A Robotic Solution to the CO2 Induced Thinking Epidemic

Rajesh Krishnan, Pranav
Independent Researcher

Abstract— Today's homes and buildings are built with energy efficiency in mind, putting at risk proper ventilation and circulation of air in the inner environment. This can cause multiple health-based problems, but the aim of this paper is to highlight, discuss and propose a solution to the suppression of cognitive function i.e., a 'thinking pandemic' and 'Sick Building Syndrome' currently caused by high levels of CO_2 concentration in indoor spaces. Project Karbonite is an innovative robotic design that seeks to address two critical aspects: reducing Carbon Dioxide (CO_2) concentration in indoor environments and enhancing mental capacity and cognitive functioning. By utilizing eco-friendly and cost-effective robotics, the project aims to create a sustainable solution for homes and offices worldwide. By effectively lowering CO_2 parts per million (ppm) levels, Project Karbonite strives to provide an environment that supports optimal cognitive performance, contributing to increased productivity and well-being using carbon sequestration methods applied in industries today.
Index Terms—Sick Building Syndrome, Carbon Dioxide (CO_2), reduced cognitive function, cognitive inhibitor, sustainability, robotic device

Introduction

During the 1970s, the surge in energy costs prompted significant alterations in building practices, with the primary objective of enhancing energy efficiency and reducing expenses. Consequently, buildings were designed to be more airtight and energy efficient.

However, this unintended consequence gave rise to a subsequent issue: a decline in air exchange rates within homes and office buildings, resulting in reduced ventilation. Thus, the indoor environment was adversely affected, leading to the emergence of numerous building-related ailments and a condition known as Sick Building Syndrome (SBS) [1]. Further support for this assertion can be found in a closely related study, which emphasizes that the imperative to curtail energy consumption incentivized the implementation of low rates of ventilation, consequently leading to elevated concentrations of indoor carbon dioxide (CO_2) [10].

The observed problems with Indoor Environment Quality prompted the introduction of "green" building rating systems, which aimed to mitigate the environmental impact of buildings and enhance the well-being of occupants. These new "green" buildings have demonstrated reduced concentrations of various key pollutants. However, it is worth noting that these reductions do not extend to carbon dioxide (CO_2) levels or air exchange rates. This observation underscores the enduring influence of energy efficiency considerations in the construction of "green" buildings [1].

I. The Case for CO_2 As A Cognitive Inhibitor

In urban areas, outdoor levels of CO_2 can reach anywhere as high as 500 ppm, and inside buildings can easily reach several thousand parts per million [10]. To outline effects of different ranges of CO_2 concentrations on human cognitive functioning: CO_2 concentration of up to 1000 ppm has no significant effects on cognitive function but are still abnormal amounts when compared to outdoor levels of 500 ppm. CO_2 concentrations of up to 2500 ppm cause reduced cognitive function, including decision-making, information usage, and crisis response and finally CO_2 concentrations of up to 5000 ppm exacerbate previous conditions. Anything above these amounts is seriously harmful to the human body, and may even cause death [7] [8]. In homes in the UK, average carbon dioxide levels can range from 1000 ppm to 4173 ppm in different houses in less ventilated housing [9]. In Japan, the average was from 1500-2500 ppm (though there was a vast difference for houses with and without combustion heating, and other factors) [6]. Flats and apartments near roads can reach over 1000 ppm of CO_2 (at which we lose 21% of our cognitive function). Bedrooms and cars can reach well over 4000 ppm of CO_2 [1]. In schools, a study reports higher than 1000 ppm in considerable proportions of classrooms. And in half of the schools investigated in this report, the classrooms reported around 1400 ppm, (a 50% decrease in cognitive function). All the above evidences indicate a strong need to reduce CO_2 concentrations in homes and buildings to reduce drastic effects on human cognitive functioning.

Proposed Solution: Project Karbonite

Project Karbonite is an eco-friendly, cost-effective, sustainable device built using Arduino that can extract CO_2 from its surroundings and convert it to pure calcium carbonate. The aim of the project is to target CO_2 concentration within households and buildings sustainably. The Calcium Carbonate produce can also be used for agriculture or sold industrially by 'neighbourhood cooperatives' with negligible hassle and cost for the users.

Karbonite uses the Air Extraction of CO_2 via Alkaline Liquid Sorbent, described extensively for industrial use by Frank S. Zeman and Klaus S. Lackner in their paper. [11]

The Procedure used here i.e., Air Extraction of CO_2 via Alkaline Liquid Sorbent has been traditionally used in power plants and industrial factories. However, this study will be using this process in Karbonite as it is suitable for a small-scale operation. The method has many benefits including its low cost for materials needed, easiness to integrate into robotic equipment, high efficiency, reliability, non-toxic and eco-friendly nature, and most of the components- even NaOH and $CaOH_2$ can be regenerated here. It also produces a lot of energy as heat, which will be important later in this paper.

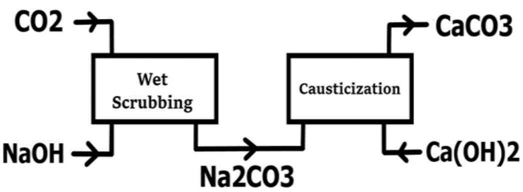


Fig. 1 – Diagram of Internal Processes

The first step is Wet Scrubbing using Alkaline Sodium Solvent i.e. NaOH to extract CO_2 out of the atmosphere.

$2\ NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O$

ΔH = −109.4kJ/mol

The second step is Causticization, where we convert the obtained Na_2CO_3 to NaOH by adding $Ca(OH)_2$.

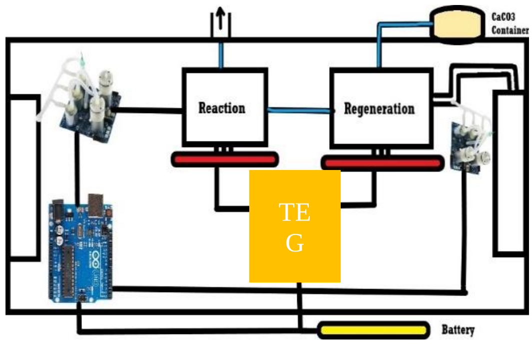
$Na_2CO_3\ (aq) + Ca(OH)_2(s) \rightarrow 2\ NaOH(aq) + CaCO_3(s)$

ΔH = −5.3kJ/mol

This is a very important step as we obtain NaOH back which can be reused for numerous cycles for the first step. In the paper [11], Dr. Zeman and Dr. Lackner discuss this as an efficient way to remove CO_2, putting a price range of 25-75 per tonne of CO_2 extracted (an estimate from their previous paper).

Proposed Method - Modification To The Method Proposed by Zeman & Lackner

While the process used by Zeman & Lackner is



already well detailed, effective and suitable, this study will be making significant changes for reasons listed further. Firstly, the project will be skipping the final process outlined in Dr. Zeman and Dr. Lackner's paper(mainly due to the production of CO_2 in the calcination step due to its unsuitability for the project). The paper does discuss that the most significant improvement to the overall potential of this method will be through efficient heat management. The process generates a lot of heat, which can cause the system to become less efficient and potentially damage the equipment. This study aims to solve this using a small thermo-electric generator that will be used as a hybrid source for electricity in powering the Arduino setup. The Thermoelectric effect, or alternatively the Seebeck Effect, is the physical phenomenon of the direct conversion of heat energy into electrical energy without moving mechanical parts. Most Thermoelectric Generators (TEGs) consist of 3 parts: First, a heat exchanger which absorbs the heat and transfers it into thermoelectric modules. Second, the thermoelectric modules which generate electricity when a temperature difference exists between their ends. These modules usually consist of Thermoelectric Couples with each couple normally a pair of p- and n-type semiconductors which are connected to two plates (as shown in figure below). Third, a heat sink which dissipates additional heat from thermoelectric modules. The Thermoelectric Generator functions by making one metal plate hot, and making the other cold. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

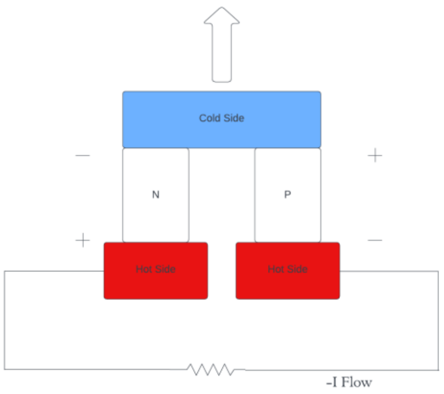


Fig. 2 - Diagram of the Thermoelectric Modules

While Thermoelectric generators are generally inefficient, most Thermoelectric Generators (TEGs) on the market today can achieve at a range of 4% to 10% efficiency. [5]. For the case of this paper, we will consider a theoretical 7% efficiency for any given TEG. This provides us enough energy to power the 2V Arduino
UNO.

II. Application In Karbonite

Karbonite comes equipped with 2 components: the CO_2 Detection system (CDS) and the Air Extraction System (AES).

Fig. 3 - Diagram of CDS & ADS

The CO_2 Detection System (CDS) uses an Arduino Gravity Infrared CO_2 Sensor V1.1. This is a high precision analog CO_2 sensor that measures CO_2 content in the range of 0-5000 ppm. [3]. Alternatively, one can also use an Arduino MQ-135 Sensor [2] or an SKU-SEN0159 [4]. The sensor activates the Arduino UNO which turns on an inlet air pump to suck in surrounding air. This continues until the sensor detects that CO_2 concentrations has dropped to safe levels. The Air Extraction System (AES), is on the interior (allowing all reactions to be contained and isolated from the surroundings). At first the inlet pump directs the incoming CO_2 rich air into the 'Reaction Chamber'. This is where the Wet Scrubbing process takes place and the NaOH extracts CO_2 from the air to create Na_2CO_3. The Na_2CO_3 (as it is in aqueous form) is then redirected to the 'Regeneration Chamber' where the Na_2CO_3 is reacted with $Ca(OH)_2$ to create $CaCO_3$ and NaOH. The aqueous NaOH is then redirected using a pump to the 'Reaction Chamber' while the $CaCO_3$ is pushed into a final chamber where it is stored (water is used to carry the insoluble $CaCO_3$ to its final chamber, after which the water is vaporised). As seen in the above diagram, there are two thermo-electric generators that will provide a hybrid source (along with the rechargeable battery/external power source). While the electricity generated is miniscule, it will allow us to redirect all heat energy that may otherwise damage the equipment or reduce overall efficiency, into powering the circuit, even in small amounts.

Commercial, Entrepreneurial & Economic Feasibility

This study believes that while this project, due to its sustainable and cost-effective nature, will be popular with the general climate-aware public, it is vital that we consider modes of furthering this plan/project into action. It is important that firstly, we put this theory into practice by building prototypes and testing it within different households to gauge practical results.

Secondly, this must be pushed via campaigns, letting people know about the larger issue and using this public awareness to engage installation and production. We also plan to release this as an open-source, Build-It-Yourself project to avoid concerns of commerciality.

Conclusion

After the Energy Crisis in the 1970s, most apartments and flats have lower ventilation to conserve energy. This has led to an increase in the concentration of pollutants in our homes. The US Environmental Protection Agency (EPA) estimates that concentrations of pollutants indoors are now 100 times greater than outdoors. Thus, carbon dioxide is slowly seeping its way into our homes.

CO_2 is poisoning everyone, and Project Karbonite is the antidote. We hope this paper brings attention to a problem that requires innovation immediately.

This paper proposes a passive carbon sequestration device can save millions from the ’thinking epidemic’ induced by the cognitive inhibiting nature of CO_2. In a world where Climate Change is an everlasting threat, we need all of our brain power- and project Karbonite can help do that.

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