GFWA (Generating Fresh Water from the Atmosphere): Exploring the Effects of Temperature on Water Vaporization

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<u>Research involving non-human vertebrates or human subjects was conducted under the supervision of an experienced teacher or researcher and followed state and federal regulatory guidance applicable to the humane and ethical conduct of such research</u>

Table of Contents

Introduction	2
Background Research	2
Materials and Methods	4
Experimental Procedure	7
Results	7
Discussion	9
Conclusion	12
Future Research	12
References	14

Introduction

Drought is a global problem with widespread economic and environmental ramifications, affecting millions worldwide. Lack of rain and dry weather is the leading cause of water scarcity. City water supply has become expensive, and traditional water supply methods can be pricey and unsustainable in the long run. A recent statistic (drought.gov, 2023) shows that 36.72% of the USA is in drought. Therefore, there is a need to find cost-efficient ways to generate water without damaging the ecosystem. There is a need for atmospherically generated water to defeat drought and utilize our current water supply. This research paper will investigate the atmospheric water generation method while utilizing the Peltier effect and see if it is a better solution compared to traditional water conservation methods. This project aims to explore the feasibility of atmospheric water generation as a cost-effective solution for households facing water scarcity. The project will evaluate the system's performance, efficiency, and sustainability to determine its feasibility in addressing water scarcity in drought-prone areas. The project aims to test the effectiveness of the atmospheric water generation prototype “GFWA” using heat compression and the Peltier effect. The project's findings will contribute to developing an innovative and cost-effective solution to address the drought issue. The hypothesis is that GFWA can generate a minimum of two fl. oz of water daily from the atmosphere, providing a cost-efficient solution for households to produce clean drinking water.

Background Research

As drought grew into a major problem, scientists and environmentalists created conventional solutions to solve these issues. Although these solutions are commonly used and seem to be solving the issue of drought there are quite a few issues with them.

Conventional Solutions

1. Rainwater Harvesting
2. Desalination
3. Irrigation Efficiency
4. Water Conservation

Rainwater Harvesting: This is the process of collecting rainwater and using it for common water uses, such as watering plants or taking a shower. Although this method is helpful, it is highly improbable. It is unpredictable to know whether it will rain or not with a 100% guarantee, so people who rely solely on rainwater harvesting do not have a guarantee that their home will be equipped with water that day. An option to avoid this is saving rainwater, but that leads to less water to use.

Desalination: Desalination is the process of removing salt from ocean water and getting clean, fresh water. Despite this method seeming very efficient, it requires significant energy and can be expensive.

Irrigation Efficiency: This process reduces water waste and makes better use of available resources. The only issue is that it may require significant upfront investments and may not be feasible for small-scale or subsistence farmers.

Water Conservation: This issue is the process of saving water for later, which reduces the water demand. The only problem with this method despite it being so widely used is that it is impractical to work in large-scale drought conditions.

Innovative Solution

The goal of GFWA is to generate clean water without taking resources from any other area, which would lead to higher costs. This device needs to be cost-efficient, efficient in water production, and produce a clean water output.

After some research, it was finalized that the key element of GFWA would be the Peltier effect. The Peltier effect is powered by a chip, the Peltier chip, that uses hot and cold temperatures with a cooling source to create a temperature gradient that will produce humid air. The air can be tweaked to generate water.

Peltier Effect Research

- The Peltier effect causes a temperature difference when an electric current flows through a junction of two conductive materials.
- This effect can be used in thermoelectric water generation to condense water from humid air.
- The process involves creating a temperature gradient across a junction using a thermoelectric module, cooling one side while heating the other.
- Humid air is passed over the cooled side, and as it cools, water vapor in the air condenses and can be collected.
- This process is useful in areas where water is scarce.

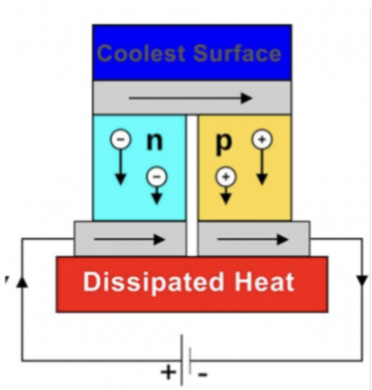

Figure 1.2, Created by Science ABC

Peltier Effect Diagram

Materials and Specifications

GFWA is constructed with two primary elements. The Peltier zone, and the water accumulation zone. **Reminder:** This is a small-scale prototype that resembles a much bigger version of this machine to power individual houses with water from the air.

Peltier Zone

For the Peltier Zone, there is a key chip that powers the water generation effect. This chip is called the Peltier chip and it essentially uses cooling and heating technology to generate water.

The only issue is that it needs a heavy cooling source to do so, and for large-scale water production, this technique is inefficient. What I needed to do was utilize this effect since it is cheap to implement, and create a mechanism that allows it to generate water. I decided to make a small-scale prototype that would generate a minimum of 2 fl oz per day.

I went through 8 variations of the Peltier zone to get to the final model of the Peltier chip effect. Many of the variations included fans that had a Peltier chip hooked up to them, but I concluded that the most effective way to cool the Peltier chip is a CPU fan. I noticed that the Peltier chip was in a CPU shape, and it can be cooled just like a CPU using the CPU fan for a PC. I realized that the previous Peltier variations had fans that were a bit too slow, which either generated ice or no water at all. To fix this, I had to use a fan that would create a spread of cold air, not only on the surface of the Peltier chip but also inside of it too. That is how I concluded a PC fan would be of great use. I attached a solar panel that I got embedded in the fan for $5. The panel gets light by using photon technology to get enough photons through the top metal gate of the heatsink. The Peltier zone was a Peltier chip attached to a PC fan.

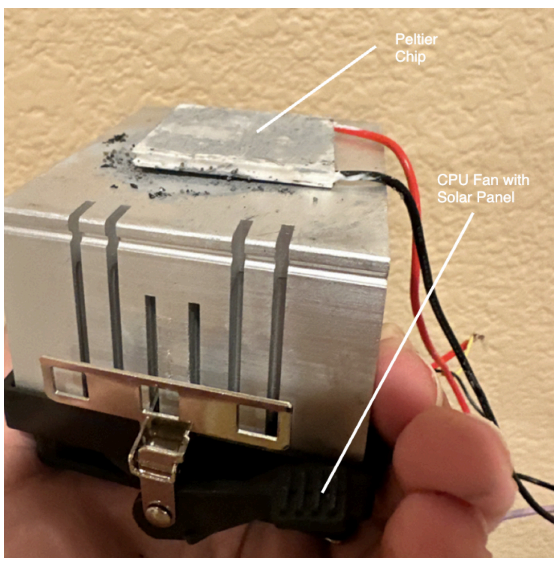

Figure 1.3, Peltier Zone

<u>Water Accumulation Zone</u>

This sector was the easiest part to make, however, I also needed to experiment with this part on creating more water with an effective water accumulation technique. I started working on this part after finishing the Peltier zone for any time I built my variations. Initially, I used a little glass dome lined with aluminum foil to maintain the air temperature for water accumulation, however, on my seventh variation, I figured out that using a metal heat sink rack would be the best way to create water. This rack would have the humid air created by the Peltier chip and the CPU fan pass over and flow through the rack, thus generating water.

Figure 1.4, Heat sink rack and Mesh

Since I wanted this prototype to resemble a large-scale machine, I planned to make a smaller prototype of exactly what the large-scale machine would resemble. I planned to filter the water generated from this machine to get clean and fresh water from the air. I used carbonated ceramic balls stored inside a filter mesh which will act as a cap for the heat sink rack mentioned above to filter the water.

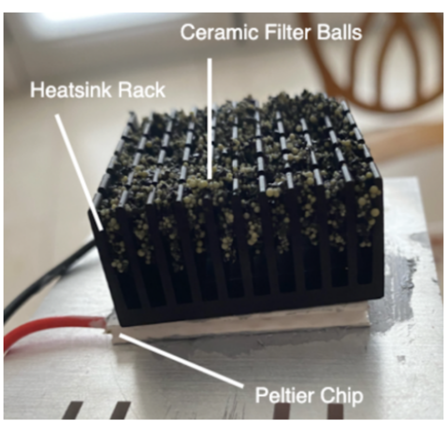

Figure 1.5, Water Accumulation Zone

To create the filter balls, I took some ceramic balls and put them in a zip-lock bag, which I then carbonated. These carbonated balls will act as a filter that absorbs the gunk it receives, thus not having to replace these balls and making them cost-effective. After this machine started generating water, it was time to perform tests.

Figure 1.6, Final Prototype

Experimental Procedure

1. Measure water generated daily for 11 days in ounces
2. Measure the cost of the device
3. Test the ppm of TDS in the water compared to regular water sources (Rainwater, Tapwater, Distilled Water)
4. Use the water generation values and map them out on a coordinate plane to get a least squares regression line
5. Create a theoretical water bill deduction to test for the cost-efficiency of GFWA

Results

There are 3 factors GFWA was tested on:

1. Water Generation for 11 days by GFWA
2. Cost of GFWA
3. Water ppm of TDS for GFWA

Water Generation for 11 days

GFWA water generation levels:

Day 1: 3.43 fl oz

Day 2: 2.97 fl oz

Day 3: 4.03 fl oz

Day 4: 3.27 fl oz

Day 5: 3.74 fl oz

Day 6: 4.23 fl oz

Day 7: 2.66 fl oz

Day 8: 4.48 fl oz

Day 9: 3.58 fl oz

Day 10: 4.12 fl oz

Day 11: 2.82 fl oz

From a look at these values, GFWA met the hypothesis requirement of more than 2 fl oz per day, but the data still needs to be plotted in the discussion section.

Cost of the Device

Product	*Cost*	*Total Cost*
CPU Fan	$11	
Peltier Chip	$6	
Solar Panel	$5	
Heat Sink Rack	$1	
Filter Mesh	$1	
Ceramic Filter Balls	$0.45	$24.45

GFWA came to a total cost of $24.45.

Water ppm of TDS

Figure 1.8, GFWA ppm of TDS

GFWA came to 6 ppm of TDS which means that the water is very clean.

Discussion

In this project, several factors were tested on GFWA. They are listed below. This section compares and discusses the results.

1. Water Production
2. ppm of Solids
3. Water Cost Efficiency

Water Production

Although all the values for the 11 days met the hypothesis, there is a need to graph the points on a plot and see the amount of water that will be generated on a completely normal day by this machine. I plotted all the points on a graph with their cumulative values (water generated that day + water generated before that day).

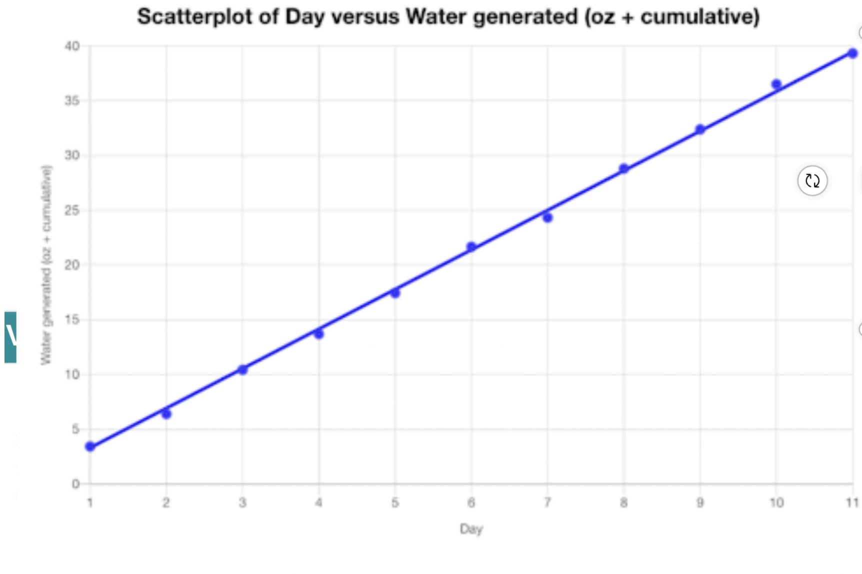

Figure 1.9, Water Regression Line

In Figure 1.9, I plotted all the points and created a regression line for all these points. The slope of this line came out to be 3.663 fl oz of water (approximately 3.7 fl oz) which validates the part of the hypothesis that states that the machine should generate more than 2 fl oz of water per day.

<u>ppm of TDS</u>

Figure 2.0, Ppm of Rainwater

Figure 2.1, Ppm of Distilled Water

Figure 2.2, Ppm of Tap Water

Figure 2.3, Ppm of Mix of AWG samples (Day 1 -11)

Santa Clara County, the county I live in, also has its own AWG machine, but that machine is currently still in testing. If this machine was actually in use without us knowing, it would be supplied through a tap. We can see in this image that rainwater and tap water both have very high ppm of TDS (162 and 157 respectively) values which shows that they are not fit for drinking or common use. Even though they might have an industrial-sized machine, while I have a small-scale prototype, health comes first before anything. People could potentially get sick due to this tap water, while my machine on the other hand produces clean water. Distilled water which is one of the cleanest water sources had an amazing ppm of TDS of 10. On the other hand, GFWA had an average ppm of TDS of 6. This shows that GFWA water is one of the cleanest water sources out there.

Water Cost Efficiency

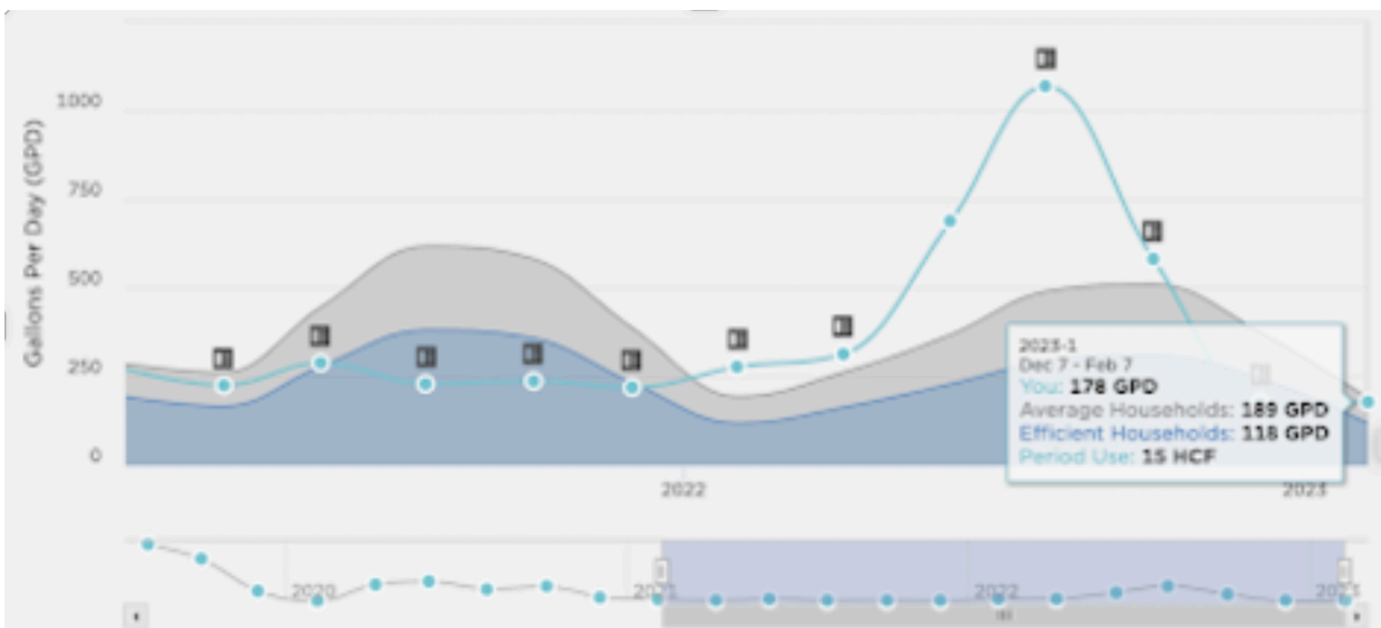

Figure 2.4, Water Bill for My Household

This is a picture of my city water bill and these metrics relate to my house. Using these water bill metrics, the way to test if GFWA is cost-efficient is by using the statistics of this bill and seeing how GFWA can make an impact. The water bill for the 60-day period from Dec 7th, 2022 to Feb 7th, 2023 shows that 15 HCF (Hundred Cubic Feet) was used, resulting in a cost of $263 for approximately 11,220 gallons of water. GFWA costs $24.45. If we were to use this money for water from the city, we would receive 1048 gallons in return. Despite the incredibly low cost of GFWA, in those 60 days, it would only generate 1.87 gallons of water (calculated based on the 3.663-gallon metric above). As far as these 60-day tests, GFWA is deemed not cost-effective, however, GFWA will be cost-effective when used for a longer period of time. Essentially, GFWA is a one-time cost of $24.45, which means that over time, if this machine were to run for a long time, it would generate the amount of water that is equivalent to its cost, 1048. Another thing to point out is that I used the GFWA prototype in this certain test which is a small-scale version of the real innovation. If it were to be larger and industrial-sized, it would generate much more water.

Conclusion

We can conclude that GFWA generated an average of 3.663 average fl oz of water per day, and this metric can be used to say that this small-scale prototype will generate 3.663 fl oz of water on a regular day. GFWA produced water with a low ppm of 6 compared to other water sources such as rainwater, tap water, and most importantly, distilled water. GFWA was somewhat cost-efficient because it generated around 3.7 fl oz of water per day for a one-time cost of $24.25. It will also be fully cost-efficient when the system that is industrial-sized and will power individual homes is developed; this stage of GFWA is just a prototype. For it to be deemed cost-effective just in its prototyping stage, the test will need to be conducted for longer than 60 days. It will save money on water bills if used for a longer period. During the 8 variations I made, I discovered that more heat sinks at a certain level will generate high amounts of water, which is what I used in my final small-scale prototype. GFWA produces more than 2 fl oz of water per day, generates clean water, and is somewhat cost-efficient, thus validating the hypothesis.

Future Research

As far as future research, the first step is to make GFWA industrial-size so it can power individual homes. A reason for making it a device that powers homes individually compared to having a general one that powers the entire county is due to the water going into a canal. Since I live in California, there are frequent earthquakes, so in the case there is an earthquake and the canal cracks, all the water will go to waste. From creating 8 variations, I figured out that this device works exponentially. This means that in the case that we have 2 GFWA prototypes and combine them by putting the Peltier chips in the middle next to each other, the machine will generate 16 fl oz (exponential amount) of water instead of 8 fl oz of water (addition amount) with the knowledge that 1 GFWA prototype makes 4 fl oz per day. A bigger machine for houses will create a very high yield of water.

Partially relating to the paragraph above, I plan to test a theory that GFWA will yield water with more heat sink racks. I inferred that the Peltier chip could spread its humid air over great amounts of surface area. To test this out, I want to add around 3 more heat sink racks and see if the machine yields around 16 oz of water. This option would be much cheaper as 3 more heat sinks will cost $9.00 while the exponential option above which requires another GFWA prototype will cost $24.45.

Another area of future research is to make GFWA a wilderness survival tool. In the wilderness, we don't have water or electricity, but GFWA can make water without using electricity. The only issue is that this compact version (current prototype) does not generate water efficiently by itself. Future research that I want to do regarding this area is to potentially make this machine much more compact, but yield around 30 oz of water daily. This makes it efficient, easy to carry, and cost-efficient. This research can benefit explorers in the wild or scientists in the wild trying to study nature.

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