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WORD COUNT	CHARACTER COUNT
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PAGE COUNT	FILE SIZE
45 Pages	2.9MB
SUBMISSION DATE	REPORT DATE
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WALCHAND COLLEGE OF ENGINEERING, SANGLI

BACHELOR OF TECHNOLOGY IN

ELECTRICAL ENGINEERING

A PROJECT REPORT ON

"SMALL SCALE DIRECT CO2 EXTRACTION FROM AIR" 2023-24

SUBMITTED BY

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UNDER THE GUIDANCE OF

Dr. R. P. Hasabe

(Department Of Electrical Engineering)

CERTIFICATE

THIS IS TO CERTIFY THAT THE PROJECT REPORT ENTITLED,

"SMALL SCALE DIRECT CO2 EXTRACTION FROM AIR"

SUBMITTED BY

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FOR THE FULFILLMENT OF THE REQUIREMENTS OF FOURTH YEAR B.TECH ELECTRICAL DEGREE OF INSTITUTE EMBODIES THE WORK DONE BY THEM UNDER MY SUPERVISION

Dr. R . P. Hasabe
(Project Guide) (External Examiner)

Dr. D . S . More
Head Of Department

ACKNOWLEDGMENT

We feel immense pleasure in submitting this Project report entitled **" Small Scale Direct CO2 Extraction From Air ".**

We would like to convey our deep appreciation to our project Guide Dr. R. P. Hasabe of the Electrical Engineering department for his valuable suggestions and encouragement throughout the duration of the project work and also our Panel members Mr. A.B.Patil and Mr. S.S.Medhekar of Electrical Engineering Department for their guidance and support.

We would also like to express our gratitude to our head of Department Dr. D.S More for providing all the required facilities to accomplish our project.

Our thanks and appreciations also go to our group members, without their support and coordination we would not have been able to complete this project.

DECLARATION

We hereby undersigned solemnly declare that the report of the project work entitled "**Small Scale Direct CO2 Extraction From Air**", is our own work carried out during the course of our study under the supervision of our Guide Dr. R.P. Hasabe. We assert that the statements made, and conclusions taken are an outcome of the project work. We further declare that to the best of our knowledge and belief that the project report does not contain any part of any work which has been submitted for the award of any other degree/diploma/certificate in this University or any other University.

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CONTENTS

ABSTRACT

This project investigates methods for capturing carbon dioxide (CO2) directly from the atmosphere on a small scale. Direct air capture (DAC) technology mimics the natural process of photosynthesis, but with a faster and more concentrated output. This project will explore techniques suitable for individual or community-based CO2 extraction, potentially using readily available materials and lower energy requirements compared to large-scale DAC facilities.

The captured CO2 could have various applications, including:

- Carbonated Drinks: Using the CO2 for making Carbonated Products.
- Conversion into usable products: Transforming CO2 into Dry Ice,.

By developing a small-scale DAC system, this project aims to contribute to efforts in mitigating climate change and reducing atmospheric CO2 levels.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

As we are living in the 21st century the human being has developed a lot in terms of Physical, Mental, Technical & Socially and still progressing towards the future with dedication and hardships. Looking behind we invented a lot of things which had given a certain direction to humanity. Invention of 'Electricity' is one of the biggest inventions which invented before, and now became a very important and necessary part of our community. But "the great the invention is, the worst is its side effect", and the side effect of mass electricity production is 'Air pollution'. And it is necessary to take it in the consideration while generating electricity so we can balance with our environment, or the outcomes will be severe.

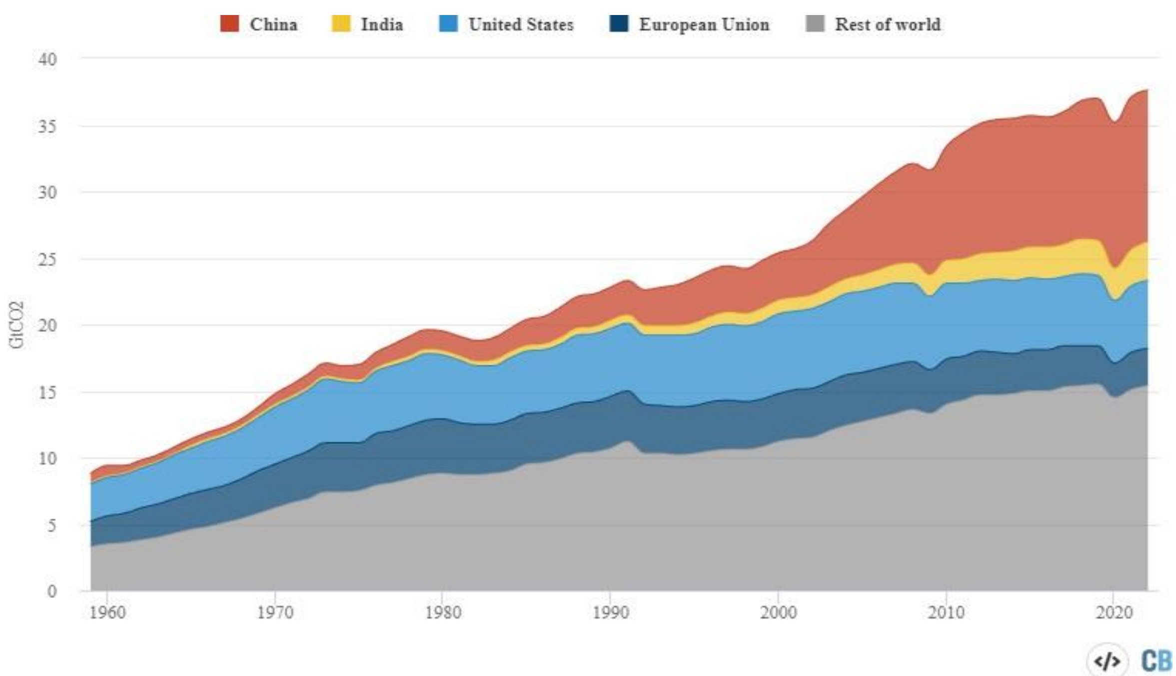


Fig. 1 CO2 Emissions from fossil fuels by region, 1960 -2020

So, to minimize the air pollution we need to take proper measures like Tree plantation, Reduce the deforestation which still won't be enough in reduction of air pollution in atmosphere. So, another thing we have to do is to extract the CO2 from air artificially with the help of DAC (Direct Air Capture) method. The DAC method extracts the CO2 from the atmosphere and separates it in form of fresh air and pure CO2.

Direct Air Capture (DAC) is a process that involves capturing carbon dioxide (CO2) directly from the air using specialized equipment. This technology holds promise for substantially lowering emissions. from hard-to decarbonize sectors, such as transportation and industry. DAC typically involves several steps, including air filtration, absorption of CO2, Separation of CO2 and Storage or utilization. The captured CO2 can then be stored or used in various applications, such as enhanced oil recovery, synthetic fuel production, and industrial processes. (4.Lackner)

There are currently 18 direct air capture plants operating worldwide, capturing almost 0.01 Mt CO2 /year, and a 1 Mt CO2 /year capture plant is in advanced development in the United States. In the Net Zero Emissions by 2050 Scenario, direct air capture is scaled up to capture almost 60 Mt CO2 /year by 2030. This level of deployment is within reach, but will require several more large-scale demonstration plants to refine the technology and reduce capture costs. (3. Wurzbacher).

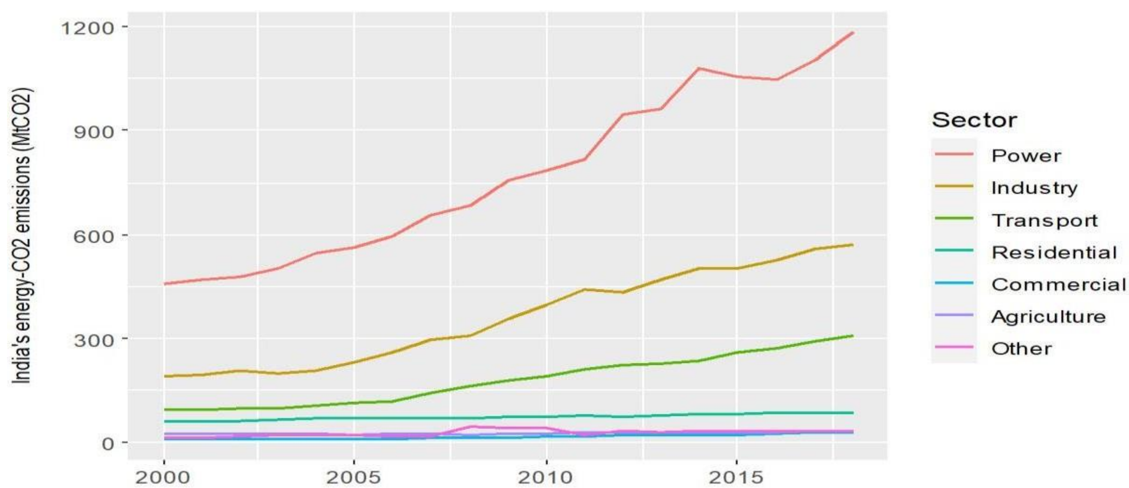
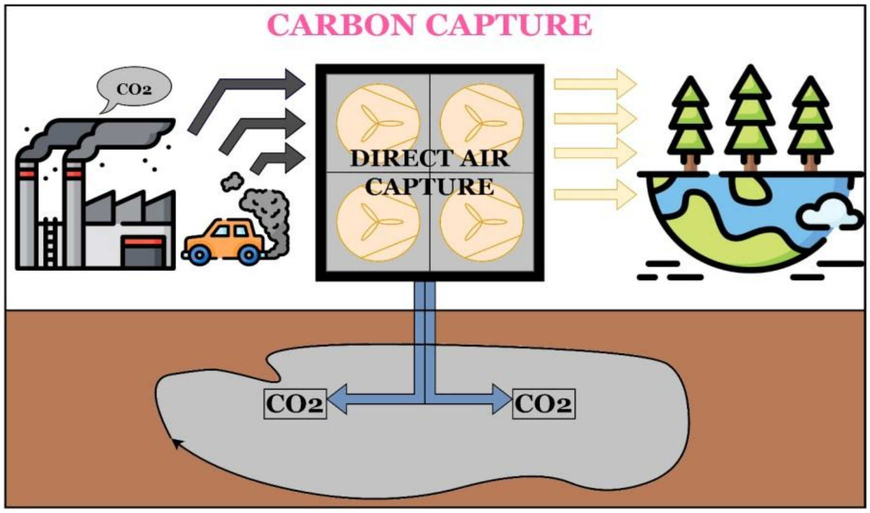


Fig 2 CO2 Emissions in India (In metric tonnes) [11]

The process begins with an air contactor, resembling industrial cooling towers, where a massive fan draws air through thin plastic surfaces coated with a potassium hydroxide solution. This solution chemically reacts with CO2 molecules, extracting them from the air and converting them into carbonate salt, which is collected in liquid form.

Next, the CO2-containing carbonate solution undergoes several chemical processes to enhance its concentration, purify it, and compress it into gas form for either immediate use or storage. The salt is separated from the solution into small pellets in a pellet reactor, inspired by water treatment technology. These pellets are then heated in a calciner to release pure CO2 gas. The calciner operates similarly to equipment utilized in large-scale mining for ore processing. Additionally, this step generates processed pellets that are hydrated in a slacker and returned to the system to regenerate the original capture chemical.

Fig 3 Carbon Capture



Direct air capture (DAC) technologies can play an important role in meeting net zero goals. Capturing CO2 directly from the air and permanently storing it removes the CO2 from the atmosphere. Air-captured CO2 can also be used as a climate-neutral feedstock to produce a range of products. (6.Fasihi)

1.2 Organization of chapters:

Further report consists of literature review in chapter 2 which includes the gap identification along with problem statement, project objectives and project scope. In chapter 3 system development is explained which consist of flow of hardware and working of prototype with flow chart. Chapter 4 consist of hardware implementation with methodology. Results and analysis are explained in the chapter 5. The challenges for the project are explained in chapter 6. Advantages and disadvantages of the project are in chapter 7. Chapter 8 explains about future scope. Conclusion and references are in chapter 9 and chapter 10 respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Survey

Lackner, K. S., & Granger, R. (2016). Carbon dioxide extraction from the air: Is it an option? Proceedings of the National Academy of Sciences, 113(21), 5847-5854.

The article is referring to, "Carbon dioxide extraction from the air: Is it an option?" by Klaus S. Lackner and Robert Granger, was published in the Proceedings of the National Academy of Sciences in 2016.

The article discusses the technical and economic feasibility of direct air capture (DAC) of carbon dioxide (CO2) from the atmosphere as a means of reducing greenhouse gas emissions.The authors explore the potential of DAC to capture CO2 from ambient air and concentrate itfor use or storage. The article provides an overview of the different DAC technologies that have been proposed, including those based on chemical absorption, solid sorbents, andmembranes. The authors also discuss the challenges associated with DAC, including the energy requirements for capturing and concentrating CO2, the costs of the technology, and the scalability of the process. Overall, the article suggests that while DAC is still in its early stages of development, it has the potential to play a significant role in mitigating climate change by providing a means of capturing CO2 from the atmosphere.[1]

Keith, D. W., Holmes, G., St. Angelo, D., Heidel, K., & Polak, A. (2018). A process for capturing CO2 from the atmosphere. Joule, 2(8), 1573-1594.

The paper titled "A process for capturing CO2 from the atmosphere" by Keith et al. (2018) proposes a method for capturing carbon dioxide (CO2) directly from the atmosphere. The authors present a detailed description of their process, which involves a combination of directair capture (DAC) and a series of chemical reactions to produce a pure stream of CO2 that can be stored or used as a feedstock for industrial processes.

The authors start by discussing the need for carbon capture technologies to mitigate the effects of climate change, and explain why DAC is a promising approach. They then describethe technical aspects of their process, which involves capturing CO2 using an alkaline solution, followed by a series of chemical reactions to produce pure CO2. They also discuss the challenges of scaling up the process, as well as the cost implications. The authorsconclude that their process has the potential to capture significant amounts of CO2 from the atmosphere, and could be an important tool in the fight against climate change. However, they acknowledge that there are still many challenges to overcome, including cost andscalability, before the technology can be widely adopted.

Overall, the paper provides a comprehensive overview of the technical aspects of DAC and the potential of this approach to address climate change. It is a valuable resource for researchers and policymakers interested in carbon capture technologies.

Reiner, D., Gibbins, J., Liang, X., & Quoilin, S. (2019). The economics of direct air capture ofcarbon dioxide. Philosophical Transactions of the Royal Society A, 377(2142), 20180139.

The paper titled "The economics of direct air capture of carbon dioxide" by Reiner et al. (2019) examines the economic viability of direct air capture (DAC) as a method for reducing carbon dioxide (CO2) emissions. The authors provide an in-depth analysis of the costsassociated with DAC, including capital and operating costs, as well as the potential revenue streams from the captured CO2.

The authors begin by discussing the importance of reducing CO2 emissions to mitigate climate change, and the role that DAC could play in achieving this goal. They then provide an overview of the technical aspects of DAC, including the different types of DAC systems and the key components of the process. The main focus of the paper is on the economics of DAC, and the authors provide a detailed analysis of the costs and revenue streams associated with the technology. They explore various scenarios, including different carbon prices and different levels of government support, and assess the economic viability of DAC in each case.

The authors conclude that DAC has the potential to be economically viable in certain circumstances, particularly in the presence of high carbon prices and government support. However, they also acknowledge that there are significant challenges to scaling up the technology and achieving cost reductions. Overall, the paper provides a valuable analysis of the economics of DAC and the potential role that this technology could play in mitigating climate change. It is a useful resource for policymakers and researchers interested in the economic aspects of carbon capture and storage technologies.

2.2 Necessity

Direct air capture is necessary because it offers a way to remove carbon dioxide from the atmosphere, which is a critical step in mitigating the effects of climate change. The concentration of CO2 in the atmosphere has been steadily increasing due to human activities such as burning fossil fuels and deforestation. This increase in CO2 levels is causing global temperatures to rise and leading to more frequent and severe weather events, rising sea levels, and other negative impacts on the environment and human health.

Traditional methods of reducing carbon emissions, such as transitioning to renewable energy sources and improving energy efficiency, are important but may not be enough to meet the goals of the Paris Agreement, which aims to limit global warming to well below 2°C above pre- industrial levels. Direct air capture can help bridge the gap by removing CO2 from the atmosphere that has already been emitted and cannot be avoided. (5.Haszeldine)

Moreover, direct air capture technology can be used in conjunction with other solutions such as carbon storage or utilization to further reduce emissions and create a circular economy. This has the potential to be a key component in achieving a sustainable future and addressing the urgent need for climate action. Overcoming past emissions: It is challenging to undo the effects of past CO2 emissions on the climate system, even with significant decreases in emissions. By actively eliminating CO2 that has collected over decades or centuries, DAC helps to bring the Earth's carbon cycle back into equilibrium.

2.3 Gap Identification

From the literature survey of the research papers that we followed it is concluding that project has a large capital cost and it is of a large-scale project which require large amount of components which has high cost. Authors provide a detailed analysis of the costs and revenue streams associated with the technology. From this literature survey we are willing to design a small-scale direct air capture technology which can be used for the small application having cost effective and high efficiency of capturing the carbon dioxide and reduce the concentration of CO2 in the atmosphere.

One potential gap in the literature survey of large-scale direct air capture (DAC) and small-scale DAC is the lack of direct comparison between the two. While both technologies aim to capture carbon dioxide directly from the atmosphere, they differ in terms of their scale, cost, and technological requirements. Large-scale DAC typically involves the deployment of large facilities that use chemical processes to absorb carbon dioxide from the air. These facilities are often designed to capture millions of tons of carbon dioxide per year, and they require significant infrastructure and capital investments.

2.3.1 Problem Statement

A unique and promising technology called Direct Air Capture (DAC) seeks to address the pressing problem of atmospheric greenhouse gas concentrations, namely those of carbon dioxide (CO2). DAC systems offer a potential way to lessen the effects of climate change because they are made to remove CO2 straight from the atmosphere. While DAC has a lot of potential, in order to successfully direct research, development, and implementation activities, it is crucial to identify the problem statement related to this technology.
Greenhouse gas emissions are contributing to global climate change, resulting in severe environmental impacts such as rising temperatures, melting ice caps, and extreme weatherevents. Encouraging innovation and research: The development and deployment of DAC stimulate innovation, research, and collaboration across sectors, fostering advancements in carbon capture technologies as a whole. This can lead to further breakthroughs in climate change mitigation strategies.

2.3.2 Objectives

- To capture (suck) atmospheric air. carbon dioxide (CO2) directly from the atmosphere.
- To Separate CO2 from captured air using chemical process.
- To store chemically separated CO2

2.3.3 Scope

The scope for Direct Air Capture (DAC) is significant, as it has the potential to play a critical role in reducing greenhouse gas emissions and mitigating climate change. Here are some potential applications and benefits of DAC:

1. To prepare small scale Direct Air Capture (DAC) model.
2. To Separate only CO2 from captured air using chemical process.

CHAPTER 3
SYSTEM DEVELOPMENT

3.1 Introduction

Direct Air Capture (DAC) is a relatively new technology that involves capturing carbon dioxide (CO2) directly from the air and converting it into a concentrated stream that can be used for various purposes such as industrial processes or sequestration. The first step in system development is defining the problem is trying to solve. In this case, the problem is the increasing concentration of CO2 in the atmosphere and its impact on climate change. Once the problem is defined, the next step is to gather requirements for the system. This includes identifying the necessary components and features that are required for the system to extract CO2 from the air. The design phase involves creating a detailed plan for the system based on the requirements gathered. This includes designing the hardware components, determining how they will interact with each other, and how the system works.

The implementation phase involves building the hardware components and integrating them with the software. This includes assembling the suction fan, filter, liquid sorbent chamber, heating chamber, heating device, CO2 sensor, and cylinder. Once the system is built, it must be tested to ensure that it is functioning properly. This includes testing the suction fan, filter, liquid sorbent, heating chamber, heating device, CO2 sensor, and cylinder to ensure that they are capturing, releasing, and storing CO2 as intended.

After the system has been tested and is functioning properly, it can be deployed for use. This involves installing the system in its intended location and monitoring its performance over time. The final phase of system development is maintenance. This involves regularly inspecting and servicing the hardware components, updating the software as necessary, and replacing any worn or damaged parts.

Overall, the system development process for the project involves identifying the problem, gathering requirements, designing the system, implementing it, testing it, deploying it, and maintaining it over time. By following these steps, we can develop a functional and effective system for extracting CO2 from the air at a small scale.

3.2 Flow of Hardware Model

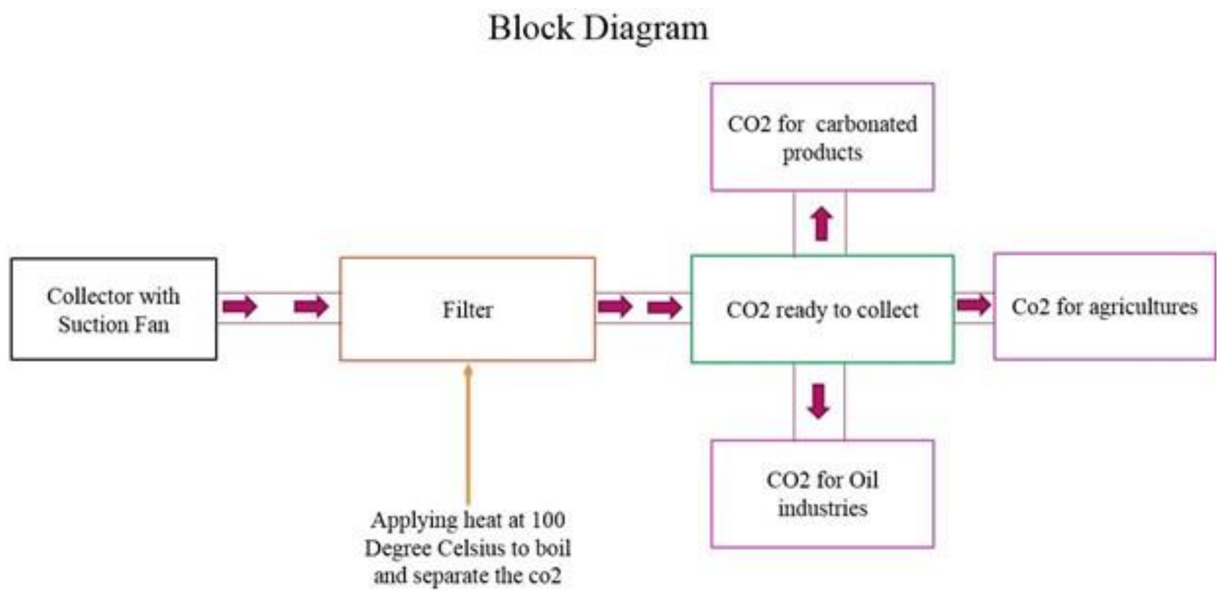


Fig 4 Block Diagram of Working Process

Above Fig. shows the block diagram of process of working of small-scale direct CO2 extraction from the ambient air. The working process of DAC involves several steps, which are outlined below:

- **Step 1: Air Intake**

The first step in DAC is to draw in ambient air. This air is typically passed through filters to remove any large particles or impurities that may damage the equipment or interfere with the chemical reactions.

- **Step 2: CO2 Absorption**

After the air is filtered, it is directed into a reactor vessel where it is exposed to a sorbent material, such as an amine solution. The sorbent material reacts with the CO2 in the air, absorbing it and removing it from the air stream

- **Step 3: Heat Treatment**

Once the sorbent material has captured the CO2, it is heated to release the CO2 molecules. This process is known as desorption. The heat treatment breaks the bond between the CO2 and the sorbent material, releasing the CO2 in a concentrated form.

- **Step 4: CO2 Capture and Concentration**

The concentrated CO2 is then captured and separated from the sorbent material using a series of separation techniques, such as distillation or adsorption. This step concentrates the CO2, making it easier to store or use.

- **Step 5: CO2 Utilization or Storage**

The final step in DAC involves either utilizing or storing the captured CO2. CO2 can be used in a variety of applications, such as the production of fuels, chemicals, or building materials. Alternatively, it can be stored in geological formations, such as depleted oil and gas reservoirs, saline formations. (Keith)

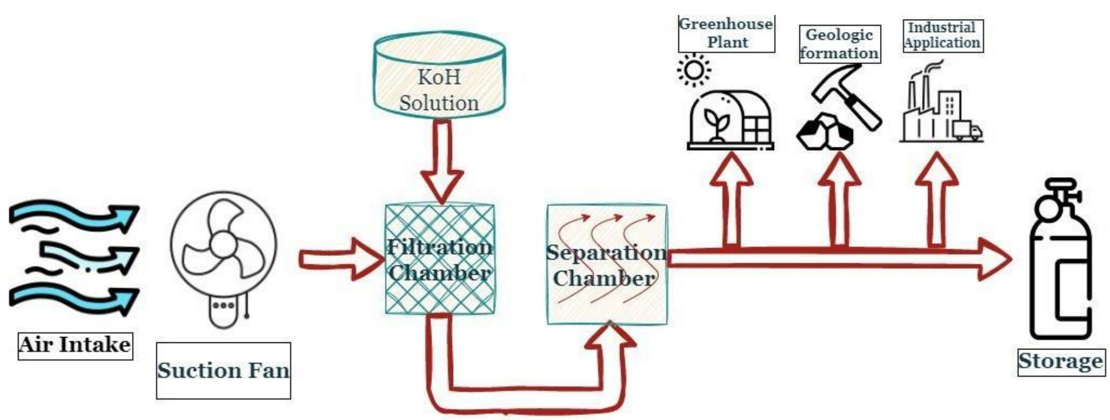


Fig 5 Working of Direct Air Capture

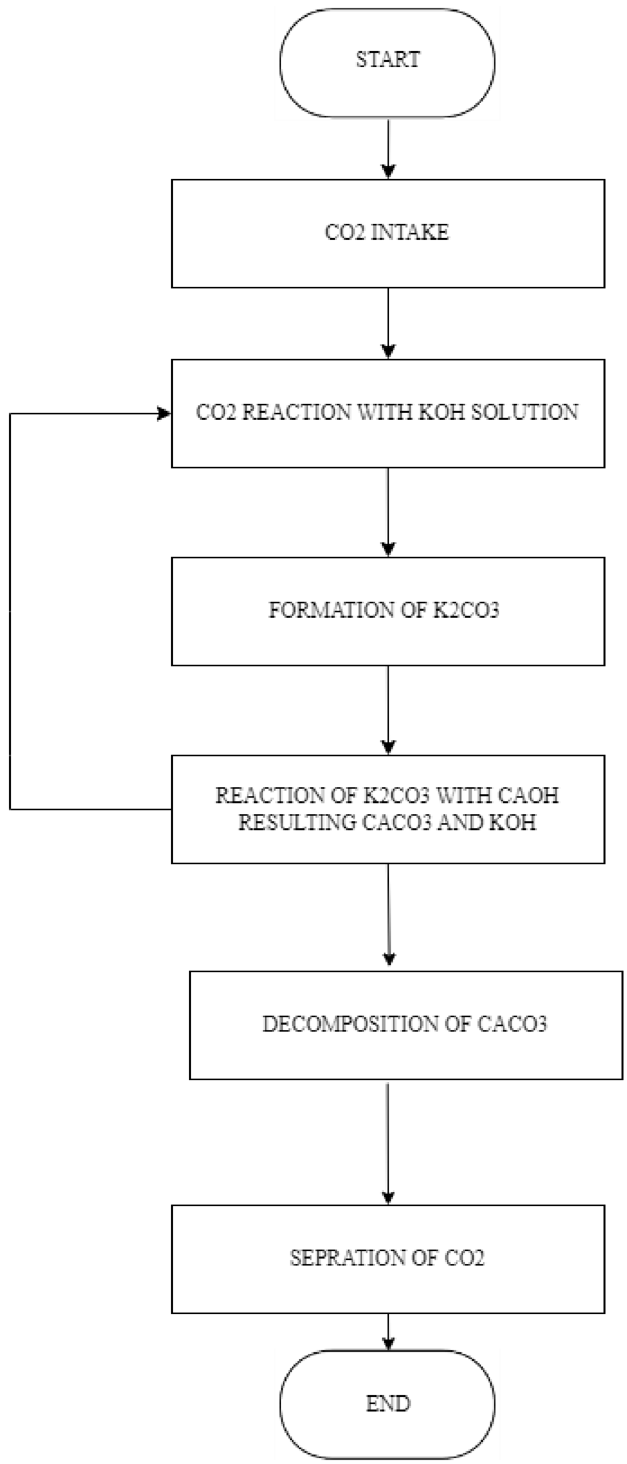


Fig 6 Flow Chart of Capturing Process

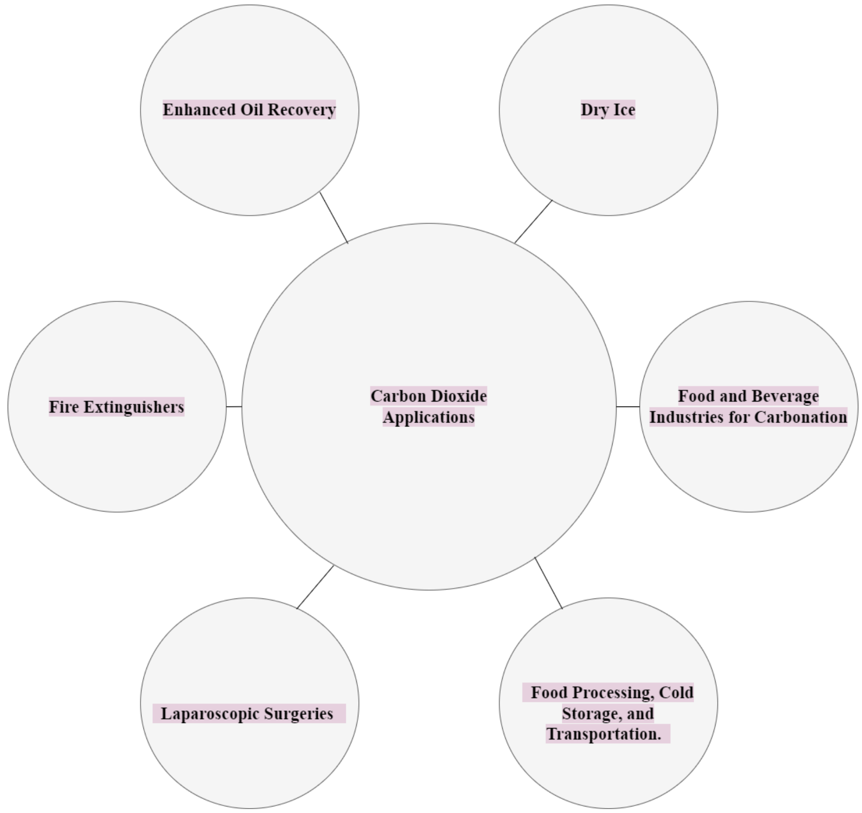


Fig 7 Applications of Carbon Dioxide (CO2)

CO2 is commonly used to carbonate soft drinks, sparkling water, and beer. It gives thesebeverages their characteristic fizz and enhances their taste. CO2 is commonly used as a fire suppression agent in areas where water or foam-based extinguishing systems are not suitable, such as electrical equipment or sensitive materials. CO2 is often used to extend the shelf life of perishable food products by inhibiting the growth of bacteria and other microorganisms. CO2 is utilized in medical procedures such as laparoscopy and endoscopy, where it is used to inflate body cavities for better visualization during surgeries. In refrigeration systems like refrigerators and air conditioners, CO2 is widely used as a refrigerant due to its low environmental impact compared to other synthetic gases. In enhanced oil recovery techniques known as carbon dioxide flooding or miscible flooding, high-pressure injections of CO2 are used to extract additional oil from depleted reservoirs by reducing viscosity and increasing pressure within the reservoirs.

CHAPTER 4
HARDWARE IMPLEMENTATION

4.1 Hardware Implementation

Direct Air Capture (DAC) can be implemented on a small scale using a range of hardware components, including air filters, absorbent materials, heat exchangers, compressors, and storage tanks. While there are many different configurations and designs for small-scale DAC systems, a typical implementation might involve the following components:

DAC systems typically begin with a series of filters that remove particulate matter and other impurities from ambient air. These filters can be designed to remove specific contaminantsor to operate in a range of environmental conditions. Once the air has been filtered, it is passed through a series of absorbent materials that selectively capture CO2. These materials can be based on a range of chemical and physical principles, such as chemical reactions, electrostatic forces, or surface area adsorption.

Heat exchangers: After the CO2 has been captured by the absorbent material, the next step is to separate the CO2 from the absorbent. This is typically done using a heat exchanger, which heats the absorbent to release the CO2. Once the CO2 has been released, it's compressed into a concentrated stream that can be stored or transported. This requires the use of compressors, which increase the pressure and density of the CO2.

Finally, the concentrated CO2 stream is stored in tanks or other storage facilities, where it can be used for a range of applications, such as industrial processes, carbon sequestration, or carbon utilization. Small-scale DAC systems can be designed to operate using renewable energy sources, such as solar or wind power, which can help to reduce the carbon footprint of the process. Additionally, the use of modular and scalable components can allow for easy expansion or adjustment of the system, depending on the specific needs of the user.

While small-scale DAC systems are still in the early stages of development, they have the potential to play an important role in reducing greenhouse gas emissions and mitigating the effects of climate change, particularly in settings where traditional carbon capture technologies may not be feasible or cost-effective.

4.2 Description of hardware model

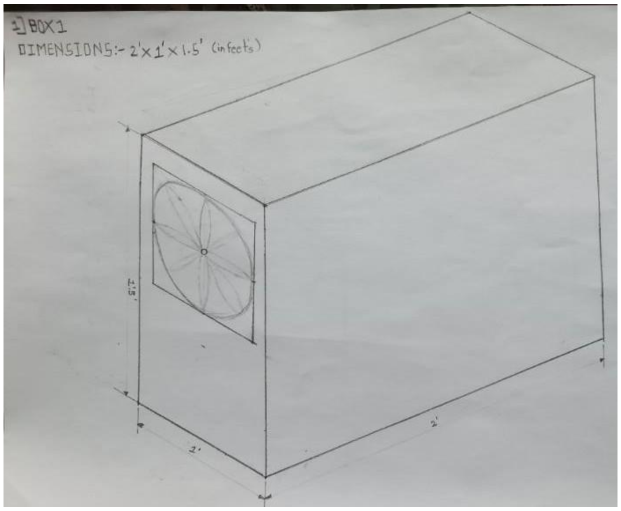


Fig 8 Schematic Diagram of Prototype Box 1

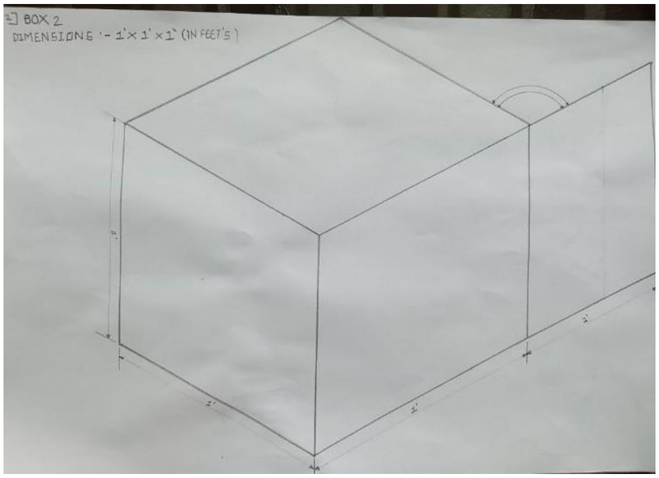


Fig 9 Schematic Diagram of Prototype Box 2

The project encompasses the creation of a 3D hardware model, meticulously designed to facilitate the efficient functioning of the project. This model is composed of two distinct box-type chambers, each meticulously crafted for a specific purpose. The 3D model of the project hardware features two purpose-built chambers, each with unique dimensions and functions. The first chamber serves as the initial processing stage for air intake and filtration, while the second chamber is dedicated to CO2 separation through a chemical process with the aid of a heating device. This detailed and thoughtful design is integral to the success of the project's overall functionality.

4.2.1 Chamber 1: Suction Fan and Filter Assembly

Dimension: The first chamber measures 2 feet in length, 1.5 feet in width, and 1 foot in height, providing ample space for its intended components. Purpose: The primary function of this chamber is to house the assembly of a suction fan and a filtration system. It acts as the initial stage in the project's process, where the intake of air and the removal of unwanted particles occur. Design Rationale: The spacious design of this chamber allows for the integration of the suction fan, ensuring that it operates optimally. Additionally, the filter assembly is positioned to effectively capture and remove impurities from the incoming air. Software Utilized: The 3D modeling of this chamber was accomplished using Blender software, enabling precise and detailed design work.

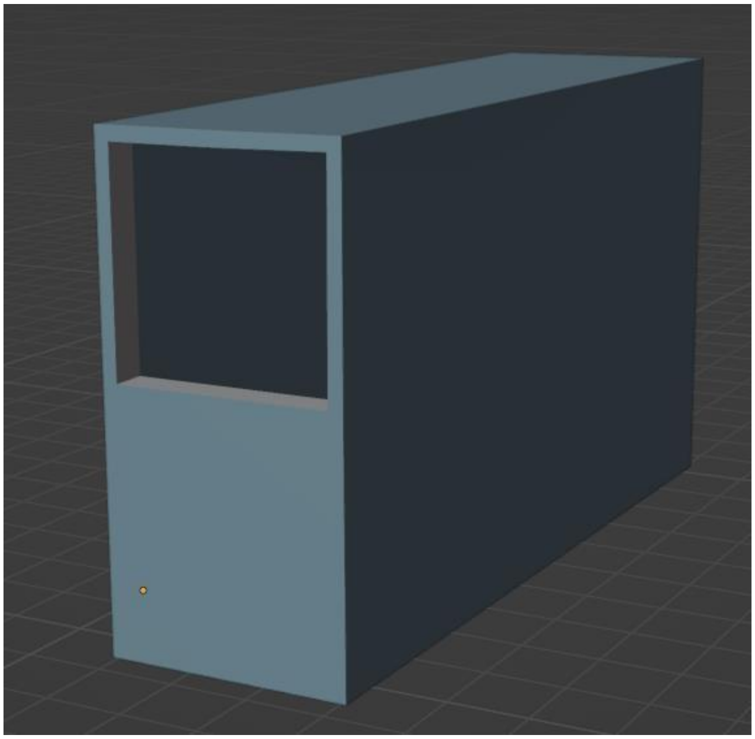


Fig 10 Filtration Chamber 3D Model

4.2.2 Chamber 2: CO2 Separation with Heating Device

The second chamber is a cube measuring 1 feet on each side, providing a compact yet functional space. This chamber is dedicated to the separation of CO2 using a chemical process. It incorporates a heating device to facilitate this separation process. The compact dimensions ofthis chamber are carefully tailored to accommodate the necessary equipment for CO2 separation, including the heating device. The smaller space ensures efficient heating and chemical reactions. Similar to the first chamber, Blender software was used to meticulously design this chamber, allowing for precise placement of the heating device and other components.

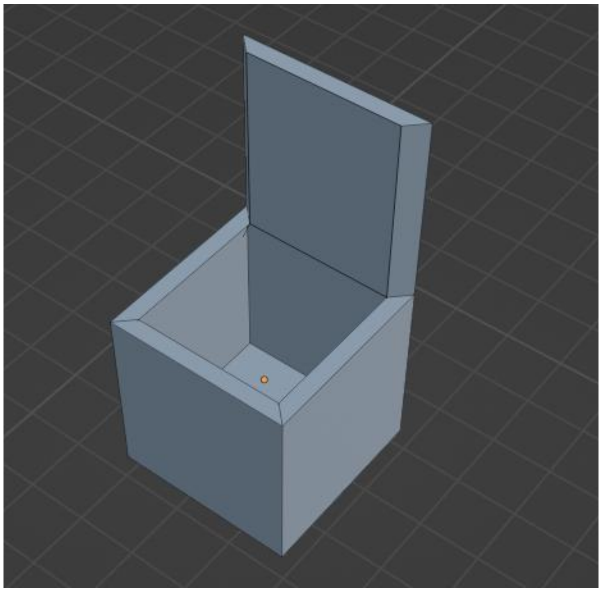


Fig 11 Heating Chamber 3D Model

The fig shows the schematic diagram of small-scale direct air capture model. In this model consisting of a suction fan, Filter, a container consisting of two chambers, one is for the storage of solution of sorbent material and water and the other one is for the heating of the solution to release the carbon dioxide from that solution.

Here, we are designing a small-scale direct air capture it consists of following components:

1. **Suction fan**

   This component is used to draw air from the surrounding environment into the system. The suction fan sucks the surrounding air as it is and passes the air on the filter assembled further inside. The suction fan has a speed of 1350rpm and has a rating of 70w only.

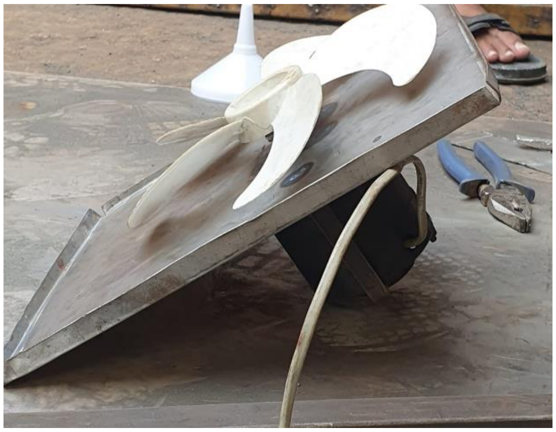


Fig 12 Suction Fan

Table 1 Details of Suction Fan

Apparatus	Rating	RPM	Cost in Rs
Suction fan	70 watts	1350	Rs 1200

2. Filter

This component is used to capture CO2 from the air that is drawn in by the suction fan. The filter holds the injected air within its loopholes. While solution of Koh (Potassium Hydroxide) is sprayed over the filter which can efficiently capture most of the CO2 present in the air while allowing other components of air to pass through.

Fig 13 Filter

3. Liquid sorbent

The choice of liquid sorbent depends on various factors, including the specific DAC, the desired efficiency, energy requirements for regeneration, cost, and environmental considerations. Researchers continue to explore and develop new liquid sorbents and improve existing ones to enhance the performance and sustainability of Direct Air Capture systems. Amines are organic compounds that can react with CO2 to form stable chemical complexes. Aqueous amine solutions, such as mono ethanol amine (MEA), are commonly used in DAC systems. Ammonia (NH3) can also be used as a liquid sorbent in DAC systems.It has the ability to capture CO2 and can release it through changes in pressure or temperature. Similar to KOH, NaOH is another strong base that can be used as a liquid sorbent for capturing CO2.

Ionic liquids are organic salts that are liquid at or near room temperature. Some ionic liquids have shown promise in CO2 capture due to their tunable properties and selectivity. Organic solvents such as tetra ethylene glycol dimethyl ether (tetra glyme) have been studied for DAC applications. These solvents have the potential to capture CO2 efficiently and can release it under specific conditions.

In this type of DAC potassium hydroxide is preferred, which is used to absorb and capture CO2 from the air that passes through the filter. The liquid sorbent is held in a chamber that is separate from the heating chamber. Further Calcium hydroxide is also used to separate the Potassium Hydroxide (Koh) from the reactions.

Fig 14 Calcium Hydroxide (CaoH)

Fig 15 Potassium Hydroxide (Koh)

Table 2 Details of Chemicals

Apparatus	Quantity	Cost in Rs
Calcium Hydroxide (CaoH)	1kg	Rs 50
Potassium Hydroxide (Koh)	1kg	Rs 50

4. Heating Kettle

The desorption process in Direct Air Capture (DAC) is a key step that enables the release of carbon dioxide (CO2) from the capture medium after it has absorbed CO2 from the atmosphere. This step is essential for regenerating the capture material, typically a liquid sorbent, so that it can be reused in subsequent cycles. Here's a concise explanation of the desorption process in DAC:

After CO2 capture, the capture medium is loaded with CO2. This occurs when CO2 molecules are chemically or physically bonded to the sorbent. To initiate desorption, the loaded capture medium is exposed to a heat source. Thermal desorption is the most common method employed. The capture medium is heated to a specific temperature, usually in the range of 100°C to 200°C or higher, depending on the sorbent's characteristics.

As the capture medium is heated, thermal energy is transferred to the CO2 molecules that are adsorbed onto or absorbed into the medium. This thermal energy disrupts the bonds between the CO2 and the capture medium, causing the CO2 to transition from a solid or liquid state back into a gaseous state. The release of CO2 from the capture medium occurs as the CO2 molecules break free due to the increased thermal energy. The CO2 is now in a gaseous form and is ready to be collected and further processed. The released CO2 can be collected and concentrated for various purposes, such as carbon sequestration, utilization in industrial processes, or other applications aimed at reducing atmospheric CO2 levels.

The capture medium, now free of CO2, is considered regenerated and can be reused in subsequent CO2 capture cycles. This process may involve cooling the sorbent to return it to its initial state for another round of CO2 capture. The desorption process is a crucial element of DAC systems, as it allows for the cyclic operation of capturing and releasing CO2. The energy efficiency of the desorption step is a critical consideration in DAC system design, as it directly affects the overall energy requirements and economic feasibility of the technology. This component is used to heat the liquid sorbent material, which releases the captured CO2. The heating chamber is separated from the liquid sorbent chamber to prevent the liquid from boiling off.

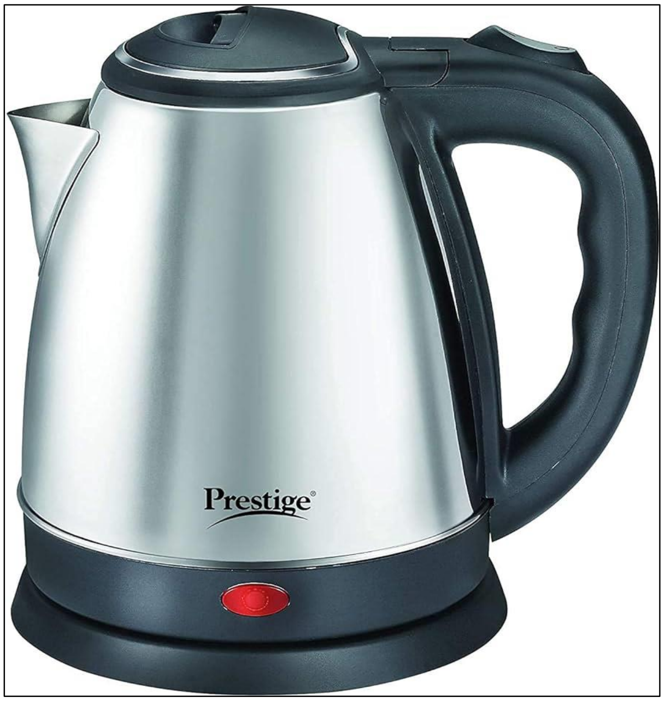


Fig 16. Heating Kettle

5. **Heating device**

This component provides the heat necessary to release the captured CO2 from the liquid sorbent material. The heating coil is one of the key apparatuses used for the heating process, where the solution formed K2CO3 can be heated up-to 650^0C to separate CO2. The coil can Attain the temperature of 800 ^{0}C and above. This heating coil will be fabricated with heating chamber and connected to the wiring setup as well as will be electrically supplied and heated according to the requirements.

Fig 17 Conduction Heating Coil

Table 3 Details Of Conduction Heating Coil

Apparatus	**Rating**	**Max Temperature**	**Cost**
Heating Coil	2200 watts	800 ^{0}C	Rs 900

6. Hardware

Fig 18 Fabricated Prototype

Table 4 Details Fabricated Prototype

Apparatus	Dimensions of component	Capacity in Liters.	Cost in Rs
Box 1	2’ * 1.5’ * 1’	84.95 Liters	Rs 2200
Box 2	1’ * 1’ * 1’	28.31 Liters	Rs 1800

Overall, the hardware model for this project appears to be a simple yet effective design for the small-scale extraction of CO2 from air. The suction fan, filter, liquid sorbent, heating chamber, heating device, CO2 sensor, and cylinder all work together to capture, release, and store CO2. With proper implementation and operation, this hardware model could be a valuable tool for addressing the issue of climate change by reducing the amount of CO2 in the atmosphere.

Fig 19: - Absorption Chamber

4.3 Chemical Reactions Taking Place

While in working condition when the Potassium Hydroxide (Koh) solution comes in contact with the atmospheric Carbon Dioxide (CO2), the solution reacts with CO2 to form Potassium Carbonate (K_2CO_3) and Water (H_2O).

Carbon Dioxide (CO2) **Potassium Hydroxide (Koh)**

Potassium Carbonate (K_2CO_3) **Water (H_2O)**

After formation of Potassium Carbonate (K_2CO_3) solution, the solution is further proceeded to mix with Calcium Hydroxide (CaoH). When the Potassium CarbonateK_2CO_3 mixed with Calcium Hydroxide (CaoH) it forms Calcium Carbonate ($CaCO_3$) and Potassium Hydroxide (Koh).

Potassium Carbonate (K_2CO_3) **Calcium Hydroxide (CaoH)**

Calcium Carbonate ($CaCO_3$) **Potassium Hydroxide (Koh)**

The Koh formed from this process can be reused for further processes

After separating Calcium Carbonate ($CaCO_3$). The Calcium Carbonate ($CaCO_3$) solution is heated, after applying heat to the solution the Calcium Carbonate ($CaCO_3$) solution starts to decompose and forms Carbon Dioxide (CO2) and Calcium Oxide (CaO).

Calcium Carbonate ($CaCO_3$) $\xrightarrow{\Delta}$ **Carbon Dioxide (CO2)** **Calcium Oxide (CaO)**

After the formation of Carbon Dioxide (CO2) and Calcium Oxide (CaO) the process of reactions completes, and the Carbon Dioxide (CO2) is ready to capture or we can directly use it in any Carbon Dioxide (CO2) based applications.

Another byproduct the Calcium Oxide (CaO) can be used as Water treatment: To eliminate contaminants and balance acidic water, calcium oxide is frequently utilized in water treatment procedures. It can aid in pH level adjustment and improve the efficiency of other treatment agents. Soil amendment: By increasing pH and decreasing acidity, calcium oxide can be applied to the soil to enhance fertility and quality. This contributes to improving the environment that supports plant growth. (Keith)

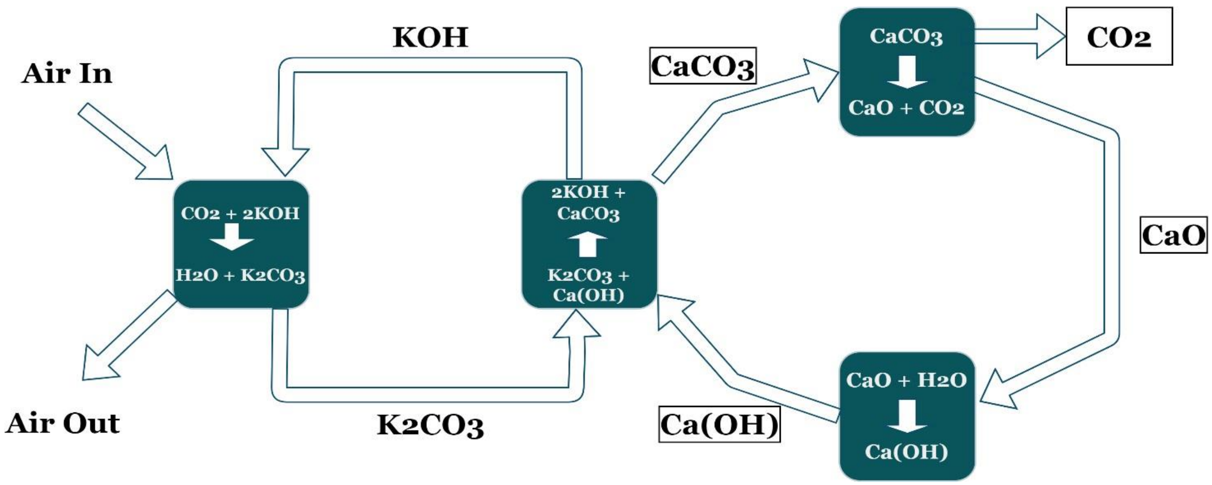


Fig 20 Chemical Process

CHAPTER 5

LIMITATIONS

5.1 LIMITATIONS

- Direct air capture is still in its early stages and is currently expensive to implement. The high cost of capturing and storing carbon dioxide from the air makes it a less viable option for large-scale deployment.

- Direct air capture requires a significant amount of energy to operate, making it an energy-intensive process. This reliance on energy sources may result in increased greenhouse gas emissions unless renewable energy sources are used.

- The efficiency of direct air capture is relatively low compared to other carbon capture methods, such as capturing CO2 emissions directly from industrial facilities or power plants. This means that a larger amount of equipment and infrastructure is needed to achieve the same level of carbon reduction.

- Scaling up direct air capture to have a meaningful impact on global carbon dioxide levels poses significant challenges. Building enough facilities and infrastructure would requiresubstantial financial investment and resources.

- Once captured, the carbon dioxide needs to be stored securely for long periods, which presents challenges related to storage capacity, potential leaks or accidents, and monitoring systems.

- The public perception and acceptance of direct air capture as a viable solution for tackling climate change may play an important role in its future implementation success.

- Proper safety measures should be followed while the maintenance of the chemicals as they can cause harm to our body, skin, or eyes to cause itching and irritations.

CHAPTER 6

CONCLUSION

6.1 Conclusion

Direct Air Capture (DAC) has the potential to play a significant role in mitigating the effects of climate change by capturing carbon dioxide directly from the atmosphere. However, there are several challenges that need to be addressed to make the technology feasible and effective. On the technical side, improving the efficiency of the adsorbent material, developing more cost-effective and reliable thermal management systems, and improving carbon dioxide collection and storage techniques are key areas of research and development. On the economic side, reducing the cost of implementing and operating the system is crucial to making the technology viable. This may require government incentives or subsidies, as well as exploring potential revenue streams such as the sale of the captured carbon dioxide.

On the environmental side, minimizing the impact of the intake system, ensuring the sustainability of the adsorbent material, and preventing leaks or accidents during the carbon dioxide storage and transport process are important considerations.

Overall, direct air capture holds promise as a tool for mitigating climate change, but further research and development are needed to make the technology feasible and effective on a large scale. In conjunction with other carbon capture and storage technologies, direct air capture could be an important component of a comprehensive strategy to reduce greenhouse gas emissions and combat climate change.

CHAPTER 6

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APPENDIX A : DETAILS OF TEAM MEMBERS

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