



**MINISTRY OF ENERGY AND ENERGY INDUSTRIES
REPUBLIC OF TRINIDAD AND TOBAGO**

**GUIDELINES TO OPERATORS FOR THE APPROVAL OF A CO₂
INJECTION PROJECT BY THE RESOURCE MANAGEMENT DIVISION**

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GOVERNMENT OF THE REPUBLIC OF TRINIDAD AND TOBAGO MINISTRY OF ENERGY AND ENERGY INDUSTRIES

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1. Introduction

This guidance document is a subset of the legal framework governing the approval of a CO₂ injection project both onshore and offshore by the Resource Management Division of the Ministry of Energy and Energy Industries (MEEI).

Enhanced oil recovery (EOR) is one of the main methods that can be implemented to boost oil production in Trinidad and Tobago's mature fields. Therefore, it is important that the MEEI plays its part in assisting and encouraging operators to carry out EOR projects. In saying this, it is imperative that the MEEI be kept abreast with the actions of the operators to ensure that the projects are successful and beneficial to all parties.

2. Objectives

Before granting approval for a CO₂ injection project, the MEEI must be provided with relevant documentation to demonstrate that the operator has:

- i. a suitable rationale for the CO₂ injection project
- ii. the required facilities and infrastructure,
- iii. technical knowledge
- iv. financial support
- v. adequate environmental protection considerations in place.

3. Authority

These Guidelines are established pursuant to the authority prescribed in the Petroleum Act Chapter 62:01 of 1969 and in the Petroleum Regulations 1970 and specifically with reference to Clause 43 (h) of the Act, which states: "*the licensee shall exert his utmost efforts to develop any discovered fields to the maximum extent consistent with good petroleum industry practice and in particular observe sound technical and engineering principles regulating the conservation of the deposits of hydrocarbons, in preventing damage to adjoining petroleum bearing strata, in controlling the flow, in preventing the escape or waste of petroleum discovered, in preventing the entrance of fluids through wells into petroleum bearing strata except in **approved fluid injection operations** and in protecting water bearing strata encountered in the course of drilling;*".

4. Applicability

There are two types of carbon dioxide injection: miscible and immiscible. The difference between the two is the pressure at which the CO₂ is injected. Miscible injection occurs when the injection pressure is above the Minimum Miscibility Pressure (MMP) but below fracture pressure of the reservoir (Verma, 2015). Immiscible CO₂ injection occurs when the reservoir pressure is below the MMP (Mohammed-Singh & Singhal, 2004).

There are three main techniques used to inject CO₂ into the reservoir:

- i. Cyclic CO₂ or huff and puff injection in which there are three phases: injection (huff), soak and production (puff). These cycles are usually repeated until the economic limit is reached. This is usually economically attractive as it requires a smaller amount of CO₂ and there is a faster payout time (Persad, 2015).
- ii. CO₂ water alternating gas (WAG) injection which as the name suggests, involves CO₂ injected in alternating cycles with volumes of water. The ratio of CO₂ and water can be varied.
- iii. Continuous CO₂ injection (flood) where CO₂ is injected continuously throughout the project.

This guidance document applies to any CO₂ injection project that falls into the categories described above.

5. Guidelines to operators on the approval process for CO₂ injection projects by the Resource Management Division

There are 2 phases of guidelines which are to be followed: Pre-approval phase and Post approval phase.

Pre- Approval Phase

- 1) Company / Operator who is interested in conducting a CO₂ Injection should present a CO₂ Injection Project Presentation in a meeting to MEEI officials. Subsequently, company / operators should officially submit a CO₂ Injection Study Proposal to MEEI in the form of two (2) hard copies and one (1) soft copy. This Study Proposal should be submitted at least 3 months prior to desired project approval date. During this period, a project site visit is required.
- 2) The CO₂ Injection Study Proposal should include but is not limited to:

Project Background and Description

- Project scope, project phases and objectives.
- State the anticipated oil production increase and incremental recovery by well.
- State type of injection pattern for example line drive, 5-spot, inverted 5-spot, etc.
- List active and inactive wells in CO₂ injection project

- Identify and map CO₂ Injection reservoirs showing the area / field of the CO₂ injection zone.
- State sands / reservoirs / formation for CO₂ injection study and state reason for choosing the mentioned.

Reservoir Description

- Provide geologic and stratigraphic description of reservoir.
- Provide well correlation over the project area. Include digital LAS files for correlated wells.
- Show georeferenced net pay, net sand and structure maps of the formation of interest with project boundaries, faults, lease or licence boundaries highlighted. Supply any reservoir simulation model of the area of interest (Petrel RE, CMG, etc).
- Show a georeferenced base/ surface map for the project area highlighting the location of proposed:
 - conversion injectors
 - new drill injectors
 - existing producers
 - new drill producers
 - observation wells.
- Give reservoir parameters and fluid properties of the project study area. (i.e porosity, permeability, saturations, bulk rock volume, current bottomhole pressure, Original Oil In Place (OOIP), Gas to Oil ratio (GOR), mobility ratio, API gravity, specific gravity etc.). Identify for each parameter/property its source as well as the date it was measured or calculated.
- Provide historical production data and cumulative production. Provide written narrative on production history.
- State sweep efficiency.
- State Primary Production Mechanism.

CO₂ injection Parameters/Criteria

- Identify type of CO₂ injection that will be carried out (continuous, WAG or cyclic) and the duration of the injection phases. Give a rationale for the choice of CO₂ injection selected.
- Identify the injection CO₂ source and state whether company / operator has adequate supply of CO₂ to carry out the CO₂ injection operations.
- State volume of CO₂ required per day to undertake the CO₂ injection as well as the total volume and how CO₂ injected would be metered.
- State proposed injection rates, injection pressure and any plans prior to injection commencement.

- State the depth to which the CO₂ would be injected and state whether the reservoir fluids will be miscible or immiscible.
- Identify the quantity of CO₂ which would be sequestered in the subsurface and provide calculations and all inputs used to determine it.
- State the well spacing and depth of all wells being used in the CO₂ injection.
- Provide complete wellbore diagrams for all injector and producer wells
- Provide a listing of the producer well names, the injector well names and the observation well names.
- State what parameters would be recorded from observation wells.
- Provide coordinates of all injectors, producers and observation wells under the CO₂ injection study. For onshore wells these should be in Naparima 1955 datum and for offshore wells these should be in WGS1984 datum.
- State whether there is any proposed CO₂ injection expansion and provide details of such.
- Provide Injectivity test results.
- CO₂ counts should be measured in all offtake wells prior to and during gas injection.
- The production and pressure data during the injection phase should be monitored closely.
- State voidage of target area and fill up time and show calculation inputs and processes.

Water Injection/ Production Criteria

- State the amount of water production from the field both historically as well as a forecasted value for project.
- State what would be done with the produce water and where do the Company / operator intend to dispose of it.
- Ensure that the injection water is compatible with the reservoir / receiving formation if water is being used alternately with CO₂. State how the compatibility of injection water with the reservoir was determined. Show what compatibility tests would be carried out as well as the water compatibility test results. This is for the case if the CO₂ injection would involve the injection of volumes of CO₂ alternated with volumes of water; water alternating gas or WAG injections.
- State the plans for treatment of water with schematic prior injection. State quality of injection water. This is for the case if the CO₂ injection would involve the injection of volumes of CO₂ alternated with volumes of water; water alternating gas or WAG injections.
- State throughput capacity of produced water injection facility.

Surface Equipment

- Show schematic of surface equipment for example: well pads, well heads, drilling/workover rigs, rod pumps, injection pumps, compressors, pressure gauges, valves, CO₂ supply trucks, CO₂ supply tanks, battery tanks, gathering stations, pipelines, roads, fencing, workman sheds and gas detecting equipment.
- State condition of all equipment / materials being used and provide details on the status and condition of the injection stations.
- Ensure that all storage tanks are up to international standard.
- Provide operational parameters for example: total pump flow rate, maximum allowable operating pressure for pump/compressor, normal operating pressure for pump/compressor, fluid temperature etc.

Drilling and Production considerations

- State procedures involved in wellbore integrity testing and state integrity of wells being used in CO₂ injection. Ensure that all injectors, producers and observation wells being used are in proper working conditions.
- Show historical and planned workover work and status of wells involved in CO₂ injection. The operator / company should implement an inspection and maintenance program to ensure the internal and external integrity of all injection wells. This programme should include, but not be limited to, ensuring the absence of leakage in the casing, tubing or packer of the injection wells. These records of such inspections and maintenance should be made available to MEEI upon request. Refer to the 'Disposal and Injection Well Technical Guidance' document.
- State intervals in wells that should be abandoned in accordance with Ministry of Energy and Energy Industries 'Procedures for the Plugging and Abandonment of Oil and Gas Wells' if any, to isolate sands under study from others to prevent any cross-flow of fluids if applicable.
- The company / operator should ensure that the injection pressure does not exceed the fracture pressure of the formation and state the method of determination of fracture pressure. The company / operator should monitor and record the injection pressure, injection depth and fracture pressure for each injection well which should be provided to MEEI.
- If the company / operator observes any significant changes in the relationship between injection pressure and injection flow rate, immediate measures should be taken to correct the problem and the company / operator should inform MEEI within 24 hours of detecting such change. Subsequently, a report should be submitted to MEEI within seven (7) days of detecting significant changes in the relationship between injection pressure and injection flow rate. The report should include:
 - The cause of change in the relationship between the injection pressure and injection flow rate.

- Measures implemented to correct the problem.
- A statement of the time taken for the situation to return to normal.
- A discussion of the environmental impacts likely to result from the change.

Environmental Considerations

- State precautionary measures that will be used to ensure that the fresh water aquifers / water tables are not contaminated by either hydrocarbons or saline water. Ensure that there is no pollution to the environment or contamination of the aquifer, rivers, lakes, water wells and earth's surface.
- A georeferenced map showing the location of the surface water sources, aquifer systems and private or Water and Sewerage Authority (WASA) wells that are located in the specific area / block being considered for CO₂ injection. State the number and depth of WASA water wells in the area / block.
- The company / operator should apply for a Certificate of Environmental Clearance (CEC) from the Environmental Management Authority (EMA). A copy of the Certificate of Environmental Clearance (CEC) should be provided to MEEI. Otherwise, it should be provided after Resource Management approval, which will be conditional upon CEC delivery.
- Give proof that the environment would not be affected in a negative way while undertaking CO₂ injection operations. Ensure that Corporate Social Responsibility is maintained for the environment. Precautionary measures should be met with relevant supporting documents to ensure that the operation of the proposed CO₂ injection would be taken in a safe manner with minimal harm to the environment upon approval.

Project Economics and Timelines

- Show project cash flow tables with inputs such as: operating expenditure, capital expenditure, discount rate, oil price assumption, royalties and taxes as well as determinants of profitability like: NPV, payout and IRR.
- State Peak Oil Rate, production decline rate and recovery.
- State risked forecasted incremental CO₂ injection production for each block / area being injected into.
- State work activities for the CO₂ injection and the timeframes for completion & procedures involved in conducting CO₂ injection.

Miscellaneous

- Provide any contracts / agreements between licensee and sub-licensee if any.
- Provide any service contracts/ agreements between operator and service companies.
- State any concerns / risks and uncertainties that may affect the project.

Post Approval Phase

CO₂ Injection Data Monitoring

- Submission of Production and Injection data as well as quality of injection data.

Quarterly Reports

- Submission of quarterly reports that should contain:
 - Integrity of wells used
 - Pressure data and flow level test data from well observation
 - Production profiles for each sand
 - Condition of equipment/ materials used

Annual Report

- Highlight performance of the project
- Major issues and key learnings of the project

Project Implementation Report

- Implementation report must be based on:
 - Completion of injectivity test for all wells under study area
 - Major changes of any proposed producers, injectors and observation wells
 - Provide a Forward Drilling Plan if new wells are being drilled in the CO₂ injection area.
 - CEC issues
 - Procedures used in the water filtration system
 - Status and condition of the injection stations and equipment used for the project

Monitoring Discussions and Site Visits

- Routine site visits and/or meetings with Ministry of Energy and Energy Industries officials as necessary.
- Recommendations should be made throughout the life of the project depending on economic factors, environmental concerns incremental oil etc.

6. References

- i. Mohammed-Singh, L. J., & Singhal, A. K. (2004). Lessons from Trinidad's CO₂ Immiscible Pilot Projects 1973-2003. Society of Petroleum Engineers
- ii. Persad, K. M. (2015). Potential for increasing recovery in mature fields onshore and offshore Trinidad using CO₂ as the major EOR mechanism. Retrieved from https://www.academia.edu/18851547/Potential_for_EOR_using_CO2_in_Trinidad_and_Tobago
- iii. Schlumberger Oilfield Glossary Definitions for *CO₂ Water Alternating Gas, Waterflood* <https://www.glossary.oilfield.slb.com/>
- iv. Verma, M. K. (2015). Fundamentals of Carbon Dioxide-Enhanced Oil Recovery (CO₂-EOR)—A Supporting Document of the Assessment Methodology for Hydrocarbon Recovery Using CO₂-EOR Associated with Carbon Sequestration. Virginia: United States Geological Survey.

7. Queries

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