Summary Report of

Developing a National Carbon Capture and Storage Programme in Trinidad and Tobago - an International Knowledge-Sharing Symposium

Hosted by

CO_2 Emissions Reduction Mobilisation (CERM)

29-30th October, 2019

Sponsors

THE UNIVERSITY OF TRINIDAD AND TOBAGO (UTT)

The development of Trinidad and Tobago is the primary focus of UTT across its 12 campuses. The mission of UTT is to contribute to the sustainable and entrepreneurial development of society through the advancement and application of research, dissemination of knowledge and public engagement in our pursuit to produce work-ready graduates, innovators and critical thinkers.

THE UNIVERSITY OF THE WEST INDIES (UWI)

UWI has provided service and leadership to the Caribbean region and wider world since 1948. The UWI has evolved to an internationally respected, regional university with near 50,000 students and five campuses. As the region's premier research academy, UWI's foremost objective is driving the growth and development of the regional economy. The Secretariat of the CO_2 Emissions Reduction Mobilisation (CERM) Project resides at UWI.

DISCLAIMER AND ACKNOWLEDGEMENTS

The International Knowledge-Sharing Workshop on Developing a National Carbon Capture and Storage Programme in Trinidad and Tobago was organised by CERM Project partners, UTT and UWI, in collaboration with IEA Greenhouse Gas R&D Programme (IEAGHG) and The University of Texas at Austin's Bureau of Economic Geology (UT-BEG). This summary report presents highlights and key points of the symposium. The report was prepared by the CERM Project Secretariat and the symposium Steering Committee as a record of the events of the symposium.

The organisers acknowledge the financial support provided by BHP and BP for this symposium and the hospitality provided by the host, UTT. We are also thankful for the support of the National Energy Corporation providing the venue for the cocktail reception.

An International Steering Committee was formed to develop the technical programme for this workshop. The steering committee members are:

Andrew Jupiter, UWI
Lorraine Sobers, UWI
David Alexander, UTT
Donnie Boodlal, UTT
Tim Dixon, IEAGHG
Katherine Romanak, UT-BEG
Mike Monea, International CCS Knowledge Centre (ICCSKC)

We acknowledge the support of staff and students of UTT and UWI and Deborah Ramdath (UTT) for assistance in drafting this summary report. This report was edited by Lorraine Sobers and Katherine Romanak.

"…Trinidad and Tobago can benefit through the use of carbon capture and storage as a means of CO_2 emissions mitigation given our large heavy petrochemical sector as well as our history in enhanced oil recovery. The time is therefore ripe for us to conduct the necessary precise feasibility studies for CCS projects locally and for us to explore opportunities to leverage international support. The opportunities for technology transfer, and for Trinidad and Tobago to join the technology leaders in CCS and climate change mitigation is to be encouraged and supported…I wish to underscore that the Government of Trinidad and Tobago will continue to play its part by setting the policy framework and by supporting activities on carbon capture and storage in the context that I have outlined. Our commitment to working collaboratively with you in this regard will remain unwavering."

The Honourable Camille Robinson Regis, Minister of Planning and Development in support of CCS technology in Trinidad and Tobago (given at the Symposium on 29 October 2019)

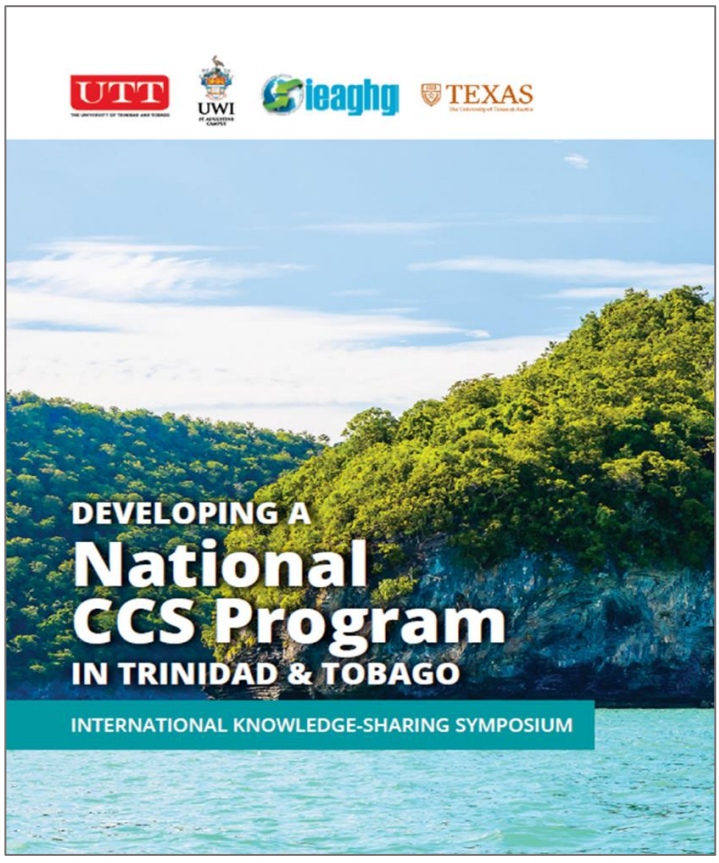
Symposium Scope

Motivation

Trinidad and Tobago (T&T) has the potential to develop Carbon Capture and Storage (CCS) as a part of their national carbon emission reduction and climate change mitigation strategy. The country is particularly susceptible to the effects of climate change such as frequent storms and hurricanes, changing rainfall patterns and rising sea levels. T&T is also a member of the Small Island Developing States (SIDS) negotiating group within the United Nations Framework Convention on Climate Change (UNFCCC) and also a member of the Alliance of Small Island States (AOSIS).

UTT and UWI, partners in The CERM Project, held an international knowledge-sharing symposium on CCS for state, academic and private stakeholders 29th-30th October, 2019 at the UTT, Point Lisas Campus.

The symposium was held in collaboration with IEAGHG and UT-BEG. The goals of the symposium were to outline the foundation that is already in place for CCS in T&T and to discuss a way forward for further development with technical support from international partners. It also explored UNFCCC and other funding sources for national CCS programme development.



Symposium Format

On the first day of the symposium there were 12 presentations grouped in four sessions beginning with a welcome to the symposium by Tim Dixon, General Manager, IEAGHG. The featured address was delivered by Minister, the Honourable Camille Robinson-Regis, Ministry of Planning and Development, Government of T&T. Speakers presented on local and international CCS road maps, research, experiences and the resources available for increasing institutional capacity.

After each session the floor was open for questions and discussions after each session. The audience consisted of government officials, energy sector representatives, academia, special interest groups and the media. At the conclusion of the sessions, the symposium was adjourned and a cocktail reception was held at the National Energy Corporation.

On the first half of the second day, the National Energy Corporation facilitated a tour of the Point Lisas Industrial Estate. In the afternoon, a closed roundtable discussion was held at the UTT Point Lisas Campus.

DAY 1- Tuesday 29th October, 2019

Session 1: Welcome, Opening Remarks and Featured Address

Chair: Andrew Jupiter, UWI

Session 2: International Experience in CCS

Chair: David Alexander, UTT

Lunch Presentation- Glenn Goddard, BPTT and Ashleigh Ross, BP

Session 3: Foundations for Building a National CCS Programme

Chair: Lorraine Sobers, UWI

Session 4: Funding, Discussion and Wrap Up

Chairs: Tim Dixon, IEAGHG and Katherine Romanak, UT-BEG

DAY 2- Wednesday 30th October, 2019

Field Trip: Point Lisas Industrial Estate

Round Table Discussion: Key Learnings and CCS Programme Development Pathways

This summary report gives an overview of each presentation beginning with the local context of the infrastructure in place for CCS in T&T followed by international knowledge sharing and discussion on way forward for T&T. We capture in this report, the key content, conclusions and recommendations reached during the symposium and the following roundtable discussion. Full presentations and the Featured Address are available for download at www.thecermproject.com

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Nomenclature

2DS	Two degree scenario
AUM	Ammonia, urea ammonium nitrate and melamine
BAU	Business as usual
BECCS	Bioethanol Carbon Capture and Storage
BPTT	BP in Trinidad and Tobago
CAD	Canadian Dollar
CCS	Carbon Capture and Storage
CCS TF	Carbon Capture and Storage Trust Fund
CCUS	Carbon Capture Utilisation and Storage
CERM	Carbon Dioxide Emission Reduction Mobilisation
CO_2	Carbon Dioxide
CO2-EOR	Carbon Dioxide Enhanced Oil Recovery
CSLF	Carbon Sequestration Leadership Forum
CTCN	Climate Technology Centre and Network
DRI	Direct Reduced Iron
EDTEA	Economic Development, Tourism & Environmental Affairs
EOR	Enhanced Oil Recovery
EU	European Union
GCF	Green Climate Fund
GDP	Gross Domestic Product
GT	gigaton
GWh	Gigawatt hour
IEAGHG	IEA Greenhouse Gas R&D Programme
ICCSKC	International CCS Knowledge Centre
LECB	Low Emission Capacity Building
MEEI	Ministry of Energy and Energy Industries
MOU	Memorandum of Understanding
MPD	Ministry of Planning Development
MT	megaton
NCCP	National Climate Change Policy
NDC	Nationally Determined Contribution
NEC	National Energy Corporation of Trinidad and Tobago
NGC	National Gas Company of Trinidad and Tobago
PETROTRIN	Petroleum Company of Trinidad and Tobago
PSSC	Project Storage Sub-Committee
SANEDI	South African National Energy Development Institute Ltd.
T&T	Trinidad and Tobago
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Carbon Capture
USD	United States Dollar
UT-BEG	The University of Texas at Austin’s Bureau of Economic Geology
UTT	The University of Trinidad and Tobago
UWI	The University of the West Indies

Session 1: Welcome and Opening Remarks

Chair: Andrew Jupiter (UWI)

UTT Welcome
Professor Clem Imbert, Deputy Chairman (UTT)

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Symposium Welcome
Tim Dixon (IEAGHG) and Andrew Jupiter (UWI)

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Overview of the CERM Project
Donnie Boodlal (UTT) and Lorraine Sobers (UWI)

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Featured Address
Honourable Camille Robinson-Regis
(Ministry of Planning and Development)
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Opening Remarks

Professor Andrew Jupiter, Professor in Practice, UWI

Background: Prof Andrew Jupiter and Dr. David Alexander attended the COP 24 meeting in Katowice, Poland in December 2019. They shared a panel with Tim Dixon, IEAGHG and Dr. Katherine Romanak, (UT-BEG). Two major outcomes from this meeting were the signing of memoranda of understanding signed between UWI and UT-BEG and between the UTT and UTBEG. The second major outcome was the collaboration among the four institutions to develop CCS in T&T starting with this symposium. The collaboration has had quick results because of the preceding ground work conducted by the CERM Project over the past three years.

Key Points

- The CERM Project will lead the development of a national CCS programme in T&T.
- As industries decline, viz a viz sugar cane production at the nearby defunct Brechin Castle Sugar Factory and Steel Manufacturing Plants at Point Lisas Industrial Estate, they may decline to zero CO_2 emissions.
- We must consider emissions reductions on the current operations and from the eleven (11) ammonia plants and (7) methanol plants at the Point Lisas Industrial Estate by implementing CCS.

UTT Welcome

Professor Clement Imbert, Deputy Chairman, UTT

Background: The Energy Systems Engineering Unit of UTT has added renewable energy programmes to the unit to address the need for sustainable development.

Key Points

- T&T possess the highest per capita CO_2 emissions in the world and as such the area of CCS must be accelerated in both research and practical projects.
- T&T should have a goal to be an exemplary model of CCS, especially for Caribbean nations.
- Emphasis must be placed in the importance of accelerating CCS implementation.

Symposium Welcome

Tim Dixon, General Manager IEAGHG

Background: The IEAGHG focuses on technologies that can reduce carbon emissions and mitigate climate change and global warming.

Key Points

- CCS is very country-specific
- During the symposium we will review how projects were executed around the world (pilot projects) and opportunities to develop CCS in T&T from the inspiration and knowledge provided by the international projects.
- Our challenge is to determine how best to implement CCS in T&T.

Overview of CERM

Dr. Donnie Boodlal (UTT)

Background: CERM consists of a collaboration led by academia, UWI and UTT with the Ministry of Energy and Energy Industries (MEEI), Heritage (formerly Petrotrin) and the National Gas Company of T&T (NGC), which are identified as key stakeholders.

Key Points:

- T&T only contributes to less than 0.1% of total global greenhouse gas (GHG) emissions.
- Though insignificant on absolute levels, on a CO_2 per capita and per GDP basis, T&T is much higher amongst global emitters, ranking 2nd on both counts with the energy sector accounting for most of the country's GHG emissions.
- The two major universities in T&T, UTT and UWI, both conduct research related to CO_2 source quantification, commodity transport and geologic CO_2 sequestration.
- Key researchers from UWI approached UTT in the initial stages and for the purpose of collaborating on carbon emission reduction followed by key stakeholders: Heritage (then Petrotrin) and NGC.
- The MEEI made a formal request to the key stakeholders for the formation of CERM on February 2nd, 2017.
- In 2017-2019, the chairs of the CERM Steering Committee were Dr. David Alexander (UTT) and Mr. Wayne Bertrand (formerly of UWI).

Dr Lorraine Sobers (UWI)

Key Points

- A national CCS programme will include all stakeholders including professional societies, regulators, the energy sector, business chambers, and financial institutions.

- CERM initially focused on CO_2-EOR and now has expanded its scope to include reducing carbon emissions in all aspects of the energy sector including methane emissions.
- There is need for public awareness and support for CCS project capacity building.
- The way forward includes public awareness, capacity building at educational institutions, international partnerships, national climate change symposia, local research & development, and local demonstration projects.

Featured Address

Minister, the Honourable, Camille Robinson-Regis, Ministry of Planning and Development (MPD)

Background: T&T has established their nationally determined contributions (NDCs) to combat the effects of climate change within the UNFCCC. T&T was the first Caribbean country and second small island state to submit its national commitment to climate change. This commitment was made formal by T&T's ratification of the Paris Agreement in February 2018. As reported in the T&T NDCs, the country aims to achieve 15% overall emissions reductions in the transport, power and industry sectors by 2030. T&T has also set up an enabling framework to address climate change, the cornerstone of which is the National Climate Change Policy (NCCP). The NCCP seeks to address the impacts of climate change, current and proposed legislation related to mitigation and adaptation, and the identification of gaps in the legislation.

Key Points:

- The NCCP addresses mitigation of GHG through the use of CCS.
- T&T conducted pre-feasibility studies into CCS implementation in 2013 including preliminary estimates of the CO_2 storage capacities and capabilities of the hydrocarbon (oil and gas) reservoirs of T&T to allow for policy decisions.
- Preliminary research shows that CCS is feasible in T&T, however this comes at a considerable cost.
- T&T can benefit from CCS as a means to CO_2 emissions mitigation given the large petrochemical sector as well as the country's history in enhanced oil recovery.
- The Ministry of Planning and Development (MPD) supports the implementation of CCS in T&T.
- Now is the time to conduct feasibility studies for CCS projects locally and to explore opportunities to leverage international support.
- CO_2 is a commodity used both directly and as a feedstock over a range of industries.

- CO_2 is an asset that can be used to provide economic benefits to T&T.
- The government of T&T will continue to play its part by setting the policy framework and by supporting activities on CCS.
- The Ministry of Planning and Development is committed to CCS and CCUS.
- CCS is a key strategy in reducing climate change.
- Response to climate change must be multi-sectoral.
- The CERM Project is recognized by MPD as the vehicle for CCS development in T&T.

Session 2: International Experience in CCS

Chair: David Alexander (UTT)

Update on the Global Scene for CCS
Tim Dixon, IEAGHG (UK)

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Project Development-Capacity Estimation and Storage Site Selection
Philip Ringrose, Equinor (Norway)

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Integration of the Whole CCS Chain- Source Sink Infrastructure
Mike Monea, ICCSKC (Canada)

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Monitoring, Safety and Stakeholder Engagement

Katherine Romanak, UT-BEG (USA)

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Decarbonising Industrial Sources of CO_2

Mike Monea, ICCSKC (Canada)

Update on the Global Scene for CCS

Tim Dixon, General Manager, IEAGHG (UK, International)

Background: IEAGHG is a technology collaboration programme which is part of the International Energy Agency's (IEA) energy technology network. The Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (2014) concluded that human influence on the climate system is clear. The more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts. However, we have the means to limit climate change and build a more prosperous, sustainable future. CCS provides a way to reduce climate change and remove the main GHG CO_2 from the atmosphere.

Key Points:

Statistics from the IPCC 5th Assessment Report (2014) show that energy production remained the primary driver of GHG emissions (35%) as of 2010. In the COP-21 Paris Agreement in Article 2, parties agreed to limit warming to "well below" 2°C by 2100 and to pursue 1.5°C. CCS plays an important role in achieving global climate ambitions.

CCS is the most important of the low carbon technologies.

- CCS plays a leading role in the energy transformation.
- CCS does not only apply to the power sector but also to industry practices (e.g. T&T's ammonia plants).
- Compared to other technologies, it is apparent that the majority of atmospheric CO_2 removal must be done by CCS using bioenergy with CCS (BECCS) or direct air capture with CCS (DACCS).
- CCS has been considered quite thoroughly within the IPCC and the UNFCCC and accepted into the Clean Development Mechanism for developing countries.
- 16 large-scale operational projects around the world were described

CCS is not "on track"

- CCS has been proven technologically, but its deployment is far from being consistent with a 2°C pathway.
- If all projects known today were to proceed, the maximum capture rate would be less than 70 million tonnes of CO2 ($MtCO_2$) per year.

The IEA tells us that accelerating future progress will require:

- Stable policies, including financial support.
- CO_2 storage project development.
- New approaches and re-focusing of efforts to promote faster development:
    - Greater emphasis on CCS retrofitting.

    - Cultivating early opportunities for BECCS.
    - Developing markets for “clean products”.
    - Moving from conventional enhanced oil recovery (EOR) practices to EOR plus CO_2 storage.
    - Disaggregating the CCS value chain to enable new business models to emerge.
- Deployment of CCS will not be optional in implementing the Paris Agreement.

CO_2 Storage: Project Development & Capacity Estimation

Philip Ringrose, Equinor & NTNU, Norway (Remote presentation)

Background: The Northern Lights full-scale integrated offshore CCS project is currently in development. The first phase of the project will store up to 1.5 $MtCO_2$ per annum. Ships will be used for CO_2 transport from multiple CO2 sources to a storage hub.

The basic concept of geological storage of CO_2 is to store captured CO_2 underground in reservoirs that would otherwise contain water, oil or gas. There are three key storage issues: (1) capacity, (2) injectivity and (3) containment. The big questions are:

- Where do we store it?
- How much CO_2 can we inject?
- Can we store it safely?
- Can we store it cost-effectively?

CO_2 storage with depth

- Stored CO_2 must be in the supercritical phase which is generally found at depths of greater than 800m.
- Geologic sealing formations become more effective with depth.
- CO_2 properties are highly variable and a function of pressure and temperature.

Containment, Leakage and Safety

- The IPCC (2005) found that the various trapping mechanisms work to increase storage security over time.
- Longer-term processes such as residual, solubility and mineral trapping would gradually work to “fix” CO_2 permanently in the subsurface.
- Capillary forces (e.g. interfacial tension) provide the essential fundamental seal. Capillary forces work both in the caprock interface (structural trapping) and in residual CO_2 that is trapped in between grains of the reservoir.
- A seal will only leak if the pressure of the fluid is greater than the threshold pressure.
- Geochemical trapping processes occur through CO_2 precipitation as carbonate minerals and CO_2 sorption or adsorption on clay minerals.

- Time-lapse seismic data were used to show that the behaviour of the CO_2 plume in the Sleipner geological storage formation matched the modelled fluid physics predictions.
- Bottom-hole pressure and rate of CO_2 injection are important for injection management.

Storage Capacity

- Mapping potential CO_2 storage formations and estimating the storage capacity
  - A CO_2 storage capacity mapping project for European countries is the EU GeoCapacity Project (2008, http://www.geology.cz/geocapacity)
  - The North American capacity estimate is over 2,400 billion metric tons.

Sleipner site overview

- CO_2 from the Sleipner field is stored in the Utsira formation under the North Sea. The reservoir unit is at 800-1100 meters in depth. More than 17 MtCO_2 have been injected.

Experience from CO_2 storage projects*:* Important learning from operational experience (saline aquifers):

- Injection rates average about 0.3-0.9 Mt CO_2/year/well.
- Injection & capacity are highly dependent on reservoir properties.
- Flexible well solutions are needed because of geological heterogeneity.
- Pressure and fluid management are important.
- There is a need for a fit-for-purpose reservoir monitoring portfolio.

Conclusion

- It is safe to store CO_2 in geological formations when best practices are incorporated.
- Geologic storage is safer than keeping CO_2 in the atmosphere.

Integration of the whole CCS chain- Source sink infrastructure

Mike Monea, ICCSKC (Canada)

Background: There are gaps between research and implementation, however there are opportunities to address financial challenges. The mandate of the International CCS Knowledge Centre is to advance the understanding and use of CCUS as a means of managing GHG emissions. The organization facilitates in an advisory role based on expertise and lessons learnt.

Canada Experience

- The world's first fully-integrated CCS project with post-combustion capture on a coal-fired power plant is the Boundary Dam 3 CCS Facility. The facility began capture operations in October 2014.
- The project was aided by a $240 million CAD federal grant and was executed as a two-part project. The first phase was power island upgrade and the second was CCS retrofit.
- Captured CO_2 was used for CO_2-EOR at the Weyburn field or stored in the deep saline formation at the Aquistore project.
- The capture plant was very expensive as it was the first large-scale capture plant, however subsequent plants are expected to cost less based on this experience.
- At the Aquistore project site, storage of CO_2 is 3.2km underground. The storage is regulated by the Ministry of Environment.
- The Weyburn site hosts the largest CO_2-EOR project in Canada and the world's largest geological CO_2 sequestration project. Over 30 million tonnes of CO_2 has been stored and monitored here since 2000.

Costs and CO_2 market value

- In Canada there is a broad carbon tax that would increase over time, ultimately reaching $50/tonne by 2022 for emissions exceeding 370 tonnes/GWh for coal plants.
- Data showed that CO_2 emissions are significantly reduced with large scale CCS. Costs will be further reduced with 2nd generation CCS. The 2nd generation design was designed to capture 2 Mt with a 67% capital cost reduction (per tonne CO_2). The cost of capture is currently at USD $45/t CO_2.

Monitoring, Safety & Stakeholder Engagement

Dr. Katherine Romanak, Bureau of Economic Geology, UT-BEG

Background: Three main questions of stakeholders are: Is it safe? Will it leak? What happens if it leaks? Geologic CO_2 storage is safe by design. Sites must be permitted which requires a high level of assurance. This includes site characterization, risk assessment, project design and a monitoring plan both in the deep surface and shallow subsurface.

Research Experience

- Potential groundwater impacts have been well-studied and include a pH decrease, mobilization of heavy metals and brine water being pushed up into the freshwater aquifer.

- Laboratory studies, field studies, and numerical monitoring have been used to study groundwater protection.
- Evaluation of metal mobilization showed that concentration of metals are not high enough to negatively impact drinking water quality and are transient.
- In the case of brine, migration impacts are related to basin size and geometry and can be avoided using pressure maintenance.
- The correct environments trap CO_2.
- CO_2 migration occurs mainly up well bores and it is important that abandoned wells be properly plugged.
- Faults are the most-likely natural avenues of transports out of traps, however, faults can self-heal and rarely reach the surface.

SACROC oilfield

- Located in Texas Permian Basin with ongoing CO_2 injection for CO_2 –EOR since 1972.
- 150 Mt CO_2 had been injected as of 2012 with 75 Mt CO_2 recovered and recycled.
- There is no evidence for CO_2 in the environment.
- The remaining balance is stored in the reservoir.

Stakeholder Engagement

- A strong outreach team should be established and should begin early in the project planning phase.
- The key stakeholders should be identified and known, and key messages/materials should be tailored to stakeholders.
- Protocols should be in place for responding to stakeholder concerns before a project begins.

Conclusions

- Scientific evidence on geological CO_2 storage shows that it works, and it is safe and ready for deployment now.
- Geological CO_2 storage is safe by design.
- Environmental protection begin before a project starts. Site selection, risk assessment, permitting and monitoring provide high levels of assurance.
- CO_2 is not likely to reach groundwater or ground surface
- In the unlikely event that CO_2 does reach the ground surface, impact will be transient and localized.

Decarbonizing Industrial Sources of CO_2

Michael Monea, ICCSKC, Canada

Background: The technology behind CCS on power plants can also be applied to capture on industrial processes like cement, iron and steel. Increased levels of CO_2 are causing the earth's temperature to rise, which is being attributed to an increased level of anthropogenic or man-made GHG emissions. GHGs are generated by a variety of industrial processes and applications. Large amounts of CO_2 are emitted by systems that include the burning of fossil fuels in power plants to make electricity, and industrial processes such as refining oil or producing iron, steel, cement and ammonia.

Key Points:

- CCS is the only technology able to significantly reduce emissions from coal and gas power plants.
- CCS can also address emissions from industrial processes, including the production of steel, cement, and chemicals.
- CCS technology has been proven and understood, so de-risked deployment can now occur.

Industrial CO_2 emissions represented 24% of global CO_2 emissions in 2014. Large process-related emissions make the cement sector the second highest CO_2 emitter in industry. To reach a 2°C target by 2060 the cement industry must reduce emissions by 485 Mt. In order to reach a 1.75°C target in the same time period, as much as 80% of global cement emissions would need to be captured.

- Iron and steel manufacturing
  - The largest source of industrial CO_2 emissions apart from power generation.
  - Applying CCS to only 15% of the steel industry would capture 8.3 Gt of CO_2.
- Cement industry
  - Accounts for 27% of CO_2 emissions in the industrial sector and 7% of global anthropogenic carbon dioxide emissions.
  - 2.5% annual growth is anticipated.
  - Need to reduce carbon dioxide emissions by 34% from 2.34 Gt to 1.55 Gt to reach climate goals.
- Hydrogen production
  - Significant for many different processes like petroleum refining, ammonia and fertilizer production, general chemical production and food processing.
  - Over 50 million tonnes of hydrogen is manufactured every year globally.
  - One tonne of hydrogen is a source of 9 to 12 tonnes of CO_2.
- Petroleum refining
  - 10% of total CO_2 emissions produced by industrial sector.

- Other sources of CO_2 emissions in the industrial sector include, natural gas processing, bio-ethanol manufacturing and pulp & paper.

Examples of international CCS projects

- Norway- The Northern Lights project is leading the integration of CCS technology into hubs and this includes emissions from cement manufacture and waste incineration. National emissions from Norwegian-based industries, including cement and gas processing are around 60 Mt CO_2 per year. This demonstration project aims to showcase CCS application on a variety of industries to lower emissions on a significant scale.

- United Arab Emirates- The Abu Dhabi CCS Project is the first CCUS project in the region. Amine solvents are used in a direct reduced iron (DRI) process to capture the CO_2. The DRI process applied at Emirates Steel fabricates a pure (98%) stream of CO_2 which is currently sent to the atmosphere. The CO_2 storage site is located around 43 km away from the city of Abu Dhabi. The facility went on line in November 2016 with a capture capacity of 0.8 Mtpa.

- United States of America- The Illinois Industrial BECCS project has the capacity to capture 1 million tonnes CO_2 per annum from an ethanol plant. Geological storage of CO_2 is at an onshore deep saline formation in Mount Simon Sandstone. Operation of the project started in April 2017. The facility is scheduled to operate for 5 years with a storage potential of around 5 million tonnes of CO_2.

- Canada- The Quest project is a fully-integrated CCS projected located in Edmonton. The project was designed to capture and store over 1 million tonnes of CO_2 annually. The facility began capturing in November 2015. Together, the Alberta government and government of Canada committed $1.24 billion to two commercial-scale industrial separation CCS projects.

Conclusions

- CCS is a proven technology around the world, ideally suited for high-emitting industrial sectors.
- Post-combustion capture can be applied to industrial sources.
- There are currently 15 industrial separation CCS projects globally.
- Large-scale CCS is the only technology that can achieve megatonne reductions in emissions.

Session 2: Discussion

1. *How many case studies thus far have CCS projects around major fault lines that are earthquake prone?*

The Tomakomai project in Japan is an example of a CCS project in an earthquake-prone area. The key part of project is that there were no induced earthquakes from the injection of CO_2. There were two natural earthquakes near the project that did not affect the project. It was shown to the public that there is no relationship between the natural earthquakes and storage. In addition, the earthquake did not affect storage (no impact on the reservoir).

2. *Issues affecting CO_2 transport.*

Around 6000 miles of pipeline in the USA is used for CO_2 transport. Regulations are in place to manage CO_2 transport which is utilized for CO_2-EOR and also by the food industry. In Canada, carbon steel pipelines are used for CO_2 transport (corrosion must be managed). Pipelines for transport have been highly monitored and no concerns have been observed.

3. *Is it possible that we can extract too much CO_2 from the atmosphere?*

We are currently way below our targets and we have too much CO_2 in the atmosphere.

Session 3: Foundations for Building a National CCS Programme

Chair: Lorraine Sobers (UWI)

Case Study on Building a National CCS Programme
Tony Surridge, SANEDI (South Africa)

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Climate Change Initiatives of T&T
Sindy Singh, Ministry of Planning and Development (T&T)

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Potential for CCS in T&T -Technical Achievements and Remaining Gaps
David Alexander, Donnie Boodlal (UTT), Andrew Jupiter (UWI)

Case Study on Building a National CCS Programme in South Africa

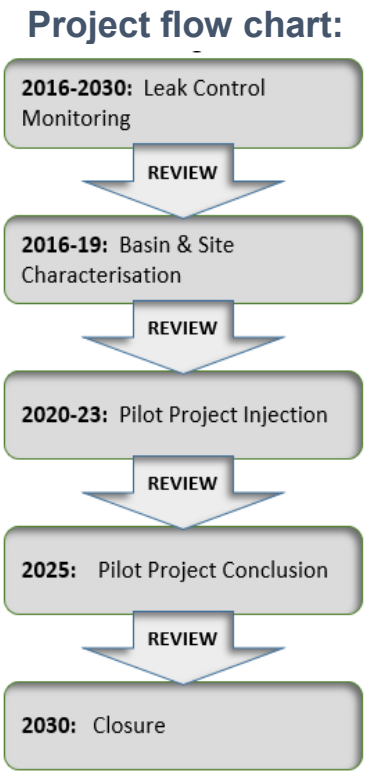
Tony Surridge, South African National Energy Development Institute Ltd. (SANEDI) (Remote presentation)

Background: CCS is identified as one of South Africa's eight near-term priority flagship programmes of the National Climate Change Response White Paper, October 2011. CCS was also identified as part of the long-term mitigation scenario endorsed the by the South African cabinet in the May 2013 CCS Road Map.

CCS Technical Road Map

Milestones:

- 2004: CCS potential (completed)
- 2010: Carbon atlas (launched by Minister)
- 2019: Pilot CO_2 storage project (current phase - 10s thousands tonnes)
- 2022: Integrated demonstration plant (planned -100s thousands tonnes)
- 2030: Commercial operation (planned – millions tonnes)



Oversight & Funding

- Technical guidance is provided by the Project Storage Sub-Committee (PSSC) members.
- Funding sources
  - World Bank CCS Trust Fund
  - South Africa Department of Energy

Project objectives:

- Increasing South African human and technical capacity for CO_2 storage.
- Raising awareness of potential importance of CCS to the public.
- Working with government to ensure the development and operations within the country's legal and regulatory environment.
- Planning/executing a pilot-scale (10,000 to 50,000 tonnes) CO_2 storage test in onshore Zululand Basin with concurrent capacity building.
- Demonstrating safe and secure CO_2 handling, injection, storage, and monitoring under South African conditions.

Stakeholder engagement objectives:

- Raising awareness of CCS as one of the climate change mitigation measures.
- Outlining the benefits and potential risks of the CCS technology.
- Building mutually-beneficial relations with stakeholders.
- Ensuring that stakeholders' perceptions are factually-informed.

Legal

- Memorandum of Understanding (MOU) between SANEDI and Kwa Zulu-Natal Department of Economic Development, Tourism & Environmental Affairs (EDTEA)

Climate Change Initiatives – T&T

Sindy Singh, Ministry of Planning & Development T&T

Background: T&T is a Small Island Developing State with a population of 1.4 million. It produces less than 1% of absolute global GHG emissions from power generation, transport, and industry. T&T ratified the UNFCCC in 1944 and the Kyoto Protocol in January 1999. T&T signed the Paris Agreement on April 22nd, 2018 and ratified it on February 22nd, 2018.

T&T Policy framework for climate change

- National Development Strategy (VISION 2030)
- National Climate Change Policy
- Carbon Reduction Strategy
- NDC of T&T under the Paris Agreement and its implementation plan

Reduction objective

- Reduce overall cumulative emissions from the three main emitting sectors by 15% by 2030 from "business as usual" equivalent to 103 MtCO2e.
- Estimated cost of implementation is USD $2 billion domestic funding and is conditional on international climate financing including through the Green Climate Fund.

National Climate Change Initiatives

- Low Emission Capacity Building (LECB) Project (ongoing)
- Third National Communication and First Biennial Update Report (ongoing)
- Initiative for Climate Action Transparency (upcoming)
- Capacity Development for improved management of Multilateral Environmental Agreements for Global Environmental Benefits (initiating)

- Technical Assistance to the European Union (EU) Environment Programme
- Technology Needs Assessment

Potential for CCS in T&T, Technical Achievements & Remaining Gaps

Dr. Donnie Boodlal (UTT)

Key Points

- Changing weather patterns in the Caribbean (e.g. Hurricane Maria in Dominica 2017) and increased rainfall is leading to flooding in T&T.
- T&T has 45 million tonnes of GHG emissions (2015) with > 80% from local petrochemical and power generation sectors.
- A high concentration of CO_2 emissions is from ammonia synthesis (1 million metric tonnes).
- There is a short distance between source and potential sinks (<100km).
- The carbon management study conducted by UTT was funded by the MEEI Techno-Economic Assessment of Carbon Capture in T&T

Dr. David Alexander (UTT)

Key Points

- Geological sequestration of CO_2 can assist in enhancing oil production.
- Geological sequestration options for T&T include deep saline aquifers.
- Major considerations/critical factors for T&T geological sequestration are cost, public acceptance and preventing leakage of injected CO_2.
- 60% of persons surveyed were uncertain about the safety of CCS and only 15% viewed CCS as safe for the storage of CO_2.

Way forward for T&T

- Capacity building at the educational institutions (UWI & UTT).
- National climate change symposiums (public awareness).
- International partnerships.
- Funding by international agencies.
- Continue conducting local research (storage capacity).
- Demonstration projects and CERM support.

What can CCUS project do for T&T?

- Overall reduction in carbon footprint - sequester CO_2 using existing infrastructure (lower net emissions quickly).
- Build local expertise with a new generation of geoscientists and engineers to design, operate and optimize CCS in T&T.
- Increase T&T's oil production by 15-20%.

Session 3: Discussion

1. *Has the Ministry of Planning accessed the Green Climate Fund readiness fund?*

This is T&T's first year trying to access readiness funds. Yes, there is a readiness fund proposal.

2. *What is the approximate cost of CO_2 to pipe and inject into a formation?*

A study was done varying the volume from 2 to 8 million metric tonnes. The price range for buying CO_2 of $15 to $55 USD per tonne was used. Transport can be done via trucking or pipelines and varies in cost from $10 to $20 USD per tonne.

3. *Foreign funding was achieved for South Africa. How this funding was achieved?*

The major source of funding came from the World Bank (4 million dollars).

4. *How many point-sources of CO_2 emissions are in T&T?*

Some point sources of CO_2 emissions include: 11 ammonia, 7 methanol, 2 steel, 1 cement, and 1 ammonia, urea ammonium nitrate and melamine (AUM) complex.

Session 4: Funding, Discussions and Wrap Up

Chairs: Katherine Romanak (UT-BEG) and Tim Dixon (IEAGHG)

World Bank Activities in CCS
Brendan Beck, Consultant to the World Bank Group

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UNFCCC Funding Mechanisms and Opportunities for Engagement
Katherine Romanak, UT-BEG
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World Bank Activities in CCS

Brendan Beck, Consultant to the World Bank Group (remote presentation)

Background: World Bank CCS Trust Fund (CCS TF) was established in December 2009 with the objectives to support strengthening capacity and knowledge building, create opportunities for developing countries to explore CCS, and to facilitate inclusion of CCS options into developing country low-carbon growth strategies and policies.

The World Bank CCS Trust Fund

- The CCS TF has two donors – the UK government and Norway government, with the funds allocation to date totalling USD $55.8 million.
- Phase I of the CCS TF provided CCUS capacity building and undertook desktop CCUS studies and analysis in nine countries/regions.
- Phase II of the CCS TF has a budget of USD $47.9 million and is focussed on the development of CCUS pilot projects in Mexico and South Africa.

World Bank support for CCUS in Mexico

- Phase I of the World Bank CCUS support for Mexico had a budget of USD $1.3 million and comprised five studies that were completed in 2015. The studies looked at CO_2 capture, monitoring and storage, legal and regulatory, public engagement and capacity building.
- Phase II consists of two components: the CO_2 capture pilot project and CO_2-EOR storage monitoring project.
    - The CO_2 capture pilot project support from the World Bank covers project preparation, construction and operation of a small CO_2 capture project at a natural gas combined cycle power station. The World Bank is providing USD 15 million budget out of a total budget of USD $27.5 million, with the balance being provided by the Government of Mexico.
    - The CO_2 EOR storage monitoring project has a World Bank budget of USD $1-5 million

World Bank support for CCS in South Africa

- Phase I was completed in 2015 and comprised of four studies looking at legal and regulatory aspects of CCS, the techno-economics, capacity building and public engagement. The budget for Phase I in South Africa was USD $1.35 million.
- Phase II in South Africa involves USD $24.7 million in World Bank funding and USD 15 million from the South African Department of Energy and comprises two components: the CO_2 capture pilot project and the pilot CO_2 storage project.
    - The CO_2 capture pilot project involves USD $2 million CCS TF support for front-end engineering design for a CO_2 capture plant at a coal-fired power

station. The total project budget to build and operate the capture plant is yet to be determined and is not supported under the current Phase II program.
    - The pilot CO_2 storage project involves project preparation, construction and operation of a small CO_2 storage project, with CO_2 storage occurring in a saline aquifer. The project will receive USD $21.5 million in World Bank funding with an additional USD $15 million being contributed by the South African government.

World Bank Decarbonizing Natural Gas using CCUS Technology Study

- Goal is to provide analysis of the role of natural gas in global CO_2 mitigation through fuel switching and the application of CCUS across the natural gas value chain, including natural gas production, industrial use and power generation.

The current and future World Bank financing for CCUS

- The World Bank could support CCUS through two mechanisms – grant funding or lending.
    - The World Bank currently provides USD $55.8 million in grant funding to South Africa and Mexico through the CCS TF. The World Bank would consider providing further grant support if requests were received by recipient countries.
    - World Bank lending or guarantees for CCUS would require recipient countries to make a request to the World Bank for a CCUS project. Currently no CCUS lending or guarantee requests have been received.

Sharing Experience & Stimulating Interest in [Offshore] CCS in Developing Countries

Dr. Katherine Romanak, Bureau of Economic Geology, UT-BEG

Background: For the IEA 2DS, a total of 94 Gt must be captured and stored through 2050, but after 20 years of research and experience in CCS, less than 1 Gt has been verified as stored as of 2016.

Key Points

- There is an urgent need to create global awareness of CCS and to get countries on the path to CCS.
- Countries must secure financial support for first steps of assessing their potential for CCS.
- There are many platforms that can help countries engage in CCS.

Climate Technology Centre and Network (CTCN)

- Countries can request technology assistance from the Climate Technology Centre and Network (CTCN).
- CTCN draws upon its network members to provide expertise for technology development and transfer activities (up to a value of $250,000 USD).
    - Network members include a broad spectrum of technology providers (including research, finance, government, and private sectors) that must apply and be accepted by the CTCN.
    - Acceptance as a network member is largely based on demonstrated expertise in relevant climate technologies.

Green Climate Fund

- Established in 2010 under the UNFCCC to direct climate finance to developing countries.
- The goal of the fund is to create “paradigm shifts” in climate action by utilizing public and private funds.
- Small island developing nations like T&T can access Green Climate funds mostly in grants and loans.
- The 2015 Report of the Carbon Sequestration Leadership Forum (CSLF) Task Force on Offshore Storage concluded that significant opportunities exist in offshore storage.

Conclusion

- UNFCCC funding mechanisms + knowledge-sharing platforms = advancement of CCS technology in developing countries.
- One proponent within a country who is willing can initiate entire national programmes.
- There are many opportunities for helping countries explore CCS.
- UNFCCC bodies must provide support for CCS technology.
- CCS which is recognized within the UNFCCC as a critical mitigation option, should be supported and explored.

Session 4: Discussion

1. *How does a small independent oil & gas producer access funding?*

First must determine if it complies with national strategy/planning. Engage with the government (Ministry of Finance, Ministry of Planning and Development).

2. *With regards to the World Bank are you talking about conditional grant funding? Do you think there is a way of funding projects such as EOR and CCS?*

The World Bank CCS TF support is grant funding and is only conditional on the World Bank's environmental and social safeguards. The World Bank will have to be careful when working with EOR part of the project. There are ways of packaging CCS other than petrochemical.

3. *If there is a carbon sequestration project that consists of two parts where the first part is CO_2 EOR and second part is carbon sequestration, will this be funded?*

Funding for such a project may be considered however the World Bank and the Green Climate fund do not easily fund fossil fuel-related projects and to our knowledge, the Green Climate Fund has not yet funded a CCS project.

4. Do countries have to be in phase one to access funding from the World Bank?

This is open to discussion and depends on the recipient. Preliminary discussion can take place and as such there is potential to take in new countries.

Conclusions and Recommendations

Background: The conclusions and recommendations reported herein include those from both the symposium and the closed roundtable discussion which followed the next day.

- During this symposium, both the Minister and the Permanent Secretary of Planning and Development communicated their support of CCUS & CCS. T&T has interest in both climate change and energy security and there is a need to define ways that CCS can help the government reach these goals However, we cannot wait until policy is formally in place to do scientific work in CCUS/CCS.

- T&T possess the highest per capita CO_2 emissions in the world and CCS must be accelerated in both research and practical projects.

- The goal of T&T should be to become an exemplary model of CCS in the Caribbean. Emphasis must be placed in the importance of accelerating CCS implementation.

- The CERM Project will lead the development of a national CCS programme in T&T. CERM has collaborations with key stakeholders already in place.

- Numerous studies have been conducted in T&T to define reservoirs that could be used for CO_2 storage. T&T possesses a combination of point-source emissions and well-defined reservoirs. UWI, UTT, the MEEI and the National Gas Corporation (NGC) have already conducted collaborative work. These collaborations must continue and become stronger.

- There is a need for a well-defined plan and greater collaboration among government, industry and academia, as well as capacity development and a legal and regulatory framework for CCS.

- There is a need for CCS to be explicitly mentioned in the T&T Technology Needs Assessment (TNA) and NDC.

- There is a need to put forward a well-defined document towards the ministry including the work that is being done. CERM can lead this.

- Both CCUS and CCS should be considered. There are no sink gaps for CCUS but gaps exist for CCS. More studies must be done on geological sinks. A study must be done on sinks for CCS application alone. The carbon management plan speaks to EOR and the sinks associated with CO_2 -EOR.

- Recommendations are for precise feasibility studies for CCS projects locally and this equates to a storage atlas which is needed (e.g. South Africa Storage Atlas).

- T&T should leverage international support and opportunities for technology transfer. It is recommended to join the technology leaders in CCS and climate change mitigation, such as IEAGHG and CSLF.

- T&T should engage with external funding opportunities such as the World Bank and the Green Climate fund. The Ministry of Planning and Development is the supporting national entity for the GCF and the Ministry of Finance is the supporting national entity for the World Bank.

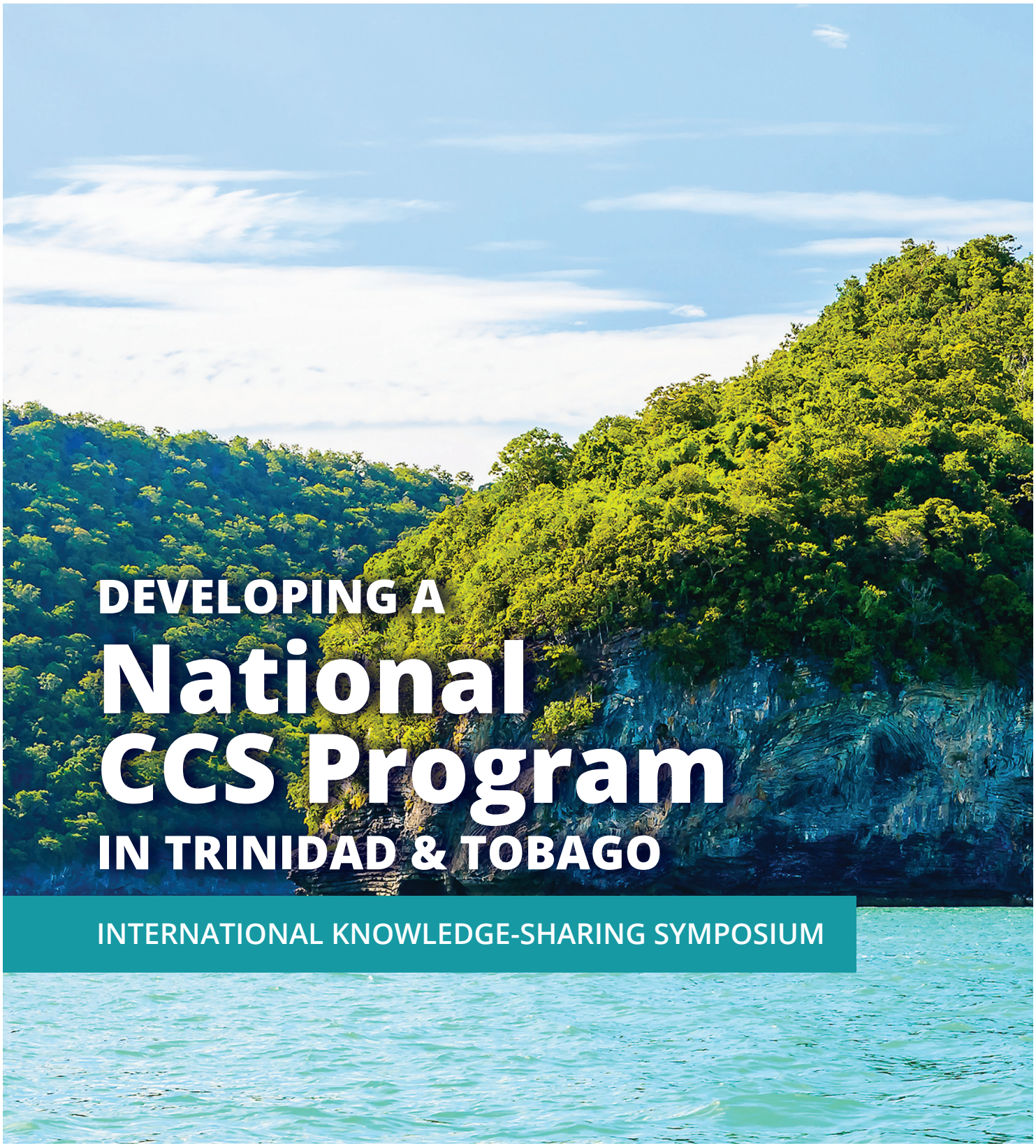
- Any proposed activities should be in line with the national priorities as outlined in the national climate change policy, carbon reduction strategy and the NDC implementation plan

- There is need for public awareness and support for CCS capacity building. The way forward includes engaging in public awareness, capacity building at educational institutions, international partnerships, national climate change symposia, local research & development, and local demonstration projects.

- T&T should consider if a regional opportunity for CCS exists. For example, could T&T benefit from becoming the storage hub for the Caribbean?

Appendices

APPENDIX 1
CERM Symposium Programme



29 - 30TH OCTOBER, 2019
UTT Energy Campus, Pt. Lisas, Trinidad and Tobago

SCOPE

Trinidad and Tobago (T&T) have the potential to develop CCS as a part of their national carbon emission reduction and climate change mitigation strategy. This workshop will outline the foundation that is already in place for CCS in T&T and the potential for further development and technical support from international partners. It will also explore UNFCCC and other funding sources for national program development.

DAY 1

INTRODUCTION AND WELCOMING REMARKS Chair, Andrew Jupiter, UWI	
8:45am	**Safety Briefing**
8:50am	**National Anthem** - Anna Gadoo-Bhagwandass
8:55am	**Welcome to UTT** - Professor Emeritus Kenneth S. Julien Chairman of UTT
9:05am	**Symposium Welcome** - Tim Dixon, General Manager IEAGHG and Andrew Jupiter, The UWI
9:15am	**Overview of CERM** - Lorraine Sobers, UWI and Donnie Boodlal, UTT
9:30am	**Featured Address** - Honourable Camille Robinson-Regis, Minister of Planning and Development
9:50am	**Tea/Coffee Break sponsored by BHP**
INTERNATIONAL EXPERIENCE IN CCS Chair, David Alexander, UTT	
10:10am	**Update on global scene for CCS** - where we are and where we need to be, projects around the world– Tim Dixon, IEAGHG (UK, International)
10:30am	**Project development** - Capacity Estimation and storage site selection – Philip Ringrose, Equinor (Norway, remote)

10:50am	**Integration of the whole CCS chain - Source Sink Infrastructure** - Mike Monea, International CCS Knowledge Centre (Canada)
11:10am	**Monitoring, safety and stakeholder engagement** - Katherine Romanak - Univ. of Texas-BEG (USA)
11:30am	**Decarbonising Industrial Sources of Carbon Dioxide CO_2** - Mike Monea, International CCS Knowledge Centre (Canada)
11:50am	**Discussion**
12:10pm	**Lunch with remarks from BP**
FOUNDATIONS FOR BUILDING A NATIONAL CCS PROGRAMME Chair, Lorraine Sobers, UWI	
1:10pm	**Case study on building a national CCS program** - Tony Surridge, SANEDI, (South Africa, remote)
1:30pm	**Climate Change Initiative of the Ministry of Planning and Development** - Sindy Singh, Ministry of Planning
1:50pm	**Potential for CCS in Trinidad and Tobago, technical achievements and remaining gaps** - David Alexander, Donnie Boodlal, UTT and Andrew Jupiter, The UWI.
2:20pm	**Discussion**
2:40pm	**Tea/Coffee Break sponsored by BHP**
DISCUSSIONS/WRAP UP Chairs, Katherine Romanak, Univ of Texas and Tim Dixon, IEAGHG	
3:00pm	**Foundations for building a CCS programme, World Bank activities in CCS** - Nataliya Kulichenko, World Bank Group
3:20pm	**UNFCCC funding mechanisms and opportunities for engagement** - Katherine Romanak- UT-BEG
3:40pm	**Open floor audience Q and A to speakers**
4:00pm	**Conclusions, next steps, and announcement of Offshore Workshop Series** - Tim Dixon, IEAGHG David Alexander, UTT, Lorraine Sobers, The UWI, Katherine Romanak, UT-BEG
4:30pm	**Adjourn**
POST-SYMPOSIUM RECEPTION	
5:00pm - 7:00pm	**Invitation only - Cocktail Reception** Location: National Energy Corporation, Rivulet Road

DAY 2

FIELD TRIP	
8:30am - 11:30am	Half-day field trip to Point Lisas Industrial Estate More information provided below.
ROUNDTABLE DISCUSSION	
11:30am - 12:30pm	**Lunch**
12:30pm - 2:30pm	**Invitation only** - UNFCCC concept note development; creating a paradigm shift for CCS in the UN environment.

FIELD TRIP: POINT LISAS INDUSTRIAL ESTATE

The Point Lisas Industrial Estate is the result of the bold and unprecedented move taken by the Government of Trinidad and Tobago to develop the country's natural gas reserves. The Estate, completed in the latter years of the 1970s, is home to over 100 companies involved in a range of activities. It is the centre of the nation's petrochemical sector and the hub of natural gas processing and distribution as a fuel and feedstock. The world's leading manufacturers of ammonia, urea, methanol and other petrochemicals have selected the Point Lisas Industrial Estate because of the ease of access to natural gas resources and Port Point Lisas.

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APPENDIX 2
Minister's Address

Honourable Minister

of

Planning and Development

Featured Speaker Address

to the

Carbon Capture and Storage Symposium

Tuesday October 29, 2019

I am deeply honoured to have been afforded the opportunity to address you at this Carbon Capture and Storage Symposium, which forms part of the Carbon Emissions Road Map Project, a partnership project between our two premier learning and research institutions, the University of the West Indies (UWI) and the University of Trinidad and Tobago (UTT).

The Ministry of Planning and Development, which has been leading the charge from a governmental perspective on this global issue, is pleased to be part of this symposium which we anticipate, will shed light on the emerging opportunities available to explore the feasibility and practical implementation of carbon capture and storage technology in Trinidad and Tobago.

Though I am by no means a scientist, and cannot even lay claim to knowledge beyond the basics, it literally does not require the brain of a rocket scientist to be aware that the world is experiencing increasing averages in temperature, shifts in the seasons, an increasing frequency of extreme weather events and other climate change impacts, and the creeping onset of events such as sea level rise. I, along with the entire population, repeatedly watch in horror as short, sharp, sudden downpours dump enough rain in 30 minutes that would usually fall in a month. We swelter in crippling heat as temperatures soar and humidity increases, causing many to either run for the protection of the air conditioned offices, or refuse to leave our offices entirely.

Like all other countries in the Caribbean region, Trinidad and Tobago is designated as a Small Island Developing States (SIDS) and therefore particularly vulnerable to the impacts of climate change. Such a nomenclature does not however absolve us from the responsibility to do our part, along with the rest of the global community, to address climate change generally, and the mitigation of our greenhouse gas emissions in particular.

The recent Special Report on Global Warming by the Intergovernmental Panel on Climate Change (IPCC) stated that, at its current rate, global warming is likely to reach 1.5^{o}C between 2030 and 2052. The 1.5^{o}C goal is particularly important for SIDS, as warming beyond this means much greater climate impacts and in many cases, the very existence of some low-lying islands become threatened. The significance of such a threat becomes magnified when one observes that only recently, photographs have emerged of new islands being discovered because of the melting of the polar ice-caps and glaciers.

Globally, there remains an enormous and ever-widening gap between what we ought to be doing, and what we are actually doing to decrease the rate of climate change. According to the United Nations Environment Programme (UNEP) Annual Emissions Gap Report 2018, countries must triple their efforts in order to achieve the 2 °C climate target, and make five times the current effort if they are to achieve no more than a 1.5 °C increase in the global temperature. Although it is still possible to keep global warming to below 2 °C, the technical feasibility of bridging the 1.5 °C gap is dwindling. Transformative action by every single country in the world is therefore absolutely critical.

Trinidad and Tobago has long recognized its responsibility to implement actions designed not only to combat the deleterious effects of climate change, but more importantly, how it contributes to the global fight by establishing national targets known as Nationally Determined Contributions (NDCs). Indeed, Trinidad and Tobago was the first Caribbean country and second small island state to submit its international commitment to climate change, doing so as far back as August 2015. This commitment formally became the NDC of Trinidad and Tobago upon ratification of the Paris Agreement in February 2018. It is arguably, the most ambitious national target in the region.

In its NDC, Trinidad and Tobago aims to achieve a reduction in overall emissions from the three sectors by 15% by 2030, which in absolute terms is an equivalent of one hundred and three million tonnes (103,000,000) of CO_2e. The estimated cost of meeting this objective is US$2 billion, which is expected to be met partly through domestic funding and internationally sourced financing including, but not limited to the Green Climate Fund. Trinidad and Tobago has also committed to unconditionally reduce its public transportation emissions by 30% or one million, seven hundred thousand tonnes (1,700,000) CO_2e compared to 2013 levels by December 31, 2030. We are indeed

hopeful that this goal could be achieved as we increase the number of CNG powered PTSC buses and Government vehicles in our fleet. Additional Governmental initiatives to ban the use of Styrofoam products and bottled water in Government buildings are all designed to dovetail with our other international commitments to treating with climate change.

Trinidad and Tobago has also set up an enabling framework to address climate change, the cornerstone of which is the National Climate Change Policy or NCCP, which seeks to address, *inter alia*, the impacts of climate change including sectoral vulnerability and mitigation potential in major emitting sectors; current and proposed legislation related to mitigation and adaptation, and the identification of gaps in the legislation. The National Climate Change Policy is currently being updated to include the latest scientific findings and international policy such as the Paris Agreement and the sustainable development goals.

Notwithstanding, the National Climate Change Policy addresses mitigation or reducing greenhouse gas emissions through the exploration of new and emerging technologies for carbon sequestration through cooperating with the international community to develop carbon capture and storage technology in geological formations utilizing the already abundant experience of Trinidad and Tobago in using carbon dioxide for enhanced oil recovery.

With this recognition, Trinidad and Tobago undertook preliminary feasibility studies into carbon capture and storage in 2013, and a pre-feasibility study for a carbon capture and storage project was also completed. This study included preliminary estimates of the CO_2 storage capacities and capabilities of the hydrocarbon (oil and gas) reservoirs of Trinidad and Tobago to allow for policy decisions. It was clear from this preliminary research that carbon capture and storage is possibly feasible in Trinidad and Tobago, and opportunities for project development in this field may indeed exist.

I do note however, the considerable costs associated with utilizing Carbon Capture Sequestration (CCS) for mitigating climate change in respect of not only the technology itself, but the costs associated with monitoring post-sequestration, if Trinidad and Tobago is to use this technology to meet its international commitments and reporting. The use of CCS in enhanced oil recovery has been suggested as a way of defraying costs, but in respect of achieving overall mitigation, the requisite carbon accounting for meeting those commitments would be expected to be part of the overall governance structure of any such project.

In this regard therefore, Trinidad and Tobago can benefit through the use of carbon capture and storage as a means of CO_2 emissions mitigation given our large heavy petrochemical sector as well as our history in enhanced oil recovery. The time is therefore ripe for us to conduct the necessary precise feasibility studies for CCS projects locally and for us to explore opportunities to leverage international support. The opportunities for technology transfer, and for Trinidad and Tobago to join the technology leaders in CCS and climate change mitigation is to be encouraged and supported.

In a very real sense though, Trinidad and Tobago is behind the proverbial eight ball where this research is concerned, which is why today's event is of such critical importance. The first dedicated research facility examining the multiple uses of Carbon Capture Sequestration technology opened in the United States some 30 years ago, and in the last decade the number of viable carbon capture technologies has grown dramatically. Moreover, huge developments in recent years have allowed carbon capture to be applied to a greater number of industries, from transportation to construction.

Recently pioneered utilization technologies have also allowed manufacturers to create a range of products – from trainers to mattresses to insulation foams – from captured CO_2. This has transformed it into an asset, potentially offsetting game-changing levels of emissions. I am advised that in the plastics sector, for example, CO_2 can actually be used as a raw material. Plastics are made from polymers, which are chains of repeating chemical groups akin to a string of beads. Typically, these chemical "beads" are made of petrochemicals like oil, so, if they were replaced with CO_2, the required amount of petrochemical feedstock would reduce, while making use of captured CO_2.

Other possible applications for CO_2 include the facilitation of enhanced fuel recovery through its injection into oilfields, causing oil to flow better into production wells. The research indicates that it can also be used in fuel and chemical manufacture as well as in construction, as demonstrated by cement production technologies from companies like Carbon8 and Solidia. And this is by no means an exhaustive list. With further backing, the potential for carbon capture to be deployed across other sectors appears to be enormous.

I congratulate the University of Trinidad and Tobago and the University of the West Indies on this important initiative, as it is from you we expect this research to both flow and produce fruit. For this, I assure you today of the Government's continued support and action.

In closing, I wish to underscore that the Government of Trinidad and Tobago will continue to play its part by setting the policy framework and by supporting activities on carbon capture and storage in the context that I have outlined. Our commitment to working collaboratively with you in this regard will remain unwavering. As Minister of Planning and Development, I am confident that we are on the right road in respect of our climate change mitigation strategies. I am convinced that the fruits of this symposium will take us closer to where we need to be, and I give you the assurance that as long as you do your part, you will find in your Government both an open door and a willing partner.

May God bless your deliberations, and I await the results of your work.

APPENDIX 3
Press Release

LIFESTYLE Environment

11 PAGES OF WHAT'S GOING ON

We have the means to limit climate change

UWI, university partners and energy stakeholders mobilise for carbon dioxide emission reduction

FOR A BETTER ENVIRONMENT: Prof of Practice at The UWI, St Augustine, Andrew Jupiter, from left, Minister of Planning and Development Camille Robinson-Regis and Tim Dixon, general manager of the IEA Greenhouse Gas R&D Programme, attend the International Knowledge-Sharing Symposium to further the development of a Carbon Capture and Storage (CCS) Programme in Trinidad and Tobago.

LIKING WHAT THEY HEAR: Participants at the symposium.

"THE more we disrupt our climate, the more we risk severe, pervasive and irreversible impacts, we have the means to limit climate change and build a more prosperous, sustainable future", said Tim Dixon, general manager of the IEA Greenhouse Gas R&D Programme (IEAGHG), at the recent International Knowledge-Sharing Symposium aimed at reducing carbon dioxide emissions in the energy sector.

This symposium, titled "Developing of a Carbon Capture and Storage (CCS) Programme in Trinidad and Tobago", was organised by the CO2 Emission Reduction Mobilisation (CERM) Project partners; The UWI St Augustine campus and The University of Trinidad and Tobago (UTT) in collaboration with IEAGHG and the University of Texas, Austin.

The symposium, which took place on October 29-30 at the UTT Energy Campus, Pt Lisas, included participants from several Government institutions, the local energy sector, the World Bank and the International CCS Knowledge Centre, and was sponsored by BHP and bpTT.

TAKING NOTES: Participants take notes during the symposium.

The UWI is partnering with the University of Texas, Austin, and UTT to create a new clean industry that will store greenhouse gases underground and mitigate Trinidad and Tobago's contribution to human-induced climate change. Notably, Carbon Dioxide Enhanced Oil Recovery (CO2EOR) and CCS have been positioned as two key technologies in carbon dioxide emission reduction. CCS has significant potential to mitigate climate change, particularly in countries with large reserves of fossil fuels and a fast-increasing energy demand. CO2EOR, on the other hand, has been identified by industry experts, researchers and local oil producers as a viable option for increasing Trinidad and Tobago's heavy oil production.

Minister of Planning and Development Camille Robinson-Regis delivered the symposium's feature address, noting Trinidad and Tobago was the first Caribbean country and second Small Island Developing State (SIDS) to submit its international commitment to climate change back in August 2015.

"This commitment formally became the Nationally Determined Contributions (NDCs) of Trinidad and Tobago upon ratification of the Paris Agreement in February 2018. It is arguably the most ambitious national target in the region. Trinidad and Tobago declared the NDC to reduce overall emissions in the power generation, transportation and industrial sectors by 103 million tonnes of equivalent carbon dioxide emissions."

Dr Lorraine Sobers, CERM project coordinator and lecturer in petroleum engineering at The UWI, St Augustine, shared public perspectives on greenhouse gas emission reduction in Trinidad and Tobago; highlighted opportunities for carbon dioxide emission reduction through CCS and CO2EOR and, the need for methane emission reduction.

Following the symposium, The UWI and its partners under the CERM project intend to build public awareness of the initiative in Trinidad and Tobago. Dr Sobers also noted CERM will focus on capacity building at educational institutions, international partnerships and local research and development of CCS and CO2EOR.

Learn more about the CERM project at http://www.thecermproject.com/

APPENDIX 4

SPEAKER PROFILES

Featured Speaker:

The Honourable Camille Robinson Regis, MP, Minister of Planning and Development

The Honourable Camille Robinson-Regis, appointed to the Senate in 1992, entered the political landscape as the youngest Senator to be appointed to the Cabinet of Trinidad and Tobago. An attorney-at-law by profession, she held the portfolios of Minister of Information from 1992 to 1994, Minister of Consumer Affairs from 1994 to 1995 and Minister in the Ministry of Planning and Development, responsible for the environment. She became Minister of Legal Affairs 2001-2003 and became the first woman to serve as a Minister of Planning and Development in Trinidad and Tobago and CARICOM. Under her stewardship, the signature Vision 2020 Operational Plan was completed, having been developed by a multi-disciplinary team of representatives from the public and private sectors, civil society and academia. Minister Robinson-Regis has also served our country as a diplomat, having been appointed High Commissioner of the Republic of Trinidad and Tobago to Canada in 2007, a position she held until 2010.

Her exceptional career path is supported by her sound educational background, beginning with her Primary School foundation at Bishop Anstey Junior School, proceeding to Bishop Anstey High School as her Secondary and later the University of the West Indies, St. Augustine and Cave Hill campuses, where she undertook a Bachelor of Laws degree and subsequently the Legal Education Certificate at the Norman Manley Law School, Jamaica. Minister Robinson-Regis was admitted to the Trinidad and Tobago Bar in 1985. With her insight and experience, Minister Robinson Regis has returned to the Ministry of Planning and Development as the Minister, having been appointed on September 11th, 2015.

Tim Dixon, General Manager, IEA Greenhouse Gas R&D Programme

Tim Dixon is the General Manager of IEAGHG, a not for profit organization that focuses on technologies that can reduce carbon emissions, and mitigate climate change and global warming. IEAGHG is an international research programme established by the International Energy Agency in 1991 and focusing on carbon dioxide capture and storage (CCS). Tim is responsible for managing IEAGHG, ensuring that it meets the needs of its members and delivers the technical evidence-base to support CCS development and deployment around the world, and inputting to international regulatory and policy developments such as UNFCCC, IPCC and CSLF. Tim is a member of many international committees, task forces, and working groups relating to CCS, including being chair of several. He has given many presentations and published many papers relating to CCS. Prior to IEAGHG, Tim worked in UK government and AEA Technology on CCS, including as a negotiator for CCS in the UNFCCC and London Protocol.

Professor Andrew Jupiter, Professor of Practice, Dennis Patrick MHTL Chair in Petroleum Engineering, The University of the West Indies

Andrew Jupiter was conferred the honorary title of 'Distinguished Fellow' by The University of the West Indies (UWI) in 2013. He is currently attached to the Department of Chemical Engineering in the Faculty of Engineering at UWI and is the co-ordinator of the M.Sc. Petroleum Engineering and M.Sc. and Postgraduate Diplomas in Petroleum Engineering and Management programmes. Professor Jupiter is the holder of the Dennis Patrick MHTL Chair in Petroleum Engineering. He is also the proud recipient of the Chaconia Medal (Gold). From 1998 to 2004 the Professor of Practice served as Permanent Secretary, Ministry of Energy and Energy Industries and was one of fifty public servants honoured on the 50th anniversary of Trinidad and Tobago's Independence. Professor Jupiter was president of the National Energy Corporation of Trinidad and Tobago Limited (National Energy) from 2009 to 2012. He was the Director on several State boards. Currently, Professor Andrew Jupiter is a member of the Society of Petroleum Engineers, Fellow of the Energy Institute and Fellow of the Institute of Materials, Mineral and Mining.

Dr. Katherine Romanak , Research Scientist, The University of Texas at Austin

Dr Katherine Romanak is a Research Scientist, Bureau of Economic Geology, Jackson School of Geosciences at the University of Texas at Austin. Dr. Romanak is an expert in near-surface geochemical monitoring and environmental impacts of geologic carbon storage and has developed and implemented monitoring programs at a number U.S. DOE Regional Carbon Partnership sites. She was the Principal Investigator of the IPAC-CO_2 response to alleged leakage at the Kerr Farm near the Weyburn-Midale CO_2-EOR oilfield and has developed an innovative process-based method for environmental assessment at CCS sites. Dr. Romanak has conducted environmental monitoring for international projects in Canada, Japan, and Australia. She has also informed global CCS policy regarding potential environmental impacts of CCS within the United Nations Framework Convention on Climate Change (UNFCCC) and the US Congress.

Phillip Ringrose, Equinor Research Centre, Norway

Philip Ringrose is Adjunct Professor in CO_2 Storage at the Norwegian University of Science and Technology (NTNU) and Specialist in Geoscience at the Equinor Research Centre in Trondheim, Norway. Philip Ringrose currently works at the Equinor Research Centre in Norway, and is Adjunct Professor at the Department of Geoscience and Petroleum, Norwegian University of Science and Technology. His research interests include CO_2 Storage, reservoir modeling, and applications of geophysical monitoring methods. He is Chief Editor of the Journal Petroleum Geoscience. In 2018 he was appointed as Honorary Professor (Sustainable Geoenergy) at the University of Edinburgh, School of Geosciences, Edinburgh, UK.

Dr. David Alexander, Associate Professor, The University of Trinidad and Tobago

Dr David Alexander is currently the Programme Leader of the Energy Systems Engineering Unit at the University of Trinidad and Tobago (UTT). His main areas of research include Enhanced Oil Recovery, Carbon Capture and Storage and Waste Oil Management among other areas. He has served on several national and international committees as a member of the Environmental Commission of Trinidad & Tobago (ECTT), the Director of New Opportunities of the Society of Petroleum Engineers (SPETT), member of the Global Training Committee of the Society of Petroleum Engineers International (SPEI) and Membership and Education Advisor in the Energy Institute UK (Caribbean Branch). Dr Alexander holds a BSc. in Chemistry/Analytical Chemistry and a M.Sc. in Petroleum Engineering from the University of the West Indies. He also holds a Ph.D. in the field of Petroleum Engineering from the University of Trinidad and Tobago (UTT) in collaboration with the University of Texas at Austin.

Mike Monea, CEO, International Carbon Capture and Storage Knowledge Centre

Mike Monea is the President and CEO of the International Carbon Capture and Storage (CCS) Knowledge Centre a non-profit organization which he helped to establish with BHP Billiton and SaskPower. As a world-leading scientist, research and development is a key component in Mike's mission to help reduce greenhouse gases through CCS technologies. His oversight of a scale-sized Carbon Capture Test Facility has ensured that progress continues to be made with international vendors on post-combustion capture systems. Progress gained in these areas can help reduce costs and advance CCS. Mike's past experience in oil and gas has allowed him to understand the benefits of and opportunities for carbon dioxide for enhanced oil recovery (EOR) and deep saline reservoir storage.

Dr. Anthony Surridge, General Manager, South African Department of Minerals and Energy

Since December 2006, Dr Surridge is General Manager- Cleaner Fossil Fuel Use at the South African National Energy Development Institute (SANEDI). During 2009, he established and is currently the Head of the South Africa Centre for Carbon Capture and Storage. During 2009, he established and is currently the Head of the South Africa Centre for Carbon Capture and Storage. He drafted South Africa's first National Integrated Energy Plan, inter alia drafted four pieces of legislation, negotiated a number of international agreements, and represented South Africa at numerous international gatherings including the United Nations Framework Convention on Climate Change. He serves on the Executive Committee of the International Energy Agency's Greenhouse Gas Programme and as Co-Vice-Chairman of the Technical Group of the Carbon Sequestration Leadership Forum.

Dr. Donnie Boodlal, CERM Co-chair, Associate Professor, The University of Trinidad and Tobago

Donnie Boodlal is Lecturer/Researcher at the University of Trinidad and Tobago since 2007. He was recently appointed as a Co-Chair to the CERM Project. His work on the Cost-Effective Strategies for Greenhouse Gas Mitigation in Trinidad and Tobago is highly rated and he is regarded nationally as being at the forefront of the field of emissions reductions. His research efforts in this field mapped carbon dioxide emissions from key industries in Trinidad & Tobago and presented a precise methodology for assessing and evaluating the financial feasibility of mitigation techniques. His work is well recognized locally and internationally. Dr Boodlal holds a B.Sc. in Mechanical Engineering, a Post Graduate Diploma in Petroleum Engineering, an M.Sc. in Industrial Innovation, Entrepreneurship and Management and a Ph.D. in Process Engineering.

Dr. Lorraine Sobers, CERM Project Coordinator, Lecturer, The University of the West Indies

In 2016 Dr Sobers developed and spearheaded the CO_2 Enhanced Oil Recovery Road Map (CERM) Project, now the CO_2 Emission Reduction Mobilisation Project, to facilitate an integrated national approach to use CO_2 emission reduction techniques in the energy sector. As the CERM Project Coordinator, Dr Sobers coordinates cooperation between government institutions and academia and develops the strategic direction of the collaborative initiative. Dr. Lorraine Sobers is a Fulbright Scholar with a first degree in Chemical Engineering and a Master's Degree in Petroleum Engineering from Texas Tech University. In 2012, Dr Sobers earned her Ph.D. in Petroleum Engineering at Imperial College, London. She is currently a lecturer at the University of the West Indies, St. Augustine specialising in CO_2 storage injection strategies to maximise storage.