CARBON DIOXIDE ENHANCED OIL RECOVERY ROAD MAP (CERM)

Collaboration for Efficiency, Resourcefulness and Maximization

The CERM Project is the innovative collaboration between academic institutions, The University of the West Indies (UWI) and The University of Trinidad and Tobago (UTT), and Government Energy Institutions- The Ministry of Energy and Energy Industries (MEEI), PETROTRIN and the National Gas Company (NGC) - toward sustainable development of known oil reserves using the technology of Carbon Dioxide Enhanced Oil Recovery (CO_2EOR).

ENERGY AND PERSISTENCE CONQUERS ALL

Then and Now: Oil Declines As A Waste Gas is Developed

"History repeats itself" is a well known adage. The book excerpt that follows (see page 2) traces the history of Trinidad and Tobago's decline in oil production and growth in natural gas development.

The authors in our lead article argued that this history may be repeated with the rise of carbon dioxide commercialization. The challenge facing the local energy sector calls for bold, decisive action in spite of technical, commercial and institutional challenges.

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> *"…we have taken what may be the more difficult road and this - accepting the challenge of entering the world of steel, aluminium, methanol, fertilizer, petrochemicals- in spite of our smallness and in spite of our existing level of technology."*

— Dr. Eric Williams

(Beginning of construction of the Iron & Steel Complex at Point Lisas , 1970s)

1940s-1970s

THEN | Waste not, want not

In the early stages of petroleum production in Trinidad, natural gas was first treated as a waste by-product of oil production. Gas produced from oil reservoirs, was routinely flared at oil wells. However, industry experts soon realised that natural gas was also a cleaner burning fuel alternative and in some instances, could provide a more economic option than refined products such as fuel oil. In 1949, Shell Leasehold Limited and the Trinidad & Tobago Electricity Commission signed a 25-year gas supply agreement.

This was soon followed by the use of natural gas as a raw material for the production of ammonia by WR Grace at Federation Chemicals Limited at Savonetta in 1958. The use of natural gas in these initial applications was the forerunner to the conceptualisation and development of the Point Lisas Industrial Estate.

1970s

THEN | (Waste) Gas Development

The Point Lisas Industrial Estate was born out of the desire of the South Chamber of Commerce to develop port facilities in the southern portion of Trinidad and, to use associated and non-associated natural gas to fuel heavy industries (Taylor). Led, in large measure, by a policy of direct investment and participation by the State, the estate became the site for the construction and operation of several large scale facilities including ammonia, urea, methanol and steel manufacture. This development was also the backdrop for the implementation of new technology and innovation in natural gas conversion. The use of new concepts in reformer and converter sizing and design, and improvements in ammonia and methanol plant conversion and energy efficiencies were successful. In 1975 the Natural Gas Company of Trinidad and Tobago was formed and mandated to manage the natural gas transmission system, purchase gas from upstream suppliers and sell to downstream users.

Early development of the Pt. Lisas Industrial Estate

"Natural gas was first treated as a waste by-product of oil production"

THEN | Peak, Decline and Development

Three years later, in 1978, oil production from Trinidad and Tobago peaked with an annual average of 229,598 barrels per day (Ministry of Energy and Energy Affairs, 2012). In the following decade as oil production began its natural decline, with production levels falling by as much as 34%, the infrastructure for natural gas development continued to expand steadily.

These trends have continued for both oil and gas respectively. Existing oil fields mature and follow the typical production lifecycle with exponential decline. In contrast, the development and monetisation of natural gas resources experienced exponential growth with the implementation of a range of export oriented projects.

NOW | Waste not, want not

In Trinidad and Tobago, carbon dioxide (CO_2) is produced mainly from the industrial sector as a result of natural gas combustion and petrochemical manufacture. Petrochemical production accounts for almost half of the total CO_2 emissions, 101 MMscf/day; of this volume, 76 MMscf/day comes from ammonia manufacture.

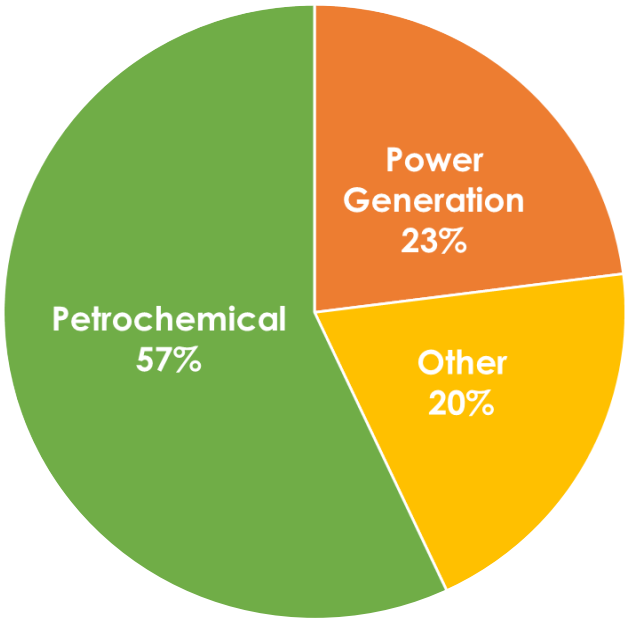


Figure 1: Trinidad and Tobago CO_2 Emissions by Sector

Although Trinidad and Tobago has earned international recognition for its model of natural gas development, the integration of downstream industries needs an in-depth review. The next stage in development should therefore be to identify and leverage on possibilities for operational integration to realize a reduction of CO_2 emissions and the optimal use of by- product streams.

"CO_2EOR is a 'win-win' scenario for Trinidad and Tobago."

THEN MEETS NOW | History to be repeated?

Carbon Capture and Storage (CCS) is a proposed technical solution to reducing the concentration of CO_2 in the atmosphere by collecting CO_2 generated at industrial sites or fossil-fuel burning power stations and injecting it deep underground, rather than allowing its release to the atmosphere. Although CCS is not purported to be a long term solution to CO_2 emissions it is a critical transitional technology for reducing emissions.

In 1990, Petrotrin operated several immiscible CO_2 floods as moderately successful pilot projects in the Forest Reserve sand found in the onshore Oropouche and Forest Reserve fields. These fields had previously undergone primary, secondary and tertiary production with water and natural gas injection. CO_2 injection resulted in incremental recovery of 2 to 8% of the original oil in place. Although preliminary results were encouraging, these projects have been discontinued with no further expansion due to concerns of CO_2 escape to surface outcrops in populated areas and other operational issues.

Even with the anticipated discovery of new oil reserves, enhanced oil recovery is needed to boost oil production in Trinidad and Tobago which has been on a steady decline since peaking in 1978. In the last 5 years, annual oil production has declined at a rate of 9% per year (Ministry of Energy and Energy Industries, 2013). At the same time CO_2 emissions continue unabated and largely unused. Geological CO_2 storage coupled with CO_2EOR is a 'win-win' scenario for Trinidad and Tobago.

(Lorraine Sobers and Selwyn Lashley. 2015. Win-Win: Enhanced Oil Recovery and Carbon Storage in Trinidad and Tobago in In the Fires of Hope: Trinidad and Tobago at 50 edited by Patrick Kent Watson, 179-90. Kingston: Ian Randle Publishers. Reproduced with publisher's consent, edited for clarity and length)

CERM | Updates

CO_2EOR Featured at SPE 2018 Energy Resources Conference

Society of Petroleum Engineers

The Hyatt Regency was the hub for the energy sector from 25th to 27th June as the local chapter of the Society of Petroleum Engineers (SPE) hosted its 5th biennial technical conference under the theme "Forging Ahead: Changes, Challenges and Opportunities". The energy sector recognises 'lower oil prices for longer' as one of the far-reaching challenges in all aspects of exploration and production.

Conference Opening Ceremony

The Honourable Minister of Energy and Energy Industries clearly stated his intention to arouse operators, PETROTRIN in particular, to increase oil production through EOR. He identified the work conducted by University of the West Indies (UWI) to stimulate increased EOR production (see page 8).

CO_2EOR on Technical Programme

The technical programme at the conference identified advances in EOR techniques as the solution to meet the demand for low cost operations to recover heavy oil. Carbon Dioxide Enhanced Oil Recovery (CO_2EOR) was the most widely presented EOR method at the conference – two technical sessions and a total of eight papers were dedicated to CO_2EOR.

In the first session, researchers from King Fahd University of Petroleum and Mines, Louisiana State University and Schlumberger presented a laboratory study, analytical model and digitalizing case study respectively. In another session, not dedicated to CO_2EOR, Texas A&M presented a combination of CO_2EOR with foam, nanoparticle and surfactant injection. The second session featured reservoir simulations studies conducted by postgraduate students from UWI and the University of Trinidad and Tobago, and an analytical study conducted by a Chinese State Laboratory and China University of Petroleum collaboration for heavy oil production.

Research and Development Trends

There are four observations to note from these sessions:

1. Interest in CO_2EOR is a local and international phenomenon within the energy sector
2. Universities are leading the way in research
3. State entities are involved in research into CO_2EOR
4. Digitalized monitoring of CO_2EOR has been used to increase productivity

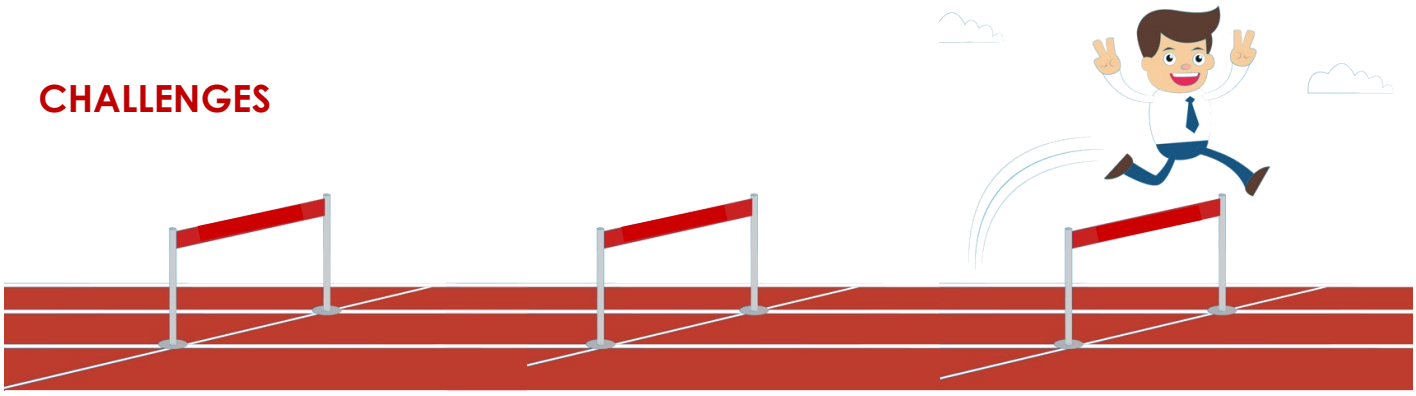
In the past, implementation of EOR techniques typically takes a nosedive when oil prices decline. However, progressive organisations continue with research and development so that they can reduce operating costs and withstand lower oil prices.

Cassandra Dewan (left), MSc Candidate (UWI), after her presentation on CO_2EOR at the SPE TT Conference

Barriers to Implementing CO_2EOR:

What do small operators have to say?

Oil producers have been considering CO_2EOR as an EOR method for decades. So the question remains, **why were there no active CO_2 floods even when oil prices were high**? We have summarized the challenges and solutions put forward by small operators:



CHALLENGES

Technical

* Risk of surface breakout in shallow heavy oil reservoirs
* Compartmentalization of reservoirs
* Reservoirs with stacked sands may need multiple production strategies

Fiscal

* Reliable access to CO_2
* Local CO_2 cost is relatively high (approximately 2.5 times that of world market price)
* CO_2EOR projects can only be successful with sustained high oil prices or high production

Regulatory

* Regulatory framework not clearly defined
* The current Heavy Oil Allowance only applies to oil fields with API gravity < 18°
* Current incentives have not been able to attract investment for CO_2EOR

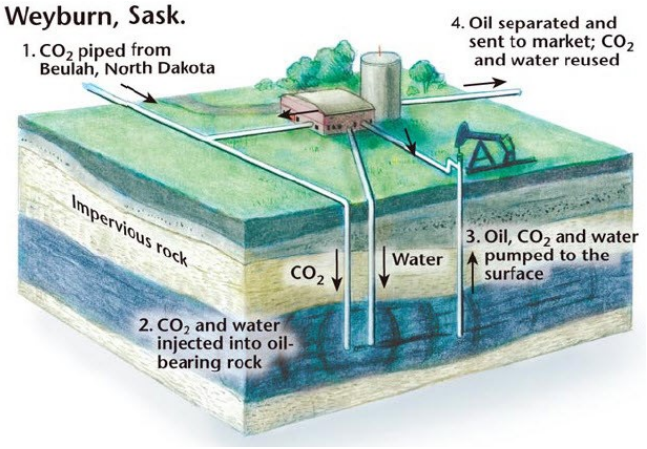
SOLUTIONS

* Clearly define regulatory framework as part of an overall EOR strategy
* Bring CO_2 feedstock prices in line with oil prices and/or with world market cost
* Replace the Heavy Oil Allowance with an EOR allowance applicable to EOR projects with no limit on oil API
* Use carbon credits to offset infrastructure cost
* Include cost of CO_2 purchase as a Project Capital expense

Global Outlook on CO_2EOR

Weyburn-Midale Carbon Dioxide Project
Canada

- The largest carbon capture and storage project worldwide.
- Between 2000 and 2011, thirty three research organizations were involved the project including eight universities.
- The project was launched by a public-private partnership with the objective to recover 220 million barrels of incremental oil while storing 14 million metric tons of CO_2.
- CO_2 is transported 190 miles (320 km) to Weyburn from the Dakota Gasification facility by pipeline.



- CO_2EOR will extend the life of the field by 20-25 years.
- Another significant goal of the project was to produce a best practice manual for CO_2EOR transition to long term CO_2 storage.
- Two current CERM team members visited this project while working with the Carbon Reduction Task Force.

Schematic of Weyburn-Midale CO_2 Project.
Source: Global CCS Institute

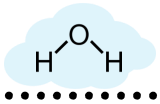
Fast Facts: Steam vs CO_2 flood

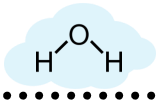
STEAMFLOODING

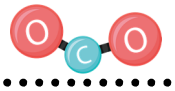
* Thermal recovery EOR process
* Suitable for crude oil with API gravity in the range 8-16 °API
* Energy intensive – steam needs to be generated before it is used in the EOR process
* Limited to reservoir depths of less than 4,500 ft.
* Accounts for the majority of EOR projects worldwide

CO_2 FLOODING

* Miscible/immiscible gas injection EOR process
* Can be used for crude oil with API gravity more than 12-36 °API
* CO_2 does not need to be generated, it is captured from other industrial processes
* CO_2EOR can be used at depths greater than 2,500 ft.
* Accounts for less than 500 of the EOR projects worldwide







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Not only would the development of a CO_2EOR program increase oil production and reduce CO_2 emissions, it also has the potential to create job opportunities in the energy sector.

"A significant amount of funds either through scholarships by energy companies and by the Government has been invested in the training of our young energy professionals. Yet, there is a substantial amount of unemployment and underemployment among these young professionals contrary to glossy adverts that seem to suggest otherwise ... I encourage the energy companies both local and foreign, to invest in the training and recruitment of our young professionals, especially engineers and geoscientists as well to institute larger internship programmes."

— Society of Petroleum Engineers (SPE) Trinidad and Tobago Energy Resources Conference, June 25, 2018

CO_2EOR & Public Safety: CO_2 Pipeline Hazards

In past issues of the CERM Newsletter, the topic of transportation of CO_2 was addressed. For the pilot project, road tank wagons and barges may be used to transport CO_2 because their initial capital investment will be lower. However, for the large scale implementation of CO_2EOR projects, a dedicated CO_2 pipeline needs to be considered.

NGC Pipeline Construction

There are regulatory and standard practices in place to ensure that safety is paramount in the design, installation, inspection, operation and integrity management of pipelines in Trinidad.

As with natural gas pipelines, CO_2 pipelines are not without a few potential hazards and risks. Some of these include carbon dioxide leaks, and corrosion of the pipeline material. A notable point of reference is in the United States of America which has an extensive CO_2 network pipeline consisting of a combined length of 4,500 miles (7, 242 km). Between 2002-2008 there were 9 incidents related to CO_2 pipeline transportation with no reported facilities and injuries. A dedicated CO_2 pipeline for CO_2EOR in Trinidad will be less than 100 km.

In our last issue, we highlighted NGC pipeline expertise, with a proven track record of safety during 40 years of constructing, maintaining and operating 1,000 km of onshore and marine pipelines. In spite of the new frontier ahead, Trinidad and Tobago has a sterling record of pipeline and safety expertise to leverage upon.

CO_2 is a known asphyxiant (it replaces oxygen in the air that you breathe), but it is only toxic at concentrations **greater than 1% (10,000 ppm).** The current atmospheric concentration of CO_2 is **0.04% (400 ppm).**

CERM Spotlight

The Ministry of Energy and Energy Industries


Honourable Minister Franklin Khan

The Minister of Energy and Energy Industries, the Honourable Mr. Franklin Khan has mentioned enhanced oil recovery in several speeches this year.. CO_2EOR has been highlighted as part of the Government's strategy to reduce greenhouse gas emissions in Trinidad and Tobago, in accordance with their ratification of the Paris Climate Change Agreement. It has also been recognized as a commendable collaborative effort to increase oil production which, if successfully implemented on a large scale, can generate more than 1 billion dollars. Recently at the Society of Petroleum Engineers (SPE) Trinidad and Tobago 2018 Energy Resources Conference in June, Minister Khan addressed the sources of anthropogenic carbon dioxide in Trinidad and Tobago, as well as Government's plan of action to reduce these emissions.

" … T&T's petrochemical sector is responsible for the majority of the large fixed sources of CO_2. The sector comprises of ammonia, methanol, urea, cement, iron and steel production as well as gas processing and the refining of petroleum … Over the years, there has been a number of proposals with respect to carbon capture, transmission and storage. These include an onshore pipeline network from Pt. Lisas to onshore oilfields in South-Western Trinidad, development of CO_2EOR infrastructure and CO_2 sinks such as depleted oil and gas reservoirs. This is a project that Petrotrin has gone to sleep on, but I intend to wake them up. The emission of greenhouse gases presents both a challenge and opportunity for the oil and gas industry. From inception, there have been challenges, but the industry has rallied through innovation to make petroleum products safe and affordable. If fossils [fuel] are to have a long term future, the issue of greenhouse gas emissions must be addressed."

— SPE Trinidad & Tobago Energy Resources Conference June 25, 2018

Hon. Min. Franklin Khan at TT Energy Conference (Source: Newsday)

Earlier this year, in his address at 2018's Trinidad and Tobago Energy Conference, the Hon. Franklin Khan echoed the theme of "Maximising Value through Collaboration" by reiterating his support for the enhanced oil recovery project and the potential benefits to both the energy sector and the environment.

"...I have instructed Petrotrin to accelerate its Enhanced Oil Recovery Program especially the CO_2 injection. This initiative will have a twofold effect – boost oil production and reduce our carbon footprint."

— TT Energy Conference, January 22, 2018

[continued on page 7]