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https://orcid.org/0000-0002-7979-1188

OPTIMIZING OIL RECOVERY AND EMISSIONS REDUCTION THROUGH CO_2 INJECTION IN MATURE OFFSHORE FIELDS

B.S. AKHYMBAYEVA,
PhD, Associate Professor,
b.akhymbayeva@satbayev.university

SATBAYEV UNIVERSITY,
Satpayev str., 22a, Almaty, 050013, Republic of Kazakhstan

The article explores the potential of CO_2 injection technology for enhanced oil recovery (EOR) and simultaneous reduction of carbon emissions through storage in oil reservoirs and aquifers. The study focuses on 23 oil fields on the Norwegian Continental Shelf, identified as promising candidates for implementing this technology. The model used in the research assesses the economic and technical feasibility of CO_2 injection, along with the integration of EOR and long-term carbon storage. The primary goal is to demonstrate that injecting 70 million tons of CO_2 annually over 40 years can result in an additional oil recovery of 5.9%-7.6% of the original oil in place, equivalent to 276-351 million cubic meters. Excess CO_2 can be stored in aquifers, further contributing to the reduction of carbon emissions.

The article outlines key aspects of the study, including economic and technical parameters, such as costs associated with CO_2 transportation, storage, and drilling of new wells, as well as various oil and CO_2 price scenarios. The environmental benefits of the project are highlighted, showing that the significant CO_2 retained in oil reservoirs and aquifers compensates for emissions from the combustion of recovered oil. The study also discusses the features of the model, including scenarios for continuous CO_2 injection and considerations of infrastructure costs.

The article emphasizes the importance of developing and implementing such projects in the context of global climate change mitigation efforts and points to the significant potential of CO_2injection technology for the oil industry.

The aim of this article is to evaluate the feasibility and potential benefits of large-scale CO_2 injection for enhanced oil recovery (EOR) and long-term carbon storage in oil fields and aquifers. The study seeks to demonstrate how CO_2 injection can increase oil recovery rates while simultaneously *reducing carbon emissions, providing a comprehensive technical-economic assessment of the process. Through the analysis of 23 oil fields on the Norwegian Continental Shelf, the article aims to present the economic, environmental, and operational advantages of integrating CO_2 storage with EOR operations.*

KEY WORDS: *CO_2 injection, enhanced oil recovery (EOR), carbon storage, aquifers, carbon emissions, economic model.*

ОПТИМИЗАЦИЯ НЕФТЕОТДАЧИ ПЛАСТОВ И СОКРАЩЕНИЕ ВЫБРОСОВ ЗА СЧЕТ ЗАКАЧКИ CO_2 НА ЗРЕЛЫЕ МОРСКИЕ МЕСТОРОЖДЕНИЯ

Б.С. АХЫМБАЕВА, PhD, ассоциированный профессор, *b.akhymbayeva@satbayev.university*

SATBAYEV UNIVERSITY,
Республика Казахстан, 050013, г. Алматы, ул. Сатпаева, 22а

Статья исследует потенциал технологии инъекции CO_2 для повышения нефтеотдачи (EOR) и одновременного сокращения выбросов углерода за счет хранения CO_2 в нефтяных пластах и аквиферах. Исследование фокусируется на 23 нефтяных месторождениях Норвежского континентального шельфа, которые были определены как перспективные кандидаты для внедрения этой технологии. Модель, используемая в исследовании, оценивает экономическую и техническую целесообразность инъекции CO_2, а также интеграцию процессов EOR и долгосрочного хранения углерода. Основной целью является продемонстрировать, что инъекция 70 миллионов тонн CO_2 ежегодно в течение 40 лет может привести к дополнительной добыче нефти в объеме 5,9%-7,6%от исходных запасов, что эквивалентно 276-351 миллионам кубических метров. Излишки CO_2 могут быть сохранены в аквиферах, что дополнительно способствует снижению выбросов углерода.

В статье изложены ключевые аспекты исследования, включая экономические и технические параметры, такие как затраты на транспортировку, хранение CO_2 и бурение новых скважин, а также различные сценарии цен на нефть и CO_2. Подчеркиваются экологические выгоды проекта, показывая, что значительные объемы CO_2, удерживаемого в нефтяных пластах и аквиферах, компенсируют выбросы, возникающие при сжигании добытой нефти. В статье также обсуждаются особенности модели, включая сценарии непрерывной инъекции CO_2 и учет затрат на инфраструктуру.

Статья акцентирует внимание на важности разработки и внедрения подобных проектов в контексте глобальных усилий по смягчению последствий изменения климата и подчеркивает значительный потенциал технологии инъекции CO_2 для нефтяной отрасли.

Цель данной статьи – оценить экономическую целесообразность и потенциальные выгоды крупномасштабной инъекции CO_2 для повышения нефтеотдачи (EOR) и долгосрочного хранения углерода в нефтяных пластах и аквиферах. Исследование направлено на демонстрацию того, как инъекция CO_2 может повысить уровни добычи нефти, одновременно сокращая выбросы углерода, предоставляя комплексную технико-экономическую оценку процесса. Путем анализа 23 месторождений Норвежского континентального шельфа, статья стремится представить экономические, экологические и операционные преимущества интеграции хранения CO_2 с процессами EOR.

КЛЮЧЕВЫЕ СЛОВА: *инъекция CO_2, повышение нефтеотдачи (EOR), хранение углерода, аквиферы, углеродные выбросы, экономическая модель.*

ЖЕТІЛГЕН ТЕҢІЗ КЕН ОРЫНДАРЫНДА CO_2 АЙДАУ АРҚЫЛЫ МҰНАЙ ӨНДІРУДІ ОҢТАЙЛАНДЫРУ ЖӘНЕ ШЫҒАРЫНДЫЛАРДЫ АЗАЙТУ

B.S. AKHYMBAYEVA, PhD, Associate Professor, *b.akhymbayeva@satbayev.university*

SATBAYEV UNIVERSITY,
Satpayev str., 22a, Almaty, 050013, Republic of Kazakhstan

Мақала CO_2 инъекциясы технологиясының мұнай өндірісін арттыру (EOR) және көмірқышқыл газының шығарындыларын азайту мүмкіндіктерін қарастырады. Бұл технологияны қолдануға әлеуетті деп танылған Норвегия континентальды қайраңындағы 23 мұнай кен орны зерттелген. Зерттеуде қолданылған модель CO_2 инъекциясының экономикалық және техникалық орындылығын, сондай-ақ EOR мен ұзақ мерзімді көмірқышқыл газын сақтау интеграциясын бағалайды. Негізгі мақсат – 40 жыл бойы жылына 70 миллион тонна CO_2 инъекциясы бастапқы мұнай қорларының 5,9%-7,6%-ын құрайтын 276-351 миллион текше метр қосымша мұнай өндіруге мүмкіндік беретінін көрсету. Артық CO_2 аквиферлерде сақталып, көмірқышқыл газын шығарындыларын азайтуға қосымша үлес қоса алады.

Мақалада зерттеудің негізгі аспектілері, соның ішінде CO_2 тасымалдау, сақтау және жаңа ұңғымаларды бұрғылау шығындары, сондай-ақ мұнай мен CO_2 бағасының әртүрлі сценарийлері талқыланады. Жоба аясында мұнай кен орындарында және аквиферлерде сақталған CO_2 көлемінің маңызды экологиялық пайдасы көрсетіледі, бұл өндірілген мұнайдың жануынан болатын шығарындыларды өтеуге ықпал етеді. Мақалада сондай-ақ үздіксіз CO_2 инъекциясы сценарийлері және инфрақұрылым шығындарына қатысты модельдің ерекшеліктері қарастырылған.

Мақала жаһандық климаттың өзгеруін жұмсарту шаралары контекстінде осындай жобаларды әзірлеу мен іске асырудың маңыздылығын атап өтеді және мұнай өнеркәсібі үшін CO2инъекциясы технологиясының маңызды әлеуетіне назар аударады.

Бұл мақаланың мақсаты – мұнай кен орындары мен аквиферлерде мұнай өндірісін арттыру (EOR) және көмірқышқыл газын ұзақ мерзімді сақтау үшін кең көлемді CO_2 инъекциясының мүмкіндіктері мен артықшылықтарын бағалау. Зерттеу CO_2 инъекциясының мұнай өндірісін арттырып қана қоймай, сонымен бірге көмірқышқыл газын шығарындыларын азайта алатынын көрсетуді мақсат етеді. Норвегия континентальды қайраңындағы 23 мұнай кен орнын талдау арқылы мақала CO_2 сақтау мен EOR операцияларын біріктірудің экономикалық, экологиялық және операциялық артықшылықтарын ұсынады.

ТҮЙІН СӨЗДЕР: *CO_2 инъекциясы, мұнай өндірісін арттыру (EOR), көміртекті сақтау, аквиферлер, көміртегі шығарындылары, экономикалық модель.*

Introduction. The pressing need to combat climate change and reduce greenhouse gas emissions has led to the exploration of innovative solutions in various sectors, including the energy industry. One of the most promising approaches is the utilization of CO_2 injection for enhanced oil recovery (EOR) and long-term carbon storage. This method not only increases oil recovery from mature fields but also provides a way to store significant amounts of CO_2, contributing to global efforts to mitigate climate change. The dual benefit of this technology makes it particularly relevant in the current context of both energy production and environmental responsibility.

The Norwegian Continental Shelf (NCS) contains numerous mature oil fields, many of which have undergone water flooding and are now reaching the end of their conventional production cycles. With high water cuts and declining production rates, these fields present an opportunity for new methods to maximize the extraction of the remaining 40-60% of oil that still resides in the reservoirs. CO_2 injection, a proven EOR method in onshore fields, offers a promising solution for offshore reservoirs as well. By injecting CO_2 into the reservoirs, the oil's viscosity is reduced, and miscible conditions are created, allowing for more efficient displacement of oil and an increase in overall recovery [1].

This article aims to explore the feasibility of combining large-scale CO_2 injection with EOR and aquifer storage in 23 selected oil fields on the NCS. A comprehensive technical-economic model is used to evaluate the potential for oil recovery, the capacity for CO_2 storage, and the associated costs over a 40-year period. The study also examines the impact of variables such as oil prices, CO_2 costs, and drilling expenses on the overall project viability. The findings from this research offer critical insights into how CO_2 injection can contribute to enhanced oil recovery while simultaneously addressing the need for carbon reduction. Ultimately, this research supports the growing movement toward sustainable energy practices by providing a practical pathway for combining resource extraction with carbon sequestration in a way that balances both economic and environmental objectives[2].

Materials and methods. A model has been developed to assess the feasibility of large-scale infrastructure that combines CO_2-enhanced oil recovery (EOR) with aquifer storage, focusing on 23 potential oil fields on the Norwegian Continental Shelf. The model proposes injecting 70 million tons of CO_2 annually over a 40-year period, with a limited sensitivity analysis. The potential oil recovery through CO_2 injection is estimated to range between 276-351 million Sm^3, equivalent to 5.9%-7.6% of the original oil in place. Key factors influencing this include the price of oil, CO_2 costs (0-50 USD/ton), drilling expenses (25-42 million USD per well), and transportation costs (8 USD/ton). Costs for storing CO_2 in aquifers are also considered (8 USD/ton). CO_2 is primarily stored in oil reservoirs during tertiary recovery, offsetting emissions from the combustion of recovered oil, with additional CO_2 stored in aquifers, further reducing carbon emissions. This model provides insights into the potential implementation of large-scale CO_2 EOR and aquifer storage, highlighting both enhanced oil recovery and emission reduction benefits [3].

Storing CO_2 in sedimentary rock formations is viewed as a viable large-scale solution to reduce anthropogenic CO_2 emissions, with the North Sea region alone having the capacity to accommodate the EU's point-source emissions during the fossil fuel era. Gas and oil fields are ideal candidates for CO_2 storage due to their proven ability to trap buoyant fluids over geological time scales.

Many of the water-flooded oil fields in the North Sea are approaching maturity, characterized by high and increasing water cuts. To optimize the remaining oil reserves-estimated to be 40-60% of the original volume-new recovery methods are urgently needed. Decisions regarding future production strategies must be made soon, including whether to adopt new enhanced oil recovery (EOR) technologies or to potentially abandon these fields.

CO_2 injection has already demonstrated success in EOR applications onshore and has significant potential for use in the North Sea's offshore reservoirs. This study focuses on large-scale tertiary CO_2 injection and has identified 23 potential oil fields in the North Sea for such operations.

A tailored technical-economic model has been employed to evaluate the practicality of integrating CO_2 storage with EOR. This model considers the specific conditions and challenges of the North Sea and evaluates the potential benefits of combining CO_2 storage with enhanced oil recovery. Previous iterations of this model provided valuable insights, and the current version allows for the study of both continuous CO_2 injection and water-alternating-gas (WAG) methods, though this study primarily focuses on continuous injection [4].

Earlier versions of the technical-economic model limited economic analysis to incremental oil production following CO_2 injection. However, the latest model version incorporates revenues from all oil produced after CO_2 injection begins.

Drilling costs account for a significant portion of total investment on the Norwegian Continental Shelf. Transitioning from water to CO_2 injection requires substantial new well drilling, which is a major investment. Various factors affect drilling costs, including rig rates, drilling time, consumable materials, and logistics. The most significant drivers of these costs are drilling time and rig rates, both of which are influenced by rig availability and market conditions. Historical data show that drilling costs on the Norwegian Continental Shelf have fluctuated. Between 2000 and 2003, the average cost was around 200 million Norwegian kroner (NOK), while from 2008 to 2013, this cost increased to approximately 500 million NOK (adjusted to 2013 levels). These cost variations reflect the changing dynamics of the offshore oil industry and the factors affecting exploration and production during different periods [5].

Figure 1 illustrates the technical-economic model, which is composed of four primary components: the transport module, EOR module, excess CO_2 storage module, and economic module. The model begins by collecting CO_2 from various land-based sources, compressing it, and transporting it to the export terminal. From the terminal, a constant flow of CO_2 is injected into the main pipeline infrastructure, which operates throughout the duration of the project.

The main pipeline distributes CO_2 to selected oil fields, where it is injected to enhance oil recovery and provide long-term storage. Each field receives only the necessary amount of CO_2, with demand gradually decreasing as breakthrough CO_2 is recycled within the system. As a result, the required CO_2 for enhanced oil recovery fluctuates over the project timeline.

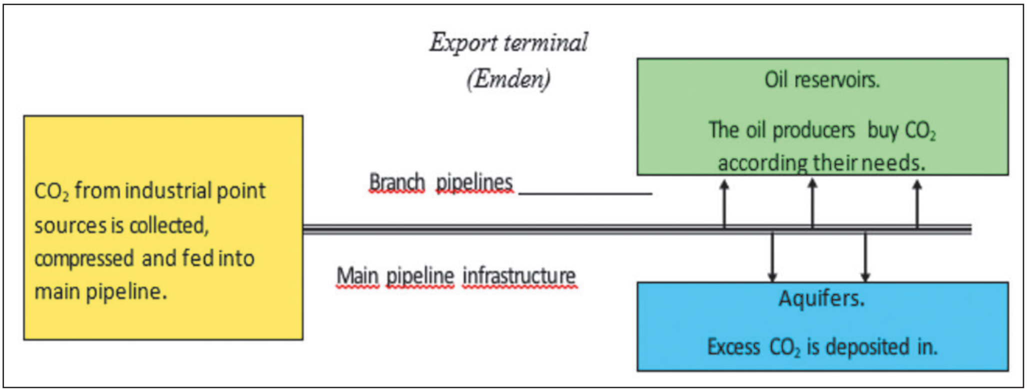

Figure 1 – **Illustration of infrastructure model concept**

Excess CO_2 that is not immediately needed for EOR is stored in aquifers, providing a secure, long-term solution for surplus CO_2 storage.

The economic module consolidates all operational costs, investments, and revenue from enhanced oil recovery to perform a comprehensive financial analysis. This analysis includes expenses related to CO_2 injection, ongoing operational costs, infrastructure and well investments, as well as the income generated from the EOR activities [6].

In summary, the technical-economic model integrates these components to assess the feasibility and economic viability of the CO_2 storage and enhanced oil recovery project. It considers key factors such as CO_2 transport, injection rates, storage in aquifers, and the overall financial implications of the process.

The primary focus of this study is the development of an EOR module that forecasts the potential for enhanced oil recovery (EOR) through CO_2 injection in water-flooded sandstone reservoirs. To accomplish this, a numerical reservoir simulator was employed to model the performance of water injection followed by CO_2 injection. Several factors were considered in the simulations, including injection rates, the duration of water flooding prior to CO_2 injection, oil density, oil viscosity, vertical permeability, and rock heterogeneity [7].

These simulations produced response surface models, which were used to create explicit functions for calculating production profiles of oil, water, and gas, as well as predicting the timing of water and gas breakthroughs. The simulations assumed that oil was displaced by CO_2 under miscible conditions, where a miscible transition zone forms between the CO_2 and oil due to multi-contact phase behavior once the reservoir pressure exceeds the minimum miscibility pressure.

The EOR module was subsequently applied to real fields that had experienced water flooding, utilizing field-specific dimensionless group values. The CO_2 injection rate for each field was designed to match the reservoir volume rate, equivalent to the oil volume plateau rate, ensuring an optimal number of injection wells. The EOR module's parameters were fine-tuned using historical and projected production data from the Norwegian Petroleum Directorate (NPD).

Figure 2 provides an example of the estimated production curves for oil, water, and gas during the water injection phase and the transition to CO_2 injection [8].

It is important to highlight that CO_2 injection in oil reservoirs is a complex process, and accurately predicting the EOR potential requires detailed reservoir modeling with a numerical simulator and a comprehensive reservoir model. While the estimates generated by the EOR module in this study offer rough approximations, the general EOR model effectively captures key aspects of the CO_2 injection process, including water and gas production profiles, CO_2 content in produced gas, and the incremental oil recovery. These field-specific production profiles, illustrated in *Figure 12*, serve as critical inputs for the subsequent techno-economic modeling [9].

CO_2 Storage Module: In the proposed infrastructure, CO_2 is transported via the main pipeline at a consistent rate throughout the project's duration. The pipeline is designed to handle the peak demand for oil production, ensuring adequate CO_2 supply for enhanced oil recovery (EOR) operations.

During the EOR phase, a constant rate of CO_2 injection is maintained for each field over the injection period. As CO_2 breakthrough occurs and recycling of CO_2 increases,

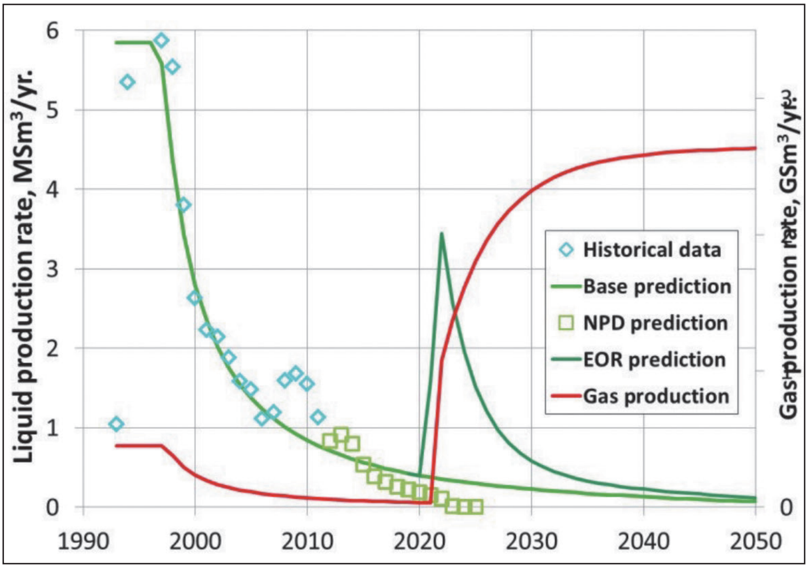

Figure 2 – **Production curves for oil, water and gas during water injection and conversion to CO_2 injection in year 2020**

the net amount of CO_2 imported to each field gradually decreases. Initially, a significant portion of the CO_2 transported is stored in the oil reservoirs, but over time, a greater share of the surplus CO_2 will need to be stored in aquifers.

The transportation cost of CO_2 is calculated at 7.96 USD per ton, covering the expenses associated with moving CO_2 through the pipeline infrastructure. This cost is a critical factor in the economic assessment of the overall CO_2 storage and EOR project.

Results and discussion. To convert a field for CO_2 injection in enhanced oil recovery (EOR), several installations and modifications are necessary:

1. Branch Pipeline: The oil facility must be connected to the main infrastructure via a dedicated branch pipeline. This line, which needs to be constructed, facilitates the transport of CO2 from the main pipeline to the injection site. The diameter of these branch pipelines is determined by factors such as the required transit capacity and the length of the pipeline.

2. Oil Production System Modifications: The existing oil production system must be upgraded to handle the increased gas quantities that arise after a significant CO_2 breakthrough [10]. These improvements allow the system to manage the additional gas production. For the plateau oil production rate, the investment for building a land-based oil production system, including the installation of first-stage compressors, is estimated at 400 USD/bbl/day. The cost model assumes that existing offshore process equipment can be reused and modified without incurring additional expenses.

3. CO_2 Compressor: A dedicated CO_2 compressor is required to pressurize the imported CO2 to the appropriate injection pressure. This compressor ensures that the CO_2 reaches at least 70 bars of pressure, keeping it in a dense phase suitable for injection into the reservoir [11].

4. CO_2 Injection Wells: Specific CO_2 injection wells must be drilled and completed to facilitate the controlled and efficient injection of CO_2 into the reservoir for EOR operations.

In calculations for compressor power, first-stage separators are assumed to operate at 60 bars, with the majority of the gas being separated at this stage. After CO_2 breakthrough, more CO_2 and hydrocarbon gas are recycled from the separator train within the oil production system.

Costs associated with these installations and modifications vary depending on factors like equipment reuse and necessary adjustments. The cost model accounts for low, medium, and high-cost scenarios and estimates that modifying the oil production system will cost approximately 400 USD/bbl/day under an index-regulated cost structure, without additional offshore expenses.

The exact locations of aquifers intended for surplus CO_2 storage have not been specified in this study. However, it is understood that alternative options for water storage in aquifers exist. Based on a unit storage cost, as previously discussed, aquifer storage was incorporated into the analysis [12].

The Norwegian Petroleum Directorate compiled an updated list of potential candidate fields, along with an initial evaluation of each field's suitability for tertiary CO_2 EOR. From this list, 23 oil fields were carefully selected for the study. For each of these fields, the optimal timing for CO_2 injection was determined, taking various factors into account.

Oil Production and CO_2 Storage:

The production characteristics for oil recovered through CO_2 injection in the 23 selected fields are illustrated in the analysis.

The specific scenario depicted in *Figure 3* was calculated using the following assumptions:

Well costs: $25 million per well

Oil price: $50 per barrel

CO_2 price: Zero (assumed no cost for CO_2)

Rate of return: 7%

Figure 14 shows the CO_2 injection profiles for these same 23 oil fields. In total, 70 million tons of CO_2 are transported annually via the main pipeline infrastructure.

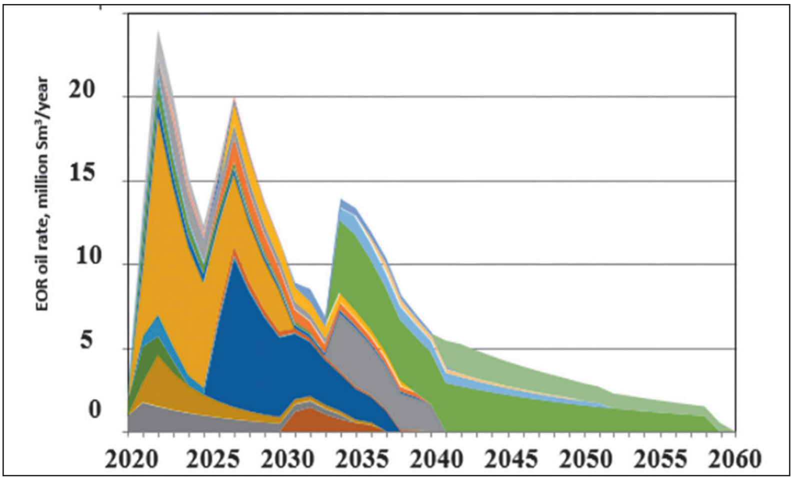

Figure 3 – **EOR output rates for 23 oil fields during tertiary CO_2 injection**

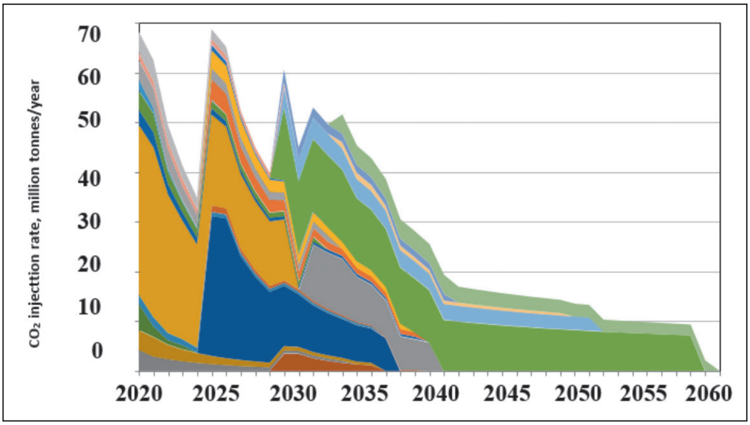

Figure 4 – **Injection rates of CO_2 during 23 oil fields' tertiary CO_2 flooding**

CO_2 Mass Balance:

The analysis presented in Figure 16 provides key insights into the CO_2 mass balance during enhanced oil recovery (EOR) and CO_2 storage:

Figure 5 compares the amount of CO_2 produced during the combustion of oil recovered through EOR with the CO_2 stored in oil reservoirs.

The figure also illustrates the total CO_2 stored, including the portion sequestered in aquifers.

The mass balance calculations for *Figure 5* were conducted under the assumptions of an oil price of 50 USD/bbl, a CO_2 price of zero, and well costs of 25 million USD per well [13].

Key Findings:

The graph shows that more CO_2 is stored in oil reservoirs than is released during the combustion of EOR-recovered oil. This is largely attributed to the significant water production caused by the CO_2 injection process.

The negative carbon impact of EOR oil, represented by the green areas in *Figure 5*, becomes more pronounced when the CO_2 stored in aquifers is included in the calculation.

The high volume of water generated by CO_2 injection increases the capacity for CO_2 storage within the oil reservoirs.

It is important to note that this analysis focuses exclusively on continuous CO_2 injection and does not consider water-alternating-gas (WAG) injection.

Although WAG injection could result in a slight increase in oil production, it would reduce the total amount of CO_2 stored in the reservoirs [14].

These findings underscore the significant CO_2 storage potential associated with continuous CO_2 injection for EOR, particularly when considering the additional storage capacity provided by the produced water. The large volume of CO_2 stored in the reservoirs can help offset the carbon footprint of EOR oil by reducing net CO_2 emissions from combustion.

The analysis focused on CO_2 injection infrastructure for delivering CO_2 into oil reservoirs and aquifers. The scenario examined 23 oil fields on the Norwegian Continental Shelf, with 70 million tons of CO_2 being injected annually for 40 years. A sensitivity

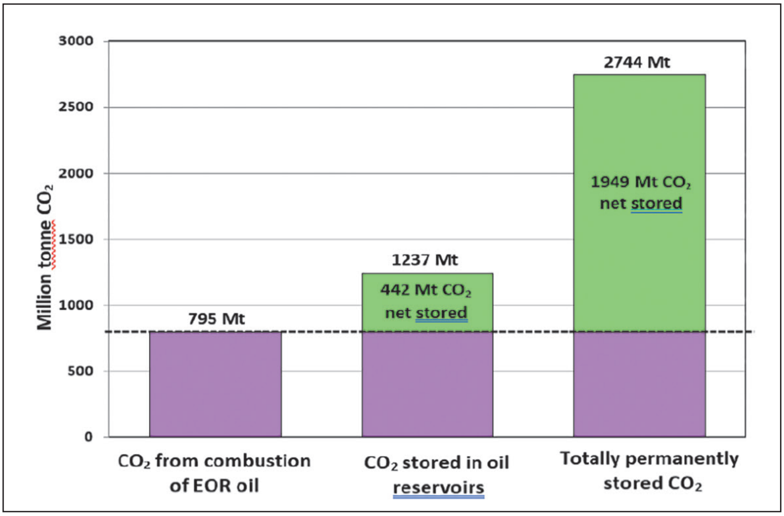

Figure 5 – **The significant CO_2 storage achieved in the oil reservoirs can somewhat offset the negative carbon footprint of EOR oil in terms of CO_2 emissions from combustion**

analysis was performed to account for variations in oil prices, CO_2 costs, and well expenses. The estimated EOR potential ranges from 276 to 351 million Sm^3, equivalent to 5.9% to 7.6% of the initial hydrocarbon pore volume. The remaining CO_2 storage occurs in aquifers, accounting for less than half of the total underground storage [15].

Injecting CO_2 into water-filled reservoirs requires significant investment in well costs. The economic feasibility of tertiary CO_2 flooding is highly dependent on keeping these well costs low. Achieving profitable CO_2 EOR could be possible if CO_2 is supplied to the terminal at no cost.

Conclusion. This study thoroughly investigates the potential of CO_2 injection technology for enhanced oil recovery (EOR) and carbon storage, focusing on 23 oil fields located on the Norwegian Continental Shelf. The research demonstrates that the implementation of CO_2 injection can effectively increase oil recovery rates while simultaneously contributing to a significant reduction in carbon emissions by storing CO_2 in both oil reservoirs and aquifers.

One of the key findings of the study is that injecting 70 million tons of CO_2 annually for 40 years could result in an additional oil recovery of 276 to 351 million cubic meters, which corresponds to 5.9% to 7.6% of the original oil in place. This demonstrates the viability of CO_2 injection as a solution to maximize the extraction of remaining oil reserves in mature fields that have undergone water flooding, especially in offshore reservoirs where recovery becomes more challenging.

The economic analysis within the study highlights the critical factors that impact the success of such projects, including oil prices, CO_2 costs, well drilling expenses, and CO_2 transportation costs. For the project to be economically viable, it is essential to maintain low well costs, especially for offshore operations, where these costs are a significant portion of the investment. The study points out that the feasibility of profitable CO_2-EOR operations is more likely when CO_2 is supplied at low or zero cost. Furthermore, the sensitivity analysis indicates that fluctuations in oil prices and well costs can strongly influence the project's economic outcomes.

From an environmental perspective, the study underscores the considerable potential for CO_2 storage to mitigate the carbon emissions associated with oil combustion. CO_2 injection into oil reservoirs not only enhances oil recovery but also sequesters large amounts of CO_2, reducing the overall carbon footprint. The additional CO_2 storage in aquifers further strengthens the environmental benefits of the project. By capturing and storing CO_2 that would otherwise be released into the atmosphere, this process provides a critical pathway toward achieving carbon reduction targets [16].

The study also highlights the role of continuous CO_2 injection as a highly effective method for both EOR and carbon storage, as it maximizes oil recovery while ensuring that surplus CO_2 is securely stored. However, the analysis notes that while water-alternating-gas (WAG) methods could potentially increase oil recovery rates slightly, they would reduce the overall volume of CO_2 stored, making continuous injection more beneficial from a carbon storage perspective [17].

In conclusion, the research underscores the importance of integrating CO_2 injection with EOR in mature oil fields, particularly in offshore environments like the Norwegian Continental Shelf. This approach offers a practical and economically viable solution to extend the productive life of oil fields while contributing to the global effort to combat climate change. The study shows that large-scale CO_2 injection not only provides a means to increase oil recovery but also serves as a crucial tool for long-term carbon sequestration, helping to offset the emissions from the oil industry. As countries continue to focus on reducing greenhouse gas emissions, the role of CO_2-EOR projects will become increasingly important in balancing energy production with environmental sustainability.

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