APPROVAL CERTIFICATE

This final year project paper entitled

“ Performance evaluation for CO_2 – EOR in tight oil reserves. simulation study ”

was prepared by the following students as partial fulfilment of the requirements for the degree of Bachelor of Science Petroleum Engineering at Al-Ayen University.

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Performance evaluation for CO_2 – EOR in tight oil reserves. simulation study.

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Abstract— **The main objective of this research is to provide basic technical information regarding the CO2-EOR process by collecting and analyzing field data. This is study will take the advantages of Data collection, CO2-EOR databases and surveys from different articles , technical papers, workshops presentations, book, ect… In this project we conducted Data processing, data analytics techniques, Screening criteria, descriptive statistics Selection scheme and comparative analyses.**

This research can be used as a manual or a guideline for engineers and workers in the oil fields through which they know when CO2 succeeds and when it fails. This research collected analyzed data from different technical aspects to investigate the best reservoir characteristics which make the CO2-EOR more successful. This research states that EOR have been found to be commercially successful where there are about 114 active commercial CO2 injection projects in US alone that together inject over 2 billion cubic feet of CO2 and produce over 280,000 BOPD. This research provided important guidelines on where and when the huff-n-puff can be used over the flooding mode and vice versa. This study pointed out some conditions where the CO2-EOR could fail.

I- INTRODUCTION

Enhanced Oil Recovery (EOR) is referred to methods which are used to increase the production of oil from oil reservoirs. One of the most-commonly used methods is Gas Injection. The first benefit, obtained with gas injection, is increase in reservoir pressure which results in higher driving force which produces more oil. Furthermore, some times injected gas mixes and is solved in oil (miscible gas injection). In this situation, viscosity of oil decreases and therefore oil can move easier than before which results in more oil production. The most-commonly gases used for gas injection are: CO2, natural gas and N2. Based on the phase behavior of CO2, in high pressures of oil reservoirs, usually it becomes miscible with crude oil (This miscibility is a function of temperature and oil composition as well).

Conventional EOR methods can increase the production of oil, however they can not produce trapped oil inside the reservoirs. Trapped oil is referred to the oil which is trapped inside the reservoir due to capillary forces in pore space. Injection of CO_2, can help us to produce that part as well taking advantages of miscibility feature of CO2.

Therefore, the main advantages of CO2 which make it a good choice for gas injection EOR, are:

Miscibility of CO2 in crude oil as it was explained above. It is less expensive compared to other choices for miscible flooding it is an excellent method for CO2 capture with its injecting into reservoirs Hence basically CO2 injection improves oil recovery and at the same time, green house gas profile is improved as well.

There are some constraints for CO2 EOR. Technology, economics and CO2 supply are the main constraints. Long pipelines are required to transfer CO2 from the source to the oil field. High pressure compressors are required as well for injecting the supplied CO2 into the reservoirs. and one should consider the amount of incremental oil to see if it will pay off the costs. Recently new methods have been applied which economize and increase the efficiency of CO2 injection. Water Alternating CO2 & Simultaneous Water and CO2 injection are the recent CO2 EOR which have been proposed to increase the recovery. Injecting water, we will need less CO2 supply and also, we can sweep those parts of reservoir which have not been by CO2.

CO2 EOR has been growing in the United States. There are considerable amount of residual oil in the US which is an excellent target for CO2 EORIncreasing domestic oil production and decreasing domestic CO2 emissions are two of the nation's highest priority goals. There are 114 CO2 projects installed in the US which provides 281,000 incremental barrels of oil per day in the US which is equal to 6% of the US oil production. It is estimated that 26 billion to 61 billion barrels of economically recoverable oil could be produced in the US using currently available CO2-EOR technologies and practices. From environmental point of view, a recent publication by the Congressional Research Service showed that theoretically, carbon-capture technology could remove as much as 80-90% of CO2 emitted from electric power plants and other industrial sources. Carbon dioxide is one of the gases in the globe. It has many uses and importance for the life of living organisms. It is considered a colourless gas, has a light smell, and a sour taste. It is also a component of the Earth's atmosphere, as it performs many processes that make some organisms on Earth survive, and it retains some of the radiation energy that the planet receives. One of its functions is that it maintains the temperature of the earth, without which the earth will become unbearably cold, and its rise causes the earth to warm, and this causes global warming.

II-Objectives

A- Providing basic technical information related to the process of reducing CO2 emissions to the atmosphere and thus reducing environmental pollution and global warming.

B- Understanding how to leverage CO2 for enhanced crude oil recovery.

C- Comparison of CO2 retention, transportation and injection costs with the benefits of increased oil production by enhanced oil recovery using CO2 gas.

D- Understand how CO2 can increase crude oil production.

E- Know the economic feasibility of using CO2 in EOR.

III OIL RECOVERY METHODS

Traditional methods of oil extraction have been the primary and secondary methods, which, according to studies by the US Department of Energy, only exhaust between a quarter and half of a well’s oil reserves. Such profligacy has been addressed by the development of a tertiary technique, more commonly known as enhanced oil recovery (EOR). But what is exactly are the differences between the three, and ?why are the first two so ineffective

A: *Primary Oil Recovery*

Primary oil recovery refers to the process of extracting oil either via the natural rise of hydrocarbons to the surface of the earth or via pump jacks and other artificial lift devices. Since this technique only targets the oil, which is either susceptible to its release or accessible to the pump jack, this is very limited in its extraction potential. In fact, only around 5% - 15% of the well’s potential are recovered from .the primary method

B: *Secondary Oil Recovery*

This method involves the injection of gas or water, which will displace the oil, force it to move from its resting place and bring it to the surface. This is typically successful in targeting an additional 30% of the oil’s reserves, though the figure could be more or less depending on the oil and of the .rock surrounding it

C: *Enhanced Oil Recovery*

Rather than simply trying to force the oil out of the ground, as did the previous two methods, enhanced oil recovery seeks to alter its properties to make it more conducive to extraction. There are three main types of enhanced oil recovery
Thermal Recovery. This is the most prevalent type of EOR in the USA and works by heating the oil to reduce its viscosity and allowing easier flow to the surface. This is most commonly achieved by introducing steam into the reservoir, which will work to heat the oil. Less commonplace is the practice of burning part of the oil in order to heat the rest (fire flooding or in-situ burning)

Gas Injection. Either natural gas, nitrogen or carbon dioxide (increasingly the most popular option) are injected into the reservoir to mix with the oil, making it more viscous, whilst simultaneously pushing the oil to the surface (similar to secondary oil recovery).
Chemical Injection. The least common method of EOR, chemical injection works by freeing trapped oil in the well. This is done by lowering surface tension and increasing the efficiency of water-flooding.

IV-TIGHT OIL RESERVOIRS

are typically characterized by low porosity (<10%) and low permeability (<0.1 mD)1. The successful economic development of tight oil reservoirs in recent years hinges on two advanced technologies: horizontal drilling and multi-stage hydraulic fracturing. U.S. Energy Information Administration2 reported that tight oil production will increase from 33% of total lower 48 onshore oil production to 51% in 2040. However, the decline curves of primary production are steep due to low permeability.
It is challenging to apply water flooding in tight oil reservoir due to low injectivity and poor sweep efficiency. Also, the oil-wet nature of some tight oil formations such as Bakken minimizes the effectiveness of water flooding.
Both recent experimental and simulation studies have shown that carbon dioxide (CO2) injection could be a feasible EOR method to improve the oil recovery and carbon storage and sequestration in tight oil reservoirs4,5,6,7,8,9. CO2 has a considerably lower minimum miscibility pressure (MMP) than other gases such as N2 and CH410,11. CO2-EOR has two common operation scenarios: continuous CO2 injection, which is referred to as CO2 flooding in this study, and CO2 Huff-n-Puff. Although CO2-EOR in conventional reservoir is well understood, it is relatively a new concept in tight oil reservoirs1. Hawthorne et al.3 proposed five conceptual steps for CO2-EOR process in tight oil formation: “(1) CO2 flows into and through the fractures, (2) unfractured rock matrix is exposed to CO2 at fracture surfaces, (3) CO2 permeates the rock driven by pressure, carrying some hydrocarbon inward; however, the oil is also swelling and extruding some oil out of the pores, (4) oil migrates to the bulk CO2 in the fractures via swelling and reduced viscosity, and (5) as the CO2 pressure gradient gets smaller, oil production is slowly driven by concentration gradient diffusion from pores into the bulk CO2 in the fractures”.

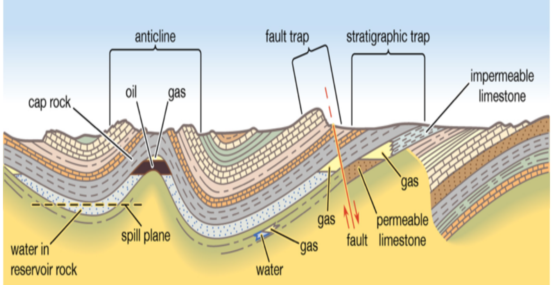

Figure 1: Tight oil reservoir [24]

The CO2 molecular diffusivity is a key physical mechanism for CO2-EOR process in tight oil reservoirs, which must be taken into account correctly when building a numerical compositional model.

V- THE PHYSICAL PROPERTIES CO2

gas of carbon dioxide are many physical characteristics, including the following: this gas can be converted into its liquid form, when it is exposed to a pressure of 75 kg per cubic metre, and at a temperature of 31 degrees Celsius. When the gas cools, it turns into ice, and is used in fire extinguishers, and it can be stored in its liquid form, and it is used because it eliminates oxygen properties that help ignite. One of the physical properties of carbon dioxide gas is that it is produced very cold, so it is also used in some cooling tools.

VI- CHEMICAL PROPERTIES OF CO2

Carbon dioxide is an active gas, when exposed to high temperatures, it decomposes into carbon monoxide and oxygen. Carbon dioxide is fast-reacting with carbon and hydrogen to result in carbon monoxide. Carbon dioxide gas can react with ammonia when there is proper pressure, to result in ammonium carbonate, and then urea. Carbon dioxide is an important product in the manufacture of fertilisers and is included in the plastics industries. One of its properties is its solubility in water, thus resulting in carbonic acid.

VII- CARBON SEQUESATION AND ENHANCED OIL RECOVERY TECHNIQUES

A lot of efforts are underway around the world to reduce greenhouse gases, and carbon dioxide is one of the greenhouse gases that raises the temperature of the globe, causing it to see the world's climate. Among the methods under the field to reduce greenhouse gas emissions, they are trying to preserve the isolation of carbon dioxide and collect it from gas emissions from power plants and oil processing plants. Crude, natural gas, petroleum refining, fertilizer production plants and other fossil fuel factories.

The artificial lifting or pumping system for oil, which is through the injection of gas associated with oil, is one of the best options for dealing with you, which is large or deep in the depths of the accompanying gas on the site. These techniques have been used in many Arab oil-producing countries, for example, injections were used in the Maududud, Kingdom of Bahrain in 1993 at a rate of 2,83-3.1 million m3 million per day. Since the early eighties, secondary recovery has been applied injecting gas in a number of oil reservoirs in three fields of the State of Kuwait, and about 93% of the Syrian wells produced use mechanical lifting media.

To take advantage of the associated gas, the field is injected with gas to sustain its production, and it is recommended to replace pumps.

Subsurface production and replacement by lifting media with associated gas as an economic alternative to oil extraction. When you have large amounts of gas associated with large fields for the production of the production of the product, a central artificial lifting station has been established to feed the wells produced with the required pressure in case they decrease. One of the benefits of implementing the central artificial gas lift system is to save the equivalent of 4.9 gigajoules (approximately 250 kWh) per 1,000 barrels produced using associated gas replaced by saturated water vapor; and collecting and benefiting from the associated gas instead of burning or dissipating it in the air,

which reduces negative impacts on the environment. Associated gas can be replaced with carbon dioxide or used in parallel as part of the central plant system for use in promoting oil recovery. In the United States and around the world, carbon dioxide emitted by industrial chimneys has been isolated for nearly 70 years and injected into the ground for 30 years to enhance oil extraction capacity. There are currently about 35 million tons of carbon dioxide

held in the United States. The main goal of That is to boost oil extraction. CO2 capture technology has emerged as one way to contribute to increasing oil well production along with Reducing the emission rates of this gas as a result of the use of oil as fuel. It has become known that injecting carbon dioxide into the oil reservoir reduces the viscosity of the oil, increases its volume and increases from its flow, which allow more oil to be extracted from the ground. But detention efforts combining carbon dioxide isolation and storage by injecting streams of gas into the ground only began in 1997. CO2 sequestration and storage projects have started on a commercial scale in various parts.

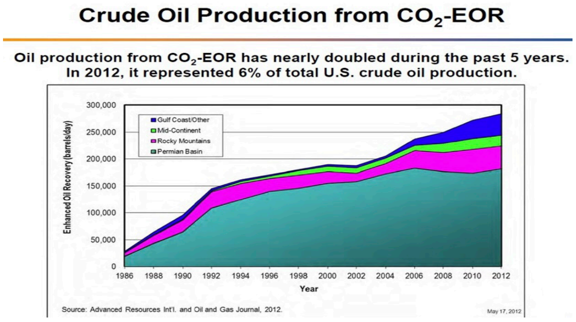

Figure 2: Crude oil production from CO2 -EOR [22]

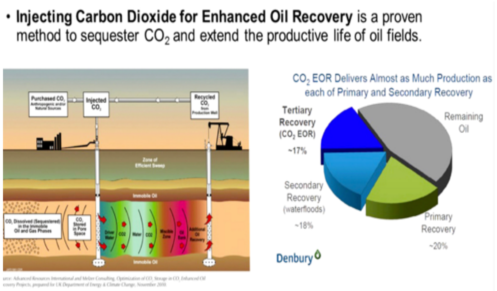

Figure3 : Injecting CO2 for EOR [22]

VIII-CO2 retention projects:

A- The first project

at the Sleipner West natural gas field in the North Sea (1996) were

Isolating carbon dioxide from natural gas because it contains 9% more carbon dioxide than commercial quality rates allow. Insulation is carried out using amino solutions (Amine Solvents), and carbon dioxide is a waste of this project. The Norwegian company (StatOil) injects and stores about one million tons annually in some

layers containing salt water on an island in the North Sea;

B-The second project

is the Wye Bern Carbon Dioxide Project in South Saskatchewan, Canada (1997). Carbon dioxide is isolated at the coal gasification plant in North Dakota, USA, where methane has been produced for 30 years. The second oxidalcarbon is transported over 204 to the Wei Bern field for use in the enhanced oil recovery process by injecting approximately 1.5 million tons of gas annually, and it is estimated that about an additional 1330 million barrels of oil from that field have been extracted within the lifetime of Project (25 years). Table2 gives details of this application.

C-the third project

is located in the Salah natural gas field in the Algerian desert (2001), and is similar to the project of the Sleeper where carbon dioxide is isolated from natural gas and injected into aquifers at a rate of 1.2 million tons of age.

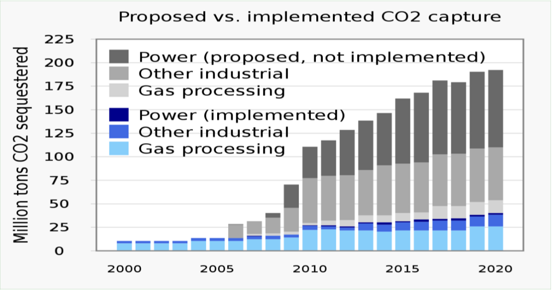

Figure 4: Proposed vs implemented CO2 Capture [22]

IX-CO2 INSULATION AND ITS USE IN OPERATION ENHANCED OIL RECOVERY

CO2 insulation systems are known to require large amounts of energy to operate, limiting their net efficiency. If we proceed from the establishment by large oil companies operating in the ESCWA region of a huge oil and natural gas processing infrastructure, in which carbon dioxide is captured, the cost of sequestration of carbon dioxide will not be included in the economic assessment of the technology of castling this gas for use in the enhanced oil recovery process. Most estimates suggest that the use of CO2 sequestration and storage systems will be widespread when prices of carbon dioxide approach $25 to $30 per tonne. Although the CO2 injection process costs between $7.5 and $8.8 per tonne, the real economic benefit of the

Injecting CO2 to extract more oil depends on prevailing oil prices.The implementation of a carbon dioxide capture and storage system in electricity production will increase the cost of electricity production from approximately US$0.0 to US$0.05 per kilowatt hour, depending on the fuel used, specific technologies, location and national circumstances. But including enhanced oil recovery benefits would reduce the additional cost of producing electricity from carbon dioxide capture and storage by approximately $0.10 to $0.02 per kilowatt-hour. The cost of this detention in the future can be reduced as research and economies of scale evolve.

Three main systems for captling CO2 from primary sources of fossil fuels can. seiztaining between 85 and 95 per hundred CO2 produced

1-Systems with CO2 separation of flue gases that are part of fuel-in-air transmissions called post-combustion systems

2- Systems in which primary fuel is processed in a steam, air or oxygen reactor to produce a mixture consisting of Mainly mono carbon and hydrogen oxidal. These systems are used in power plants that use composite cycle technology and are called pre-combustion systems;

3- Systems that use oxygen instead of air in the fuel combustion process, so flue gas consists of water vapor and carbon dioxide and are called oxygen fuel combustion systems.

The process of producing and injecting saturated water vapor consumes 2.2 gigajoules of thermal energy to produce 1,000 barrels of oil, compared to the consumption of 2.2 gigajoules when using concomitant gas or CO2 injection technology, is available in close locations. It is expected that the methods of displacement of dioxide are more economical in the Arab oil because of natural sources of carbon dioxide, with some gas treatment plants and factories that produce from other federal agencies and the industrial sector. This gas as a by-product and in close proximity to the fields of the

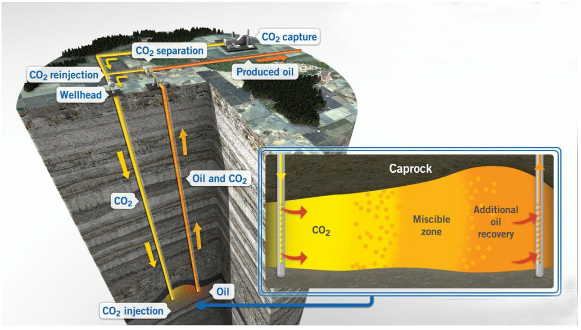

Figure 5: Mixing Of CO2 with Oil [23]

X-ECONOMICS OF CARBON DIOXIDE AND ITS USE IN OPERATION OIL RECOVERY

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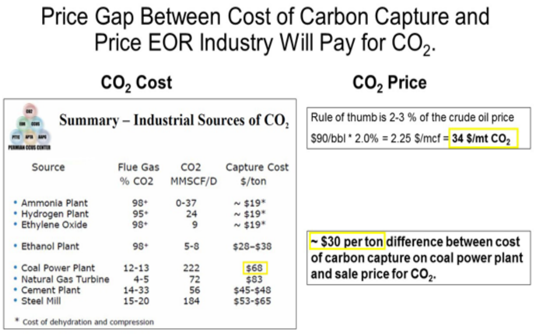
Table 1 : Price Gap between cost of carbon capture and Price EOR industry Will pay for CO2 [22]



Price Gap Between Cost of Carbon Capture and Price EOR Industry Will Pay for CO_2.

CO_2 Cost

Summary – Industrial Sources of CO_2

Source	Flue Gas % CO2	CO2 MMSCF/D	Capture Cost $/ton
• Ammonia Plant	98^+	0-37	~ $19*
• Hydrogen Plant	95^+	24	~ $19*
• Ethylene Oxide	98^+	9	~ $19*
• Ethanol Plant	98^+	5-8	$28–$38
• Coal Power Plant	12-13	222	$68
• Natural Gas Turbine	4-5	72	$83
• Cement Plant	14-33	56	$45-$48
• Steel Mill	15-20	184	$53-$65

* Cost of dehydration and compression

CO_2 Price

Rule of thumb is 2-3 % of the crude oil price

$90/bbl * 2.0% = 2.25 $/mcf = **34 $/mt CO_2**

~ $30 per ton difference between cost of carbon capture on coal power plant and sale price for CO_2.

XI- CO2 TERMS OF USE

The field of use of CO2 gas is large compared to the use of other methods of subsidized investment, but there are several conditions that must be taken into account when using this method:

A- The depth of the layers to be treated in this way must be located at sufficient depths of more than 600 m so that the minimum mixing pressure of CO2 gas with oil can be reached.

B- Absence of gas cap and a high concentration of free gas.

C- The presence of a source of CO2 gas not more than 700 km from the injection site in order to reduce the economic cost.

D- Securing the CO2 gas storage process in a way that does not affect the structure.

E- Providing injection wells and production wells with special equipment for this process (high-capacity stations, a special distribution network for CO2 gas, even injection wells, water, oil and gas separators, compressors...etc).

F- That supplying and securing CO2 gas is not costly and uneconomical when we resort to the combustion method to secure CO2 gas, especially when large quantities are needed.

XII- CO2 INJECTION WELL DESIGN

The technologies for drilling and completing CO2 injection wells are well developed. American Petroleum Institute published a number of Specification and Recommended Practices for Casing and Tubing, and Well Cements such as: API Specification 5CT Specification for Casing and Tubing, API RP 5C1 Recommended Practices for Care and Use of Casing and Tubing, API RP 10B-2 Recommended Practice for Testing Well Cements, API Specification 10A Specification on Cements and Materials for Well Cementing, API RP 10D- 2 – Recommended Practice for Centralizer Placement and Stop Collar Testing, and API Specification 11D1- Packers and Bridge Plugs. Most aspects of drilling and completing such wells are similar or identical to that of drilling and completing a conventional gas (or other) injection well or a gas storage.

the downhole equipment (e.g., casing and tubing, safety valves, cements, blowout preventers) must be upgraded for high pressure and corrosion resistance, The well is completed at the surface by installing a wellhead and "Christmas Tree" that sits on top of the wellhead and is an assembly of valves, pressure gauges and chokes. Devices are connected to the "Christmas Tree" that allow the monitoring of pressure, temperature, and injection rates.

The combined wellhead has casing annulus valves to access all annular spaces to measure the pressure between the casing strings and between the casing and production tubular. Above the Christmas tree a CO2 injection valve is mounted and an access valve for running wirelines from the top. The typical components of an injection well that are relevant to maintaining mechanical integrity and to ensuring that fluids do not migrate from the injection zone into USDWs are the casing, tubing, cement, and packer. and the well components should be designed to withstand the maximum anticipated stress in each direction axial direction (tensile, compressive) or radial (collapse, burst), and include a safety factor. The loading in each of the stress directions should be compared to the strength of the material in that direction. The loadings correspond to the burst, collapse, and tensile strengths of the material.

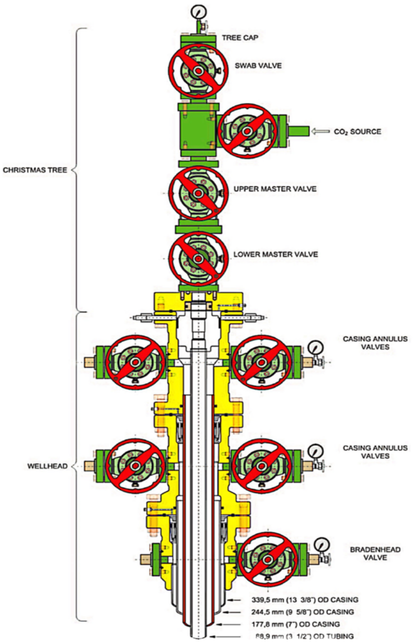


Figure 6: Injection well head [12]

A- Casing

An injection well typically consists of one or more casings. Leaks in the casing can allow fluid to escape into unintended zones or allow fluid movement between zones. The construction materials selected for the casing and the casing design must be appropriate for the fluids and stresses encountered at the site-specific down-hole environment. Carbon dioxide in combination with water forms carbonic acid, which is corrosive to many materials. Native fluids can also contain corrosive elements such as brines and hydrogen sulfide. In CO2 injection wells, the spaces between the long string casing and the intermediate casing, and between the intermediate casing and the surface casing as well as between the casings and the geologic formation are required to be filled with cement, along all casings.

B - Tubing

The tubing runs inside the long string casing from the ground surface down to the injection zone. The injected fluid moves down the tubing, out through the perforations in the long string casing, and into the injection zone. The tubing ends at a point just below the packer. The space between the long string casing and tubing must be filled with a non-corrosive packer fluid. The tubing forms another barrier between the injected fluid and the long string casing. It must be designed to withstand the stresses and fluids with which it will come into contact. The tubing and long string casing act together to form two levels of protection between the carbon dioxide stream and the geologic formations above the injection zone. A safety valve/profile nipple can be used to isolate the wellbore from the formation to allow the tubing string to be replaced. Injection will be conducted through the perforated casing. In the base case there is no stimulation method used, but hydro fracturing may be an option. Using acids to improve injectivity is not recommended because of the possible damage to the cement sheath and casing.

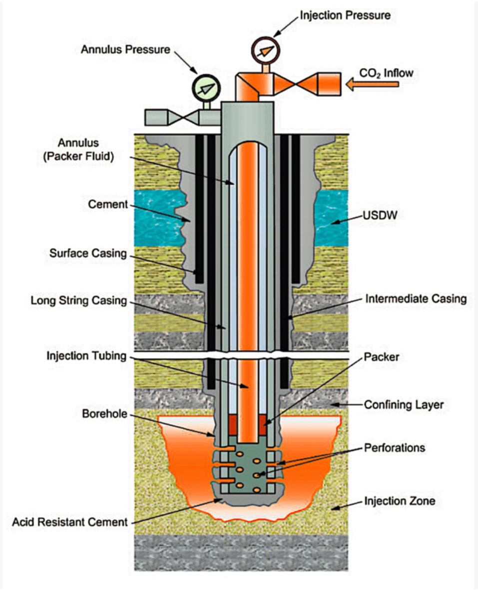


Figure 7: Schematic of a CO2 injection well [12]

XIII-CONVERSION OF PRODUCTION WELL FOR INJECTION WELLS

Production wells can be converted into injection wells. this relates to several factors:

- Selected injection well distribution pattern.
- Well conditions.
- The pattern of distribution of primary production wells and the initial spacing between those wells.
- Initial development stages.

These factors will determine the number of wells that will be converted or drilled. Converting existing production wells into injection wells requires careful analysis of available wells, assuming that the pattern of existing wells and the spacing between them allows some of them to be used as injection wells. Then the economic feasibility must be studied. In some cases, the cost of obtaining a suitable injection well by conversion process may be greater than the cost of drilling a new well. The temptation may be strong to convert productive wells that penetrate the edges of the reservoir or low-yielding wells into injection wells in order to reduce the loss of current oil production. However, poor productivity may be caused by leverage. Low which in turn will lead to a decrease in the effectiveness of injection and therefore the reservoir's response to injection will be delayed and this will lead to increased costs, while converting production wells into injection wells these things should be taken into account.

There are several strategies for injecting CO2 and recovering oil in CO2 EOR operations. Most straightforward is to inject CO2 into a single well over a finite time, leave the CO2 in the reservoir for days, weeks or even months (soak period), and then produce reservoir fluids using the same well. This is called cyclic stimulation or the ‘huff n puff’ method (Figure 3) and is generally used only in small fields or in a pilot test to establish suitability or potential for CO2 EOR. More usually, fields targeted for CO2 EOR are relatively large involving tens to hundreds of existing wells and which have already undergone a secondary process for oil recovery (Edwards et al., 2002). Often the wells are configured in patterns; a single injector well surrounded by several producing wells, or several injector wells surrounding a central producer. The style of the patterns can be highly variable depending on reservoir and operator preference and may include both horizontal wells and vertical wells. The operator may need to drill new wells and decommission others to prepare the field for the flood and several years may be needed to implement the required changes to.

XIV- CO2 INJECTION METHODS

CO2 gas is injected in several ways, and these methods depend on the characteristics of the reservoir to be cleared, including:

A-Continuous injection: CO2 gas is continuously injected into the layer until the percentage of gas produced with oil becomes very high and so that the process remains economical.

B- Alternating injection: CO2 gas is injected in this method in small batches and with a certain percentage of the size of the pores, in alternating with water batches, were the mobility of CO2 gas is reduced widely and large quantities of it are quarantined in the water. Finally, all gas and water seals are water-driven. Controlled in this way by the following:
1- The size of the initial plug.
2- The ratio of CO2 gas to the injected water.
3- The size of the pores.

The effectiveness of this method of injection depends on the ratio of gas to wat". When the ratio of CO2 to water decreases, the probability of its penetration in front of the decreases, and this means reducing the possibility of gas crossing into highly permeable layers in injection wells. When the ratio of gas to water increases, the effect of gravitational forces can appear due to the difference in the density of CO2 and water, and then the water will enter the lower section while the gas goes to the upper section, and gas will pass into production wells through the high permeable layers. The primary factor in choosing the CO2 to water ratio is not to allow the gas to permeate into the producing wells.

C- CO2 gas injection in batches: A batch of CO2 gas is injected and pushed horizontally by a scavenging fluid, most likely water, so that it is caught in the water when decreases. But when the scavenging is vertical, the expelling or propellant fluids are lighter gases than the injected CO2 gas, such as nitrogen gas.

D- Annular injection: it is the activation or induction of heavy pressures to movement, as several tons of CO2 gas are injected into the well and then we close it until a portion of the CO2 gas is dissolved in the oil.

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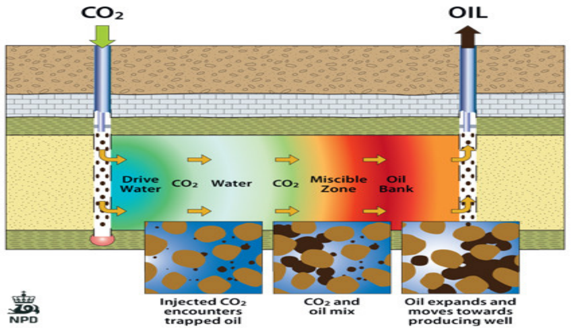


Figure 8 : Modeling of CO2 EOR process [8]

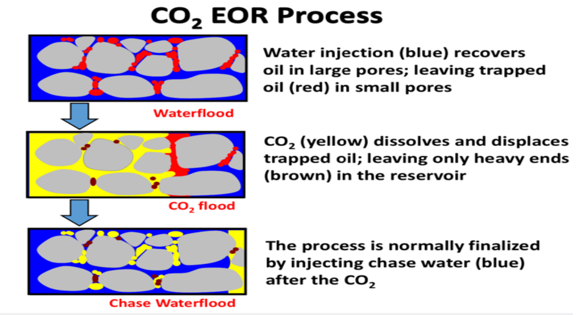


Figure 9: CO2- EOR process [19]

XV- THE FORMATION OF THE DISPLACEMENT FRONT

The injected CO2 gas mixes first with oil by decay until the saturation pressure then the mixture area (HC + CO2 gas) appears with (oil in balance with gas). The mix area has a large area for lexchange, and during the CO2 gas path in the porous medium there is a quick physical exchange between CO2 gas and parts of oil.

The front of the mix front gradually becomes richer with light parts of hydrocarbon compounds until the boundary between oil and CO2 disappears, and here the two phases are completely mixed. The end of the remaining oil front is becoming more and more heavy, saturated with CO2 and has less wet ability due to the loss of all light and medium vehicles.

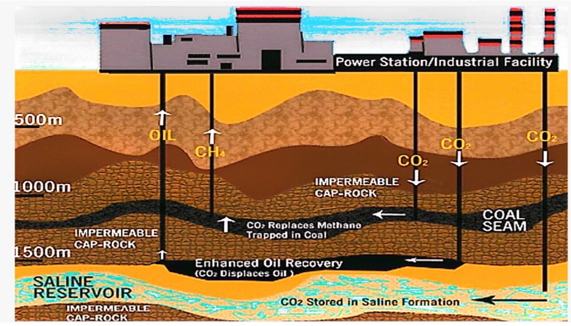


Figure 10: The formation of the displacement front

XVI- PROBLEMS AND DISADVANTAGES OFC02 INJECTION INTO THE LAYER

A- Deposition of paraffins and other materials (such as the deposition of salts and asphaltenes) The main cause of asphalt deposition is the occurrence of structural disturbances (the difference in the structure of phases) caused by the mixing displacement process and the sedimentation increases whenever the oil is colloidal.

B- Corrosion of metal equipment used in injection, as well as equipment of production wells, due to the formation of carbon acid. Corrosion can be avoided by using corrosion contraindications.

C- The decrease in the layer enclosure during the displacement of CO2 gas compared with the displacement in normal water due to the fact that the CO2 gas is not wetted phase.

D- CO2 gas takes the light extracts from the oil. As for the heavy ones, they remain in the layer and extract it becomes more difficult than before due to its lack

E- Loss of efficiency of productive pumps due to the leakage of CO2 gas in the annular vacuum. Therefore, it is preferable to use gas lift production.

F- Loss of a quantity of CO2 gas that remains confined within the narrow pore spaces and within the isolated areas,
and this percentage may reach 75% of the total amount of CO2 injected, and this increases the cost of extracting one ton of oil using this method.

G- The transport of CO2 gas requires special conditions, as well as special tubes made of resistant mixtures, and this raises the cost of the process and thus the cost of the extracted in this way.

H- Deposition of salts in the layer and its decrease in permeability due to the presence of carbonic acid.

XVII- ECONOMIC FEASIBILITY AND EVALUATE THE PERFORMANCE OF CO2 AT EOE

The Economic benefit benefit of the second Oxidal carbon injection process in the hope of extracting more oil Depends on prevailing cost prices.

(A) The net-refunds of the injection of the second oxidal carbon bin has been valuated $10 and $16 when
the price of a barrel of oil is between $15 and $20, rising to between $30 and $50 US$ per tonne of gas when oil prices range from US$50 to US$70 .

(B) CO2 capture systems require significant amounts of power to operate, limiting the net efficiency of the plant, and power plants need an additional amount of fuel to produce per kilowatt-hour of electricity produced. The increased fuel requirements result in an increase in most other emissions per kilowatt-hour generated compared to the latest new plants that do not have a system.

(C) The redesign of natural gas transmission lines networks using transport and dioxide carbon storage will reduce the cost of the option of using carbon capture technologies in the Arabian Gulf region, thereby enhancing the opportunities of these countries to take the lead in the use of these technologies globally to alleviate the phenomenon of thermal retention .

(D) Advanced plant designs will reduce energy needs, and compared to many existing old plants, new, more efficient or rebuilt plants may already achieve net reductions in their environmental emissions .

(E) The sensitivity of the cost of storing CO2 for enhanced oil recovery can be recognized in increases in well depth, CO2 effectiveness, recycling ratio, and pipeline extension all of which increase the final cost, while increases in these factors reduce the rate of production Oil, Changes in the price of oil also have a great impact on the cost of storage.

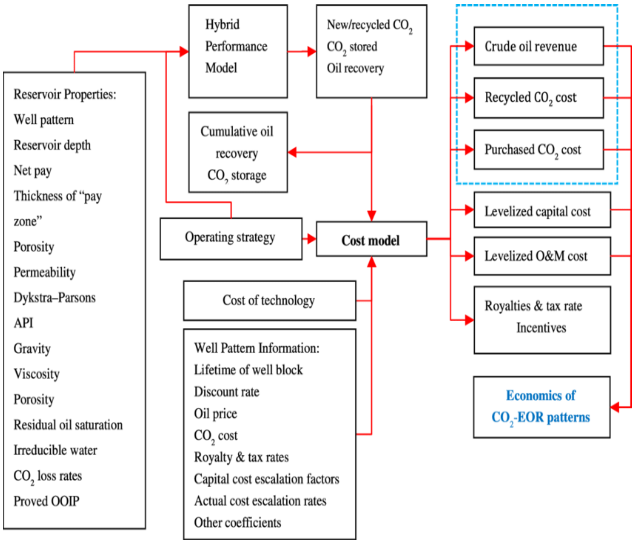


Figure 11: Workflow for technical-economic evaluation of CO2-EOR patterns [8]

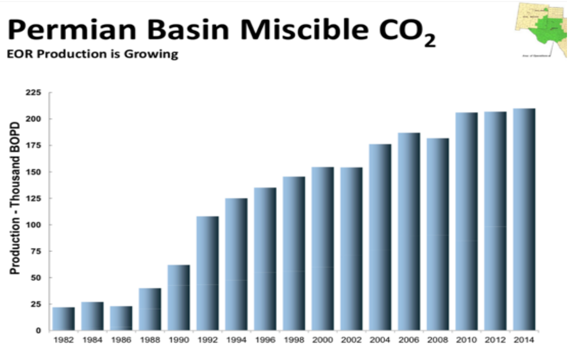
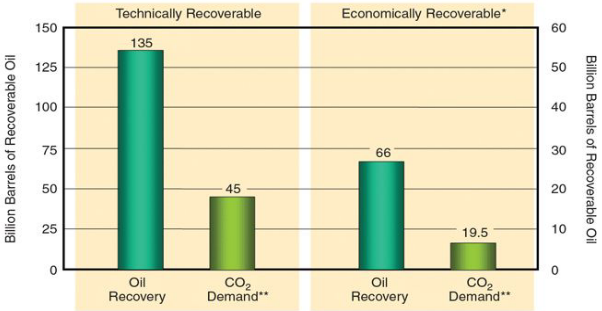


Figure 12: EOR production Growing [19]



*Oil price of $85/bbl, CO_2 market price of $40/metric ton and a 20% before-tax rate of return.
**Includes 2.3 billion metric tons of Co_2 from natural sources and 2.6 billion barrels already produced/being developed with miscible CO_2 EOR.

Figure 13: Potential U.S. Oil Supplies and CO2 Demand (Storage) Volumes From 'Next-Generation' CO2 EOR Technology [25]

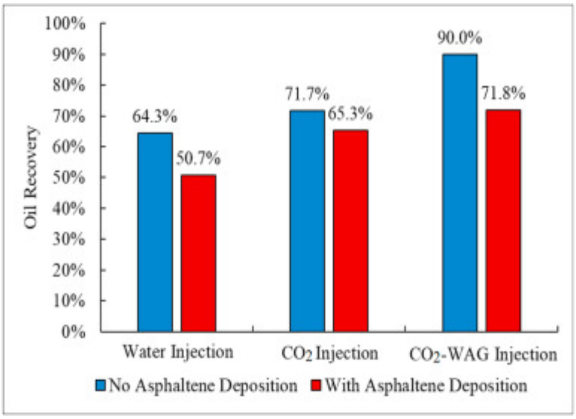


Figure 14 : Evaluation of CO2 performance in EOR [25]

XVIII- PROBLEMS AND DISADVANTAGES OF CO2 INJECTION INTO THE LAYER

A- Deposition of paraffins and other materials (such as the deposition of salts and asphaltenes) The main cause of asphalt deposition is the occurrence of structural disturbances (the difference in the structure of phases) caused by the mixing displacement process and the sedimentation increases whenever the oil is colloidal.
B- Corrosion of metal equipment used in injection, as well as equipment of production wells, due to the formation of carbon acid. Corrosion can be avoided by using corrosion contraindications.
C- The decrease in the layer enclosure during the displacement of CO2 gas compared with the displacement in normal water due to the fact that the CO2 gas is not wetted phase.
D- CO2 gas takes the light extracts from the oil. As for the heavy ones, they remain in the layer and extract it becomes more difficult than before due to it lack .
E- Loss of efficiency of productive pumps due to the leakage of CO2 gas in the annular vacuum. Therefore, it is preferable to use gas lift production.
F- Loss of a quantity of CO2 gas that remains confined within the narrow pore spaces and within the isolated areas,

and this percentage may reach 75% of the total amount of CO3 injected, and this increases the cost of extracting one ton of oil using this method.

G- The transport of CO2 gas requires special conditions, as well as special tubes made of resistant mixtures, and this raises the cost of the process and thus the cost of the extracted in this way.
H- Deposition of salts in the layer and its decrease in permeability due to the presence of carbonic acid.

XIX- PROGRAMS USED TO SIMULATE CO2

CMG

Computer Modeling Group Ltd. CMG, abbreviated as CMG, is a software company that produces reservoir simulation software for the oil and gas industry. The company offers three reservoir simulation applications. IMEX, a conventional black oil simulator used in primary and secondary oil recovery processes; GEM, a synthetic and unconventional advanced Equation of State (EoS) simulator; The STARS thermal and advanced process simulator with a value of k. In addition, CMG introduces CMOST, a reservoir engineering tool that performs automatic date matching, sensitivity analysis, and reservoir model optimization. Simulation enables companies to maximize production from oil and/or gas reservoirs, thus achieving a direct impact on revenue. CMG offers a paradox - quick answers to complex cabinets with easy-to-use products and workflows. CMG continues to break new ground for simulation capabilities, model building and the improvement of advanced recovery processes. With a focus on research and development (R&D), CMG has created the market-leading reservoir simulation software, which is recognized worldwide as the standard for advanced recoveries.

XX- SIMULATION ON CMG

At the beginning we will make several changes in the permeability and porosity and apply them in the primary production of oil and note the size of the change in oil production that is, before CO2 injection, then we inject CO2 and compare the results before and after the injection.
In the table 1, we note the effect of the change in permeability on the primary production of oil, and we see this more clearly in Figure 16

Table 1: Effect of permeability change on the amount of oil recovered in production primary

Case	Porosity	Thickens	Permeability	Oil Recovery
1	0.085	6	0.001 md	1.70
2	0.085	6	0.003 md	1.20
3	0.085	6	0.005 md	0.70
4	0.085	6	0.007 md	0.40

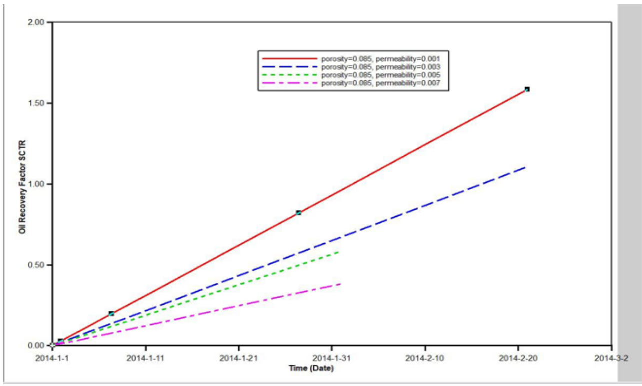


Figure 15: Cases of change in permeability values and their impact on the values of recovered

In Table 2, we notice the effect of changing the porosity on the primary production of oil, and we see this more clearly in Figure 19

Table 2 : Effect of porosity change on the amount of oil recovered

Case	Permeability	Thickness	Porosity	Oil Recovery
1	0.009	6 ft	0.065	1.70
2	0.009	6 ft	0.045	1.20
3	0.009	6 ft	0.035	0.70
4	0.009	6 ft	0.015	0.40

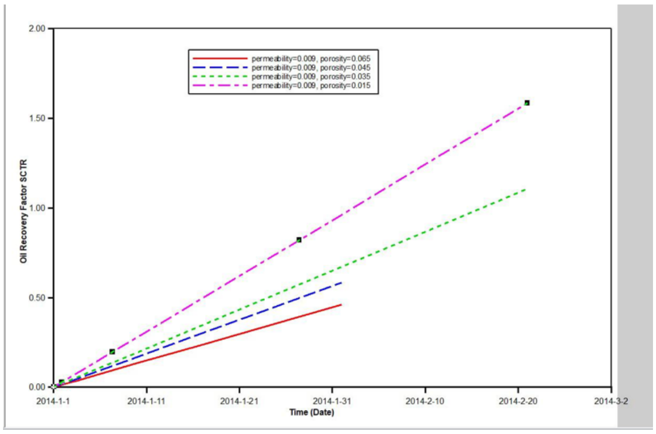


Figure 16: Cases of change in porosity values and their impact on the values of recovered oil

Table 3: The effect of changing porosity, permeability and thickness on oil extraction

Case	Thickness	Porosity	Permeability	Oil Recovery primary production SCTR
1	6 ft	0.085	0.009 md	0.175
2	6 ft	0.075	0.009 md	0.180
3	6 ft	0.085	0.005 md	0.148
4	5 ft	0.085	0.009 md	0.152

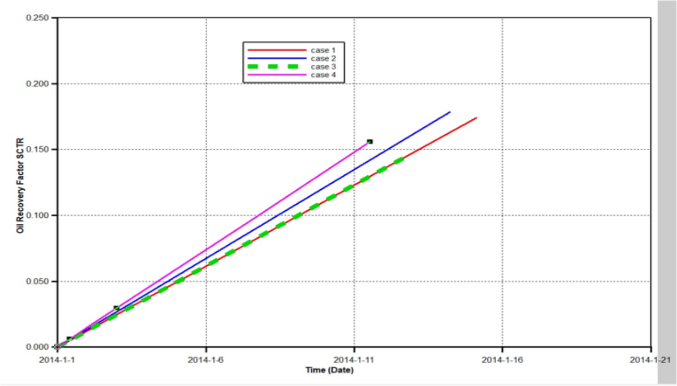


Figure 17 : Primary production cases

Table 4: The effect of changing porosity, permeability and thickness on oil recovery after CO2 injection by the Huff-n-puff method

Case	Thickness	Porosity	Permeability	Oil Recovery Huff-n-puff (CO2) SCTR
1	6 ft	0.085	0.009 md	0.30
2	6 ft	0.075	0.009 md	0.34
3	6 ft	0.085	0.005 md	0.31
4	5 ft	0.085	0.009 md	0.33

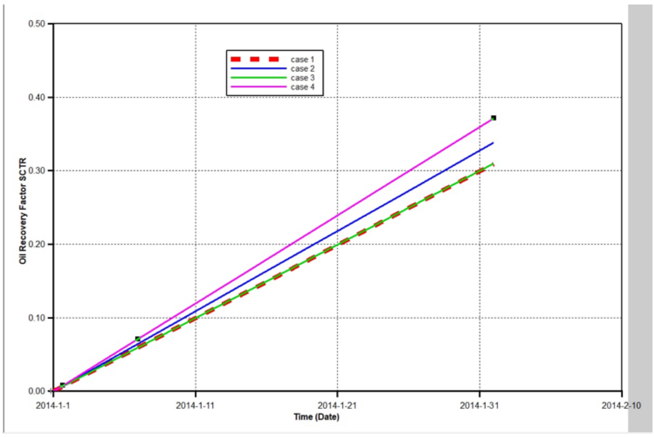


Figure 18: Cases EOR-CO2 by Huff-n-Puff

Table 5: The effect of changing porosity, permeability and thickness on oil recovery after CO2 injection by the flooding method

Case	Thickness	Porosity	Permeability	Oil Recovery Flooding (CO2) SCTR
1	6 ft	0.085	0.009 md	0.51
2	6 ft	0.075	0.009 md	0.21
3	6 ft	0.085	0.005 md	0.15
4	5 ft	0.085	0.009 md	0.46

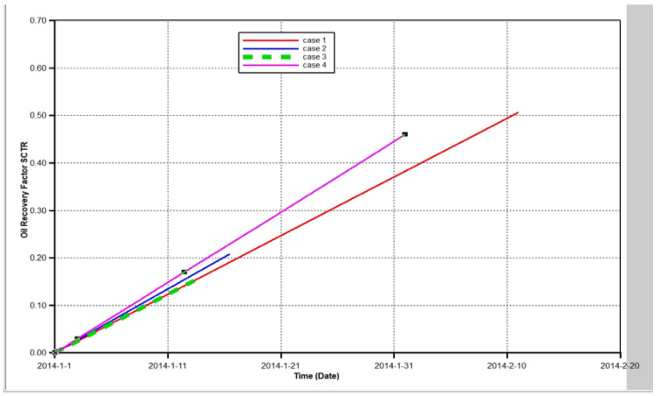


Figure 19 : Case EOR-CO2 by Flooding method

Table 6: Comparison of Primary Production, Flooding and Huff-n-puff

Case	Oil Recovery Primary production SCTR	Oil Recovery Huff-n-Puff (CO2) SCTR	Oil Recovery Flooding (CO2) SCTR
1	0.175	0.30	0.51
2	0.180	0.34	0.21
3	0.148	0.31	0.15
4	0.152	0.37	0.46

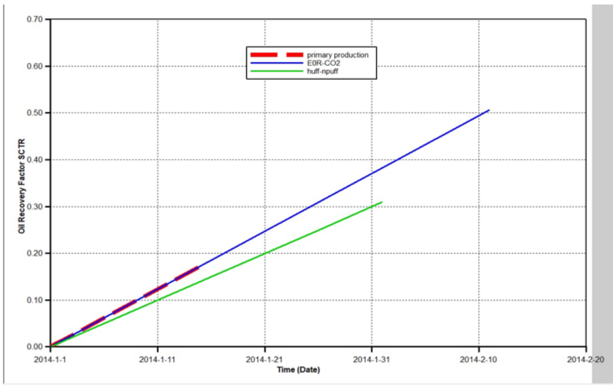


Figure 20: Comparison between Case 1 primary production and Case 1 EOR-CO2 and Case 1 Huff-n-puff

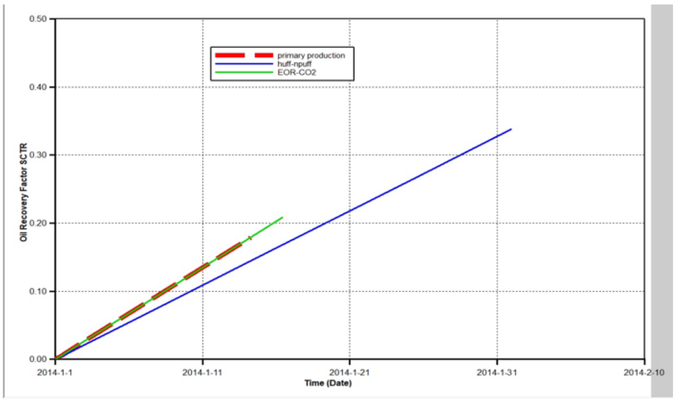


Figure 21 : Comparison between Case 2 primary production and Case 2 EOR-CO2 and Case 2 Huff-n-puff

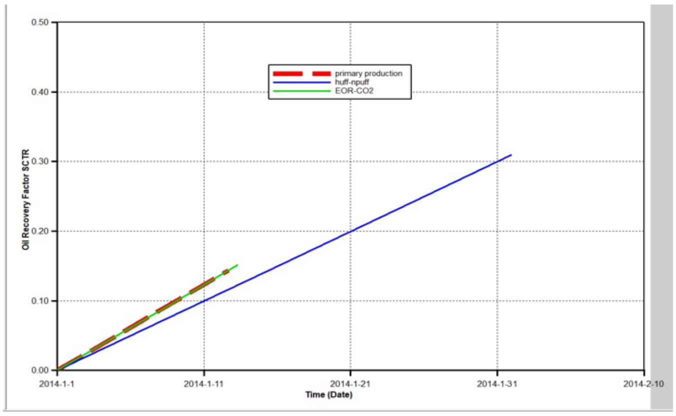


Figure 22 : Comparison between Case 3 primary production and Case 3 EOR-CO2 and Case 3 Huff-n-puff

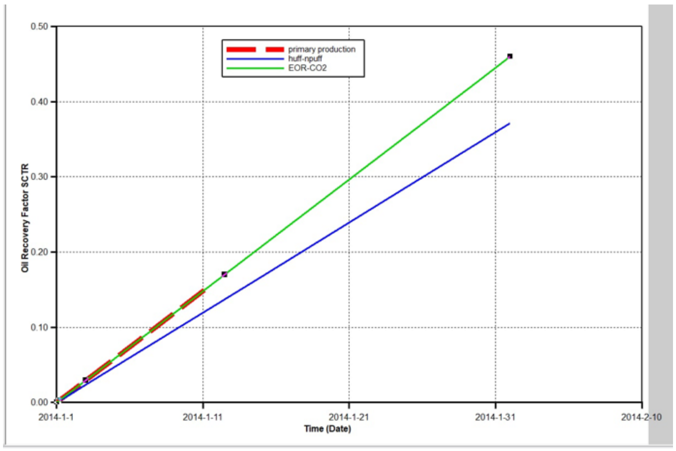


Figure 23: Comparison between Case 4 primary production and Case 4 EOR-CO2 and Case 4 Huff-n-puff

XXI- CONCLUSIONS

- Different scenarios were simulated using the CMG program to check how successful CO2 injections are, and where they can be successfully applied.
- There are some factors that affect carbon dioxide floods, such as the impact of porosity, permeability, and thickness.
- the results were also compared with each other where the comparison was between primary production and production in the improved extraction method using carbon dioxide and from that we obtained results showing Increased oil production when injecting CO2 .
- We also compared the results of Huff-n-puff injections with the results of flooding injections and found that flooding injections give higher results than huff-n-puff.

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