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).

CERM SURVEY RESULTS: PERSPECTIVES ON CO_2EOR

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Executive Editor	Dr. Lorraine Sobers
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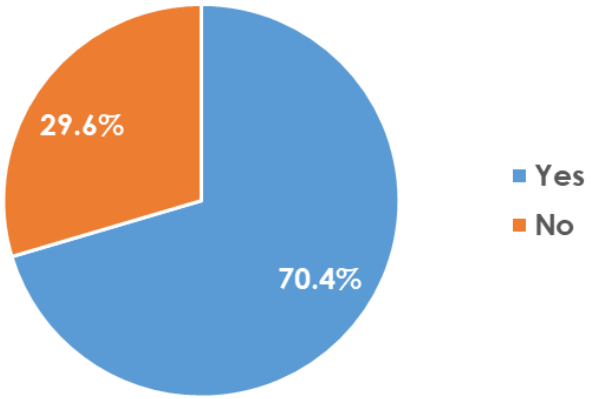
CERM Survey | Perspectives on CO_2EOR

In this issue of the CERM Newsletter, readers were given a chance to voice their opinion on the future they envision for CO_2EOR. Below is a summary and analysis of the survey results . The editor would like to thank all respondents for their prompt feedback and valuable input.

CO_2 Utilization Tax Incentives Needed for CO_2EOR

While over 90% agree that CO_2EOR can economically increase the country's oil production, 30% of our readers do not believe that CO_2EOR will be implemented in Trinidad and Tobago, even if the price of oil rises above US$70/bbl in the next 3 to 5 years (see Figure 1).

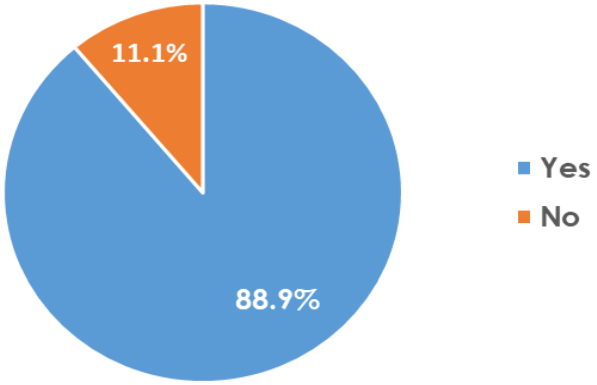
Figure 1: Do you believe Trinidad and Tobago will implement CO_2EOR?



Eight nine percent (89%) of readers agree that the Government of Trinidad and Tobago should provide special tax incentives for CO_2 EOR to increase of conventional and heavy oil production (see Figure 2).

Together these responses show that while there may be confidence in the technical and economic feasibility in the project, there is less confidence in other factors which determine whether or not CO_2EOR is implemented.

Figure 2: Do you believe special tax incentives should be provided *specifically for* CO_2 to be used to increase conventional and heavy oil production?



A possible reason for this outlook is the absence of fiscal policy specifically for CO_2EOR. Current heavy oil tax incentives are limited to oil gravities less than 18 °API. Although CO_2EOR is more effective with medium crude (19-30 °API) there are no tax breaks available for EOR of medium crude oil. This is contrary to the global trend where most CO_2 floods are implemented on medium crude for miscible displacement (See *Fast Facts: Miscible vs Immiscible* on page 9). Given Trinidad and Tobago's ratification of the Paris Agreement, an incentive for reducing CO_2 emissions using CO_2EOR should be considered.

Another factor to be considered is the legacy of steamflooding and infill drilling. Onshore EOR operations have used steam flooding as the sole means of EOR for over forty years and as a result there is more technical and operational confidence in steamflooding than in CO_2EOR. This position may lead some readers to believe that, as in the past, higher oil prices will facilitate expansion of steamfloods and infill drilling programmes instead of CO_2EOR development.

Safe CO_2EOR Operations Onshore Trinidad

Sixty percent of persons surveyed anticipated CO_2EOR to be carried out onshore (see Figure 3). Our readers identified the need for:

1. Public education on the risks and benefits of CO_2EOR
2. Sound decisions regarding the sourcing, transportation and storage of CO_2
3. Emergency plans to address uncontrolled releases either into the underground water table or into the atmosphere.

Through established legal and regulatory frameworks for the approval of CO_2EOR operations , the Ministry of Energy and Energy Industries (MEEI) and the Environmental Management Authority (EMA) are at the forefront of pre-emptively addressing these issues .

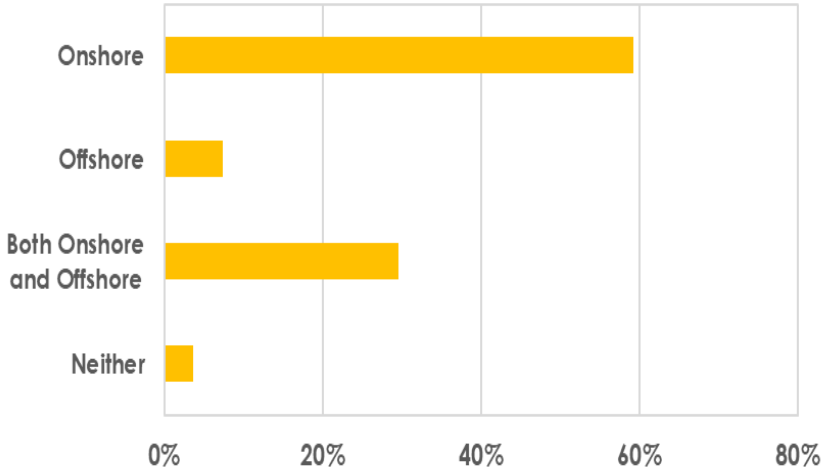
Institutional Capacity Building

CERM Newsletter Readers believe that both the University of the West Indies (UWI) and the University of Trinidad and Tobago (UTT) can facilitate the development and implementation of CO_2EOR through either training or providing technical and analytical research of the feasibility of CO_2EOR.

Most of respondents (62%) were under the age of 40 with 10-15 years experience in the energy industry. The responses show that future decision makers expect this new wave of EOR to be economically beneficial to Trinidad and Tobago (see Figure 4).

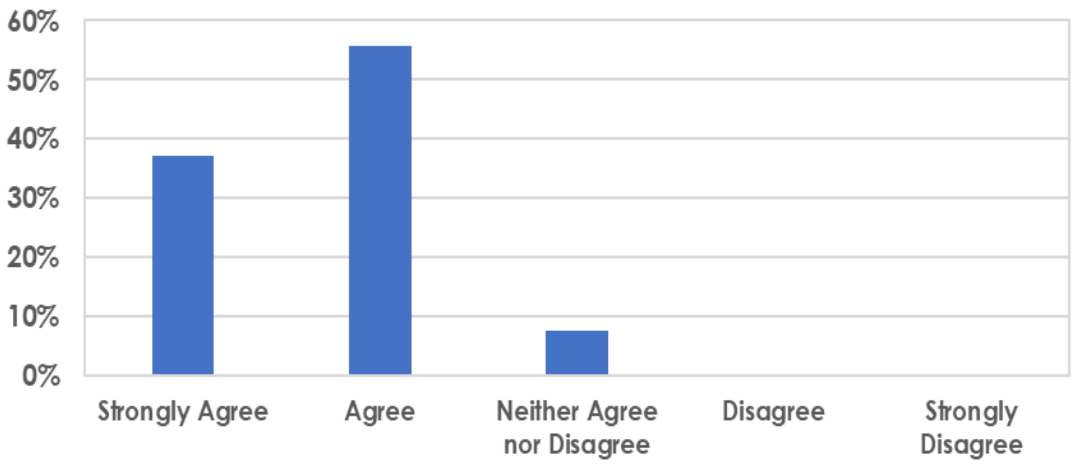
Onshore or Offshore CO_2EOR

Figure 3: Where do you anticipate CO_2EOR to be implemented in Trinidad?



Increased Oil Production

Figure 4: Currently there are no active CO_2EOR projects in Trinidad and Tobago. Do you agree that CO_2EOR can economically increase the country's oil production?



CERM | Updates and Progress

Ministry of Energy and Energy Industries

* Permanent Secretary Selwyn Lashley, who was instrumental in bringing together parties to the CERM Project has retired from public service. We thank Mr. Lashley for his timely contribution in the establishment of the CERM Project. In his final public speech as MEEI Permanent Secretary at the Energy Spotlight Symposium held in March this year, Mr. Lashley endorsed the CERM Project as one of MEEI's collaborative initiatives with energy stakeholders.
* CERM Steering Committee, Member Mrs. Penelope Bradshaw-Niles, is now the acting Permanent Secretary at the MEEI.

Former MEEI Permanent Secretary Mr. Selwyn Lashley

Permanent Secretary MEEI (Ag.) - Mrs. Penelope Bradshaw-Niles

Mrs. Bradshaw-Niles has been with the Trinidad and Tobago Ministry of Energy and Energy Industries for the past twenty years. She holds a BSc. in Chemical Engineering and MSc. in Engineering Management from the University of the West Indies and an MBA in Petroleum Management from the University of Kansas.

Her past roles include being the Team Leader, Acreage Management in the Resource Management Division with responsibility for the oversight of the Trinidad and Tobago Natural Gas and the Crude Oil Reserves Audit and coordination of competitive bid rounds since 2012.

PETROTRIN

* The CERM Project was first presented to Former Vice President of Exploration and Production, Stephen Awah, in August 2016. As he leaves PETROTRIN and the CERM Steering Committee we thank him for his contribution in the critical start up phase of the CERM Project .

TOGETHER WE ASPIRE, TOGETHER WE ACHIEVE

CERM Working Group Activities

Despite earnest efforts and unmatched enthusiasm from team members ,the Subsurface, Transport and Facilities Working Groups have not been able to move forward in the timeframe anticipated, mainly due to major changes being currently undertaken at PETROTRIN. In the interim, the Transport, Commercial, Legal and Regulatory Groups will been conducting preliminary analyses for presentation to the MEEI and key stakeholders.

The Energy Chamber of Trinidad and Tobago Conference

* Hon. Minister Franklin Khan calls for CO_2EOR development at Petrotrin
* CERM Major Achievements presented to local energy sector under the theme "**Maximising Value through Collaboration**"

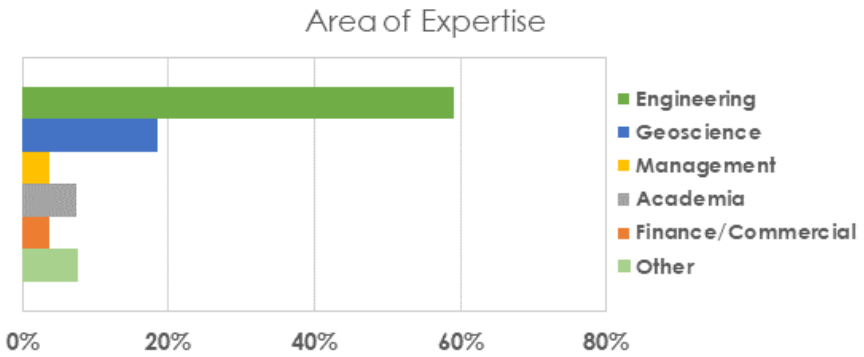
Dr. Lorraine Sobers, CERM Project Coordinator
Photo courtesy: Energy Chamber of T&T

Dr. Sobers was invited to provide an update of the CERM Project at The Energy Chamber of Trinidad and Tobago Conference January 24, 2018 at Hyatt Regency , Port of Spain, Trinidad.

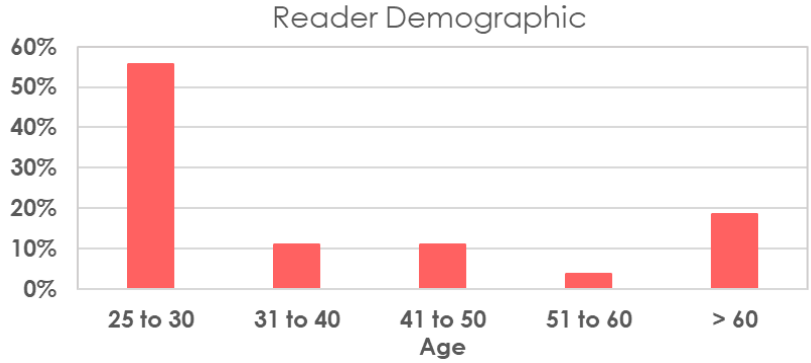
Dr. Sobers outlined the major achievements of the CERM Project since its launch at the Energy Conference last year. In her presentation, Dr. Sobers highlighted the positive impact the CERM Project will have on the local energy sector. The audience was also poignantly reminded of their responsibility to the nation's youth- ensuring sustainable and timely development of known hydrocarbon reserves.

Get to know our readers!

The CERM Newsletter community consists of academic and industry professionals with less than 5 to over 25 years of experience. The following is a breakdown of the current areas of expertise of our readers, and the CERM Newsletter readership demographic.



Current Areas of Expertise of CERM Newsletter Readership



Age of CERM Newsletter Readership

First Major Steps Taken to Implement CO_2EOR - Part II

During the period of high oil prices (2009-2014), apart from steam injection, no additional EOR methods were implemented in Trinidad and Tobago even as declining oil production persisted. The CERM Project which, once successfully completed, will place Trinidad and Tobago in the position to economically implement CO_2EOR on a large scale. In the last CERM Newsletter we discussed the three major considerations in the selection of area for study for the pilot project study: (i) Safety, (ii) Reservoir Considerations for CO_2 injection and (iii) Oil Properties for Successful CO_2EOR. In this issue we continue with three additional considerations:

⇒ Existing Third Party Arrangements

⇒ Accessibility

⇒ Applicability

Third Party Arrangements

The CERM Project Team is mandated to producing a technically sound development plan that can be implemented within the short term. For this reason the Subsurface Working Group has ensured that the selected area of study was unencumbered by third party agreements which can cause delays. The proposed area is solely operated by Petrotrin. Barring regulatory approval and requirements, the format and the execution of the CERM Project development plan is entirely dependent on Petrotrin.

Accessibility

Onshore

Onshore fields may be accessible by road tankers for the smaller volumes needed in the pilot stage. Road tankers are currently used to transport CO_2 by land and also loaded onto marine vessels for export. For short distances (less than 50 km) and small volumes road tankers are more economical than a pipeline. The Transport Working Group Leader, Terrance Ali, discusses this further on page 10.

Offshore

CO_2 injection can be implemented in either onshore or offshore fields. In Trinidad and Tobago we have a legacy of onshore CO_2 injection. However, there are reservoirs in the Gulf of Paria which may be candidates for CO_2EOR. On one hand, the transportation and facilities cost of offshore operations may be higher, but on the other hand, the incremental oil recovery due to better reservoir conditions for CO_2EOR-greater depths, higher pressure and the presence of lighter oil can be justifiable.

If a pipeline is needed to supply CO_2 for full field offshore development , the cost of the pipeline more than doubles but on the other hand, there will be no need to purchase right of way- an expensive and possibly controversial component of onshore pipeline installation. The selected area of study must allow for implementation in the short term, but the regulatory framework for CO_2 transportation by barge and the required storage and injection facilities are not yet in place.

Applicability

In Trinidad, oil deposits are found almost exclusively in sandstone formations. Production from a single field or even from a single well can come from several oil deposits encountered in several sandstone formations, also referred to as a 'sand'; a single sand or multiple sands can be found in several fields. A critical long term objective of the CERM Project is to gather information that will guide the decision to deploy CO_2EOR to several fields onshore and offshore. The CERM Project study area will consist of multiple sands so the data obtained can then be used to predict incremental oil recovery and production rates from the same sands, and similar sands, in other fields under consideration for CO_2EOR.

Source: Interfax Global Energy

Summary

The following describes the current status of the selected study area for the CERM Project:

- The CERM Project Subsurface Working Group has selected a fault block (geologic compartment) to conduct a pre-feasibility study for the implementation of CO_2EOR.
- The selected area has a low population density and is located a safe distance from community centres.
- In the selected fault block there are multiple reservoir sands with oil deposits.
- The information gleaned from this field study will provide valuable information for large scale application of CO_2EOR.
- If no additives are injected with the CO_2, immiscible displacement is expected to be the mechanism for the given reservoir depth, pressure, temperature and oil composition.
- Preliminary analysis indicate that road tankers can be used in the short term to transport CO_2 to the field.
- There are no lease operations, joint ventures or farm outs in the selected area that can cause legal or administrative delays.

Global Outlook on CO_2EOR

America's Policy Drivers for Carbon Capture and CO_2EOR

As of 2015 there are 138 CO_2EOR projects in the United States, and they are considered to be at the forefront of commercialization of carbon capture. The growth of America's carbon capture and CO_2EOR industry would not have been possible without the implementation of state and federal policies that were developed by the governors, state policy makers and other stakeholders.

America's current policy landscape poses several limitations to the further development of the CO_2EOR industry and stands to be improved. In 2016 the Western Governors Association (WGA) called for the support of Congress in extending the Section 45Q tax credit for the capture and storage of CO_2 through EOR and other geologic storage. The Southern States Energy Board (SSEB) also reiterated the importance of financial incentives and state policies to encourage CO_2 capture at industrial facilities.

The proposed recommendations at the federal level include increasing the tax credit from $10 to $30 per metric ton of CO_2 used in EOR, and extending and uncapping the amount of metric tons of carbon capture and storage that can qualify for the aforementioned tax credit, which was previously capped at 75 million metric tons distributed on a first-come, first-serve basis. Before companies could claim this tax credit, they needed to meet the minimum eligibility threshold of 500,000 tons per year, but this limit excluded other industry sectors. It was proposed that this limit be reduced to 100,000 tons to be more inclusive and to encourage smaller industries like ethanol to participate in carbon capture and storage projects. In doing so, future project investors can be assured that the tax credit would be available to them. It should be noted that these incentives are performance-based – the credits can only be claimed after successful capture and injection. Additionally, the U.S. Department of Energy (DOE) also provides grants through their Industrial Carbon Capture and Storage Program to support facilities at carbon capture projects. The state policy makers have also suggested that a contract for differences (CfD) be put in place at the federal level to stabilize the price of carbon dioxide being sold to the operators of EOR projects, to alleviate some of the risk associated with fluctuating CO_2 prices.

These changes attempt to reduce the commercial uncertainty and other economic challenges associated with projects involving the capture and storage of CO_2 and CO_2EOR, thereby making it a more feasible option for industries looking to reduce their carbon dioxide emissions.

In Trinidad and Tobago, heavy oil production incentives have failed to stimulate EOR production. One of the deliverables of the CERM project is to review Trinidad and Tobago fiscal regime and compare to other jurisdictions.

Be sure to join us for our next issue as we continue the global outlook on CO_2EOR with an immiscible CO_2EOR case study.

At A Glance: Trinidad & Tobago Tax Incentives

Supplemental Petroleum Tax (SPT) – tax credit of 20% of the qualifying expenditure with respect to approved development activity in mature oil fields (either land or marine). EOR projects and machinery and plant acquisition are also eligible for this tax credit. Unused credits can be carried forward for one year.

Petroleum Profits Tax (PPT) – heavy oil allowance of 60% of capital expenditure for the financial year in which it is incurred, followed by 18% for each of the next five years.

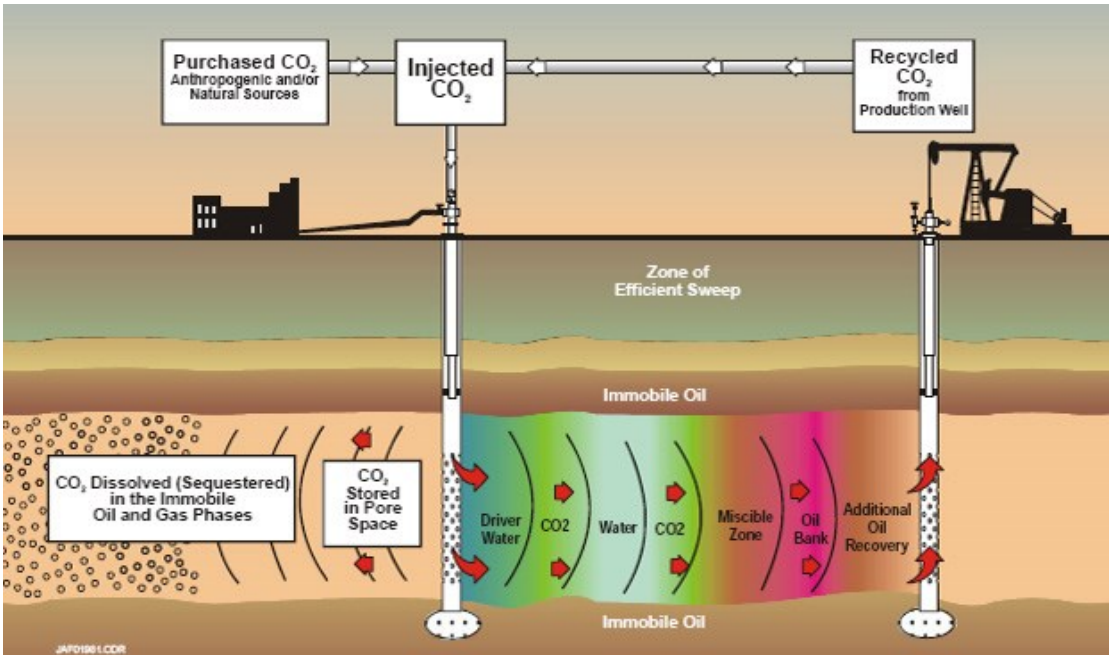
Fast Facts: Miscible vs Immiscible CO_2 Flood

MISCIBLE

* When two fluids are *miscible*, they are completely soluble
* In miscible flooding, the carbon dioxide and oil form a single phase
* Higher recovery rate (15-45 %)
* Suitable for lighter oil
* Miscibility can be lost with pressure decline
* Less storage of CO_2

IMMISCIBLE

* When two fluids are *immiscible,* there is limited solubility
* In immiscible flooding, the carbon dioxide and oil form multiple phases
* Lower recovery rate (8-15 OOIP%)
* Suitable for heavy oil (< 20 °API)
* Can become miscible with additives
* Greater storage of CO_2



One-Dimensional Schematic of Miscible CO_2EOR Process

Source: Advanced Resources International and Metzer Consulting, Optimization of CO_2 Storage in CO_2 - Enahnced Oil Recovery Projects, prepared for UK Department of Energy & Climate Change, November 2010

CERM | Transport Working Group

Terrance Ali, Working Group Team Lead

Transportation, is the movement of molecules, whether feedstock, intermediate or final products from one point to another is a critical aspect of any process. Within the CO_2-EOR process, carbon dioxide needs to be safely transported from the source site to the injection site. The transportation process needs to be fully contained with no negative effect to person, flora, fauna and infrastructure. The most common and economical method of large-scale CO_2 transport is the use of pipelines. For small scale projects, such as pilots, there are other options which can be used to move the CO_2 which may not involve such a significant initial capital investment; these include Road Tank Wagons (RTWs) and barges.

Together with the Working Group Members, Mrs. Candace Subero-Bailey (NGC) and Mr. Stephon Jimenez (NEC), we have conducted preliminary research and meetings with relevant stakeholders within the industry, which has resulted in the acquisition of valuable information for the analysis of available transportation options. At this point, the result from this exercise is that RTWs are the preferred option for the Pilot, based on availability, cost and ease of application to the project. However, further work is ongoing to confirm preliminary findings particularly on the assessment of risk to people and the environment along the potential RTW route. Moving forward with the project, the specific temperature and pressure at which the CO_2 would be transported needs to be ascertained. This would, of course, be subject to specification by the transport contractor. Further work between the Transport Working Group and the Facilities Working Group is needed to finalize the loading and offloading mechanisms as well as to determine the feasibility of injection site storage.

Terrance Ali currently serves as the team lead for the Transport Working Group. He graduated the University of the West Indies in 2012 with a BSc. in Chemical and Process Engineering with First Class Honours. He then pursued the MSc. in Petroleum Engineering at the UWI graduating with Distinction in 2016. Terrance has worked at the Ministry of Energy and Energy Industries for over five (5) years within the Petroleum Engineering Group of the Contract Management Division.

As part of the fulfilment of the requirements for the MSc. in Petroleum Engineering, he conducted research into the use of Carbon Dioxide for Enhanced Oil Recovery. The primary focus of this research involved the evaluation of the transmission options for Carbon Dioxide from the Point Lisas Industrial Estate to the Forest Reserve oilfields. Both technical and economic factors were employed to yield recommended pipeline parameters for the transmission of the Carbon Dioxide. His work resulted in him being awarded the National Energy Corporation Prize for the Best Project.

NGC Pipeline Expertise

[continued from page 12]

With over 40 years of experience as the sole transporter of natural gas in Trinidad and Tobago, NGC has constructed and maintained 1,000 km of onshore and marine pipelines. They have also achieved one million man-hours worked without a Lost Time Incident in 2001. It is this proven track record of safety and efficiency that makes NGC a valuable partner in the CERM project. Though pipelines are not needed for the pilot project, they may become necessary for the widespread implementation of CO_2EOR.

Pipeline

Pipeline laying

Photos courtesy NGC Photo Gallery

NGC Commitment to Sustainability and Corporate Social Responsibility

In the April edition of GASCO News, NGC highlighted their numerous sustainability projects, and their commitment to sustaining the industry, national development, the community and the environment. As they strive towards a more sustainable gas industry, NGC has collaborated with the Trinidad and Tobago Upstream Operators Group (TTUOG) and the Point Lisas Energy Association (PLEA) to more effectively manage gas supply to its downstream network. They are also joining forces with a number of stakeholders to come up with innovative solutions to increase efficiency in power generation. In addition, they have teamed up with the Light Industrial Sector (LIC) to incorporate use of renewable energy technologies and CNG.

NGC has further demonstrated their commitment to building a sustainable future by partnering with Habitat for Humanity Trinidad and Tobago to develop more sustainable housing solutions. The athletics program "NGC Right on Track" (ROT) has been providing a starting block for aspiring athletes for the last 19 years, affording them the training and resources to become world class sportsmen and women. In the last 13 years the NGC Reforestation Programme has replanted approximately 267 hectares of apamate, teak, cedar, mahogany and fruit trees across areas in South Trinidad. NGC partnership with the CERM Project is a continuation of its commitment to environmentally sustainable national development.

"NGC has been proactively collaborating with upstream suppliers, downstream consumers, the government and international players to help restore Trinidad and Tobago's energy sector to a path of sustainable growth."

— GASCO News April 2018

ngc

CERM SPOTLIGHT

The National Gas Company of Trinidad and Tobago Limited (NGC)

Mark Loquan,
President, NGC

In this issue of the CERM Newsletter, we highlight the National Gas Company of Trinidad and Tobago Limited (NGC) and their importance to the CERM Project.

NGC has been a key player in the development of the Energy industry of Trinidad and Tobago. It seems only fitting that a company so integral to the history of natural gas be involved in this promising venture to secure the future of Trinidad and Tobago's energy landscape.

Point Lisas Industrial Estate

By being a part of this project, NGC reinforces their commitment to building a better future today. Their association with the CERM Project is also in keeping with the tenets of their Environment and Safety Policy to "minimize the generation of waste, prevent pollution and conserve our natural resources; and to promote the advancement of environmental quality, and safety wherever possible, in partnership with Government and other organizations."

[continued on page 11]

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NGC Facts

* The National Gas Company of Trinidad and Tobago Limited is located at Orinoco Drive, **Point Lisas Industrial Estate**, Couva
* NGC incorporated as a wholly-owned state enterprise by the Government of Trinidad and Tobago in **August 1975**
* **Leadership** - Chairman: Mr. Gerry Brooks (2015-present), President: Mr. Mark Loquan (2016-present)
* NGC owns, maintains and operates a **1000 km** gas pipeline network
* NGC is part of the **NGC Group of Companies** along with Phoenix Park Gas Processors Limited, Trinidad and Tobago NGL Limited, NGC CNG Company Limited and the National Energy Corporation of Trinidad and Tobago.

Mission Statement: To create exceptional national value from natural gas and energy businesses.