ADDIS ABABA
SCIENCE AND
TECHNOLOGY
UNIVERSITY
UNIVERSITY FOR INDUSTRY

Integrated Engineering Team Project

Project Proposal: A System Designed To Capture And Remove CO_2 From The Air.

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Project Overview

Our project focuses on designing an innovative air purification system to reduce atmospheric CO_2 levels in urban areas, aiming to improve air quality, support public health, and contribute to climate action. Using a chemical absorption chamber with sodium hydroxide (NaOH), this system captures CO_2 from the air, converting it into sodium carbonate, a process that effectively removes CO_2—a major greenhouse gas. Equipped with sensors, including a pH monitor, the system assesses NaOH solution saturation levels, triggering an LED alert to signal when the solution needs replacement, ensuring continuous and efficient operation.

This project has a direct application within Ethiopia's expanding urban infrastructure, especially in the bustling capital, Addis Ababa, where new recreational spaces are being developed to enhance the city's livability and appeal to both residents and tourists. Addis Ababa, as an emerging global destination, now hosts a rising number of tourists drawn by its culture and vibrant public spaces. However, air pollution poses challenges to both the environment and public health. Our project aligns with Ethiopia's clean city initiative, seeking to reduce CO_2 levels in popular areas, improve air quality, and create a refreshing and enjoyable atmosphere for visitors and residents alike.

This solution holds significance in promoting healthier, more sustainable urban spaces, contributing to a cleaner city and supporting Addis Ababa's position as a hub for tourism and cultural experiences. By addressing urban air pollution directly, our system not only enhances the quality of life but also aligns with Ethiopia's national vision for cleaner, greener cities.

Background And Justification

Carbon dioxide (CO_2) is a greenhouse gas present in Earth's atmosphere, playing a critical role in the greenhouse effect, carbon cycle, photosynthesis, and oceanic carbon cycle. As one of the three primary greenhouse gases, CO_2 has garnered attention due to its increasing concentration, which reached 0.04% in 2024 [1]. This rise in atmospheric CO_2 poses significant environmental challenges as it contributes directly to global warming.

The following figure illustrates the growth in CO_2 emissions, which has intensified since the Industrial Revolution and the widespread adoption of vehicles.

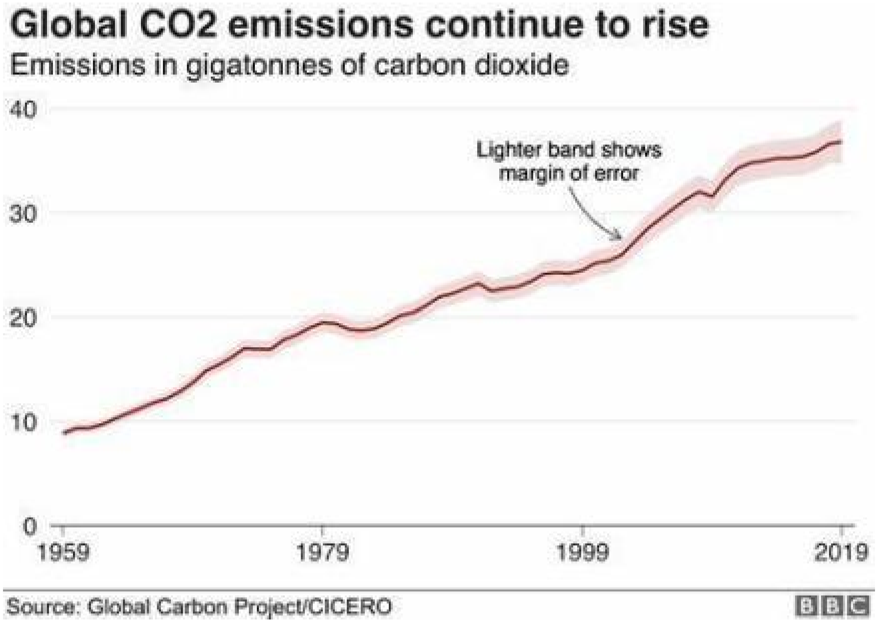
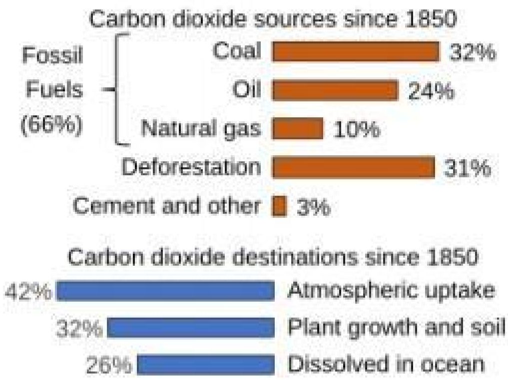


Figure 1[2]

The primary drivers of increased atmospheric CO_2 levels are the combustion of fossil fuels for energy, deforestation, and agricultural activities [3]. To ensure the sustainability of our planet for future generations, it is essential to implement strategies aimed at reducing CO_2 emissions in the atmosphere.

The next bar chart represents sources and sinks of CO_2 recorded since 1850.[4]



As shown in the chart the uptake of CO2 to the atmosphere is the highest among the three, so we decided on a project that aims to reduce the CO2 levels in the immediate surroundings.

Objective

General Objective

The primary objective of this project is to design an air-purifying machine that uses a chemical absorption process, where sodium hydroxide reacts with carbon dioxide to reduce indoor CO_2 levels, thereby improving air quality and supporting healthier indoor environments.

Specific Objectives

1. **Develop a Sodium Hydroxide-Based CO_2 Absorption System**: Create a dedicated absorption unit within the machine that utilizes sodium hydroxide as the primary reagent to capture and convert CO_2 from indoor air.
2. **Optimize the Chemical Reaction Efficiency**: Ensure efficient CO_2 capture by optimizing the reaction conditions between sodium hydroxide and carbon dioxide. This may include controlling factors like NaOH concentration, airflow rate, and temperature to maximize reaction efficiency.
3. **Ensure Safe Handling and Containment of Chemical Byproducts**: Develop a safe containment and disposal system for the byproducts of the reaction, primarily sodium carbonate (Na_2CO_3). Design the unit to ensure that these byproducts do not escape into the air and are safely stored.
4. **Develop a System for Replenishing Sodium Hydroxide**: Design a mechanism that allows for easy replenishment or replacement of sodium hydroxide when it becomes saturated with CO_2 and converts fully to sodium carbonate, ensuring continuous air purifier operation.
5. **Energy-Efficient Operation**: Develop an energy-efficient system to maintain airflow and CO_2 capture while minimizing power consumption. This could include optimizing the fan and control systems for lower energy costs.
6. **Conduct Comprehensive Testing in Various Indoor Settings**: Test the air purifier in different indoor environments to validate CO_2 reduction efficiency, monitor reaction stability, and assess the overall impact on indoor air quality.
7. **Integrate a Visual LED Notification System for Monitoring and Maintenance**: Incorporate an intuitive LED light system that notifies users of CO_2 levels, air quality status, and necessary maintenance actions, such as sodium hydroxide replenishment or byproduct removal.

Significance of the Project

The uses of CO_2 absorbing technologies are multifaceted and crucial in addressing the environmental impact of excess CO_2 emissions. To reverse the damage caused by years of CO_2 buildup, it is essential to employ technologies that prevent further emissions and achieve negative emissions—removing more CO_2 than is being emitted. CO_2 absorbing units contribute to this goal by capturing atmospheric CO_2 and safely storing it underground or converting it into useful products, thereby acting as a form of carbon sequestration. These technologies play a critical role in stabilizing global temperatures, as they can help slow down or even reverse the effects of climate change, particularly when combined with other emissions-reduction efforts. This is essential for keeping global warming within safe limits. Furthermore, CO_2 absorbing technologies could be integrated into a larger circular carbon economy, where captured CO_2 is repurposed for use in industries such as synthetic fuel production, building materials, and agriculture. This reduces carbon emissions and creates economic value from carbon that would otherwise contribute to climate change, thus fostering innovation in sustainable technologies.

Methodology

This methodology outlines the approach used for designing and fabricating a CO_2 absorption system. The goal is to develop a system that effectively reduces atmospheric CO_2 levels while also purifying air pollutants. The process involves the following key steps:

System Components

- CO2 Capture Technology: develop a dedicated absorption unit within the machine that utilizes sodium hydroxide as the primary reagent to capture and convert CO_2 from the atmosphere.
- Maximizing the sodium hydroxide and carbon dioxide reaction, i.e. by controlling factors like NaOH concentration, airflow rate, and temperature.
- Energy Source: Integrate power supply units for the systems sustainably.
- Monitoring Sensors: Deploy sensors for real-time monitoring of CO2 levels, particulate matter, and other pollutants.

Design Phase

With the information gathered, the team initiated the design phase by drafting initial sketches and conceptualizing the overall layout of the CO_2 absorption unit. Computer-aided design (CAD) models were created to optimize the placement of the sodium hydroxide absorption
chamber, airflow mechanisms, sensors, and power sources, ensuring an efficient, compact design.

- **Site Assessment**: Evaluate potential installation sites based on CO_2 concentration levels and other air quality metrics, ensuring the unit is positioned for maximum impact in high-emission areas.
- **System Sizing**: Calculate the required capacity of the absorption unit based on local CO_2 emissions data and desired reduction goals, determining the optimal quantity of sodium hydroxide and airflow specifications.

- **Integration Plan**: Design how the components will function together, focusing on airflow dynamics, chemical absorption processes, and energy requirements for sustained operation and effective CO_2 reduction.

Implementation Steps

1. **Air Purification Setup:**
   - Develop the absorption unit within the system that uses sodium hydroxide as the primary reagent to capture and convert CO_2 from the atmosphere.
   - Optimize the chemical reaction efficiency by controlling factors like NaOH concentration, airflow rate, and temperature to maximize CO_2 capture.
   - Design a mechanism for easy replacement of sodium hydroxide when it becomes saturated with CO_2 and fully converts to sodium carbonate, ensuring continuous operation.
2. **Energy Supply Installation:**
   - Connect energy storage solutions (e.g., batteries) to provide continuous operation for the system, ensuring an uninterrupted energy source.
3. **Sensor Deployment:**
   - Install sensors at strategic locations within the system to continuously monitor air quality parameters (e.g., CO_2 levels, particulate matter, VOCs).
   - Ensure data is transmitted to a central monitoring system for real-time analysis and feedback.
4. **Operation Phase:**
   - Regularly operate the DAC units to capture CO_2 from the atmosphere.
   - Maintain air purification systems by replacing filters as needed and ensuring UV-C lamps are functional for additional air quality improvement.
   - Monitor energy consumption and optimize operations based on renewable energy availability to reduce overall energy costs.
5. **Data Collection & Analysis:**
   - Collect data from sensors monitoring CO_2 levels, particulate matter, VOCs, and overall air quality.
   - Analyze data trends to assess the effectiveness of the system in reducing atmospheric CO_2 and improving air quality, adjusting the system for optimal performance.

6. **Maintenance Protocols:**
    - Schedule routine maintenance checks for all components of the system to ensure proper functionality and avoid downtime.
    - Replace consumables like filters and NaOH regularly based on usage metrics to maintain system efficiency.
7. **Evaluation & Reporting:**
    - Evaluate system performance against initial objectives after a set period (e.g., annually) to assess the CO_2 reduction and air quality improvement effectiveness.
    - Prepare detailed reports summarizing CO_2 reductions, improvements in air quality, and operational efficiency, and provide recommendations for future system upgrades and enhancements.

Projected Outcomes

1. CO_2 Reduction Efficiency:

- **Target CO_2 Reduction**: We project that our machine will significantly reduce indoor CO_2 levels in a variety of common environments, leading to a noticeable improvement in air quality. We anticipate achieving this within a reasonable timeframe under controlled conditions, particularly in spaces where CO_2 levels tend to be higher, such as classrooms or small offices.
- **Testing Environment**: We plan to test the machine in various indoor environments, including classrooms, small offices, and other enclosed spaces.

2. Air Quality Improvement:

- **Air Quality Metrics**: We anticipate a reduction in CO_2 concentration, contributing to an improved air quality index score.
- **Impact on Health**: By improving indoor air quality, we expect a reduction in respiratory problems, headaches, and fatigue among occupants.

3. System Performance:

- **Continuous Operation**: Our design incorporates a mechanism for automatic replenishment of sodium hydroxide to ensure consistent CO_2 reduction over extended periods.

- **Energy Efficiency**: We have focused on optimizing the fan design and using low-power components to minimize energy consumption.
- **Maintenance**: The system is designed to be easily maintainable, with clear visual indicators for maintenance needs and easy access to replaceable
components to minimize downtime and user effort.

4. User Interface and Experience:
    - **LED Notification System**: We have developed an LED notification system to provide users with real-time feedback on CO_2 levels, air quality, and maintenance requirements.
    - **Easy to Operate**: The system is designed to be user-friendly, with simple controls and clear instructions, making it accessible to a wide range of users.
5. Project Deliverables:
    - **Prototype**: A functional prototype of our CO_2 reduction and air purification system will be presented, demonstrating its design and performance.
    - **Technical Documentation**: We will provide comprehensive technical documentation, including schematics, design calculations, testing data, and operational manuals.
    - **Presentation**: Our final presentation will showcase the project's key features, technical achievements, and potential impact on indoor air quality.

Project Timeline

1. **Project Initiation and Planning:**
    - **Duration:** October 17, 2024 – October 21, 2024
    - **Tasks:**
        - Discuss initial ideas, and challenges, and select the project focus: the CO_2 absorbing system.
        - Define project goals, objectives, and success criteria, focusing on CO_2 reduction and air purification.
        - Assign roles and responsibilities to team members based on skill sets
2. **Research and Role Assignment:**
    - **Duration:** October 21, 2024 – October 28, 2024
    - **Tasks:**
        - Assign team roles according to individual expertise (e.g., chemical engineers, electrical engineers, software developers).
        - Research the chemical absorption process and select suitable materials (e.g., sodium hydroxide, sensors).

    - Identify technical requirements and constraints for building the CO_2 absorption system.
    - Evaluate available resources and determine feasibility.

3. **Conceptual Design and Component Selection:**
    - **Duration:** October 28, 2024 – November 18, 2024
    - **Tasks:**
        - Create conceptual designs and system sketches for the CO_2 absorption unit, including the absorption chamber, airflow mechanism, and sensor layout.
        - Select necessary components: sodium hydroxide, CO_2 sensors, microcontrollers, air pumps, and energy sources.
        - Plan for the integration of the sensors for real-time monitoring of CO_2 levels, air quality, and system performance.
        - Outline data transmission methods and interfaces for easy monitoring and maintenance.
4. **Material Procurement and Worksite Setup:**
    - **Duration:** November 18, 2024 – November 21, 2024
    - **Tasks:**
        - Procure all necessary materials and components, ensuring they meet the project's technical specifications.
        - Select a convenient and equipped worksite for the assembly of the CO_2 absorption system.
5. **Hardware Development:**
    - **Duration:** November 21, 2024 – December 1, 2024
    - **Tasks:**
        - Assemble hardware components, including the CO_2 absorption unit, airflow mechanisms, sensors, and power supply.
        - Integrate the sodium hydroxide absorption system, ensuring proper chemical handling.
        - Prototype the physical structure, including housing for sodium hydroxide and sensors.
        - Focus on ensuring the durability and ergonomic setup of the system for ease of use and maintenance.
6. **Software Development:**
    - **Duration:** December 1, 2024 – December 10, 2024
    - **Tasks:**
        - Develop software for controlling the CO_2 absorption system, including monitoring sensors, data collection, and user interface.
        - Implement a mobile app or web dashboard for real-time monitoring of CO_2 levels and air quality.
        - Design an intuitive interface for user notifications (e.g., LED alerts for maintenance or CO_2 saturation levels).
7. **Testing and Iteration:**
    - **Duration:** December 10, 2024 – December 20, 2024
    - **Tasks:**
        - Test each component for functionality, including the chemical absorption process and sensor accuracy.

    - Conduct integration tests to ensure seamless operation of the system’s hardware and software.
    - Debug any issues found during testing and address them to optimize the system's performance.
8. **Final Adjustments and Enhancements:**
    - **Duration:** December 20, 2024 – December 27, 2024
    - **Tasks:**
        - Implement final improvements to the CO_2 absorption system based on testing feedback.
        - Optimize the energy efficiency and user interface to ensure ease of use and maintenance.
        - Ensure secure, fully operational integration of all system components, ready for final presentation.

Work budget and Material

No.	Name of component	specification	Quantity	The cost of each item in ETB	Total cost in ETB
1	2V,1A Power adapter	Powers the device	1	800	800
2	12V,3-inch exhaust	Drives airflow through the device	2	600	1200
3	Arduino Uno	Processes the information that came from the sensor	1	3000	3000
4	Aquarium air pump	Circulates the NaOH to increase CO2 absorption	1	3000	3000
5	wire	Connecting The circuit	-	300	300
6	resistor	Limit the current	1	100	100
7	Ph sensor	Shows the PH level of the solution	1	3040	3040

8	Air tube	Directs airflow through the system	1	200	200
9	LED Light	Arduino triggers an LED light. Which gives a notification as an alert.	1	100	100
10	Plastic sheet	To separate the solution	1	200	200
11	NaOH	Absorbs CO_2 from the air	2 liters	-	-
12	PVC Box	housing the NaOH solution	1	200	200
				Grand Total	12,140

The budget we are given for this project by the department is 10,000 ETB but the cost of the components that we need to build the project is a little over 10,000 by 2140 ETB.

References

[1] U.S. Environmental Protection Agency, "Greenhouse Gas Emissions," [Online]. Available: https://www.epa.gov/ghgemissions. [Accessed: Nov. 13, 2024].

[2] International journal energy applications and technologies, policy intervention and its consequences on the environment to combat climate change by Hemlal Bhattarai , international journal of energy applications and technologies.

[3] Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge University Press, 2021

[4] Petroleum and Petrochemical Engineering Journal, “ real time automotive and gas emission effluents, industry vents and flue gas emissions liquifiers” volume 7, issue 2