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Decarbonizing the Environment: Reduction of Black Carbon Concentration in the Atmosphere

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***Abstract*— One of the main environmental issues is global warming caused by the release of CO2 into the atmosphere. CO2 has been accumulating for a very long time, even before the advent of the industrial revolution and the appearance of fossil fuels. At present, it is not only necessary to reduce the emission of CO2 as much as possible, but also to work to reduce the concentration of CO2 in our atmosphere. To this purpose, a number of possible solutions have been developed, four of which are presented in this paper. Three of them are based on the capture and storage of CO2 and the remaining one on the capture, storage and reuse of CO2 emitted by a distillery.**

***Keywords:* carbon dioxide, decarbonisation, solutions.**

***Resumen*— Una de las principales problemáticas ambientales es la del calentamiento global, provocado por la liberación de CO2 a la atmósfera. Este mismo se ha ido acumulando desde hace muchísimo tiempo, incluso desde antes de la llegada de la revolución industrial y la aparición de los combustibles fósiles. Actualmente, no solo es necesario reducir la emisión de CO2 lo más posible, sino también trabajar para reducir la concentración de este en nuestra atmósfera. Con esta finalidad, se han elaborado distintas posibles soluciones, cuatro de las cuales se presentan en este trabajo. Tres de ellas se basan en la captura y almacenamiento del CO2 y, la restante, en la captura, almacenamiento y reutilización del CO2 emitido por una destilería.**

***Palabras clave:* dióxido de carbono, descarbonización, soluciones.**

I. INTRODUCTION

Environmental pollution, a product of carbon dioxide (CO2) emissions, is one of the main causes of global warming. CO2 is a greenhouse gas that helps to keep the planet at an ideal temperature for the development of life. The problem is that due to human energy production and consumption systems, the concentration of CO2 in the atmosphere has not stopped increasing because plants are not able to absorb all the CO2 that is produced. If there are too many greenhouse gases, it makes it difficult for the heat from the sun to pass through the atmosphere and out into outer space. As a result, it concentrates on the earth and heats it up. Furthermore, if concentrations remain too high for too long, gaseous CO2 can precipitate as black carbon (CO2 in solid form) into the soil or ice, making it much more difficult to extract later. Based on a report by a group of scientists from the Desert Research Institute (DRI) and the British Antarctic Survey, entitled "*Early human Impact on global atmosphere*" [1], it has been determined that much of the black carbon pollution began in the pre-industrial period, contrary to what most people believe. As shown in [Fig. 1, 2], the concentration of CO2 in the atmosphere is currently over 400 parts per million (ppm). Almost double the level of 300 years ago.

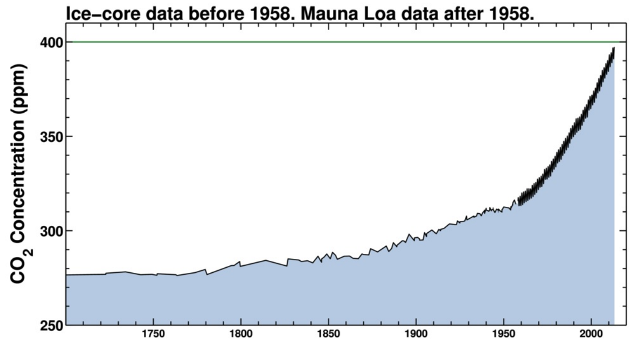

Fig. 1. Evolution over the last 300 years of the CO2 concentration in parts per million (ppm) in the atmosphere [2]

When analysing ice core samples taken from Antarctica's James Ross Island, scientists noticed something unusual: a substantial increase in black carbon levels dating back to the year 1300 A.C. By compiling historical data, scientists came to the conclusion that "ancient Māori land-burning practices in New Zealand conducted at a scale that impacted the atmosphere across much of the Southern Hemisphere and dwarfed other preindustrial emissions in the region during the past 2,000 years" [1, p. 1]. CO2 arrived from New Zealand to Antarctica in a gaseous state and then condensed in the ice as black carbon. This is something that continues to happen to this day and is very serious because it is almost impossible to extract the black carbon from the ice or from the ground.

Although the pollution produced by the Māori as a result of burning land as shown in [Fig. 2, 3] was very high, it does not represent the totality of the problem. The soot produced by the first steam engines, which required coal for their operation, was the first major environmental impact of modernity. This continued with the creation of the internal combustion engine and the massification of products that fitted it, such as the automobile. Every technological improvement that humankind has created has brought with it severe damage to the ecosystem, including the ancient Māori land-burning practices.

Fig. 2. Land-burning in New Zealand [3]

At present, "there are six hundred eighty million tons of carbon in the soil" [5, p. 1]. These levels are a result of both pre-industrial pollution, deforestation and the production processes that have been implemented in the world since the 19th century. Even if deforestation were to stop across the planet, plants only feed on CO2 during the day. This means that at night, at least half of the world's plants would not be filtering the air while still emitting pollutants into the atmosphere.

The data are extremely alarming when, for example, the case of the oil industry is analyzed since according to data "only 20 companies are responsible for 35% of the world's carbon dioxide and methane emissions related to energy production" [6, p. 1]. It is crucial to look for a replacement for fossil fuels but also to find ways to reduce the concentration of CO2 in the atmosphere, given the fact that "55 million years ago CO2 levels rose from about 300 parts per million to about 1000 ppm due to volcanic activity. This happened over a period of about 20,000 years" [7, p. 1].

In this sense, Geophysics and climate change expert at Imperial College London, Martin Siegert warns that "if we continue to burn fossil fuels at the rate we are now, we will reach 1000 ppm by the end of this century. That means that what it took the earth 20,000 years before, we will do in 80 years" [7, p. 1].

The objective of this paper is to address possible measures to decarbonize the environment. In order to achieve this aim, four possible solutions to this problem will be presented. One of the solutions is based on the capture, storage and reuse of CO2 produced by burning biomass, the following two on the capture and storage of CO2 and the last one on the capture, storage and reuse of CO2 emitted by a distillery.

II. METHODS BASED ON CAPTURE AND STORAGE OF CO2

Four methods to reduce the concentration of CO2 in the atmosphere, which are already being implemented, are presented below.

A. Bioenergy with Carbon Capture and Storage in the Subsoil

Every year, industries, especially the energy industry, release enormous amounts of CO2 into the atmosphere. Although nature filters out much of the accumulated CO2, they are insufficient.

Bioenergy with carbon capture and storage (BCCS) is a potential greenhouse gas mitigation technology that produces negative carbon emissions combining the use of biomass energy with geological CO2 capture and storage. This system functions as a complement to the natural process of photosynthesis in plants. When plants have grown, they are harvested and the biomass is used for the production of biofuels, the CO2 generated by burning this biomass is captured by a large vacuum cleaner and stored underground [8].

The BCCS system comes into operation at the end of the biomass combustion cycle, capturing the CO2 produced and re-injecting it underground for storage in the subsoil or in tanks for use in other applications, such as cement manufacture. The burning of the biomass takes place inside the green container where the gaseous CO2 rises and circulates through the yellow pipe to a drying chamber for further cooling in order to reduce its density so that it takes up less space inside the storage tank and under the subsoil [Fig. 3, 7].

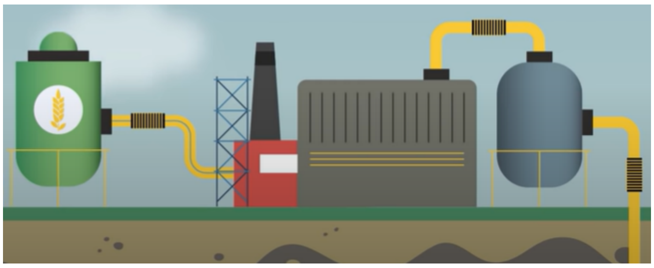

Fig. 3. Capture and re-injection of CO2 produced at the end of the biomass combustion cycle into the subsoil [7]

Unfortunately, this technique is currently inefficient and rather costly. But it is expected that by implementing the BCCS system at the end of other processes that currently release large amounts of CO2 into the environment, its operating cost will be reduced.

B. Selective Reforestation

This is a method that works towards reducing the excess CO2 already present in the atmosphere through selective reforestation. This work was conducted by researchers from the National University of Entre Ríos (UNER), in Argentina, and focuses on demonstrating that reforestation of native forests can act as the planet's main carbon sinks. The study was carried out in the province of Entre Rios, Argentina, in a native forest in the Protected Area "Estancia El Caraya", located in the Mesopotamian Spinal as shown in [Fig. 4, 8]. Because the ranch covers an area of 11,000 hectares, of which 1,500 hectares are farmland and the rest is native forest, the researchers assessed the carbon stocks found in the soil, shrubs and tree canopy, both outside and inside the forest.

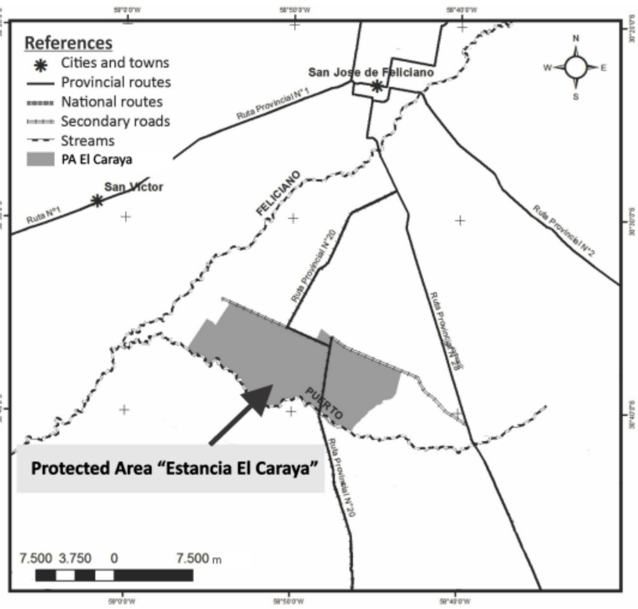

Fig. 4. Protected area “Estancia El Caraya” [8]

In a comparative study, it was determined that the storage capacity of the forest floor was estimated at 29,173 TONS of CO2 thanks to the large presence of one tree in particular, the Quebracho-Grecco, which captured 44.9% because of its size. 73% of the carbon storage from this subtropical native forest, characteristic of the Mesopotamian Spinal, was concentrated in the surface fraction of the soil [8].

By concentrating reforestation and forest care work in specific areas, the recovery of CO2 and consequently the cleaning of the air is achieved much more efficiently than if the same amount of trees were planted randomly in different locations. This way, something as logical as planting a tree can contribute much more to the care of the environment if it is done in a selective way.

C. Direct capture of CO2 from the air with reinjection into the subsoil

The process of capturing CO2 and reinjecting it underground has long been used in the oil industry as a final part of the fuel distillation process by storing the pollutant gases in the empty layers. However, direct capture of pollutant gases from the atmosphere is a relatively recent technique. This is mainly due to the cost of the technology required to carry out this operation.

The Swiss engineering company “Climeworks” is the main operator of so-called “*Direct Air Capture* (DAC)” [9]. This machine [Fig. 5, 9] is made up of eight boxes the size of shipping containers, each equipped with a dozen fans that suck in air. In this process, the CO2 is filtered, mixed with water and pumped into deep underground wells, where over the course of a few years it turns to stone, effectively removing it from circulation in the atmosphere.

Fig. 5. World’s largest direct CO2 capture plant, called Orca. Opened in Iceland, will pull about 870 cars-worth of emissions from the atmosphere every year [9]

As is the case in selective reforestation, the location of these CO2 harvesting plants is essential. The main factor to take into account is that there are underground chambers which store CO2 in a gaseous state. While the ideal situation would be for the DAC system to be located in an area with high levels of CO2 in the air, for example, on the outskirts of a city, a separate storage chamber would have to be built. This extra cost would make this project directly unfeasible in addition to the noise and visual pollution that it would cause.

D. CO2 recovery from a maize ethanol distillery

A study conducted in Tucumán, Argentina, proposed the recovery of CO2 generated during the production process of obtaining ethanol from corn, in the distillery of the company Trigotuc located in Santiago del Estero province, Argentina, using economically viable and environmentally friendly technology [10].

This project proposes the recovery and storage of the CO2 generated during the distillation process and its subsequent sale on the market, within the food industry for soft drinks and beers. This process is very similar to bioenergy with carbon capture and storage in the subsoil. However, the captured CO2 could not be used since, coming from the burning of organic matter and not from the distillation of alcohol, it would have to be subjected to a filtering process to make it fit for human consumption. This would be very expensive and consequently not profitable.

The process starts with the gaseous CO2 produced by the fermenters passing through a foam filter and then being purified in a scrubber to remove impurities. The next step is to compress the gas to a certain temperature so that it occupies a space equivalent to one-sixteenth of its original volume. After compression, the CO2 will pass through a deodoriser to remove bad odours and impurities. The clean CO2 is then passed through a dryer to reduce its humidity and is further compressed at a low temperature to make it liquid. Finally, the NOx gases (highly reactive gases) are removed by a filtering process and the ready-to-use CO2 is stored in a special tank.

III. Conclusion

From the four possible solutions presented for the problem of excess CO2 in the atmosphere, we conclude that each one has its advantages and disadvantages. Not all of them are viable in every context. In solutions where CO2 is artificially stored underground, a subsoil with existing storage cavities is needed so that it can withstand the high pressure of re-injection. In the reforestation of native forests, it is necessary for them to last over time, which means providing protection against fires and illegal logging. Moreover, if CO2 recovered by any artificial method is to be used, it must be subjected to a series of treatments, each with different costs, in order to be feasible to implement.

As engineers we can work to improve these technologies, broadening their field of application and reducing their cost of implementation and operation to help the environment. All over the world, new technologies are permanently being developed to improve the quality of life of human beings, but we must always take into account the environmental impact they may have.

Reducing the amount of CO2 that has accumulated in the atmosphere, from Maori burning practices to that produced by modern industries, would have a positive impact on the planet, such as reducing global warming and stabilising the start and end dates of the seasons. And, in some cases, as in solution D, the captured CO2 would be used for economic gain.

If we add to these proposals an education campaign on environmental care and the changes that are already taking place, for example, the elimination of the internal combustion engines, the level of CO2 in the atmosphere would return to what it was several decades ago. Using our engineering knowledge to "repair" our planet is certainly something we should do.

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