. street lamp

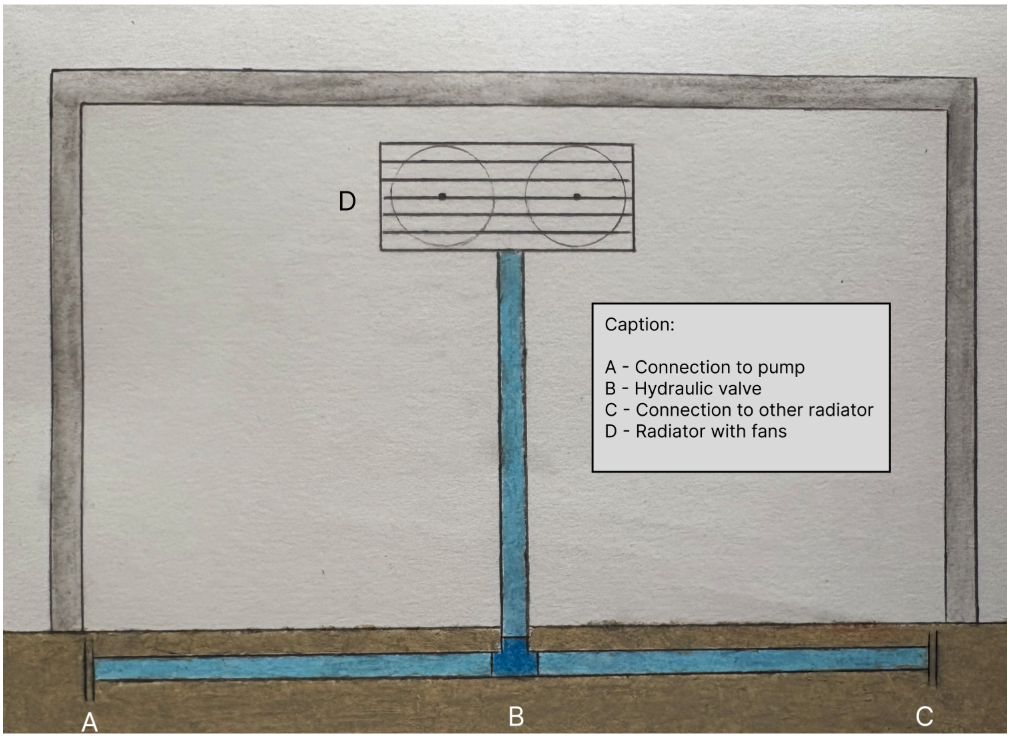

Figure 8 – Scheme of construction of an indoor radiator - ex. greenhouse

4 Conclusions

Geothermal refrigeration technology, when applied with modern agriculture techniques, has the potential to improve food yield and quality - helping to combat hunger that still plagues the world. Additionally, when applied in areas surrounding desertified regions, it can redirect water from melting polar ice caps to combat desertification. In summary, this thesis should not only be read as a hope against the Climate Crisis, but as the beginning of a Green Revolution on the planet. If the results of the experiment described here are positive, it could mark the start of global climate agreements that address both the fight against hunger and desertification worldwide.

The fossil fuils are essential for the functioning of modern society, and even though they are currently considered the cause of climate disasters, it is still difficult to imagine a society without their use. The main objective of this thesis is to place the blame for climate change where it belongs: on air conditioners. However, fossil fuels are still a non-renewable energy source, and society must begin to plan for the *Post-Oil Era*.

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