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PURIFI: A NEW COST EFFICIENT WAY TO CAPTURE CARBON

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ABSTRACT

Global warming is a clear existential threat, and its impacts are very dangerous. The increase in CO2 levels across the world is explained by the greenhouse effect. The high levels of CO2 in some areas trap the Sun's energy within the Earth itself instead of properly reflecting it back into space, which is detrimental for the environment as the global temperature will slowly begin to rise with the addition of more radiation. To combat this, a few carbon capture systems have been implemented around the world. A key issue is that these systems cannot capture carbon from the root sources and are mostly in low carbon dioxide density areas. Our project is aimed at increasing the efficiency of current carbon capture technologies and specifically factory emissions. The purpose of our project is to make it cost-effective to separate CO2 from flue gas and therefore reduce carbon within the environment. Specifically, Purifi will take in gases from a factory and use a solution to liquify CO2, which will then be cooled so it can be stored as a liquid.

MOTIVATION AND APPROACH

Carbon Dioxide makes up 81% of the United States' total greenhouse gas emissions (Stein, 2019). This statistic alone clearly demonstrates the major role carbon dioxide plays in air pollution. However, natural carbon dioxide, when organisms respire or decompose, is good for the environment and shouldn't be confused with extra carbon dioxide found in the greenhouse effect. Human activities like burning fossil fuels and agriculture are increasing the amount of Carbon Dioxide and furthermore trapping heat within the Earth, causing a slow rise in temperatures. The annual temperature increase since the 1880s is 1.8°F(U.S Global Change Research Program, 2020). There are 3 systems that can be used to capture carbon:

Pre-Combustion, Post-Combustion, and Oxy-Combustion. Pre-Combustion is used to separate CO_2 and create a synthesis gas, which consists of carbon monoxide and hydrogen. This is done through using a carbon-based fuel and reacting it with steam and oxygen. The carbon is captured

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from this synthesis gas and then the gas is combusted. The heat generated from this can be used to create electricity (Rubin, Mantripragada, Marks, Versteeg, & Kitchin, 2012, pp. 4-6). An instance of this process being used is in the Kemper Project in Mississippi. The Kemper Project used a process called integrated gasification combined cycle, or IGCC (Duddu, 2014).

Pre-combustion is a process that hasn't been studied much and because of that, it's hard to scale. Due to this, the Kemper Project was demolished in October 2021 (Schlissel, 2021).

Currently, there are many solutions that use post-combustion. The most well-known of which is the Orca by Climeworks. This carbon capture plant in Iceland is the first large-scale implementation of the post-combustion system. The post-combustion system is when a reaction with the solvent monoethanolamine (MEA) results in the most effective method of carbon capture from flue gas. To begin the process, the flue gas makes contact with the MEA to separate the CO2 in the absorber chamber. The efficiency of this chamber ranges from 85 to 90 percent of the entire CO2 density in the flue gas. Next, in the regenerator chamber, "CO2-laden solvent" is heated up to 600℃ and then is cooled down to a solid state where it can then be moved into the last chamber: the storage chamber. The storage chamber essentially hosts all the solid CO2 that is ready to be disposed of underground or be made into other forms of CO2. However, the newly cleaned flue gas without CO2 will also be released back into the atmosphere after the regenerator chamber (Rubin, Mantripragada, Marks, Versteeg, & Kitchin, 2012, pp. 4-14). Orca mimics this design and is essentially the first large-scale implementation of such post-combustion carbon capture processes that is extremely effective with a successful CO2 net removal rate of more than 90% (Climeworks, 2021). The final system that is being developed for Carbon Capture is Oxy-Combustion. Essentially, this process uses oxygen for energy instead of glasses within the air. This is different from a post-combustion system in that it is much cheaper, but it is also a machine to separate the oxygen needed for combustion. The main caveat with this method is that it hasn't been implemented commercially and is largely theoretical (Rubin, Mantripragada, Marks, Versteeg, & Kitchin, 2012, pp. 23-26). Although the current carbon capture technologies may be sufficient, the way they are implemented is inadequate for 2 main reasons. The current carbon capture plants are stationary and extremely hard to build. As such, creating many plants would be bothersome for governments who want to invest in such technology. Current carbon capture technology is also extremely expensive. For example, the Orca plant by climeworks cost $15 Million to build and manufacture (Judge, 2021). These plants have built-in ways to convert the carbon extracted for other uses. The objective of our project is to simply extract carbon dioxide in a cost-effective way that allows for flexible use of extracted carbon dioxide.

(Assume Mounted).

1. After the device is mounted, the intake fan will turn on and begin to take in flue gas from

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the output gas in factory chimneys.

2. All the particle in the air will make contact with the MEA and 2-MAE solution within the box

3. The chemical will react and the liquid carbon dioxide that is created from the reaction will be transported from the first chamber into another chamber through a pipe and the remaining cleaned flue gas will be released.

4. The remaining solution in the captured chamber will be disposed of and refilled.

5. The carbon dioxide in the second chamber will be be cooled using the peltier refrigeration mechanism and received after the cooling is done

Purifi will target poorer countries to help them reduce their annual carbon emission with the ultimate ambition of slowing down the annual temperature increase across the globe.

Through our system, these countries can afford our carbon capture system and directly target a root source of the problem: factory emissions. Purifi also doesn't require constant supervision as it is all automated, reducing the need for labor. Current solutions are very expensive and very labor-intensive to construct as the builders are faced with constant challenges with the type of materials, especially in the regenerator chamber. Purifi is a viable alternative to current carbon capture technologies as it's significantly cheaper than existing solutions. A key difference between our idea and existing plants is that the retrieved carbon dioxide isn't being used within the system. This leaves an opportunity for the carbon dioxide to be used in a variety of ways in other systems. This versatility is crucial as it allows for carbon dioxide to be split further into carbon and oxygen. The carbon created from this can be used in soft drinks, funneled deep underground, et cetera. Even with just carbon dioxide, owners can sell this to the medical industry and the food industry. Now, developing countries start their journey to being carbon neutral or even carbon positive for an affordable price.

PROJECT LOGISTICS AND ORGANIZATION

Purifi will be commercially available on the market for governments and companies to purchase. Our system is to be placed on top of a factory and directly intake the flue glasses that are being emitted from the factory chimney directly into the environment. Our project is inexpensive due to the low-cost materials and the optimized system we have created, which is feasible because of the various research and development that have been published regarding the MEA and 2-MAE usability with CO_2 absorption. The conclusions reached in numerous research papers regarding a similar process show that our approach will be extremely effective by capturing ~90% of Carbon

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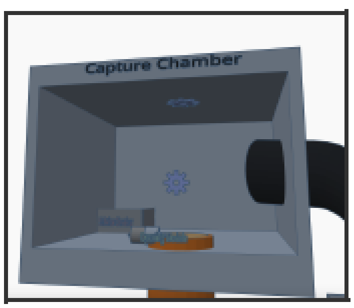
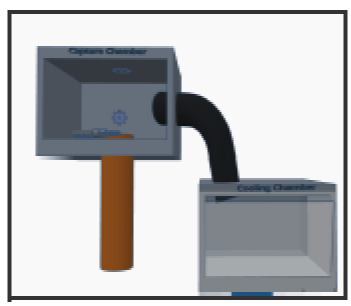
Dioxide in the environment (Maneeintra, Photienb, & Charinpanitkulb, 2018).

We will require many basic chemical tools and a welding machine to shape the metal for our purposes. We understand that we, as high schoolers, have certain limitations, and thus, we will be actively searching for mentorship from various sources, including MIT professors. In addition, our project is heavily reliant on its funding, and our budget table displays this information.

For the success of this project, we have outlined 3 goals: minimize MEA loss, produce a way to test safety, and test a way to maximize CO2 net efficiency. With regards to minimizing MEA loss, research shows that mixing 2-(Methylamino)ethanol(2-MAE) and Monoethanolamine (MEA) with a ratio of 20:10 wt% allows for a cheap cost, high overall MEA type capacity, and low energy consumption (Maneeintra, Photienb, & Charinpanitkulb, 2018). Additionally, to maintain safety measures in the storage component, we would combine the cooling and storage chambers into one so that the precooled carbon dioxide would keep its state due to external heat and evaporation. CO2 net efficiency can be calculated by the CO2 product(liquid amount left over) divided by the CO2 supply(total amount in flue gas). A standard net efficiency among the most well-known carbon capture systems is anything above 90% and our goal is to match, but preferably exceed this level of performance.





Since this is a partner-based project, we have effectively matched our personal goals and came up with an effective plan for the completion of our system. We have divided work and responsibilities with our strengths and weaknesses in each area of our project. For example, we have prior experiences in chemistry and robotics and we divided the project accordingly with one of us working with the sensors and control of the motors and the other mainly working with the Monoethanolamine and 2-(Methylamino)ethanol reaction. Both of us are extremely capable in both fields as we are in constant communication online with each other so we could come together and produce meaningful results and can overcome countless obstacles during research and even implementation.

The following addresses possible issues and solutions:

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1. Too much flue gas entering the absorber chamber and reacting to the MEA solvent.

    a. Reducing the diameter of the pipe between the absorber chamber and the intake fan and a sensor to manage the open close mechanism of the pipe

2. The carbon steel having the property of corrosion and rust

    b. Even though carbon steel has unpreferred chemical properties, it is still very cheap and durable for our purposes, and we will strive to make sure that the MEA reaction doesn't cause any additional humidity which could cause rust or corrosion. Our refrigeration system aims to evaporate the water molecules in the chamber so it would also remove any additional humidity, decreasing the chance for rust to build up.

3. The fan freezing up in the refrigeration system.

    c. Adding adequate insulation throughout the refrigeration chamber with the addition of foam or another affordable insulation material.

Timeline:

1. 2/7/22: Order all materials
2. 2/14/22: Create the MEA and 2-MAE solution using the proper ratio
3. 2/28/22: Weld Two Carbon Steel Chambers and carve appropriate holes
4. 3/7/22: Weld Pipe between Carbon Steel Chamber
5. 3/28/22: Create and attach Sensor mechanism to the pipes
6. 4/7/22: Create and attach thermoelectric cooling mechanism to second chamber
7. 4/18/22: Test Mechanism by burning coal in safe environment
8. 5/26/22: Extra time for modifications.

Current Work and Need for funding:

We have created 3D-modeling blueprints and thoroughly researched to gather proper information regarding the resources and we would need the funding to purchase these resources as they are very expensive. The stipend would go to the purchase of intake fans, steel pipes and sheets, and

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sensors, and refrigeration system(all displayed accordingly in our budget table below) and the most important aspect of the need for MIT funding is the level of specific guidance we would get to improve our product and make it ready for commercial use. After the refrigeration of the solution, we are curious about the storage and even how to reuse some of the gases to potentially re-power our system. We would be closely in touch with MIT professors to better understand potential upgrades that will be safe for our product and its intended use case. The THINK mentors would also give a meaningful opportunity to learn to use advanced technology and better understand concepts we are working with. This opportunity inspires us to create a project that can have a tremendous impact by paving the way for a cleaner future.

Budget:

Item	Amount	Cost	Link
2-(Methylamino)ethanol, ≥98% Product Number: 471445-250ML	2	$35.90	https://www.sigmaaldrich.com/US/en/substance/2methylaminoethanol7511109831
Ethanolamine(monoethanolamine) Product Number: C5513-1L	1	$60.00	https://www.laballey.com/products/monoethanolamine-lab
Bagged Coal (Nut) – Individual	1	$6.30	http://thecoalshop.com/product/bagged-coal-nut-individual/
3" Nom. Schedule 40 Carbon Pipe A500 -Part #: 23672 Product Specifications: 24" (2 ft.) wt. 15.14 lb	1	$51.60	https://www.onlinemetals.com/en/buy/carbon-steel/3-nom-schedule-40-carbon-pipe-a500/pid/23672
0.05" Blue Tempered Spring Steel Sheet 1075 Product Specifications: 12" X 12"	12	$43.82 15% off with code: BAR2X	https://www.onlinemetals.com/en/buy/carbon-steel/0-05-blue-tempered-spring-steel-sheet-1075/pid/26237

VIVOSUN 8 inch Inline Duct Fan 240 CFM, HVAC Exhaust Intake Fan, Low Noise & Extra Long 5.5' Grounded Power Cord	2	$30.99	https://www.amazon.com/Tjernlund-FAI4-Fresh-Intake-Hood/dp/B00JMCSILU
2 24 Volt Motors	1	$26.58	https://www.amazon.com/weelye-30000RPM-Childrens-Accessory-Replacement/dp/B07Z1HLD16/ref=sr_1_19?crid=11UM2N010WK6A
PCCOOLER GI-X3 CPU Air Cooler 12V	2	25.99	https://www.ebay.com/itm/194025595523?chn=ps&mkevt=1&mkcid=28
Peltier Cooler Module Thermoelectric Cooler 200 W	1	29.70	https://www.ebay.com/itm/224516797508?hash=item34463e7444:g:OeAAAOSwZS9g3RY3
W1209 Digital Thermostat Temperature Control Switch 12v Sensor	1	9.03	https://www.ebay.com/p/583941329?iid=252062159071
40mm 4cm 2 Pin 7 Blades Computer Chipset Cooling Fan DC 24V	5	1.36	https://www.aliexpress.com/item/32809043232.html?channel=twinner
3-1/2 in. Satin Nickel 5/8 in. Radius Security Door Hinges Value Pack (3-Pack)	1	$9.98	https://www.homedepot.com/p/Everbilt-3-1-2-in-Satin-Nickel-5- 8-in-Radius-Security-Door-Hinges-Value-Pack-3-Pack-14874/202818703

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MEAN WELL RSP-500-24 DC Power Supply 500W/24V/21A PFC for 3D Printer, LED Strip Light, Industrial Control System NES/SE/S	1	$85.00	https://www.amazon.com/MEAN-WELL-RSP-500-12-Computer-Project/dp/B085G65K3Y
Total	27	$996.51	

PERSONAL INTEREST

Our interests lie in the field of chemistry and robotics. We have conducted various research in our science research class under GMU advisors in segmenting MRI scans and using 3d computer vision models to test the best form during weightlifting, which will be presented at a regional science fair later this year. Our ability to quickly grasp new concepts and learn new topics during research has proven beneficial for all the projects we have completed.

We are proficient in cutting metal as we have done this previously for robotics and our technical education class in middle school. Although we are familiar with the methods for welding and aspects surrounding, we still need to learn to weld by doing it. Furthermore, we areboth familiar with coding sensors and motors, as we have done this in robotics. We are familiar with coding in C, C++, Kotlin, and Java, all languages that are used in doing projects like this. However, we are willing to learn new software if the project requires it.

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