

## ASPECTS REGARDING CO<sub>2</sub> STORAGE IN DEPLETED NATURAL GAS FIELDS

### ASPECTE PRIVIND STOCAREA CO<sub>2</sub> ÎN ZĂCĂMINTE DEPLETATE DE GAZE NATURALE

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**Abstract:** According to the Paris Agreement regarding climate change, every nation must reduce their carbon output in order to keep the rise of the average global temperature below 2°C compared to pre-industrial levels and, ideally, to limit the rise to 1.5°C above pre-industrial levels, assuming that this would significantly reduce the risks and impacts of climate change. One way of reducing the carbon footprint would be to capture the CO<sub>2</sub> waste from industrial sources, transport it to storage sites and then deposit it underground so that the CO<sub>2</sub> would not re-enter the atmosphere. Once the CO<sub>2</sub> waste is captured, this must be stored in underground sites like: depleted oil and gas fields, saline aquifers, salt caverns or abandoned mines. The major advantage of using depleted oil and gas fields for storage is that we have a good knowledge of the geological model and the petrophysical parameters. This paper will address the advantages, disadvantages, as well as the screening parameters for selecting depleted gas fields and the estimated risks related to the CO<sub>2</sub> storage process.

**Key words:** CO<sub>2</sub> storage, depleted gas field, screening parameters.

**Rezumat:** Conform Acordului de la Paris privind schimbările climatice, fiecare națiune trebuie să își reducă amprenta de emisii de carbon, pentru menținerea creșterii temperaturii medii la nivel mondial sub 2,0 °C față de nivelurile preindustriale și, în mod ideal, sub 1,5 °C, presupunând că acest lucru ar reduce semnificativ riscul și impactul schimbărilor climatice. Un mod în care amprenta de carbon ar putea fi redusă este de a captura "deșeurile CO<sub>2</sub>" din sursele industriale, de a le transporta către zone de stocare, ca mai apoi acesta să fie depozitat subteran fără a mai reintra în atmosferă. Odată

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*captat “deșeur CO<sub>2</sub>” acesta trebuie stocat în cavități subterane care pot fi: zăcăminte depletate de petrol și gaze, acvifere, caverne salină sau mine depletate. Marele avantaj al zăcămintelor depletate îl constituie cunoașterea modelului geologic și a parametrilor petrofizici. Această lucrare se va adresa avantajelor, dezavantajelor precum și a criteriilor care stau la baza de selecție ai unui zăcământ depletat de gaze și presupusele riscuri aferente procesului de stocare de CO<sub>2</sub>.*

**Cuvinte cheie:** stocare CO<sub>2</sub>, zăcământ depletat de gaze, parametrii de selecție.

## 1. Introduction

Based on the observations starting from the middle of the 20<sup>th</sup> century, an increase in the mean annual temperature has been found, which gives a global warming trend with direct implications in the melting of the worlds ice caps.

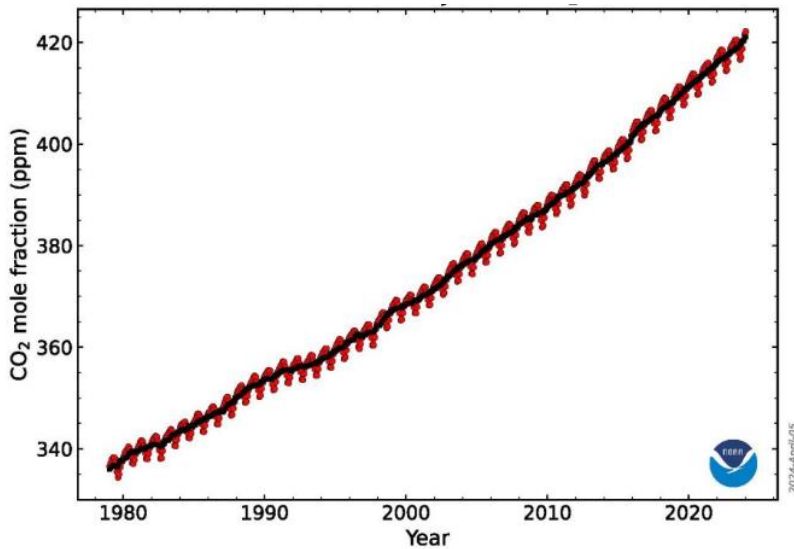
Following these observations, it was identified that one of the main factors that accelerates this warming phenomenon is generated by the emission of greenhouse gases. The most common greenhouse gas is CO<sub>2</sub> resulted from combustion processes of various sources.

Thus, concerns regarding the increase in the concentration of CO<sub>2</sub> in the atmosphere (see figure. 1), considered to be one of the factors directly responsible for the global warming phenomenon, are rising. As a result, the Paris Agreement [8] regarding climate change sets a long-term goal to guide all nations to substantially reduce global greenhouse gas emissions to hold global temperature increase to well below 2°C above pre-industrial levels and pursue efforts to limit it to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

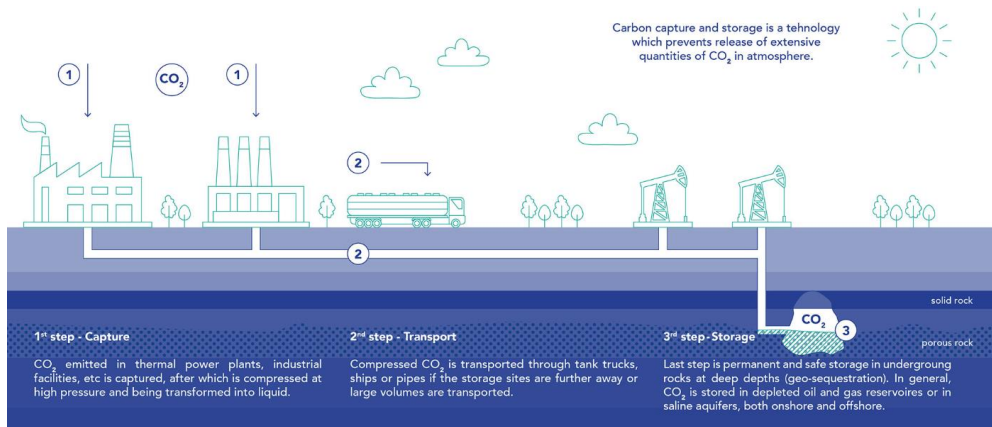
One way in which the carbon footprint could be reduced is to capture the „CO<sub>2</sub> waste” from the industrial facilities, to transport it to storage sites and then to store it safely underground so that it won’t re-enter the atmosphere. This technological flow is shown schematically in figure 2.

There are various underground storage site possibilities, for example depleted oil and gas fields, saline aquifers, salt caverns or depleted mines.

Regardless of the chosen storage site, the main goal is to store the CO<sub>2</sub>, as safe as possible, over a geological time.



**Figure 1.** Globally averaged monthly mean carbon dioxide abundance measured at the Global Monitoring Laboratory's global network of air sampling sites since 1980 [1].



**Figure 2.** The steps of implementing a carbon capture and storage (CCS) project [2].

In this paper we have chosen to give an insight in the storage of CO<sub>2</sub> in depleted oil and gas fields, detailing advantages, disadvantages and the risks associated, but also the screening parameters that a depleted oil and gas field must meet in order to be taken into consideration as a candidate for CO<sub>2</sub> storage site.

## **2. Advantages, disadvantages and risks related to the storage of CO<sub>2</sub> in depleted oil and gas fields**

### **Advantages**

The main advantage/asset of storing in depleted oil and gas fields is the proof of the capability to retain fluids over geological time, thus reducing the risks of a possible CO<sub>2</sub> migration.

Depleted oil and gas fields offers the advantage of knowing various information about the geology of the reservoir and the exploitation behaviour throughout the production phase of the reservoir.

Thereby, knowing the:

- Geological, geophysical and petrophysical properties of the depleted oil and gas field (porosity, permeability, seismic data, lithology, facies model, mineralogical composition, etc.) reduce the uncertainties of the geological model regarding storing capacity and decrease the time and cost for creating the storage site.

- Production history and the reservoirs behaviour throughout the production phase (initial and final pressures and temperatures, volumes of hydrocarbon extracted, fluid displacement mechanism and different coefficients such as compressibility and flow resistance, etc.) offer a multitude of advantages regarding technical aspects and risks associated that are so critical for these CO<sub>2</sub> storage projects.

Form a financial point of view, the possibility of reusing the infrastructure or the partial replacement of facilities and installations with ones specific to the CO<sub>2</sub> storage activity is a great advantage as it reduces the time needed for transforming the field to a CO<sub>2</sub> storage site and lowers the overall costs related to the implementation of the project [5].

The significant contrast of density and viscosity between CO<sub>2</sub> and methane (CH<sub>4</sub>) limits the mixing of the two fluids. Therefore, remaining methane in the reservoir does not affect the storage of CO<sub>2</sub> except by filling some pore spaces. In addition, due to these differences, after the injection phase, the CO<sub>2</sub> plume will tend to accumulate towards the bottom of the formations allowing the methane to form a layer at the top, which will act as a barrier for the cap rock, thus reducing the possibility of a migration through this rock.

## **Disadvantages**

The main disadvantages in the development of CO<sub>2</sub> storage sites in depleted oil and gas fields are economic, considering the high costs of technically developing the storage site and then operating it during the injection period.

In addition, possible maintenance expenses such as interventions and repairs in the injection wells to maintain their injection capacity throughout the storage process must be taken into account, and then, after reaching the maximum storage capacity, the expenses related to the safely abandon the CO<sub>2</sub> injection wells.

Withal, the post-abandonment costs of the storage sites are high, due to the obligation to monitor it for a minimum period of 20 years or less if it can be proven to the competent authorities that the stored CO<sub>2</sub> plume will be permanently retained [4].

## **Risks**

The main risk related to CO<sub>2</sub> storage in depleted oil and gas fields is the safe sequestration of the CO<sub>2</sub> plume over a geologically time period. The depleted reservoirs offer the proof of a cap rock that allowed the containment of methane. Nevertheless, it is very important to monitor the factors that could potentially compromise this cap rock and eventually allow the CO<sub>2</sub> plume to migrate, resulting in the possible contamination of fresh water aquifers and emanations of the CO<sub>2</sub> in the atmosphere generating locally anaerobic environment conditions.

Pathways for the CO<sub>2</sub> plume to migrate from the depleted reservoirs are:

- Through the wells located on the storage site (legacy wells or active injection wells) in case the existence of integrity problems.
- Natural ways: either it occurs along faults and fractures, or following the dissolution of CO<sub>2</sub> in a fluid that reaches the surface through the natural cycle or following the degradation or the cap rock by the interaction between CO<sub>2</sub>, reservoir water and the reservoir geological formation.

These risks can be prevented to a certain extent by inspecting the abandoned wells and implementing geological and technical programs to remedy any identified integrity problems (cementing acoustics, Multifinger, or other investigations to determine the condition of the column and the cement ring in the annular space) and by creating a detailed model for the storage site.

Another risk that should be taken into consideration is the affinity of CO<sub>2</sub> to migrate and interact with iron structures/buildings, eventually leading to their corrosion. In order to prevent the occurrence of this risk, it will be necessary to establish safety distances from infrastructure objectives such as hydrocarbon transport pipelines, metal structure buildings, high voltage lines, railways, etc.

### 3. Screening parameters for depleted oil and gas fields

The screening parameters for depleted oil and gas fields for its transformation into a CO<sub>2</sub> storage site can be grouped as follows: subsurface parameters, containment security, infrastructure and public acceptance [5], [7].

#### Subsurface parameters for storage

A first screening parameter is the **total storage capacity**. The storage is desired to have an estimated storage capacity of 25-50% over the amount of CO<sub>2</sub> expected to be stored. A minimum boundary condition for this parameter would be an estimated storage capacity approximately equal to the amount of CO<sub>2</sub> expected to be stored [3].

**The depth** of the reservoir is desired to be over 800-1000m and 2000m, but it could also be shallower as long as the CO<sub>2</sub> is stored below fresh water aquifers in a dense phase [5].

**The porosity** of the reservoir formations is desired to be over 20%, **the permeability** near wellbore should be greater than 100 mD and **the net thickness** of the reservoir should be over 50m. However, a depleted reservoir could be taken into consideration even with porosities under 10%, permeabilities between 10 and 100 mD and a net thickness over 20m.

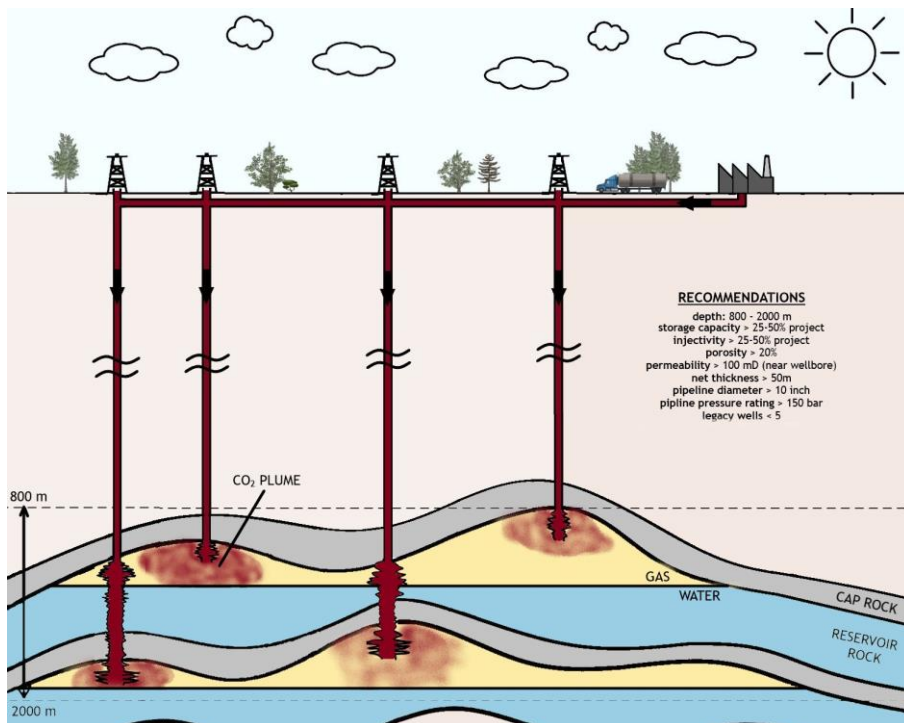
**The rock type** is another screening parameter. It is desired to have quartz rich sandstone and/or carbonate reservoirs, which ideally would have pressures lower than the hydrostatic pressure, a low **temperature** gradient and low **salinity** aquifers.

Regarding the **injectivity**, it is desirable to be 25-50% over the project requirements and to place the injection wells at a safe distance from possible faults or fractures.

#### Containment security

The main element regarding containment security is represented by the **cap rock capacity**. In this case, for depleted oil and gas fields, this cap rock

has proven its containment by allowing hydrocarbon to accumulate. The injected CO<sub>2</sub> column should not be greater than the initial gas column.



**Figure 3.** Overview in section of an oil and gas field.

The reservoir formations in which CO<sub>2</sub> will be stored should not be affected by faults or fractures. It is desired that ne number of **legacy wells** to be between 5 and 20, with an **age of the legacy well** to be younger than 1980. The more legacy wells, the greater the cost to review and potentially remediate them.

### Infrastructure

A main role has the **current status** of the field. It is desirable to be in active service or near end of field life. The **pipeline diameter** is project specific but suggested to be over 10 inch (25 cm), as it is considered that 10 inch should be sufficient cu carry 1 Mtpa supercritical CO<sub>2</sub>.

The **pipeline pressure rating** is desired to be greater than 150 bar, suggested to be minimum over 82 bar. Lower pressure ratings can be used at the expense of needing injection-site compression[5].

Production data, geological data, 3D seismic and well logs should be as complete, accessible and of good quality as possible. If data is missing, it can be gathered, but this will lead to increased expenses.

### **Public acceptance**

The majority of carbon capture and storage (CCS) projects from Romania will most likely be implemented onshore. From the experience of implementing these projects in other countries, public perception has played a crucial role in their realization, acceptance not being guaranteed and depending on several factors [7].

Local projects successfully in operation and complete legal framework could lead to the public acceptance of a CCS project and reduce the risk of delays of implementation or even eliminate the risk of its abandonment.

## **4. Conclusion**

Based on the observations starting from the middle of the 20<sup>th</sup> century, an increase in the mean annual temperature has been found, which gives a global warming trend with direct implications in the melting of the worlds ice caps.

The Paris Agreement regarding climate change sets a long-term goal to guide all nations to substantially reduce global greenhouse gas emissions to hold global temperature increase to well below 2°C above pre-industrial levels and pursue efforts to limit it to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

One way in which the carbon footprint could be reduced is to capture the “CO<sub>2</sub> waste” from the industrial facilities, to transport it to storage sites and then to store it safely underground so that it won’t re-enter the atmosphere.

CO<sub>2</sub> storage in depleted oil and gas field offer several major advantages, such as proof of the ability to contain fluids over a geological time, thus reducing the risks of a possible CO<sub>2</sub> migration. It also has a known set of geological data (porosity, permeability, seismic data, etc.) and a complete production history (pressures, volumes of extracted hydrocarbon, etc.) that reduce the uncertainties related to the nature of the reservoir and its storage capacity.

Financially it offers the possibility of reusing the infrastructure reducing the time needed for transforming the field to a CO<sub>2</sub> storage site and lowers the overall costs related to the implementation of the project.

The significant contrast of density and viscosity between CO<sub>2</sub> and methane (CH<sub>4</sub>) limits the mixing of the two fluids. Therefore, remaining methane in the reservoir does not affect the storage of CO<sub>2</sub> except by filling some pore spaces. In addition, due to these differences, after the injection phase, the CO<sub>2</sub> plume will tend to accumulate towards the bottom of the formations allowing the methane to form a layer at the top, which will act as a barrier for the cap rock, thus reducing the possibility of a migration through this rock.

The disadvantages of developing a storage site in a depleted oil and gas field are mostly financial given the high costs of implementing the CCS project, the operating and maintenance costs, the abandon costs after the storage capacity is reached and the monitoring of the field for a minimum of 20 years after the abandonment.

The main risk related to CO<sub>2</sub> storage in depleted oil and gas fields is the safely sequestration of the CO<sub>2</sub> plume over a geologically time period. The depleted reservoirs offer the proof of a cap rock that allowed the containment of methane.

Another risk that should be taken into consideration is the affinity of CO<sub>2</sub> to migrate and interact with iron structures/buildings, eventually leading to their corrosion. In order to prevent the occurrence of this risk, it will be necessary to establish safety distances from infrastructure objectives such as hydrocarbon transport pipelines, metal structure buildings, high voltage lines, railways, etc.

Considering that CO<sub>2</sub> will be a “foreign” fluid in the reservoir compared to the previously contained hydrocarbons and that the thermodynamic behaviour of CO<sub>2</sub> is a critical operating element, any depleted oil and gas field must pass through a series of screening parameters that determine the subsurface parameters for storage, containment security, infrastructure and public acceptance of such a project.

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