

CO₂ SINK; A MINI CLOSED-LOOP ALGAE CARBON CAPTURE DEVICE FOR SEQUESTRATION AND STORAGE

Proponents:

Cayetano, Mark Apollo V.

Cuadra, Helen C.

Jamilano, Aizhar T.

Lubiano, Jannah Mae R.

Rea, Zion Andrew B.

Valdejueza, Sheryn P.

STEM 12-F (RCE)

Luis Palad Integrated High School

Senior High School

CHAPTER I

INTRODUCTION

Background of the Capstone Project

A. Related Personal Experience

From a personal experience of one of the proponents about algae started at a young age, for the reason that the proponent's father used to go on fishing trips and always talked about the reason why the water on the pond turns green at certain times. Eukaryotic organisms bloom when there are a lot of minerals, carbon dioxide, and sunlight. Fast forward to 2016, the proponent had read an article while browsing the web on how algae capture carbon dioxide just like plants do. It developed the interest of the proponent in the possibility and sustainability of an algae bioreactor. The proponent recognizes the feasibility of interconnected algae carbon sequestration bio-reactors and the impacts it has on the community.

The potential of algae was not clearly visible before. With the events of global warming and climate change all over the world, various proposals for devices that can minimize the excess carbon dioxide are prominent. From another personal experience, the proponent had asthma caused by air pollution that served as a driving force to conduct a study that can promote cleaner air to breathe. Through reading articles, and the personal background of the proponent found a microorganism that can capture the huge emissions of carbon dioxide that is a threat to Earth's atmosphere, the algae. In fact, algae as a carbon capture is a feasible and greener way to solve air pollution. The proponent noticed the potential of algae to minimize the carbon dioxide in the atmosphere.

B. Related Literature

According to a statistic, The World Bank, & Rozowska (2021, June 7), there are 36.7 billion metric tons of carbon dioxide in 2019. Similarly, the urbanization of the Philippines has reached 47.41% in 2020. In fact, Statista (2022) stated that there's a resulting decrease in land use for ecological sites. According to U.S. Geological Survey, (2022) Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide.

Britannica (2016) defines algae as a group of predominantly aquatic, photosynthetic, and nucleus-bearing organisms that lack the true roots, stems, leaves, and specialized multicellular reproductive structures of plants. Microalgae gather solar energy through a photosynthetic process and store it as chemical fuels (Mussnug et al., 2007).

According to Onyeaka, H., Miri, T., Obileke, K., Hart, A., Anumudu, C., & Al-Sharify, Z. T. (2021), microalgae CO₂ bio-capture efficiency varies based on algal physiology, pond chemistry, and temperature.

Furthermore, according to research conducted by Keffer and Kleinheinez (2002), CO₂ collection efficiencies range from 80 to 99 percent under typical circumstances, with gas residence times of less than two seconds. In the case of a 200 MWh natural gas-fired power station.

According to Nwoba, E. G., Parlevliet, D. A., Laird, D. W., Alameh, K., & Moheimani, N. R. (2019). In microalgal cultures, the major obstacle limiting their photosynthetic efficiency and output is the lack of light (at the appropriate intensity and wavelength). Appropriate light management has the ability to simultaneously increase photosynthetic productivity while also controlling the temperature of microalgal photobioreactors, lowering total production costs.

According to Gao, Y., Gregor, C., Liang, Y., Tang, D., & Tweed, C. (2012). The closed algal system enables better control over environmental conditions and biological contaminants, as well as higher productivities and harvesting rates and less contamination, which open systems are more sensitive to.

In conclusion, the findings summarized that carbon dioxide capture by closed-loop (system) algae bioreactors appears to be a viable option. A promising technology for reducing or eliminating environmental pollution.

Significance of the Problem

The capstone project is essential for capturing the excess carbon dioxide in the atmosphere of a particular community. This part of the research contains the beneficiaries of the project. It is presented as follows:

- **The Community:** Through implementing the device in every home, the research may help to lessen the carbon dioxide levels that lead to pollution within the community.
- **The Students:** This project will increase the student's understanding of the potential and importance of algae in capturing, sequestering, and storing carbon dioxide, as well as the student's creativity in making or enhancing a device that will play a vital role in reducing the huge effects of pollution caused by the excess carbon dioxide in the atmosphere.
- **LGUs:** To promote community-based carbon capture in a real-world scenario. And think of ways to better implement such devices.
- **The School Administration:** The research will be an eye-opener to identify how to implement new and effective devices that can anticipate the problems of excessive carbon dioxide production.
- **The Future Researchers:** The findings of this project can be used by researchers who need to continue with the previously mentioned research. It will assist them in formulating their ideas.

Statement of the Problem

General Objective:

The capstone project was directed towards its primary objective of conducting an experiment in a particular community regarding the effectiveness of algae in a mini closed-loop carbon capture device to capture the emissions of excess carbon dioxide in the atmosphere.

Specific Objectives:

1. What is the level of the mini closed-loop algae carbon capture device in terms of:
 - 1.1 Carbon dioxide storage
 - 1.2 Carbon dioxide in the atmosphere
2. What is the significant difference between the level of carbon dioxide with and without the addition of algae?
3. What amount of light is the carbon capture device most effective in?
4. What time is the device most effective in reducing carbon dioxide in the atmosphere?

Scope and Limitations

The project aims to reduce smoke pollution in urbanizing areas. More specifically, the capstone project's primary concern is to solve community-based carbon dioxide pollution by generating the proposed device. the mini closed-loop algae carbon capture device aims to capture emissions from the atmosphere and pipe them into the algae, in a twist on carbon sequestration.

Two groups of experimental and control tests were studied, they are "with the treatment of algae" and "without the treatment of algae" and the identification of time and light levels with the highest experimental group and control group difference. This study will also include calculating the total CO₂ sequestered from the environment.

The study will be focused on the results of the control group and the experimental group, which became the basis of the t-test.

The algae sample used in this project will not be tested for its species and its lifetime while being studied for the reason of lack of time and finance. Through its limited scope, the project aims to create the possibility of interconnected carbon sequestration devices that can be implemented in polluted areas.

CHAPTER III METHODOLOGY

The capstone project's primary goal was to undertake an experiment in a specific neighborhood to determine the effectiveness of algae in a mini closed-loop carbon capture device to capture excess carbon dioxide emissions in the atmosphere. To achieve this objective, the researchers will use the following methods:

Research Design

The proponent will use a quasi-experimental design to identify if the algae carbon sequestration is effective in a community-based manner. Cook, T. D. (2015) defines quasi-experimental as the evaluation of the causal effects of long-term treatments. However, unlike "real" trials in which treatment is assigned at random, assignment in quasi-experiments is by self-selection or administrative discretion (p.1). Subjects are assigned to groups based on non-random criteria. More specifically, the proponents will use the one-group posttest only design in which the outcome of interest is measured once after exposing a non-random group of elements to a certain intervention.

Methods for Product/Process

The proponents created an idealization of a carbon capture device. The product was created to demonstrate how it can capture CO₂ in a residential setting. The device was initially designed on the basis of a 3D simulated prototype. The proponents designed the body of the device based on available materials that can be recycled to lessen its environmental impact.

The proponents realized that in order for the device to become carbon negative, the power needed to be supplied to the different electrical components must be generated renewably, thus a solar panel is added to the design. The proponents realize from reviewing multiple related literatures that algae is most effective at high levels of sunlight, It is convenient for the proponents to use a solar panel since there is no point in running it at low levels of sunlight.

Heat transfer is also a factor to be considered when building the device. According to Aly, S. P., Barth, N., Figgis, B., Essadiqi, E., Faqir, M., Ennaoui, A., & Ahzi, S. (2016, November), Solar panels work more efficiently at lower temperatures.

To store excess energy from the device, a battery is necessary for a sudden obstruction of the solar panel, which decreases its power output, though not necessarily a significant decrease in light level on the algae side. In order for the battery to charge up and work while there is less ideal sunlight, a relay is used to switch the load from using the solar panel to the battery. When sufficient sunlight

returns, the relay switches to use the solar panel instead. In addition, the proponents added a battery switch to save energy when the device is not used. The proponents then thought of ways to improve the CO₂ sequestration capability of the device.

According to one study, continually injecting 10% CO₂ gas increased algal productivity by 39% while significantly improving nitrogen removal capability. CO₂ bubbling had no harmful effect on phosphate removal. The lipid content of algal biomass and lipid production in the A-MBR rose, and membrane fouling was reduced dramatically with continuous CO₂ bubbling, most likely due to less mineral precipitation on the membrane surface at lower pHs. (Tang, T., Wan, P., & Hu, Z., 2018, p. 656). The proponents used the results of this study and incorporated a bubbling technique and a fan to increase sequestration capabilities and lessen the buildup of algal biomass. Next, an electronic schematic diagram of the power management was made.

Based on the 3D model design, the parts were assigned to their respective placements. Inside the utility box, the proponents mounted a power bank and charge controller with a speed controller, as well as a battery switch and a 5v solar panel tilted and raised from the junction box to reduce heat. The proponents connected a 16-mm PVC pipe to the junction box in the upper half of the utility box. A particulate filter to lessen dust buildup inside the pump, a 5v air pump, and an aquarium silicone hose are attached inside of the junction box, and a 5v fan intake is added to the cover plate of the junction box. Another 16mm PVC pipe linked to a 16mm Tee-joint is joined to the right side of this junction box. Inside the 16mm PVC pipe connected to the 1.5-liter plastic bottle, an aquarium silicone hose with an air stone and algae is attached to the lower half of the 16mm Tee-joint. An outtake chamber made from two 300mL plastic bottles is fitted to the upper section of the 16mm Tee-joint with a cloth on the opening to lessen evaporation and create a good seal with the outtake chamber. To prevent contamination of the readings of air quality, cotton was used to plug up and prevent atmospheric air from moving through the different parts of the device. The electrical devices were then tested and verified by a professional.

Algae is then sourced from the wastewater of aquariums nearby the proponent's community. Roughly around 1.5 liters of it was used and grown over a period of 2 days under a controlled environment before testing.

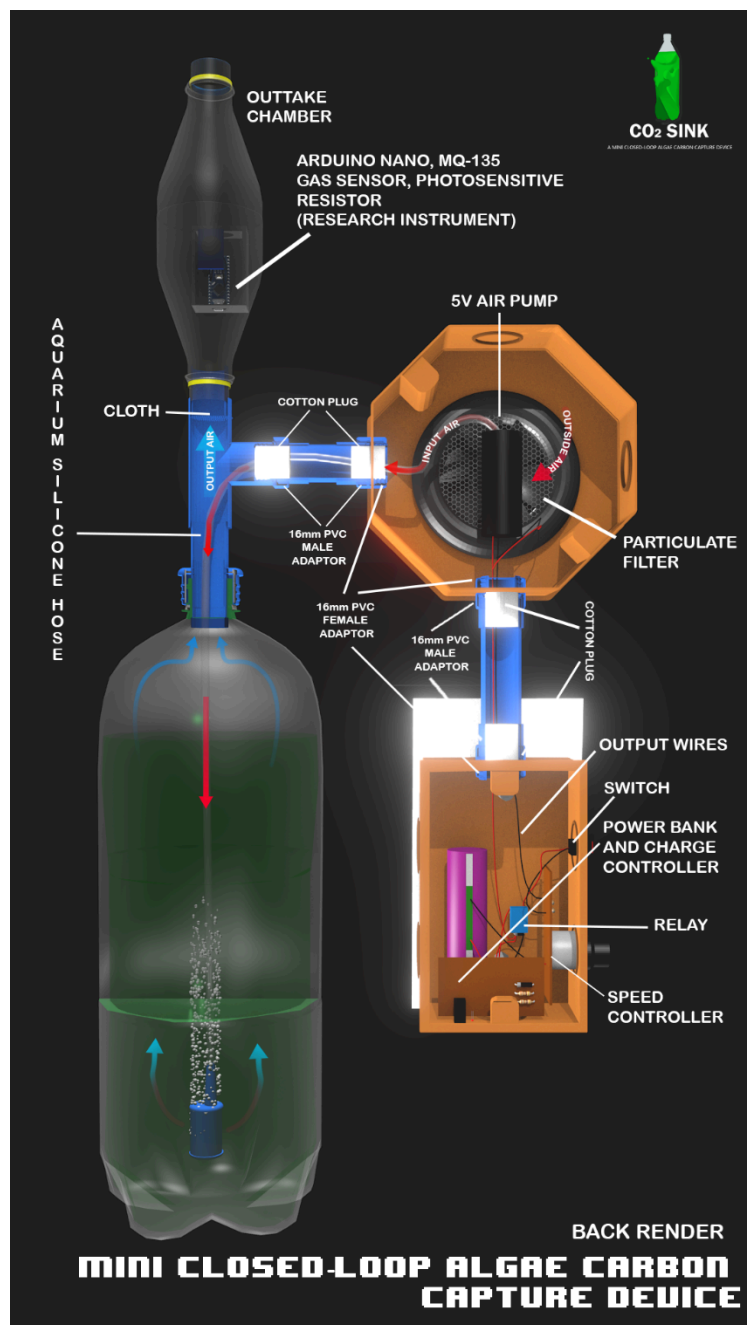
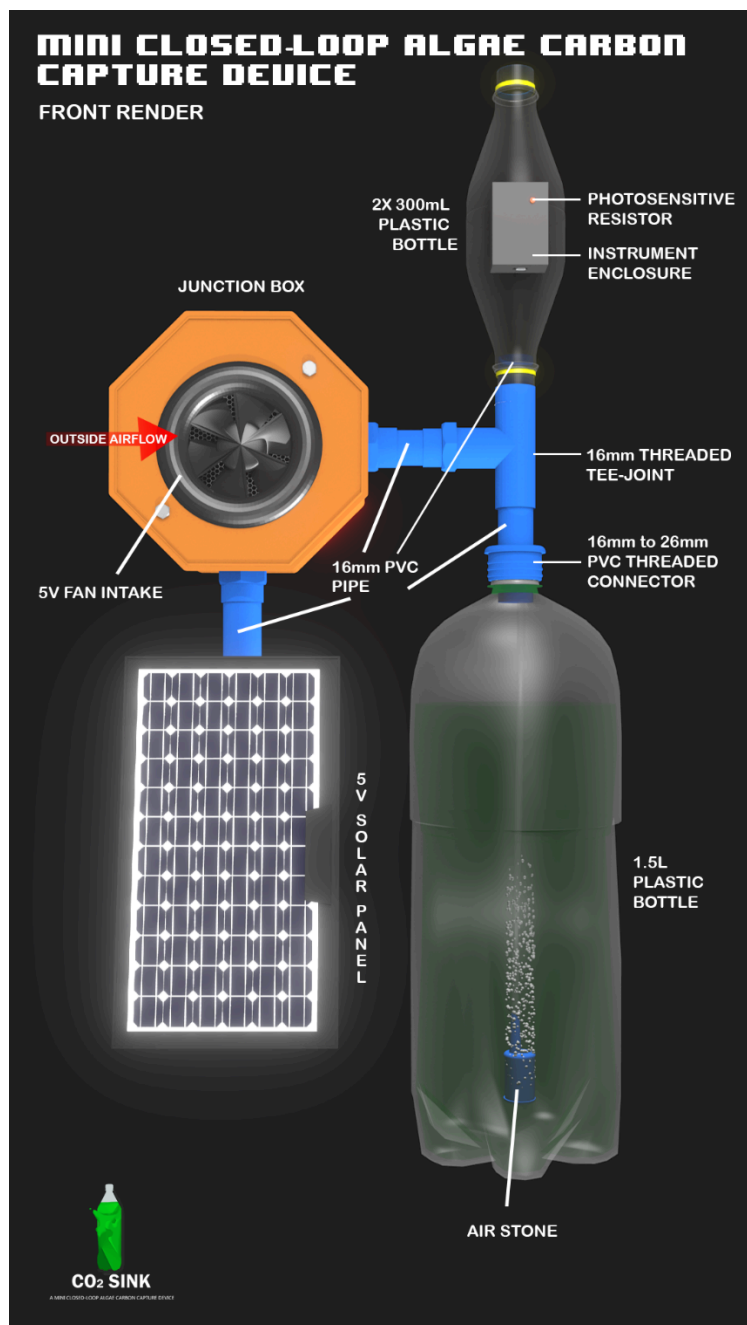


Fig 1a,1b. The figure above (Figure 1a, 1b) shows the front and back render of the 3D prototype model, its components and the demonstration of the air flow.

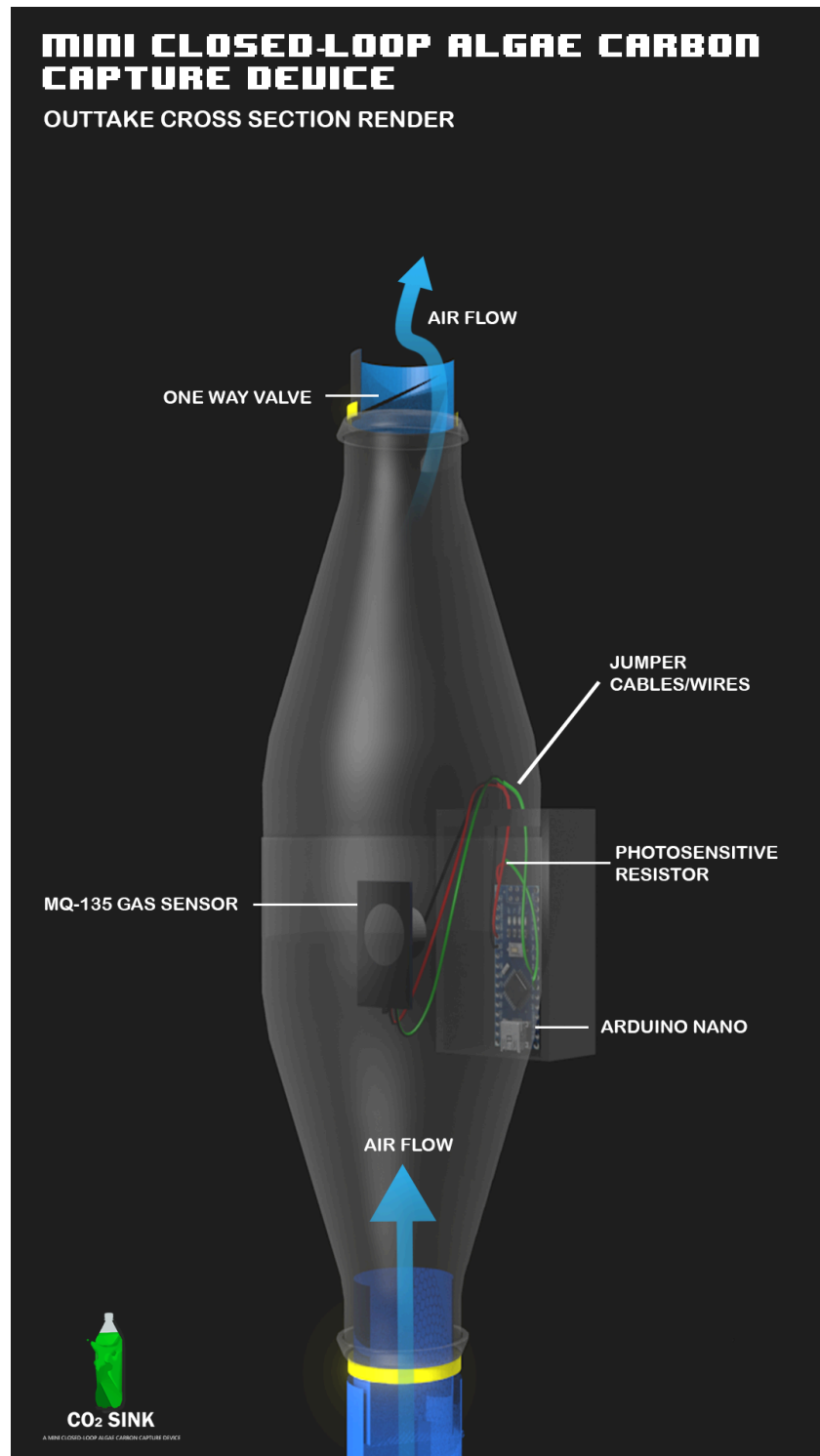


Fig 1c. The figure above (Figure 1c) shows the 3D prototype cross-section of the outtake chamber and the demonstration of the airflow.

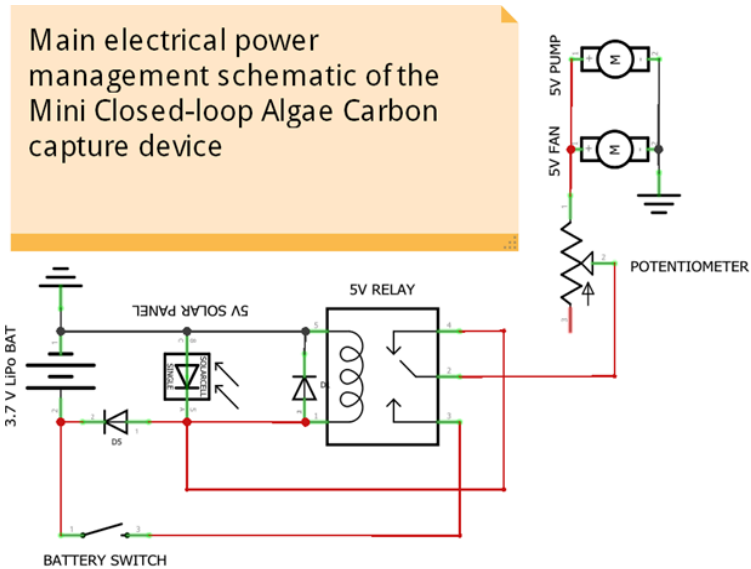


Fig 1d. The figure above (Figure 1d) shows the electrical power management schematic diagram of the proposed device.

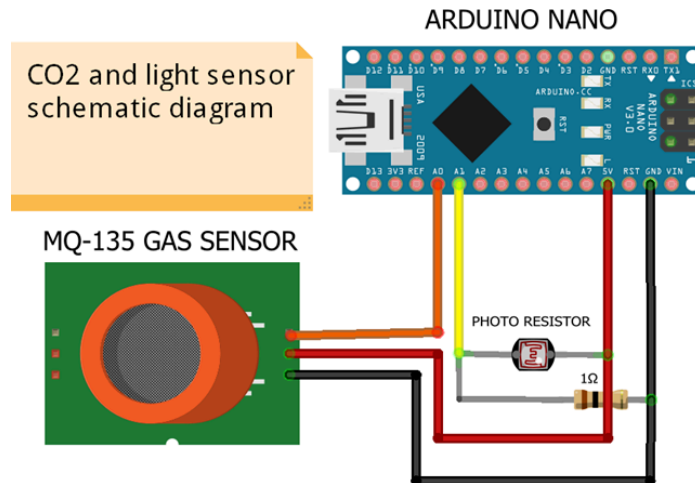


Fig 1e. The figure above (Figure 1e) shows the schematic diagram of the Arduino-based CO₂ sensor and light sensor (research instrument).

Data Gathering Methods

A. Research Instrument

The proponents will use a calibrated MQ135 gas sensor and a photosensitive resistor (LDR) controlled by a microcontroller (Arduino NANO) and log the data through serial communication with the proponent's laptop where it was also programmed. The output is then compiled by a program called "CoolTerm" and then manually tabulated in a spreadsheet.

The use of the gas sensor and microcontroller was adopted from a research paper, "To measure the gases in PPM (parts per million), the analog pin need to be used. The analog TTL is operated and operates at 5 volts, thus it can be used with the most common microcontrollers. In our project, we will use the (MQ135) gas sensor[6]" (Abbas, F. N., Saadoon, M. I. M., Abdalrdha, Z. K., & Abud, E. N., 2020, p. 2955). The proponents subsequently calibrated it using their methods. The proponents have adapted the programming in which all of the data will be measured every 15 minutes and averaged out for 1 hour automatically by the microcontroller before logging.

The use of LDR or photosensitive resistor was also adopted from a research paper, "Light level or luminance refers to the total measure of the brightness of light incident on a surface per unit area (lumens/m² or lux). Depending on the light source used, different luminance values are available, sunlight as natural light source also emits different energy levels depending on natural conditions. A typical office room, for example, requires 250lumens/m²" (Cruz, et al, 2019, p. 4), in which the proponents based the microcontroller's program to output the correct amount of lumens output by the LDR or photosensitive resistor.

The sensors will print an output through the serial monitor every 15 minutes, and this will be manually averaged to an hour. Every hour, the out-take chamber is removed to measure the atmospheric CO₂ and then returned to measure the device's output. All of the data will be tested for 9 hours (from 9:00 AM to 5:00 PM) in three different households at a similar elevation.

Based on the mathematical method and monthly horizontal radiation, a new sun-tracking system was proposed (azimuth angle of solar PV is optimized at three fixed positions daily: in the morning - eastward, noon -southward and afternoon -westward) (Ma, Y., Li, G., & Tang, R., 2011) and thus, the proponents decided to face the device south in each test. Comparison will be drawn from the control group (without treatment of the algae carbon capture device) and the experimental group (with the carbon capture device).

Data Analysis Methods

The proponent will utilize quantitative research approach to analyze data gathered by the instruments stated with this approach to statistically prove the results. Quantitative Approach refers to a variety of methodologies for conducting

systematic investigations of social issues utilizing statistical or numerical data. As a result, quantitative research entails measurement and presumes that the phenomenon under investigation can be measured. It intends to analyze data for trends and correlations, as well as to validate the measurements made (Watson, R. 2015, p. 44). A one-tailed t-test is used in order to find if there is a significant difference between the groups with a confidence level of 99%.

The statistical tools that the proponents will use to answer the SOP are:

The **Mean**, to find the average CO₂ levels in the control group and the experimental group,

$$m = \frac{\text{sum of the terms}}{\text{number of terms}}$$

Variance to measure of the amount of dispersion in the set of values,

$$s^2 = \sqrt{\frac{\sum(x_i - m)^2}{N}}$$

Where, s^2 = sample variance

N = the size of the population

x_i = each value from the population

m = the population mean

And **One-Tailed T-test**, to compare the means of the experimental group and the control group, and to test if there is a significant difference.

$$t = \frac{m_1 - m_2}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2} \right)}}$$

Where, T = t-test

m_1, m_2 = means of the two groups

n_1, n_2 = number of observations in each of the groups

s_1^2, s_2^2 = variance of the difference

The one-tailed t-test will be done on the three households, and the result is then accepted or rejected with a confidence level of 99% or $p = 0.005$, with a sample size of 9 or 8 degrees of freedom, according to the following t-distribution table;

Table 1. T- distribution Table

t Table											
cum. prob	<i>t</i> _{.50}	<i>t</i> _{.75}	<i>t</i> _{.80}	<i>t</i> _{.85}	<i>t</i> _{.90}	<i>t</i> _{.95}	<i>t</i> _{.975}	<i>t</i> _{.99}	<i>t</i> _{.995}	<i>t</i> _{.999}	<i>t</i> _{.9995}
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

* Table source from: <https://www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf>

3.355 will be the critical value for rejecting or accepting the null hypothesis in the proponent's analysis. The following verbal interpretation is then given to the result;

Table 2. Verbal Interpretation of T-test

Value	Verbal Interpretation
$t > 3.355$	Reject H_0 or null hypothesis (There is a significant Difference)
$t < 3.355$	Accept H_0 or null hypothesis (There is no significant Difference)

Therefore, the proponents can statically prove if there is a significant difference with and without the treatment.

Additionally, the proponents will count the total CO₂ stored by the device by adding up the sum of the PPM differences in the level of carbon dioxide with and without the treatment. This sum will be converted into mg/m³.

According to (Rickets, M., 2021 p.44) "At normal temperature and pressure, one mole of any ideal gas occupies a volume of about 24.45 liters. Under these conditions, we convert from ppm to mg/m³ with the formula:

$$mg/m^3 = \frac{PPM \times MW}{24.45 L}$$

Where, mg/m^3 = concentration of the gas/ vapor mixture by mass, in milligrams of the substance per cubic meter of dry air

PPM = concentration of the gas/vapor mixture by volume, in parts of the substance per million parts of the total air/contaminant mixture

MW = molecular weight (i.e., molar mass) of the contaminant gas or vapor in atomic mass units (amu)

24.45 L = volume (in liters, L) occupied by one gram-mole of an ideal gas at normal temperature and pressure (25 °C and 760 mmHg).”

According to (National Center for Biotechnology Information, 2022) The molecular weight of CO₂ is 44.01 g/mol.

Timeline of the Capstone Project

Table 3. Timeline

ACTIVITIES	MARCH				APRIL				MAY				JUNE			
	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4	W 1	W 2	W 3	W 4
Orientation																
Checking and finalization of the title																
Making the draft of proposal																
Revision and editing																
Checking and submission																
Presentation of the capstone proposal																
Consultation with the Work Immersion teacher																
Preparation of materials and acquisition of online items																
Creation of the device and consultation																
Data collection from research instruments																

2. 5V Solar Panel	1	Php 259
3. Arduino NANO	1	Php 245
4. MQ135 Gas sensor	1	Php 133
5. 10cm, 16mm Diameter Pipes	3	Php 100
6. 16mm PVC Male adaptor	4	Php 27
7. 16 mm Female PVC adaptor	4	Php 27
7. Power bank	1	Php 135
8. Potentiometer	1	Php 12
9. Switch	1	Php 15
10. Relay	1	Php 24
11. 16mm Threaded Tee-Joint	1	Php 11
12. Jumper wires (pack)	1	Php 28
13. 5v Fan	1	Php 78
14. Fertilizer	1	Php 120
15. Glue Sticks	2	Php 15
16. Junction Box	1	Php 35
17. Photosensitive resistor (LDR)	1	Php 3
18. 16mm to 26mm PVC Connector	1	Php 11
19. One-way valve	1	Php 28
20. Cotton (one pack)	1	Php 12
21. PVC cement	1	Php 38
22. Diode 5v	2	Php 5
TOTAL		Php 1,520

CHAPTER IV RESULTS AND DISCUSSION

This chapter provides the presentation of statistical data relative to the problems stated in the SOP. The corresponding analysis and interpretation are incorporated in this portion of the capstone project.

Table 5a, 5b, 5c. Data gathered from household numbers 1, 2, and 3.

HOUSEHOLD NUMBER: 1

DATE: 4/23/2022

TIME	GROUPS		Difference in (CO ₂ PPM)
	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	
9:00	386.75	410	23.25
10:00	316.5	420	103.5
11:00	208.25	430	221.75
12:00	173.75	500	326.25
13:00	179.25	532	352.75
14:00	167.5	501	333.5
15:00	242.5	569	326.5
16:00	249	423	174
17:00	411	415	4
TOTAL PPM:	<u>2334.5</u>	<u>4200</u>	<u>1865.5</u>
Mean:	<u>259.3888889</u>	<u>466.6666667</u>	
Variance:	<u>8459.579861</u>	<u>3619.553571</u>	

HOUSEHOLD NUMBER: 2

DATE: 4/24/2022

TIME	GROUPS		Difference in CO ₂ (PPM)
	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	
9:00	388.75	402	13.25
10:00	384.75	480	95.25
11:00	273.25	485	211.75
12:00	286	500	214
13:00	356.5	620	263.5
14:00	280.5	587	306.5
15:00	313.25	581	267.75
16:00	484.5	639	154.5
17:00	584	584	0
TOTAL PPM:	<u>3351.5</u>	<u>4878</u>	<u>1526.5</u>
Variance:	<u>372.39</u>	<u>542</u>	
Mean:	<u>10906.70486</u>	<u>6157.5</u>	

HOUSEHOLD NUMBER: 3

DATE: 5/2/2022

TIME	GROUPS		Difference in (CO ₂ PPM)
	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	
9:00	405.25	449	43.75
10:00	347.75	419	71.25
11:00	315.25	407	91.75
12:00	229	415	186
13:00	311.75	418	106.25
14:00	328.75	414	85.25
15:00	339	423	84
16:00	358.75	411	52.25

17:00	406	406	0
TOTAL PPM	<u>3041.5</u>	<u>3762</u>	<u>720.5</u>
Mean:	<u>337.9444444</u>	<u>418</u>	
Variance:	<u>2855.793403</u>	<u>165.75</u>	

As shown in tables 5a, 5b, and 5c; in household number 1, with treatment, got a total CO₂ of 2334.5 PPM with a mean of 259.39 and a variance of 8459.58, without treatment it got a total CO₂ of 4200 PPM with a mean of 466.66 and a variance of 3619.55, its total difference got 1865.5 PPM with its highest difference at 13:00. Household number 2 on the other hand, with treatment, got a total CO₂ of 3351.5 PPM with a mean of 10906.70 and a variance of 372.39, without treatment, it got a total CO₂ of 4878 PPM with a mean of 542 and a variance of 6157.5, its total difference got 1526.5 PPM with its highest difference at 14:00. In household number 3 however, with treatment, it got a total CO₂ of 3041.5 PPM with a mean of 337.95 and a variance of 2855.79, without treatment, it got a total CO₂ of 3762 PPM with a mean of 418 and a variance of 165.75, its total difference was 720.5 PPM with its highest difference at 12:00 and is relatively low.

As the proponents anticipated, there is a difference in the level of CO₂ with and without the device. Another study has concluded, “Certain microalgae species have been proven to efficiently remove CO₂ in settings at rates 10–50 times greater than terrestrial plants” (How Much CO₂ Does an Acre of Algae Absorb, 2021). The proponents also discovered that 12:00, 13:00, and 14:00 have the highest difference in CO₂ which is also concluded by a study on microbiology, Herzog and Golomb (2004), that algae are most efficient at daylight hours.

Table 6. Average PPM Differences of all the samples.

HOUSEHOLD NUMBER	TOTAL PPM DIFFERENCES WITHIN A DAY
1	1865.5 PPM
2	1526.5 PPM
3	720.5 PPM
Average PPM	1370.83 PPM
mg/m³ Equivalent	2467.494 mg/m³

As shown in table 6, the total carbon dioxide difference of household 1 is 1865.5 PPM, in household 2 it was 1526.5 PPM and in household 3 however, only got a total of 720.5 PPM. From the three samples, its average CO₂ difference level is 1370.83 PPM with a g/L equivalent of 2467.494 mg/m³.

The results show that the average difference in the three households is 1370.83 PPM or 2467.494 mg/m³ within a day. This study's results are in line with the average CO₂ absorbed for a 1.5 liter of algae as reported by a similar study on microbiology in algae that found that Certain algal species has a CO₂ a fixation rate of 250 to 3450 mg/m³/day (Cheah, W. Y., Show, P. L., Chang, J. S., Ling, T. C., & Juan, J. C., 2015 p.38).

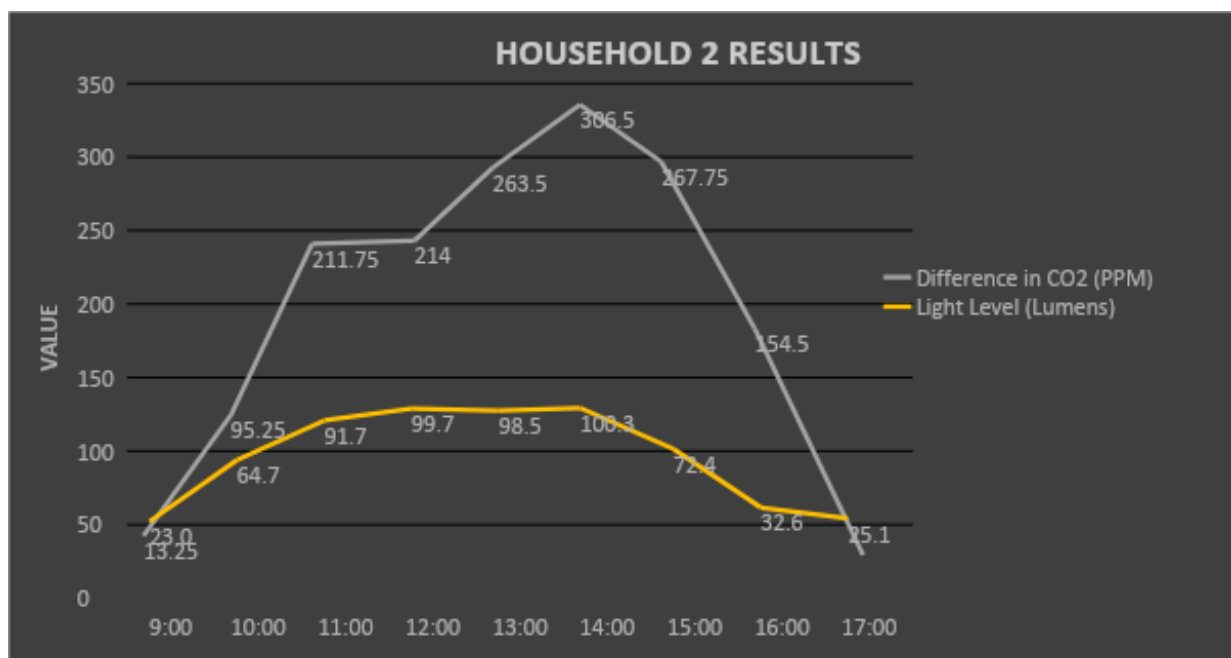
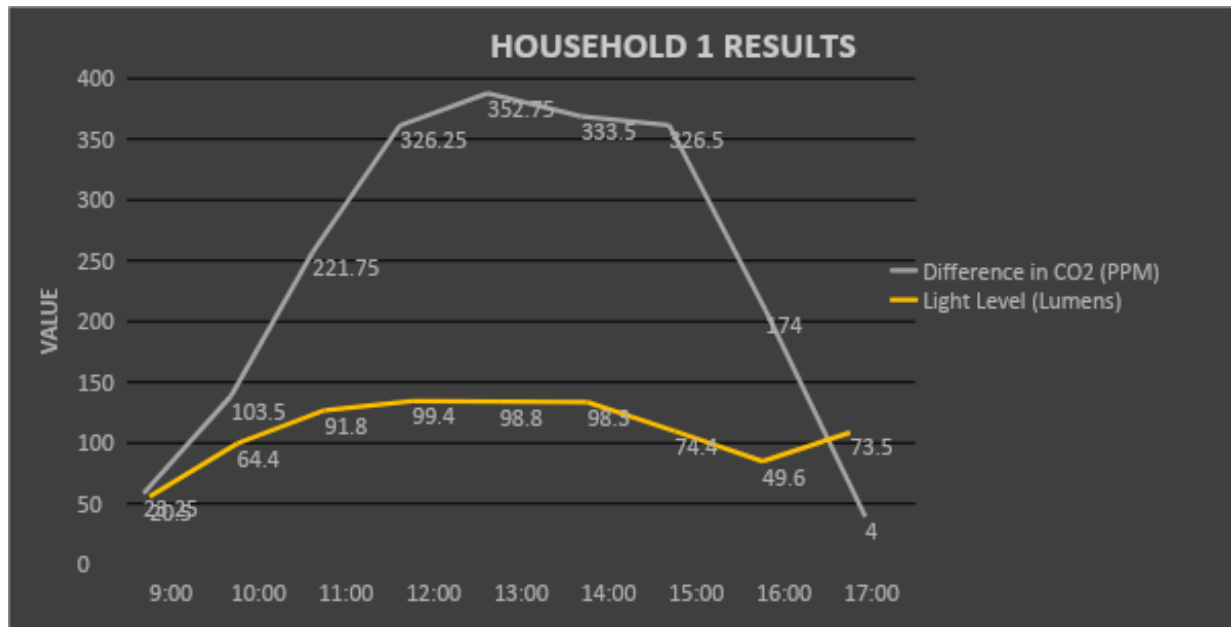
Table 7. T-Value and T-Test of the three samples.

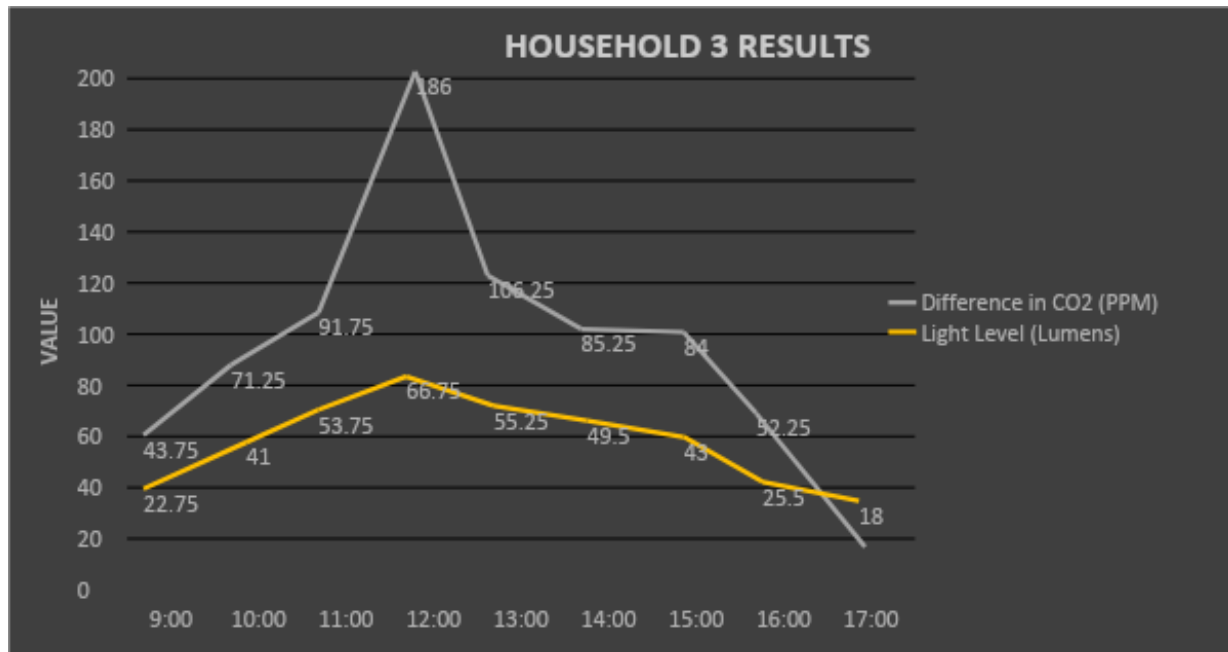
HOUSEHOLD NUMBER	t-Value	t-Test	Decision	Verbal Interpretation
1	5.659	$t > 3.355$	Reject Ho	There is a significant Difference
2	3.895	$t > 3.355$	Reject Ho	There is a significant Difference
3	0.239	$t < 3.355$	Accept Ho	No significant Difference

As shown in table 7; household numbers 1 and 2, the t value is 5.659 and 3.895 respectively. Compared to the critical value, the t value is " $t > 3.355$ " in which it was decided that both will reject the null hypothesis, meaning it has a significant difference. in household number 3 though, it only scored a t-value of 0.239 which is lower than the critical value or " $t < 3.355$ ", and so, accept the null hypothesis where there is no significant difference in using the device.

As the proponents predicted; with the low amount of external CO₂, there is no significant difference in the air quality or CO₂ level. A literature is also in accordance with the results; according to Boretti, A., & Florentine, S. (2019), "A higher concentration of carbon dioxide (CO₂) in our atmosphere aids photosynthesis, thus contributing to increased algae growth. CO₂ is essential for photosynthesis."

Figure 2a, 2b, 2c Light level and CO₂ Difference values in the three households.





The Figures 2a, 2b, and 2c shows that the light level with the highest difference in CO₂ in the three households is 98.8 lumens, 100.3 lumens, and 66.75 lumens respectively, while their mean is 88.62 lumens

According to Nwoba, E. G., Parlevliet, D. A., Laird, D. W., Alameh, K., & Moheimani, N. R. (2019), the need for light (suitable intensity and wavelength) and temperature control in microalgal cultures remains the most significant challenge, limiting their photosynthetic efficiency and productivity. The proponents found out that this is also the case in this study's result. The highest relative lumen amount of light, which in this case is an average of 88.62 lumens, can yield a greater carbon dioxide reduction.

CHAPTER V

CONCLUSION

Summary of Findings

The primary objective of this project is to conduct an experiment in a particular community regarding the effectiveness of algae in a mini closed-loop carbon capture device to capture the emissions of excess carbon dioxide in the atmosphere. The proponents achieved this objective by using a quantitative approach in a quasi-experimental method on 3 different samples using the research instruments.

The following results were established; (1) with the three households or samples, there is visible evidence of carbon dioxide sequestration after the treatment, with a total difference of 1865.5 PPM, 1526.5 PPM, and 720.5 PPM respectively, (2) The highest difference in CO₂ levels happened on 12:00, 13:00 and 14:00, (3) The results show that the average differences in Carbon dioxide levels of the atmosphere and the output of the device in the three households is 1370.83 PPM or 2467.494 mg/m³ (4) Household number 1 and 2 has a t-test score higher than the critical value, therefore, the proponents reject the null hypothesis or there is a significant difference when using the device in these households, however on the third household the t-value is lower than the critical value, therefore, it is decided that the proponents accept the null hypothesis or there is no significant difference when using the device in this household. (5) the mean or average light level with the highest difference in CO₂ in the three households is 88.62 lumens.

Conclusions

Based on the result gathered from the study, it can be concluded that:

1. The mini closed-loop algae carbon capture device level in terms of:
 - 1.1. Carbon dioxide storage, the device fixated carbon dioxide with an average of 2467.494 mg/m³ from the atmosphere within a day.
 - 1.2. The level of carbon dioxide reduced in the atmosphere, the device reduced 1370.833 PPM of carbon dioxide.
2. The study proved that 2 out of 3 households have a significant difference in the carbon dioxide levels outside and inside the device with a confidence level of 99%.
3. The light level in which the device is most effective is an average of 88.62 lumens.
4. The most effective time in reducing carbon dioxide in the atmosphere is roughly at noontime (12:00-14:00).

Recommendations

Based on the findings gathered from the study, the researchers recommend that:

1. The Community should consider supporting in the implementation of the mini-closed loop carbon capture device in households that qualify the needs for algae growth to significantly lessen carbon emissions.
2. The Students may engage in understanding of the potential and importance of algae in capturing, sequestering, and storing carbon dioxide to reduce the huge effect of pollution caused by excess carbon dioxide in the atmosphere.
3. The LGUs may consider the uses of algae in the infrastructure projects to lessen environmental impact.
4. Future Researchers may continue to research the importance of algae and its uses on carbon sequestration so they can improve this concept and use it in the near future, identify and validate the species of algae, and test on a larger scale to further improve the effectiveness of the device.

REFERENCES

- Abbas, F. N., Saadoon, M. I. M., Abdalrdha, Z. K., & Abud, E. N. (2020). Capable of gas sensor MQ-135 to monitor the air quality with Arduino Uno. *Int J Eng Res Technol*, 13(10), p. 2955.
- Algae | Definition, Characteristics, Classification, Examples, & Facts. (2016). *Encyclopedia Britannica*. <https://www.britannica.com/science/algae>
- Aly, S. P., Barth, N., Figgis, B., Essadiqi, E., Faqir, M., Ennaoui, A., & Ahzi, S. (2016, November). Mitigating the effect of heat and dust to enhance solar panels efficiency. In *2016 International Renewable and Sustainable Energy Conference (IRSEC)* (pp. 835-841). IEEE.
- Boretti, A., & Florentine, S. (2019). Atmospheric CO₂ Concentration and Other Limiting Factors in the Growth of C₃ and C₄ Plants. *Plants (Basel, Switzerland)*, 8(4), 92. <https://doi.org/10.3390/plants8040092>
- Cheah, W.Y, Show, P.L., Chang, J-S., Ling, T.C., Juan, J.C., (2015). Biosequestration of Atmospheric CO₂ and flue gas-containing CO₂ by microalgae. *Biores Techn* 184, 190– 201. doi:10.1016/j.biortech.2014.11.026.
- Cook, T. D. (2015). Quasi-experimental design. *Wiley encyclopedia of management*, 1-2.
- Cruz, R. J. E., Ibardaloza, F. V. I., Roga, A. J. M., Cuizon, K. L. M., Zadeh, N. R. N., & Estacio, R. R. (2019). Smart Room Lighting System with Light Intensity Controller for Curtain and Light Appliances using Raspberry Pi. *IJASC*, 1(4), 1-6.
- Gao, Y., Gregor, C., Liang, Y., Tang, D., & Tweed, C. (2012). Algae biodiesel-a feasibility report. *Chemistry Central Journal*, 6(1), 1-16.
- Gerstman, B. B. (2016). *StatPrimer (Version 7.0)*. San José State University. Retrieved May 31, 2022, from <https://www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf>
- How much Co₂ does an acre of algae absorb. (2021, December 9). *Lisbdnet*. <https://lisbdnet.com/how-much-co2-does-an-acre-of-algae-absorb/#:%7E:text=does%20algae%20remove%3F-,One%20acre%20of%20algae%20can%20-remove%20up%20to%202.7%20tons,times%20higher%20than%20terrestrial%20plants.>
- Keffer, J., Kleinheinz, G., (2002). Use of Chlorella vulgaris for CO₂ mitigation in a photo-bioreactor. *J of Indus Micro and Biotech* 29, 275–280. doi:10.1038/sj.jim.7000313
- Ma, Y., Li, G., & Tang, R. (2011). Optical performance of vertical axis three azimuth angles tracked solar panels. *Applied Energy*, 88(5), 1784-1791.

- Miller, R. (2017, November 21). *Pond Aeration & Algae Growth*. Home Guides | SF Gate. Retrieved March 20, 2022, from <https://homeguides.sfgate.com/pond-aeration-algae-growth-52613.html>
- Mussnug, J.H., Thomas-Hall, S., Rupprecht, J., Foo, A., Klassen, V., McDowall, A., Schenk, P.M., Kruse, O., Hankamer, B., (2007). Engineering photosynthetic light capture: impacts on improved solar energy to biomass conversion. *Plant Biotech J* 5, 802–814. doi:10.1111/j.1467-7652.2007.00285.x.
- National Center for Biotechnology Information (2022). *PubChem Compound Summary for CID 280, Carbon dioxide*. Retrieved May 31, 2022 from <https://pubchem.ncbi.nlm.nih.gov/compound/Carbon-dioxide>.
- Nwoba, E. G., Parlevliet, D. A., Laird, D. W., Alameh, K., & Moheimani, N. R. (2019). Light management technologies for increasing algal photobioreactor efficiency. *Algal research*, 39, 101433.
- Onyeaka, H., Miri, T., Obileke, K., Hart, A., Anumudu, C., & Al-Sharify, Z. T. (2021). Minimizing carbon footprint via microalgae as a biological capture. *Carbon Capture Science & Technology*, 1, 100007.
- Statista. (2021, November 22). *Annual global emissions of carbon dioxide 1940–2020*. Retrieved March 20, 2022, from <https://www.statista.com/statistics/276629/global-co2-emissions/>
- Statista. (2022, February 1). *Urbanization in the Philippines 2020*. Retrieved March 20, 2022, from <https://www.statista.com/statistics/455910/urbanization-in-philippines/>.
- Tang, T., Wan, P., & Hu, Z. (2018). CO₂ Bubbling to Improve Algal Growth, Nutrient Removal, and Membrane Performance in an Algal Membrane Bioreactor: Tang et al. *Water Environment Research*, 90(7), p. 656.
- Watson, R. (2015). Quantitative research. *Nursing Standard* (2014), 29(31), 44.
- What is carbon sequestration? | U.S. Geological Survey. (2022, February 1). *U.S. Geological Survey*. <https://www.usgs.gov/faqs/what-carbon-sequestration#:~:text=Carbon%20sequestration%20is%20the%20process,carbon%20sequestration%3A%20geologic%20and%20biologic>.
- Xue L, Zhang Y, Zhang T, An L, Wang X. Effects of enhanced ultraviolet-B radiation on algae and cyanobacteria. *Crit Rev Microbiol*. 2005;31(2):79-89. doi: 10.1080/10408410590921727. PMID: 15986833.

APPENDICES

Charts and Tables

Table 8. Used spreadsheet to log data of mean-per hour average

HOUSEHOLD NUMBER: X		DATE: <u>XX/XX/XXXX</u>		
TIME	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	Difference in CO ₂ (PPM)	Light Level (Lumens)
9:00				
10:00				
11:00				
12:00				
13:00				
14:00				
15:00				
16:00				
17:00				
Average:				
Variance:				
sum of difference in PPM				
sum of difference in g/L				

T-Test Value:

**This spreadsheet is used in all of the samples*

Table 9. Raw Data for CO₂ levels with and without algae per 15 minutes.

HOUSEHOLD NUMBER 1			
TIME (MILITARY HOURS)	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	Light Level (Lumens)
9:00	401	410	20.0
9:15	397		20.2
9:30	390		20.4
9:45	359		21.4
10:00	382	420	47.4
10:15	351		55.0
10:30	266		73.8
10:45	267		81.6
11:00	265	430	82.4
11:15	254		89.1
11:30	156		96.6
11:45	158		99.2
12:00	160	500	99.9
12:15	174		97.4
12:30	180		100.2
12:45	181		100.2

13:00	179	532	100.1
13:15	178		99.8
13:30	181		97.6
13:45	179		97.6
14:00	176	501	100.2
14:15	159		100.2
14:30	168		98.9
14:45	167		94.0
15:00	226	569	81.7
15:15	235		79.1
15:30	255		73.6
15:45	254		63.3
16:00	217	423	56.9
16:15	229		49.2
16:30	261		49.3
16:45	289		43.0
17:00	411	415	35.1
HOUSEHOLD NUMBER 2			
TIME (MILITARY HOURS)	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	Light Level (Lumens)
9:00	402	402	20.0
9:15	378		30.2
9:30	390		20.4
9:45	385		21.4
10:00	296	480	48.4
10:15	283		56.0
10:30	277		72.8

10:45	283		81.7
11:00	275	485	82.4
11:15	270		90.0
11:30	276		96.1
11:45	272		98.2
12:00	283	500	98.8
12:15	288		99.6
12:30	282		100.2
12:45	291		100.2
13:00	381	620	100.1
13:15	365		99.5
13:30	351		97.7
13:45	329		96.6
14:00	287	587	100.1
14:15	279		100.4
14:30	277		100.4
14:45	279		100.2
15:00	268	581	91.7
15:15	264		89.1
15:30	354		55.6
15:45	367		53.3
16:00	401	639	42.9
16:15	474		35.2
16:30	489		29.3
16:45	574		23.0
17:00	584	584	25.1

HOUSEHOLD NUMBER 3			
TIME (MILITARY HOURS)	CO ₂ With algae (PPM)	CO ₂ Without algae (PPM)	Light Level (Lumens)
9:00	449	449	19
9:15	435		18
9:30	370		26
9:45	367		28
10:00	351	419	26
10:15	361		35
10:30	349		47
10:45	330		56
11:00	313	407	56
11:15	309		56
11:30	325		47
11:45	314		56
12:00	313	415	58
12:15	326		59
12:30	279		78
12:45	278		72
13:00	302	418	56
13:15	301		54
13:30	326		56
13:45	318		55
14:00	316	414	53
14:15	346		53
14:30	331		39
14:45	322		53

15:00	347	423	45
15:15	346		39
15:30	330		42
15:45	333		46
16:00	342	411	37
16:15	357		23
16:30	366		22
16:45	370		19
17:00	406	406	18

Figures

```

Algae_microcontroller2 $
1 #define anInputG      A0           //analog feed from MQ135
2 #define anInputL      A1           //analog feed from LDR
3 #define co2Zero       -354         //calibrated CO2 base level
4
5
6 void setup()
7 {
8     pinMode(anInputG, INPUT);       //MQ135 analog feed set for input
9     pinMode(anInputL, INPUT);       //LDR analog feed set for input
10    Serial.begin(9600);              //serial comms for debugging
11 }
12
13 void loop()
14 {
15
16     int co2now[10];                 //int arrays for all arguments
17     int co2raw = 0;
18     int co2ppm = 0;
19     int zzz = 0;
20     int yyy = 0;
21     int ldr=A1;
22     int value[10];
23     int lightLux = 0;
24     int lightraw = 0;
25     int Lumenss = 0;
26
27     for (int x = 0;x<10;x++)         //sample co2 10x over 15 min (every 1.5 sec)
28     {
29         co2now[x]=analogRead(A0);    //read MQ135 output
30     }
31
32     for (int x = 0;x<10;x++)         //add samples together
33     {
34         zzz=zzz + co2now[x];
35     }
36
37     co2raw = zzz/10;                 //divide samples by 10 to average each sample
38     co2ppm = co2raw - co2Zero;       //get calculated ppm
39
40     Serial.print("Co2 Level = ");
41     Serial.print(co2ppm);            // prints the value of co2 level to Serial Monitor.
42     Serial.println(" PPM");
43
44     for (int y = 0;y<10;y++)         //LDR reads 10 times
45     {
46         value[y]=analogRead(ldr);    //Reads the Value of LDR(light).
47     }
48
49     for (int y = 0;y<10;y++)         //Sample LDR 10x over 15 min (every 1.5 sec)
50     {
51         yyy=yyy + value[y]* 0.1;     // for calibrating into lumens
52     }
53
54     lightLux = yyy/10;               //divide samples by 10 to average each sample
55     Lumenss = lightLux;              // to separate arguments
56
57     Serial.print("Light Level = ");  //Prints the output value of LDR to Serial Monitor.
58     Serial.print(Lumenss);
59
60     Serial.println(" Lumens");
61     delay(900000);                  //a delay for 15 minutes
62 }

```

Fig 3. Used Source code for the Arduino based sensors