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Chapter 1

1 Introduction

1.1 Project Title

Design and fabrication of carbon capture tool for residential application.

1.2 Project overview

This project focuses on the design and fabrication of carbon capture tool for residential application. Climate change is becoming more visible as globally carbon emissions keep growing, resulting in more catastrophic storms, wildfires, and flooding. [1] It is vital to lower greenhouse gas (GHG) emissions, for example, by engaging in energy efficiency, installing solar panels, and reducing deforestation. At the same time, current climate research suggests that such efforts would be insufficient to limit warming of the planet below 1.5-2 degrees Celsius, which would avert the worst effects of climate change. [2]

While methods to curb GHG emissions should still take precedence, achieving climate targets would need carbon dioxide removal technologies – systems that remove carbon straight from the air — on a billion-tonne magnitude by mid-century. The exact quantity required will be determined by how quickly the globe reduces emissions. Carbon removal can come in many different forms, involving natural and artificial methods that speed up present CO2 removal rates. [3]

Direct air capture (DAC) is gaining popularity as a viable carbon-reduction strategy that will almost certainly become a crucial component of a wider carbon-reduction strategy. To guide siting and minimize resource effects, careful assessment of DAC's energy, land, and water demand will be required.

1.3 Project scope

To be finished, this project demands much investigation and comprehension. The purpose of this study is to gain a better understanding of the concept and principles that must be utilised while creating a carbon capture equipment. The project focuses on ways to capture the air

directly and remove the CO2. The whole device is designed in such way it can be used in residential buildings.

DAC technique does this by sucking in ambient air and extracting the carbon dioxide (CO2) from it before releasing the remaining of the air to the environment. Plants and trees accomplish this repeatedly as they photosynthesize, but DAC technology does it far quicker, with a small farm footprint, and produces carbon dioxide in a clean, compact form that can be stored beneath or reused.

1.4 Project objectives

The aim of the product is to design and fabrication of carbon capture tool for residential application. We defined following objectives to obtain our aim:

- Review of growth of carbon dioxide in the environment and major factors responsible for it. Effects of the growth of the carbon dioxide and possible solutions.
- Review of techniques to capture the carbon dioxide for small areas like residential buildings.
- Design and fabrication of carbon capture tool.
- Results analysis on quality of air released by carbon capture tool, conclusion and future recommendations.

1.5 Thesis structure

Introduction, literature review, methodology, design, findings & discussion, and conclusion & suggestion are the six key chapters of this thesis. The main points of each chapter are summarised here.

- Chapter 1: Introduction, Project aim/ objectives, Project scope
- Chapter 2: Literature review
- Chapter 3: Requirement specifications, Initial design of device
- Chapter 4: Design of the device
- Chapter 5: Testing and Result discussion
- Chapter 6: Conclusion and suggestions.

Chapter 2

2 Literature review

2.1 Introduction

The author will evaluate the works and publications of others that are relevant to the project in this chapter. Because the project's title is "Design and fabrication of carbon capture tool for residential application," we will look about the carbon content in the atmosphere, problems that arise because of increased carbon content, and other topics such as related data and methods for capturing carbon from the air. The project can use the ideas and efforts of earlier studies to implement that concept and attempt to enhance even more in order to finish the project.

2.2 QFD

The Quality Function Deployment (QFD) approach aids in the decision-making process for engineering projects. To begin, a survey will be delivered electronically or physically to the community or targeted customers to get input. The customer and engineering requirements are then acquired and compared to determine the strength of the link. [3] All of this data will be included into the House of Quality (HOQ), which will allow for a more systematic comparison. The HOQ will determine the probable relevance of each of the specified criteria. A morphological diagram will be constructed based on the criteria that have been selected.

2.3 Carbon content in air

The combustion of fossil fuels depletes oxygen and releases CO2. We can simply calculate the amount of CO2 emitted into the atmosphere as a result of world coal, oil, and natural gas use. Some reputable organisations [4] have compiled statistics on fossil fuels and calculated CO2 emissions.

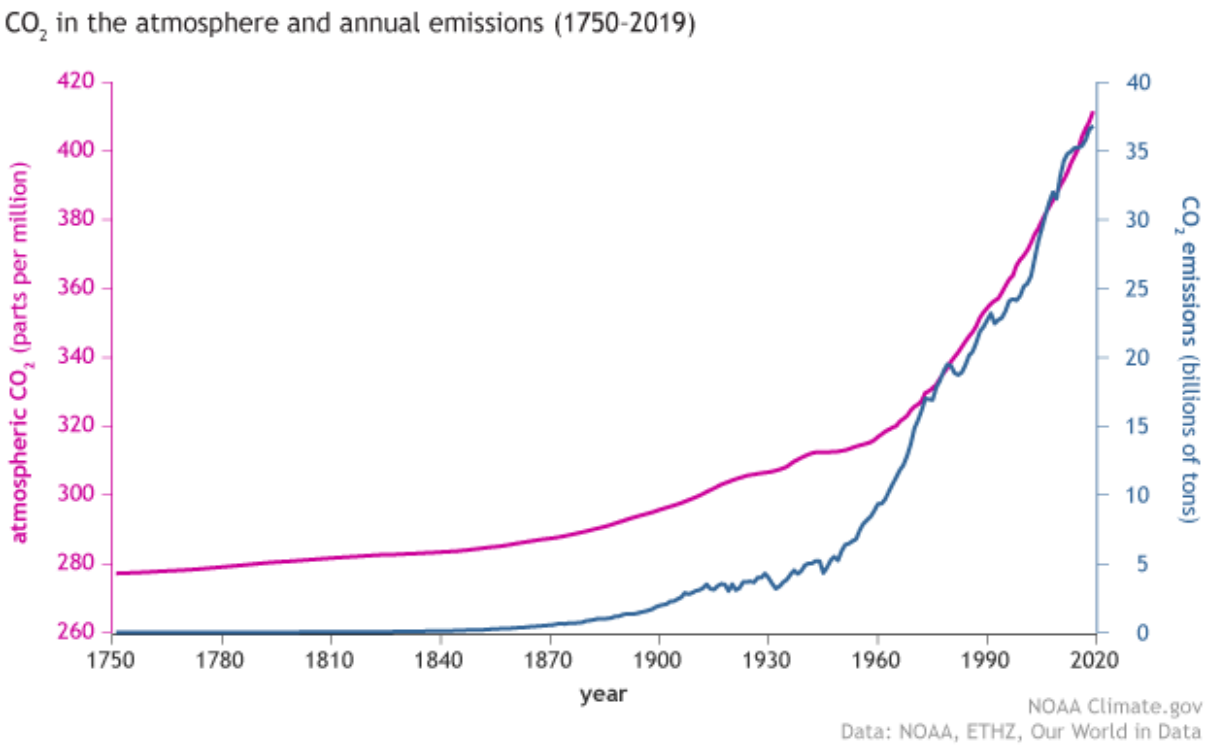


Figure 1 Carbon content in air [Image credit: NOAA Climate.gov]

2.4 Problems arising due to increased carbon content

2.4.1 Increasing earth's average surface temperature

The earth's average surface temperature in 2018-2019 was the fourth hottest in over 140 years of record keeping, according to NASA. It also marked the continuance of a clear warming trend. [4-5] Since eighteen of the 19 hottest years have happened after 2001, this is the case. Extreme heat in Australia, protracted droughts and coastal floods in the United States (US), and the disappearance of Arctic ice, according to NASA experts, are all signs of global warming.

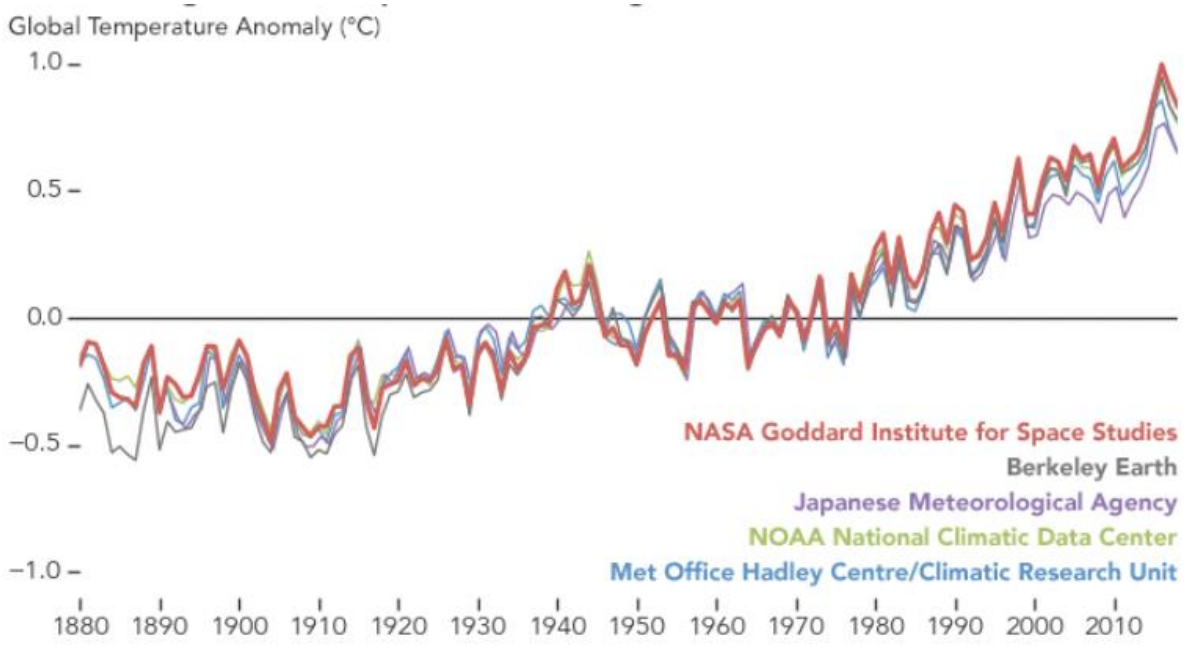


Figure 2 Rising trend of earth's average surface temperature [Data source: as mentioned in figure]

According to scientists, the world's record-breaking temperature in 2016, especially severe heat in Asia, was caused by global warming caused by human activity such as the combustion of fossil fuels. Human-caused climate change had previously been thought to increase the likelihood of some floods, droughts, storms, and heat waves, but not as the primary reason. In a 1975 essay, Wallace Smith Broecker, the man who popularised the phrase "global warming," projected that growing CO2 concentration in the atmosphere would result in significant warming. [5]

According to University of California researchers, rising temperatures increase the concentration of air pollution-causing aerosols in the atmosphere. [6] Aerosols are microscopic solid or liquid droplets that float in the air. They can originate from natural causes such as dust or wildfires, as well as man-made ones including car and industrial pollution. Aerosols have an effect on the climate, as well as the water cycle and human health. They also contribute to smog and other forms of air pollution, both of which can be harmful to one's health.

According to many studies, polycyclic aromatic hydrocarbons, which are typically present in high-traffic areas, lead to the loss or destruction of white matter in the brain. Pollutants not only impair new-borns' growing lungs, but they can also hurt their developing brains. [7]

Many studies, particularly those done on Chinese children, have found a correlation between stunted development and reduced lung capacity because of air pollution. [8] The amount of air pollution obtained by older adults when taking a two-hour stroll on a busy city street stiffens

the arteries and affects lung function, according to a research published in the British journal The Lancet. According to the findings, short-term exposure to traffic pollution reduces the cardio-respiratory effects of physical exercise.

2.4.2 Affecting the soil health

As per a guide gave by the United Nations' Food and Agriculture Organization (FAO), the best 30 cm of the world's dirt contains roughly two times as much carbon as the entire climate. Soil is the second most prominent regular carbon sink after the seas, surpassing woods and different plants in its capacity to retain carbon dioxide from the climate. [9]

Environmental change is as of now being felt globally and on European soil, as per analysts. Soil dampness has declined in the Mediterranean region and expanded in segments of northern Europe during the 1950s, as per the EEA's latest review on environmental change, impacts, and weakness in Europe. [10] As normal temperatures increase and precipitation designs shift, the paper predicts comparative repercussions later on many years.

Proceeded with soil dampness misfortunes might expand the prerequisite for water system in agribusiness, bringing about lower yields and maybe desertification, with possibly terrible ramifications for food creation. Thirteen EU part states have recognized that they are desertification-impacted. In spite of this acknowledgment, the European Court of Auditors has expressed that Europe comes up short on extensive comprehension of the hardships related with desertification and land corruption, and that the actions carried out to address desertification are garbled..

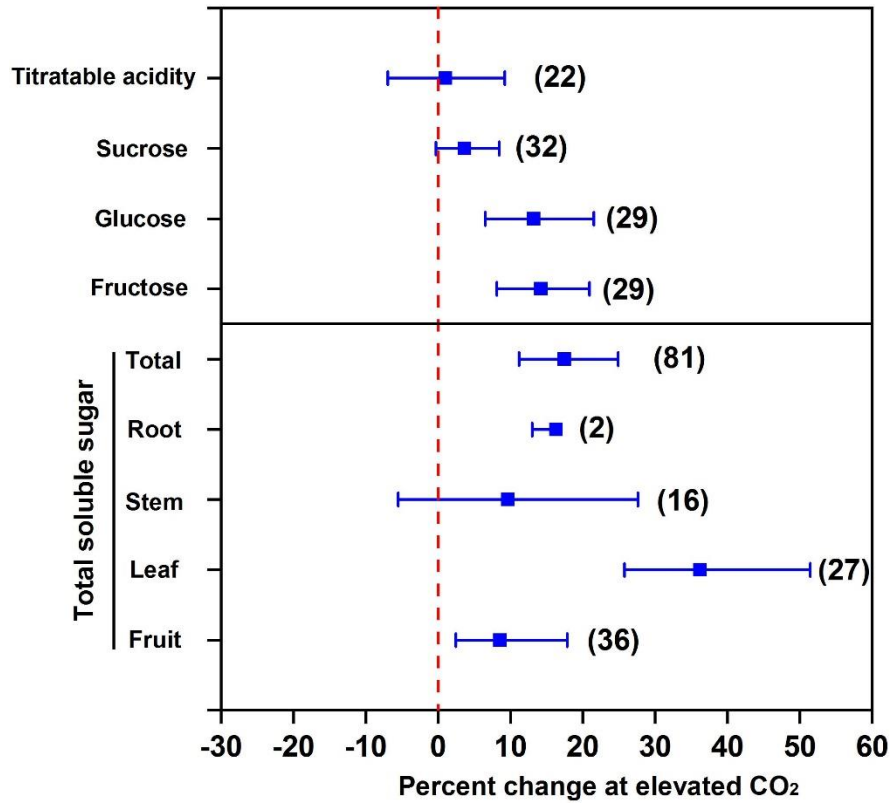


Figure 3 Effect of increased carbon content on vegetable nutrition [Image source:]

Occasional temperature changes can likewise make yearly plant and creature cycles modify, bringing about diminished harvests. Spring, for instance, may show up before the expected time than anticipated, and trees might sprout before their pollinators have brought forth. With the anticipated ascent in worldwide populace, worldwide food creation should extend as opposed to decline. This is reliant in huge part on the protection of good soil and the reasonable administration of rural districts. Simultaneously, the squeezing need to supplant petroleum products and decrease ozone depleting substance emanations is driving up interest for biofuels and other plant-based merchandise.

2.4.3 Affecting the rain fall pattern

Scientists have uncovered another element that influences rainfall patterns in a location: the interplay between atmospheric CO2 levels and tropical vegetation. Increased precipitation across African & Indonesian forests might be caused by high CO2 levels in the atmosphere, which could lead the Amazon rainforest to dry up. Large-scale changes in rainfall can occur as a result of how tropical forests react to the excess CO2 humans are spewing into the atmosphere, as shown in a study published in Nature Climate Change. [11]

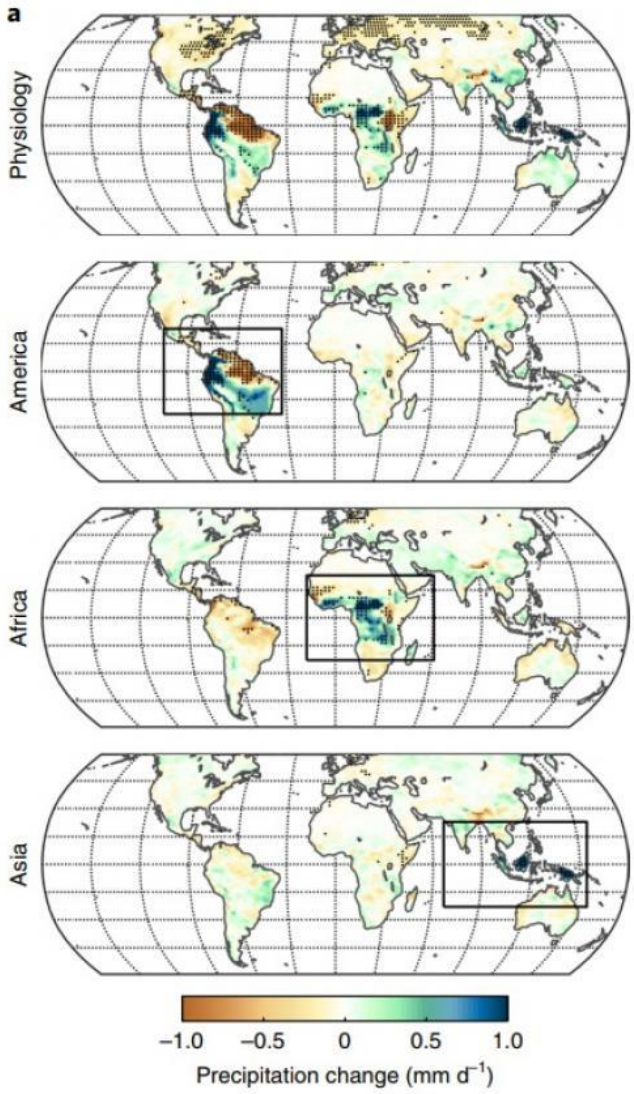


Figure 4 Change in rain fall precipitation [Image credit:11]

Stomata are small apertures on the underside of trees' leaves that open and shut to control CO2 uptake and water vapour discharge into the atmosphere. When ambient CO2 levels are exceedingly high, the stomata need not open as widely, releasing less water vapour. According to the research, when this little plant-level activity is reproduced across the rainforest, it creates changes in the atmosphere, influencing the way winds are blowing and the flow of rainfall from the ocean.

2.5 Methods to remove the carbon dioxide from air

Direct Air Capture (DAC) has emerged as a potential strategy to atmospheric Carbon Dioxide Removal (CDR), also known as Negative Emissions, in recent years. CDR technologies like DAC, on the other hand, will only become climate important if they swiftly reach gigaton scale, towards the middle of this century, due to the amounts likely to be removed. [12]

Conspicuous ways to deal with CDR examined in the logical writing incorporate afforestation and change of land use, upgraded enduring, bioenergy and carbon catch and capacity or BECCS, as well as immediate air catch and capacity of CO2. DAC alludes to a scope of innovative arrangements that can separate CO2 from surrounding air at any area in the world This is conceivable in light of the fact that in encompassing air, CO2 is almost equally dispersed all over the planet at normal convergences of, at present 405.5 parts per million and rising. [12]

There are now just a few businesses working in the DAC industry, all of which are creating and deploying distinct DAC technologies in order to target different customers.

Carbon Engineering (CE) in Canada employs liquid alkali metal oxide sorbents that are regenerated by heat at 800°C. CE presently runs its machines on natural gas, trapping CO2 both from the flue gas stream of the burned natural gas and from the atmosphere [12].

Global Thermostat (GT) is another important DAC player in the United States. A solid amine-based sorbent material is used in the GT process, which is regenerated at roughly 80–100°C [12].

2.5.1 Removal of CO2 based on adsorption/desorption process

Climeworks AG, located in Switzerland, employs a DAC design based on an alkaline-functionalized adsorbent adsorption/desorption process. CO2 adsorption is done at room temperature, while CO2 desorption is done using a temperature-vacuum-swing (TVS) technique [13]. The CO2 is released by lowering the pressure in the system and raising the temperature to 80 to 120°C throughout this process. After a period of cooling

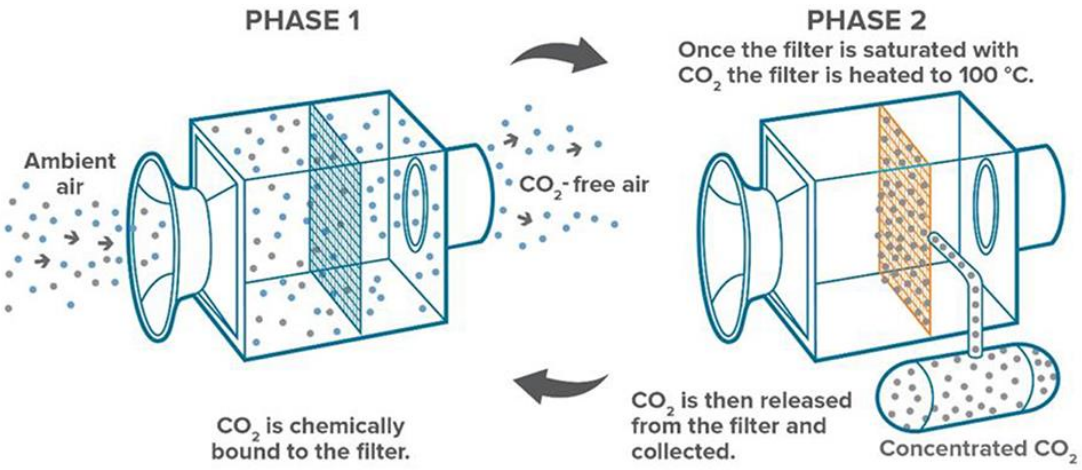


Figure 5 Process of capturing the CO2, Image credit [13]

The technique produces gaseous CO2 with a purity level of >99.8% at a pressure of 1 bar. The present Climeworks technique may extract H2O from the air as a byproduct depending on the ambient circumstances, particularly relative humidity.

Climeworks took on a measured plan to diminish fabricating and working expenses, support versatility and variety in organization, simplicity of mobility and empower robotized mass assembling. CO2 adsorption and desorption is performed inside similar gadgets, alluded to as "CO2 Collectors" or "Authorities." Collectors are designed to fit effectively into a steel outline, with 6 Collectors squeezing into a standard 40-foot steel trailer. The current ostensible yearly CO2 Collector limit is 50 tons of CO2. This will increment as the innovation is advanced. The secluded Collectors are intended to work all together and can be scaled with the expansion of new modules to grow limit. They have been intended for business large scale manufacturing that utilizes customary metal creation innovation.

Every DAC method accomplishes the goal of extracting carbon from the ambient air in two stages: carbon dioxide capture and regeneration. To begin, a chemical is utilised to collect carbon from the atmosphere and bind it in a contactor. The carbon capture material, which can also be a solid sorbent or indeed a liquid solvent, is the most important deciding element in constructing a DAC plant at this stage.

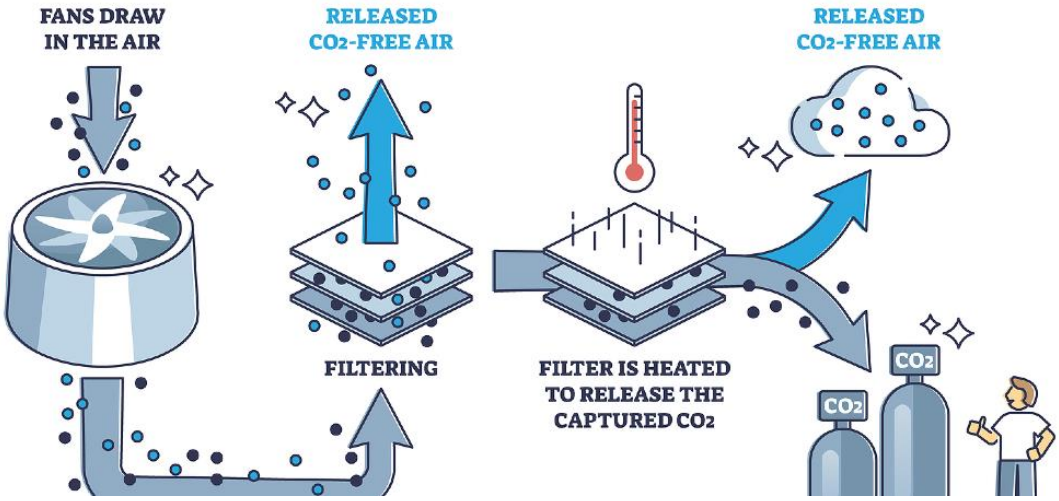


Figure 6 Direct air capture methodology [14]

The trapped carbon is removed from the binding chemical during the regeneration phase. Depending on the type of material utilised in the capture process, the regeneration process necessitates a great deal of energy inside this form of heat, power, stress, or a combination of these. After the CO2 has been removed, the material is ready to use.

2.5.2 CO2 capture using electrodes

Carbon dioxide (CO2) emissions through human activities must be reduced as part of any carbon reduction strategy. CO2 capture equipment has been installed in several power stations to capture CO2 from their exhaust. However, these technologies are each one the size of the a factory, cost huge amounts of money, consume a lot more energy to function, and only work on CO2-rich exhaust streams. Concisely, they aren't a viable alternative for aeroplanes, residential heating systems, or vehicles.

Finding a "sorbent" that will take up CO2 in a blast of air and then release it such that the material is clean and suitable for reuse and the release CO2 stream may be used or delivered to a concentration site for prolonged storage is a fundamental difficulty with CO2 collection. The majority of research has concentrated on sorbent materials, which are microscopic particles with "active sites" on their surfaces that trap CO2 through a process known as adsorption. CO2 attaches to particle surfaces when the report high (or pressure) is decreased. CO2 is emitted when the temperature increased (or the pressure is dropped). However, generating such temperature or pressure "swings" takes a lot of effort, partly because it involves treating the entire mixture, not just the CO2-bearing sorbent.

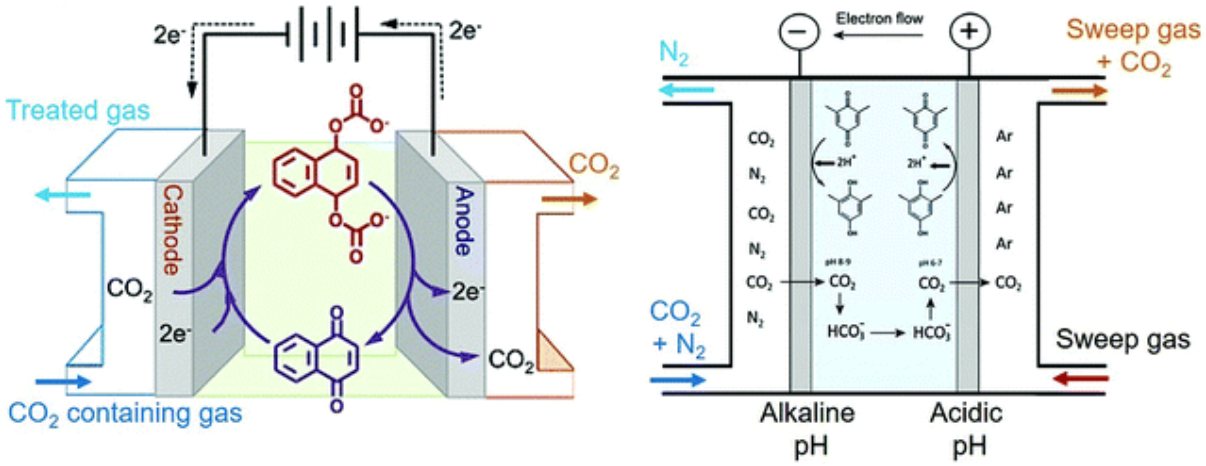


Figure 7 Removal of carbon based on electrochemical process, Image credit: [15]

In spite of the fact that redox-dynamic frameworks still can't seem to accomplish modern utility, they have the capability of delivering an unadulterated CO2 stream even from weaken gas blends, like air. Among various classes of redox-dynamic accumulates that have been investigated, for example, bipyridines, disulfides and copper/amine frameworks, the quinone species are specifically noteworthy, owing their solid restricting liking for CO2 in their diminished structure contrasted with that of their impartial state. Quinones are natural mixtures got from aromatics, through transformation of a significantly number of - CH[double bond, length as m-dash] bunches into - C([double bond, length as m-dash]O)- gatherings. Quinones have additionally acquired incredible interest as expected ideal contender for PCET instrument propelled by their part in organic frameworks.

CHAPTER 3

3 Project planning

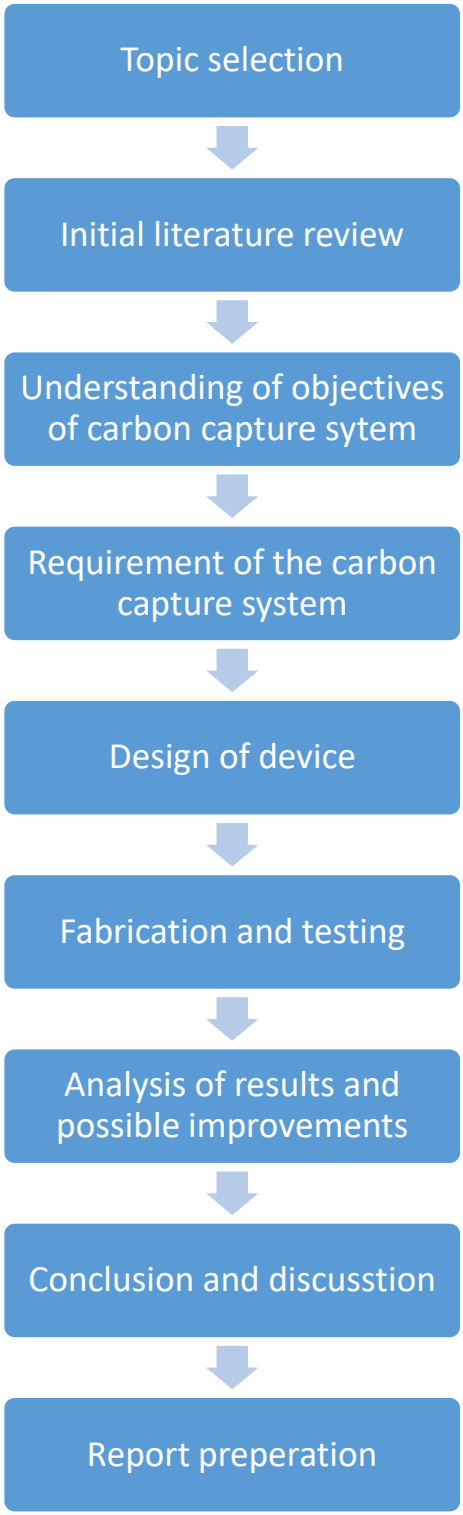
3.1 Gantt chart

Following gantt chart shows the list of detailed project activity with time frame.

Task	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing on final year project														
Selection of project topic with consultation of supervisor														
Initial study to get idea about topic														
Initial literature review of the topic														
Define the aim of the project														
Detailed literature review of the work														
Preparation of progress report 1														
Primary discussion on the possible solutions of the carbon capture for residential application														
Preparation of progress report 2														
Design of device														
Fabrication and testing														
Conclusion														
Final report & presentation preparation														

3.2 Work- flow chart

Following flow chart shows the important steps to complete the project work



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