

REDUCTION OF ATMOSPHERIC CO₂ BY REMOVAL OF CARBON FROM THE CARBON CYCLE

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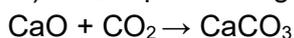
In addressing the greenhouse effect, absolute priority must be given, and it is now an urgent necessity to immediately make use of technologies we already possess in order to: 1) cease burdening the atmosphere with CO₂ and 2) remove CO₂ from the atmosphere.

METHODS PROPOSED AND ALREADY PARTIALLY USED FOR CO₂ REMOVAL

Two methods are being utilized experimentally for CO₂ capture:

1) CO₂ capture using specific amines. CO₂ is a weak acid, and amine is a weak base. Their reaction yields a salt. This salt has the property of decomposing upon heating into CO₂ and amine. The amine is then reused to capture another quantity of CO₂. The released CO₂ is collected and converted into a liquid or solid form. Subsequently, it is planned to be trapped in natural cavities from depleted hydrocarbon reservoirs.

2) CO₂ capture using CaO.



The CaCO₃ produced is calcined to convert it back to CaO and CO₂. The CaO is reused while the CO₂ undergoes processing as in the previous method.

Advantages of the methods: Direct capture of atmospheric CO₂ or CO₂ produced from industrial activity.

Disadvantages of the methods: 1) They are extremely costly in the capture process, as well as in the storage of CO₂, regardless of its physical state. 2) The stored CO₂ has limited use. It is mainly used as dry ice or as an inert gas. Converting CO₂ into chemical compounds of C requires energy consumption, whereas conversely, when C or its compounds are converted into CO₂, energy is released.

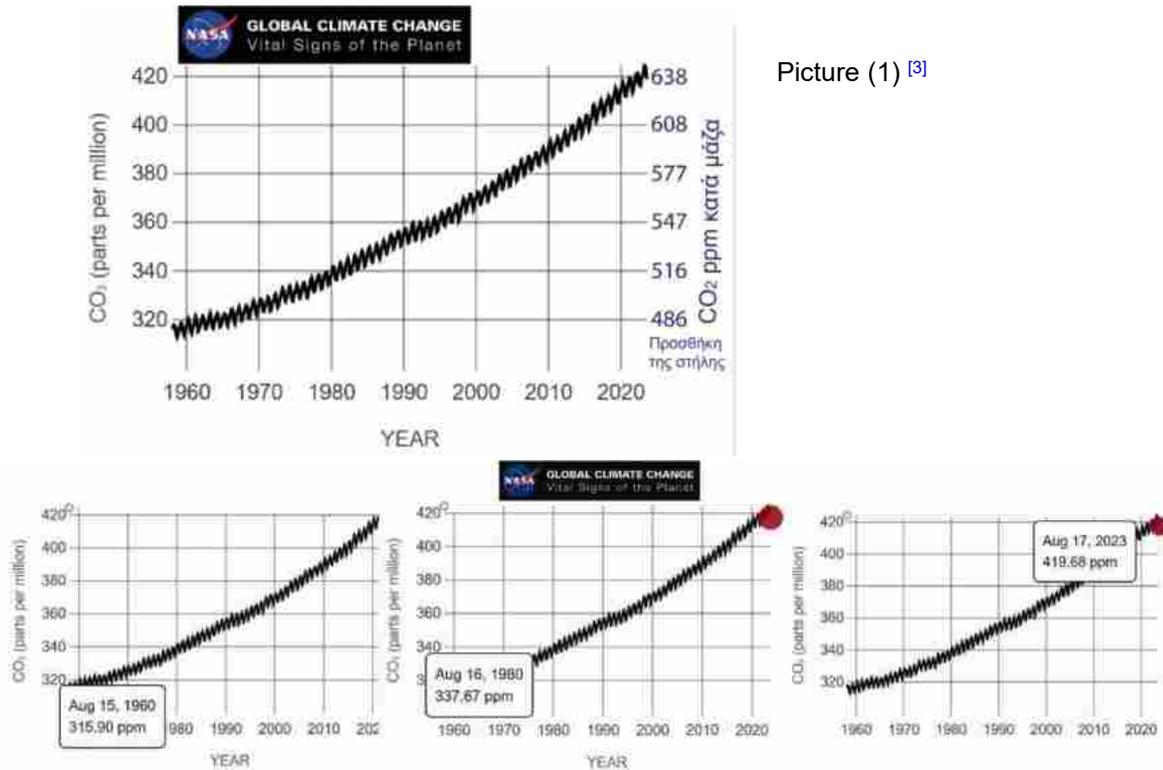
REMOVAL OF CARBON FROM THE CARBON CYCLE

VARIATION OF CO₂ QUANTITY IN THE ATMOSPHERE FROM 1960 TO 2023

From 1960 until today, due to human activity, $8.42 \cdot 10^{11}$ tons (t) of CO₂ have been added to the atmosphere. This amount of CO₂ contains $2.3 \cdot 10^{11}$ tons of C.

Therefore, to return the Earth's atmosphere to the levels of 1960 in terms of CO₂ content, $8.42 \cdot 10^{11}$ tons of CO₂ must be removed from the atmosphere, or $2.3 \cdot 10^{11}$ tons of C must be removed from the carbon cycle. If the removed C were to have a density of 1 t/m³ (tons per cubic meter), this quantity of C would occupy a volume of $2.3 \cdot 10^{11}$ m³. This volume fits into a cube with edges of 6125 m.

The final calculation aims to provide the reader with a visual representation of the magnitude of the carbon quantity that needs to be removed. It is worth noting that the length of the Corinth Canal is 6346 m.



Picture (1) [3]

Calculations:

Picture (2) [3]

The total mass of gases in the Earth's atmosphere is $5.3 \cdot 10^{15}$ tons^{[1],[2]}.

In August 2023, the atmospheric CO₂ concentration was 420 ppm by volume^[3].

The atomic masses of C and O are 12 g/mol and 16 g/mol, respectively. The relative molecular mass of CO₂ is 44 g/mol, and the average relative molecular mass of air is 28.79 g/mol.

Therefore, the by-weight content of CO₂ in the atmosphere was $420 \cdot 44 / 28.79 = 642$ ppm by weight.

Hence, the mass of CO₂ in the atmosphere in August 2023 was $(483/10^6) \cdot (5.3 \cdot 10^{15}) = 2.56 \cdot 10^{12}$ tons.

In August 1960, the atmospheric CO₂ concentration was 316 ppm by volume.

Thus, the by-weight content of CO₂ in the atmosphere was $316 \cdot 44 / 28.79 = 483$ ppm by weight^[3].

Therefore, the mass of CO₂ in the atmosphere in August 1960 was $(483/10^6) \cdot (5.3 \cdot 10^{15}) = 2.56 \cdot 10^{12}$ tons.

Difference from 1960 to 2023: $3.4 \cdot 10^{12} - 2.56 \cdot 10^{12} = 0.84 \cdot 10^{12} = 8.4 \cdot 10^{11}$ tons of CO₂.

This quantity of CO₂ contains $(12/44) \cdot 8.4 \cdot 10^{11} = 2.3 \cdot 10^{11}$ tons of C. (C: 12, CO₂: 44)

If the carbon is slightly compressed to have a density of 1 t/m³ (ton per cubic meter), this quantity of C would have a volume of $2.3 \cdot 10^{11}$ m³. This volume corresponds to a cube with edges of $(2.3 \cdot 10^{11})^{(1/3)} = 6125$ m, for the entire Earth, and of course, it won't be just one storage space. Each country will have its own.

The quantity of C that needs to be removed from the carbon cycle to return the atmosphere to the levels of the 1960s, 1970s and 1980s is shown in the table below:

Έτος	CO2 content by weight ppm	Tons (t) of CO2 in the atmosphere	Difference tons from the year 2023	Correspondence to tons C	Cube edge of quantity C in m
2023	642	$3.40 \cdot 10^{12}$			
1980	517	$2.74 \cdot 10^{12}$	$6.64 \cdot 10^{11}$	$1.81 \cdot 10^{11}$	5658
1970	497	$2.63 \cdot 10^{12}$	$7.70 \cdot 10^{11}$	$2.10 \cdot 10^{11}$	5943
1960	483	$2.56 \cdot 10^{12}$	$8.42 \cdot 10^{11}$	$2.30 \cdot 10^{11}$	6125

The Excel file with the calculations is [here](https://www.polkarag.gr/11/CO2.xlsx), or on the link:
<https://www.polkarag.gr/11/CO2.xlsx>

BRIEF DESCRIPTION OF CARBON CAPTURE

Logging of a large number of trees. Immediate replacement of the felled trees with new ones. Drying and compression of the logging products. Storage of the compressed product with protection against decay, so that it does not turn into inorganic matter and return the carbon (C) to the carbon cycle.

For the deforestation process, machines are used, primarily fueled by DIESEL. Therefore, the quantity of CO₂ produced during this process must be calculated. The calculation is provided on page (4).

Main Disadvantage:

The reduction of atmospheric CO₂ will occur when the new trees have grown enough to consume the CO₂ equivalent to the stored carbon, meaning after the time it takes for them to reach the weight of those that were harvested, which is typically 10 to 20 years. A 20-year period is significant for the impending impacts, therefore improvements to the method are necessary.

Key Advantages:

a) Less costly method b) The quantity of wood that needs to be sequestered is smaller in weight than the corresponding quantity of CO₂ to be removed from the atmosphere, with a mass ratio of 6:11. c) Dry wood is easily stored, unlike CO₂, which is difficult to manage in its storage, regardless of its physical state. d) During crises, the stored quantity of carbon or firewood can be utilized for energy production. Each country will have its own storage space.

IMPROVEMENTS:

1) Conversion of dry woods, i.e., harvested products, into charcoal. Dry woods contain approximately 50% carbon, while charcoal contains about 95% carbon. The mass ratio of carbon dioxide to carbon in charcoal is 11:3, according to the stoichiometry of the chemical formula CO₂. Relevant atomic masses: C: 12g/mol, O: 16g/mol, relative molecular mass of CO₂: 44.

Therefore, if forest products are converted into charcoal, it will occupy approximately half the volume of dry wood, provided that wood and charcoal will acquire, with slight compression, the same density as water, 1t/m^3 .

It's worth noting that charcoal is not susceptible to insects, fungi, and microorganisms, hence it doesn't require any special protection during storage to prevent the final product from returning to the carbon cycle.

2) Collection of dried annual plants, agricultural residues, and forest cleaning products on an annual basis. This type of material cannot be easily converted into charcoal. It needs to be dried, compressed, and stored as is.

3) Replacement of harvested trees with fast-growing broad-leaved species. **This process shortens the time to achieve the desired outcome to 10 years.**

4) Prioritizing the harvesting of flammable pine trees and replacing them with broad-leaved species.

BRIEF REPORT ON THE IMPORTANCE OF BIOFUELS

Wood fuels, as dead plant matter, are part of the carbon cycle. Burning them does produce CO_2 , similar to coal. However, it doesn't burden the atmosphere with CO_2 because if dead plants are left in nature, over time, through the process of decomposition, they will be converted into inorganic matter, returning CO_2 , H_2O , and energy back into the environment. These are the components that plants absorbed during their lifetime. In contrast, burning fossil fuels adds carbon to the carbon cycle. If the fossil carbon is not converted into CO_2 , it doesn't enter on the carbon cycle.

CALCULATION OF CO_2 PRODUCED DURING THE CARBON REMOVAL PROCESS

The aforementioned process requires the use of machinery that consumes crude oil derivatives.

There are several studies to estimate the fuel consumption, mainly diesel, for converting forest trees into firewood, but with significant deviations on the result.

According to one of these studies ^[5], the cutting of trees, their chopping, and transportation over a distance of 31.4 km (the distance for which the study was conducted) results in the consumption of 2.1 liters of diesel, which equals 1.747 kg. ^[5], per ton of wood. The specific weight of diesel is 0.832 kg/L. Since each kg of diesel produces 2.77 kg of CO_2 when burned, the aforementioned process releases 4.84 kg CO_2 per ton of freshly cut wood.

Since the water content in freshly cut wood is at least 50% of their weight, the amount of CO_2 released into the atmosphere is $2 \cdot 4.84 = 9.68$ kg for every ton of dry wood.

Other studies estimate higher fuel consumption for the harvesting of forest trees [6].

Additionally, because the proposed carbon removal process does not stop at converting forest trees into firewood, other factors must be considered, such as:

1) Transportation will occur over much greater distances.

2) Firewood will be converted into charcoal, which will then be compressed. For this conversion, about half of its quantity is burned. While burning firewood does not burden the atmosphere with CO_2 since firewood originates from the carbon capture of the atmosphere, their harvesting requires the consumption of fossil fuels.

3) Energy from fossil fuels will be consumed for the final storage of compressed charcoal or dry wood.

I assume that the energy consumption for the entire process will be ten times higher, thus the resulting CO₂ quantity will also be ten times higher, namely $10 \cdot 9.68 = 96.8$ kg per ton of stored carbon.

This quantity is not very significant, so the deviation from the calculations in Table (1) is much less than 10%.

PREDICTION

The increase in CO₂ levels, as indicated by NASA's interactive chart in the literature [3], is escalating rapidly. The causes are numerous, and it is not beneficial to evaluate them as logical or illogical, including industrial competition, defensive rivalry, military conflicts, the cost of replacing diesel-consuming engines, and many others.

Within a span of 10-15 years, the increase in the planet's average temperature due to rising CO₂ levels will contribute to the melting of $\frac{1}{4}$ of the ice sheets in Antarctica and Greenland. The result will be the Earth losing a significant portion of its reflective capacity for solar radiation. As we know, solid water, such as ice or snow, reflects more radiation than liquid water. The situation will become irreversible because after this stage, in just a few years, the ice sheets in Antarctica and Greenland will disappear completely. We do not possess the necessary technology to restore the ice sheets to their pre-decades state.

We must immediately leverage the technology we already have and not rely solely on research such as nuclear fusion, which, of course, must continue.

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