TECHNOLOGIES USED IN CARBON CAPTURE AND STORAGE

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ABSTRACT: Carbon capture is a method in which carbon emissions resulting from industrial processes are stopped from polluting the atmosphere through specific technological installations. The collected carbon is then either reused in various industrial applications or, using the CCS process (Carbon Capture and Storage) or, compressed and transported to specially provided places in order to be stored deep underground. Other carbon capture technologies include collecting it in specific filters that can then be recycled. Carbon capture and storage technologies are being used both at international and, still sparsely at national level in various industrial applications.

KEYWORDS: carbon emissions, carbon flux balance, geological and oceanic storage, carbon capture from Li-Ion batteries, activated carbon filters.

1. Introduction

Carbon capture followed by storage refers to a range of technologies that capture carbon emissions at a certain stage from industrial processes such as combustion or gasification of materials. Although there is no specific legislation in Europe on carbon emissions, many industrial processes, in particular cement, iron and steel manufacturing and the treating of natural gases, intrinsically produce carbon emissions, hence the reason why equipping them with carbon capture technologies (and subsequently, its storage) is imperative [1].

Most often, these technologies involve capturing carbon dioxide (CO_2) emitted by industrial processes, compressing it to about 100 bar (or more) and transporting it to a special storage site where it is then injected and stored in certain geological or oceanic formations, thus preventing its subsequent emission into the atmosphere. This type of technology is called "carbon capture and storage process" and although it has been implemented for decades, it is still used on a small scale in industry [4].

The present paper aims to present the impact of carbon emissions resulted from industrial activities while highlighting the importance of implementing appropriate solutions for carbon capture and storage, and to uncover both classic and modern technologies used in carbon capture and storage in the industry.

In the following chapters will be presented: the influence on both the way we lead our lives and on the environment of industrial carbon emissions and, implicitly, the importance of capturing these emissions, the main solutions for storing carbon after its capture, the types of current technologies used in carbon capture and storage and a case study - "Technologies for capturing the carbon emitted in the manufacture of Li-Ion batteries at ROMBAT SA Bucharest".

The paper will wind up with the conclusions of the data, concepts and observations presented throughout it.

2. The importance of capturing industrial carbon emissions

Carbon is the 15th most abundant element in the earth's crust, its large natural distribution, the specific diversity of its organic compounds, and its unique ability to form polymers at normal temperatures allows it to be the most common chemical element of the living world. It is part of human DNA, it is present in food and products widely used by the population (fuels, building materials) and, most importantly, it is the foundation on which a great deal of the industry is built.The flow of carbon is continuous (in the atmosphere, oceans, vegetation and the earth's crust) but permanently in an imbalance caused by industrial activities:

In the last 20 years alone, CO_2 emissions have increased considerably, reaching in 2022 almost 4 times more than in the 1960-1970 period (36.8 billion tons compared to 9.39 billion tons in 1960).

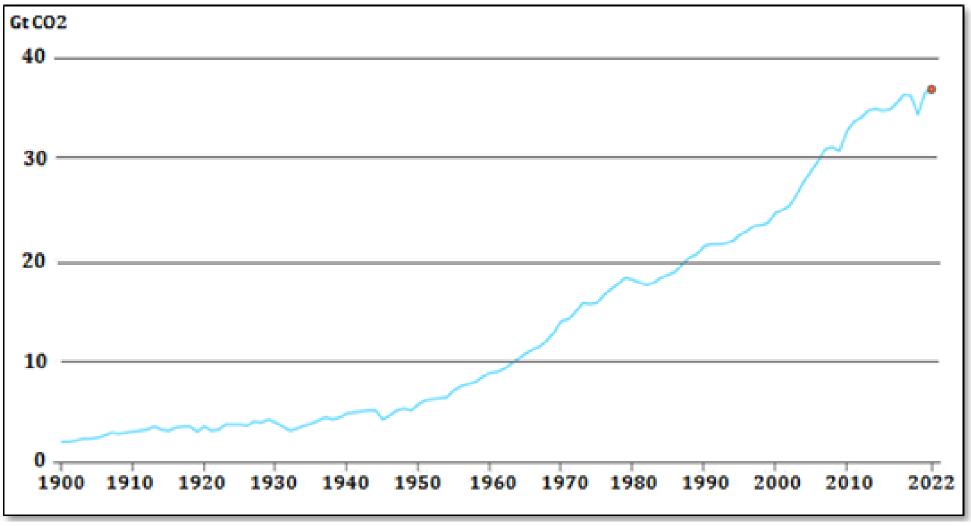

Fig. 1. Global CO_2 emissions resulting from industrial processes, 1900-2022 [8]

The great majority of these emissions come from industries such as: natural gas, synthetic fuels, electricity, oil, construction materials, cement, etc.

Therefore, in order to maintain the balance of the carbon flow, it is essential to implement carbon capture solutions for as many industrial processes that are producing carbon emissions as possible. If these emissions cannot be reused after capture, suitable carbon storage solutions must be sought.

3. Carbon storage solutions

Once captured, carbon that cannot be reused can be compressed and then transported in order to be stored deep underground - in geological formations, in the ocean or in carbonate minerals.

There are two main types of compressed carbon storage solutions, that have been used for over 50 years (the first large-scale project to inject CO_2 into the soil was launched in 1972):

a) Ocean storage

It involves direct release into the oceanic water column or seabed followed by industrial fixation of CO_2 in inorganic carbonates. This type of storage is less preferred because, according to recent studies, it could worsen the acidification of the ocean [2].

b) Geological storage

Geological storage is defined as placing CO_2 in an underground formation so that it remains safely conserved.

There are five common types of underground formations used in this geological carbon storage process:

- saline formations;
- empty oil and natural gas tanks;
- unworkable coal beds;
- organic shale formations;
- basaltic formations [8].

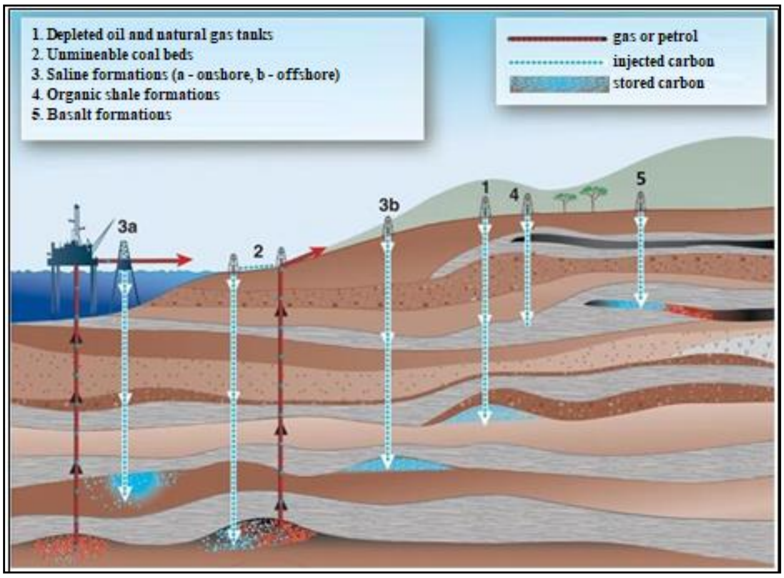

Fig. 2. Types of underground formations used in geological storage [1]

Oil and natural gas reservoirs are ideal geologic storage sites because, once oil and natural gas are extracted from an underground formation, they leave a permeable, porous volume that can easily be filled with CO_2. These reservoirs also offer an economic opportunity as CO_2 injection contributes to a process called enhanced oil recovery.

Saline formations are also a good carbon storage option. These are porous formations filled with salt water that extend over long distances and lie deep underground (below the shore or underwater). Coal beds with high permeability that cannot be exploited due to the fact that they are either too deep or too thin to be mined (due to geological, technological and economic factors) are another carbon storage solution. Coal seams can also contain methane, which can be produced in combination with CO_2 injection in a process called enhanced coal seam methane recovery.

Basalt formations can also offer a good alternative for carbon storage. These types of formations occur when a large lava stream spreads, cools and then solidifies.

Although recent studies offer insights on how these current storage methods can involve significant risks for the environment (pollution of ocean water or earthquakes in the event of leaks), so far no major accidents have broken out [2].Carbon capture technologies

There are various technologies that can be used to capture carbon, varying in efficiency, cost and level of development. These generally fall into one of three broad categories: post-combustion carbon capture, pre-combustion carbon capture and oxy-fuel combustion systems – the carbon captured through these technologies being compressed and transported through pipelines, vehicles or ships to a storage location.

a) Post-combustion:

This technology is commonly applied in the chemical, gaseous fuel, fertilizer and power generation industries and involves the separation of CO_2 from flue gases derived from burning fossil fuels – coal, natural gas or oil – in air.

b) Pre-combustion:

This technology involves the splitting of hydrocarbons by gasification of the fuel followed by the separation of carbon dioxide, representing a process often used in industrial processes (for example in the production of ammonia) due to its relatively low costs compared to other technologies. Compared to post-combustion technology, which removes dilute CO_2 (~5-15% CO_2 concentration) from flue gas streams and is at low pressure, the offset syngas stream in pre-combustion processes is rich in CO_2 and at higher pressure, which allows for easier removal before the H2 is burned off.

Due to the higher CO_2 concentration, pre-combustion capture is usually more efficient, but the underlying process costs are often higher than in traditional pulverized coal plants [3].

c) Combustion with oxy-fuel

In oxy-fuel combustion (oxycombustion), the fuel is burned in an environment consisting almost entirely of pure oxygen, to avoid the nitrogen in ordinary air, which results in a more concentrated stream of CO_2 emissions (which becomes lighter and, implicitly, cheaper to capture) [5].

However, these 3 methods, although the most often used, are not the only technologies that can be used to capture the carbon resulting from certain industrial processes, new technologies also allow faster and cheaper solutions, such as capture with the help of special filters.

4. Case study - "Technologies for capturing the carbon emitted in the manufacture of Li-Ion batteries at ROMBAT SA Bucharest"

Rombat SA company is recognized on the national market for the production of classic lead-acid batteries for cars with internal combustion engines, but, in recent years, following the increased interest in the European automotive industry for electric cars, the company has also begun to invest in the manufacture of Li-Ion batteries.

Thus, in 2019 Rombat in partnership with Prime Technologies announced the inauguration of the first Li-Ion battery production unit for electric cars in Romania. The unit was placed near Bucharest, in Cernica, occupying an area of approximately 5,000m2 and was supplied with unique equipment and technologies in Romania, designed and used in South Korea. Within this unit the manufacturing and assembly of the component parts of Li-Ion battery cells (anode, cathode, electrolyte, separator) was pursued. These types of processes automatically generate substances potentially harmful to the environment and the well-being of employees, either from emissions of carbon found in the component parts, or from the non-recycling of the solvent used in this type of procedure - NMP (N-methyl-2-pyrrolidone C5H9NO - an organic solvent used to the cathodic mixture).

To prevent the spread of these substances and to ensure the safety of employees and the environment, two large auxiliary systems are found within the facility: the NMP recovery equipment and the air filtration system.

The solvent recovery facility consists of a steam recovery and water supply piping system, pumps, three solution wash basins, a NMP collection and separation basin from water, and a recovered NMP storage basin .

In the manufacturing process of Li-Ion batteries, in the discussed unit, there can be found: black carbon of mineral origin and graphite. They play a role in electrical and thermal conductivity and are the material for the anode and cathode of Li-Ion batteries.

Fig. 3. NMP recovery equipment (1) and air filtration system (2) [source: personal archive]

In the filter installation, the carbon emissions resulting from the process of coating the aluminum foils corresponding to the cathode with cathode paste, are picked up by the fans located along the roller system that transports the cathode foil and then filtered.

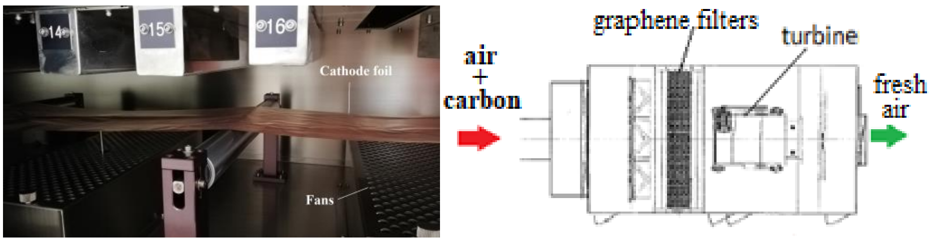

Fig. 4. Schematic of operation and related fans and filtration plant [source: personal archive]

Thanks to its graphene filters, the filter installation manages to efficiently capture the carbon resulting from the manufacturing and processing of the cathode, allowing clean air to be released into the atmosphere. Once full, the carbon-loaded graphene filters are taken over by a specialized company based in Poland that handles their recycling.

Rombat proposed the production of 100 Li-Ion battery cells daily. According to the average intensity of carbon emissions related to the production of these cells (about 475 grams of CO_2 eq/kWh), the production of 100 Li-Ion battery cells with a total capacity of about 13 kWh would produce, in a single day:

$$13\ kWh \times 100\ celule = 1300\ kWh \tag{1}$$

$$1300\ kWh \times 475\ gCO2eq/kWh = 617.5\ kgCO2eq \tag{2}$$

The filter system, put into operation, would reduce up to about 95% of the emissions associated with the production of battery cells, leaving about 30.88 kgCO2eq unfiltered:

$$617.5\ kgCO2eq \times (1 - 0.95) = 30.88\ kgCO2eq \tag{3}$$

Although Rombat Li-Ion was unable, due to the pandemic, to start its production at the established location, and only to made trial Li-Ion cells, the unique equipment and technologies found here, including the filtration solutions presented, remain sustainable solutions.

5. Conclusions

Capturing and reusing or, as the case may be, storing the carbon resulting from industrial applications is a way to reduce carbon emissions that continue to pollute the atmosphere, exacerbating climate problems and, implicitly, the imbalance of biodiversity.

Carbon capture technologies have been in use for over 7 decades (the first carbon capture facility was proposed in 1938, and the first large-scale CO_2 injection project into the soil was launched in 1972) and are mostly focused on the CCS process (Carbon Capture and Storage) that follows three main steps: carbon capture in the form of CO_2 (through one of three technologies: pre-combustion, post-combustion or oxycombustion), compression of CO_2 and its underground storage in geological or oceanic formations.

However, these classic capture and storage technologies involve significant costs and, more than that, the related storage solutions involve high risks: if an underwater tank leaks, the emissions will pollute the water, and if gas leaks occur underground, the pressure can cause earthquakes.

As presented in the case study, in recent years modern technologies have appeared on the market that help to capture carbon from certain industrial applications (in the present case, the manufacture of Li-Ion battery cells), such as installations equipped with fans that take the emitted carbon particles, then filtering the air loaded with them through special recyclable graphene or active carbon filters.

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