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Front Cover: NGC personnel engaged in reforestation exercises.

Phoenix Park Valve Station

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INDUSTRIAL GREENHOUSE GAS EMISSIONS:

A Case for Harmonizing Industry Efforts to Reduce Industrial Carbon Dioxide Emissions and Enhancing Natural Terrestrial Carbon Sinks in Trinidad

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Environmental Coordinator,
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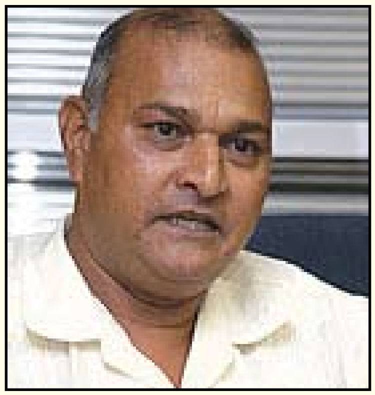


Within a few years, Trinidad and Tobago would have embarked on dramatically expanding its manufacturing sector to include the establishment of industrial plants producing aluminium and natural gas-derived olefins. Such developments will result in an increase in greenhouse gas production and emissions, particularly carbon dioxide. This paper seeks to illustrate how atmospheric levels of this gas can be reduced by improving and enhancing natural and man-made carbon sinks.

1.0 Local Carbon Dioxide Emissions and Carbon Sequestration Scenario

1.1 Carbon Dioxide Emissions

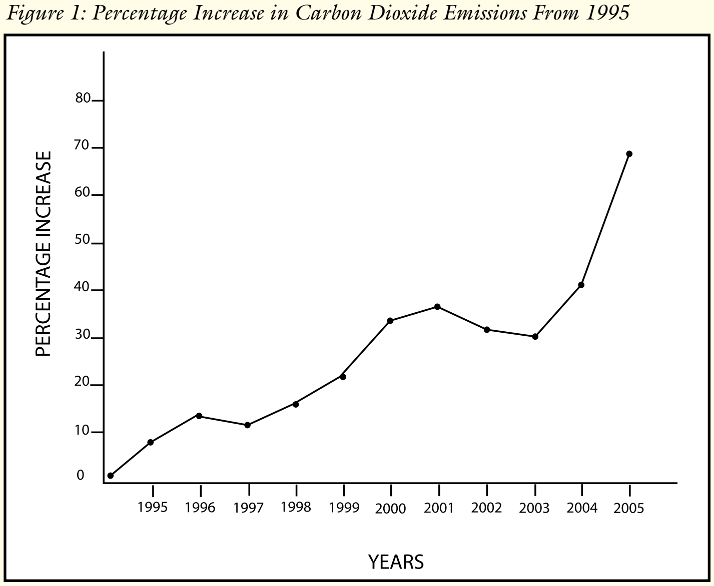
Trinidad and Tobago was ranked number seven in 2004 for carbon dioxide emissions on a per capita basis according to the US Energy Information Administration (Flaring and Consumption of Fossil Fuel Report, 2004). Just one year later in 2005, Trinidad and Tobago was ranked number six in terms of carbon dioxide ($C0_2$) emissions per capita, having released some 30 and 36 million metric tonnes of $C0_2$ in 2004 and 2005, respectively, into the atmosphere.

Within a few years Trinidad and Tobago will embark on dramatically expanding its manufacturing sector

Carbon dioxide emissions have steadily increased over the 10-year period 1995 to 2005. When benchmarked against emissions for 1995 (the year from which local carbon dioxide inventory data is available), carbon dioxide concentrations increased 69% from 22 million metric tonnes in 1995 to 38 million metric tonnes in 2005. (Figures 1 and 2 refer).

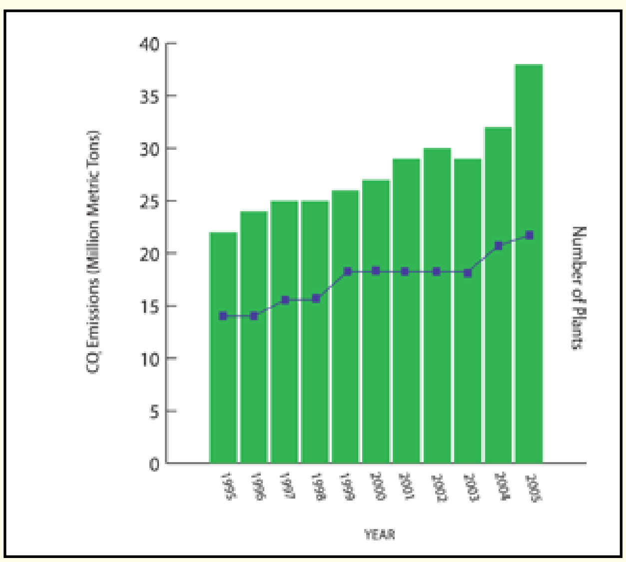
Figure 2 illustrates the trend of increasing carbon dioxide emissions in Trinidad and Tobago from 1995 to 2005. The figure shows a strong positive correlation between CO_2 emissions and the growth in natural gas-based

Figure 1: Percentage Increase in Carbon Dioxide Emissions From 1995



Source: Data taken from Energy Information Administration, International Energy Annual 2005 for calculation of percentages.

Figure 2 : Trinidad & Tobago CO_2 Emissions and Incremental increase in World Scale Industrial Plants 1995-2005



Source: Energy Information Administration, International Energy Annual 2005. http://www.energy.gov.tt industrialization. (Table 1. refers) It should be noted that these values were derived from the combustion of natural gas and crude oil over the 10-year period (1995 to 2005) and does not take into account other major sources of carbon dioxide such as vehicular exhaust emissions.

1.2 Carbon Sequestration

Carbon sequestration refers to efforts to capture excess CO_2, condense it and store it in a benign way. This is an important strategy in the fight against greenhouse gases. The simplest form of carbon sequestration is to plant more trees since trees take CO_2 from the atmosphere and expel oxygen. Much of the carbon from the CO_2 is integrated into their biomass and released safely into the soil on the death of the tree.

However, the clearing of vegetation to accommodate oil and gas infrastructure such as seismic lines, oil and gas pipelines, electrical power lines, rights of way, well sites, access roads and other facilities associated with oil and gas sectors has led to the degradation of forested areas (natural carbon sinks) in south and central Trinidad. There has also been a degradation of the forests through illegal hunting, logging, marijuana cultivation and agricultural squatting. (ITTO, 2003)

The decrease in sugar-cane cultivation has also negatively impacted the equilibrium of the carbon sequestration capacity of Trinidad's natural sinks since sugar-cane is a recycler of carbon dioxide.

Trinidad and Tobago's ratification of the Kyoto Protocol on January 08, 1999 obliges the State to reduce or offset greenhouse gas emissions from anthropogenic sources (due to human activities) and hence mandates the State to seek solutions to mitigate this situation.

The Kyoto Protocol was developed to give effect to the implementation framework of the United Nations Framework Convention on Climate Change (UNFCCC) Policy whereby industrialized countries (referred to as Annex 1 countries) are required to reduce their collective emissions of greenhouse gases by 5.2% benchmarked against emissions for the year 1990 over the period 2008-2012. Trinidad and Tobago, while not an Annex 1 country, can still be proactive in seeking to reduce emissions during this period.

Table 1: World Scale Petrochemical Plants at Pt. Lisas Industrial Estate 1995-2005

Year	New Plants	Total No. Plants	Company
1995	1	14	Trinidad & Tobago Methanol
		Company II	
1996	-	14	-
1997	2	16	Pt. Lisas Nitrogen
			Methanol IV
1998	1	17	PCS Nitrogen Plant 4
1999	2	19	Methanex Trinidad Unlimited
		Caribbean Steel Mills	
2000	-	19	-
2001	-	19	-
2002	1	20	Caribbean Nitrogen
		Company	
2003	-	20	-
2004	2	22	Atlas Methanol Plant
			Caribbean Nitrogen Company II
2005	1	23	Methanol Holdings M5 Plant

Indeed, following the Commonwealth Heads of Government Meeting in Uganda, in 2007, participating heads (including T&T's Prime Minister) agreed to a climate change action plan, which expressed their governments' concern about climate change and the threat it represented to human existence and economic wellbeing. This action plan, while being mindful of the need for energy efficiency and conservation within the context of sustainable development, also supported "ambitious solutions, particularly through unqualified support for the work through the UNFCCC to reach an agreement on global action". The plan, however, noted its recognition of the constraints faced by the least developed and developing nations in combating climate change and the importance of developed countries taking the lead.

This plan followed the Intergovernmental Panel on Climate Change (IPCC) Third assessment report 2005 which stated that "no single technology option would provide all emissions reductions needed to achieve stabilization and a portfolio of mitigation measures would be needed. In this regard therefore, all options must be assessed in terms of both their carbon dioxide abatement potential and their feasibility".

Thus within these frameworks, Trinidad and Tobago, in keeping with its thrust towards developed country status, would be prudent to start the process of seeking solutions, moreso as the country presents a unique case for carbon capture and sequestration activities:

1. There is a well-developed and rapidly expanding petrochemical and metals sector with identifiable point sources of carbon dioxide emissions;
2. Trinidad has a mature oil industry with a large number of on and near shore oil wells in close proximity to point source emissions of carbon dioxide;
3. The country has experience in the utilization of carbon dioxide for Enhanced Oil Recovery (EOR) operations;

4. The country possesses a well developed technical, engineering and geological expertise and sector-specific skills bank.

Notwithstanding the potential for development and use of Carbon Capture and Sequestration (CCS) technology in Trinidad however, full scale implementation of CCS technology is constrained at this time by the need for focused research and development in this area.

The strong endorsement by the Kyoto Protocol of the use of reforestation as a greenhouse gas mitigation strategy, combined with the embryonic stage of development of carbon capture and sequestration ventures in Trinidad and Tobago, renders the option of carbon sink enhancement through reforestation as the most feasible option at the present time. In this regard, there are two possible approaches to enhancing natural carbon sinks locally; the first is through increasing carbon sequestration through reforestation and plantation forestry. The second involves preservation of already sequestered carbon through sustainable management of forests, and conservation of forest resources through protected areas. This paper will promulgate increasing carbon sequestration through reforestation.

2.0 Relevant Multilateral Environmental Agreements (MEA's) – International Legislative Framework

In response to the growing concern and the mounting evidence of global climate change, experts assembled by the United Nations concluded after detailed scientific reviews that there was a discernible human influence on global climate. This human influence on climate comes from emissions, in particular carbon dioxide, methane and nitrous oxide when they act like a blanket around the earth, trapping heat (greenhouse effect) emitted from the earth's surface. Overall, about 80% of greenhouse gas (GHG) emissions are related to the production and use of energy, and particularly, the burning of fossil fuels. The bulk of the remaining 20% is associated with agriculture and changes in land use such as deforestation.

The effects of this have been widespread melting of snow and ice and rising global average sea levels, a growing concern for Small Island Developing states such as Trinidad and Tobago. In fact, rising sea levels have already resulted in minor, yet significant signs of coastal erosion along Trinidad's north and southwestern coastal areas, at an annual rate of 1.3mm and 1.6mm, respectively (IPCC, 2007). Global warming also has implications for atmospheric phenomenon such as hurricanes and tropical cyclones to which small island states are particularly vulnerable.

Moreover, average global ambient temperatures have increased over the last one hundred years (1906-2005) by 0.74 degrees Celsius (IPCC, 2007) in tandem with global atmospheric concentration of carbon dioxide which has increased by 35% from 280 parts per million (ppm) to 379 ppm in 2005 (IPCC, 2007).

3.0 Mitigation Strategies For Reducing Carbon Dioxide Emmissions

There are several mechanisms by which CO_2 emissions can be reduced. These include:

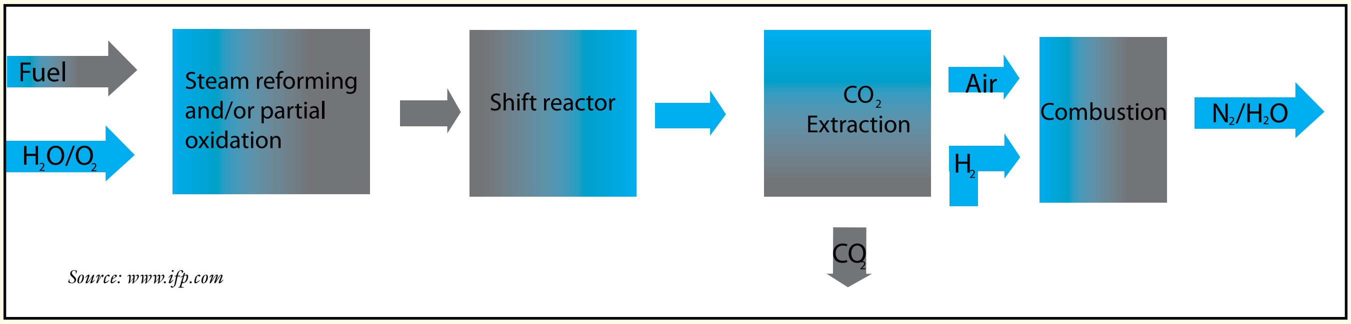
1. Reducing energy demand by increasing the efficiency of energy conversion and/or utilization devices through the use of Best Available Techniques or BAT;
2. Decarbonizing energy supplies by switching to less carbon intensive fuels (Diesel to natural gas, for example), or by increasing the use of renewable energy sources such as biofuels, and/or nuclear energy;
3. Pre-and post-combustion capture.

3.1 Carbon Capture – Pre-and Post-Combustion

Carbon capture entails the separation of carbon dioxide from the flue gases of electricity generation or industrial processes. It is already performed for some industrial purposes such as chemical synthesis and purification of natural gas. There are three main approaches to carbon capture: these include pre-combustion, post- combustion and oxy-fuel carbon capture.

The strong endorsement by the Kyoto Protocol of the use of reforestation as a greenhouse gas mitigation strategy, combined with the embryonic stage of development of carbon capture and sequestration ventures in Trinidad and Tobago, renders the option of carbon sink enhancement through reforestation as the most feasible option at the present time.

Figure 3: Pre-Combustion Carbon Capture



Pre-combustion carbon capture (Fig.3) involves the removal of all or part of the carbon content of a fuel before burning it. The main way in which this is achieved is through reforming natural gas with steam, to produce carbon dioxide and hydrogen.

The hydrogen is then burnt as a clean fuel since it produces only water vapour upon combustion and the CO_2 is sent for storage rather than being emitted into the receiving environment.

Post-combustion carbon capture (Fig. 4) involves the extraction of carbon dioxide from flue gases produced post-fossil fuel combustion. The most well established industrial method of carbon capture is chemical absorption using amine or carbonate solvents, also known as scrubbing.

3.2 Oxy-Fuel combustion

A refinement of the pre-combustion carbon capture approach above involves the combustion of flue gas in a mixture of oxygen and recirculated flue gas in order to reduce the net volume of flue gases from the process and to substantially increase the concentration of carbon dioxide (CO_2) in the flue gases.

Carbon capture entails the separation of carbon dioxide from the flue gases of electricity generation or industrial processes

4.0 Post-Emissions Strategies for Reducing Atmospheric Carbon Dioxide Levels

There are three modes of carbon sequestration: geological sequestration, biological sequestration, and ocean sequestration. A carbon dioxide (CO_2) sink is a carbon dioxide reservoir that is increasing in size and is the opposite of a carbon dioxide "source". The main natural sinks are: (1) the oceans and (2) plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass and releasing oxygen into the atmosphere. This concept of CO_2 sinks has become more widely known because the Kyoto Protocol allows for the use of carbon dioxide sinks as a form of carbon offset.

Figure 4: Post-Combustion Carbon Capture

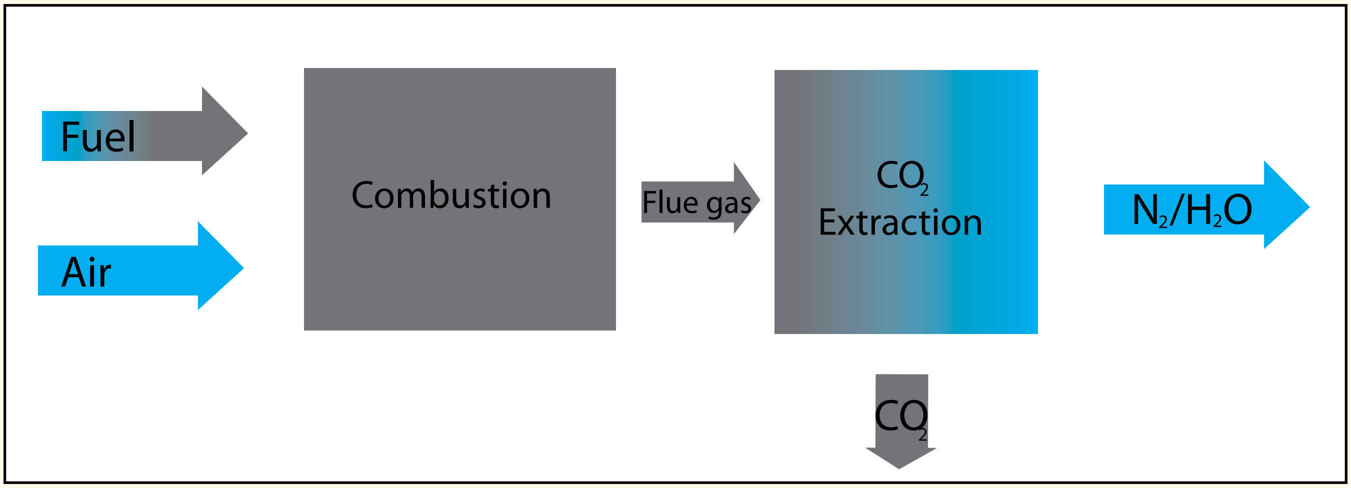
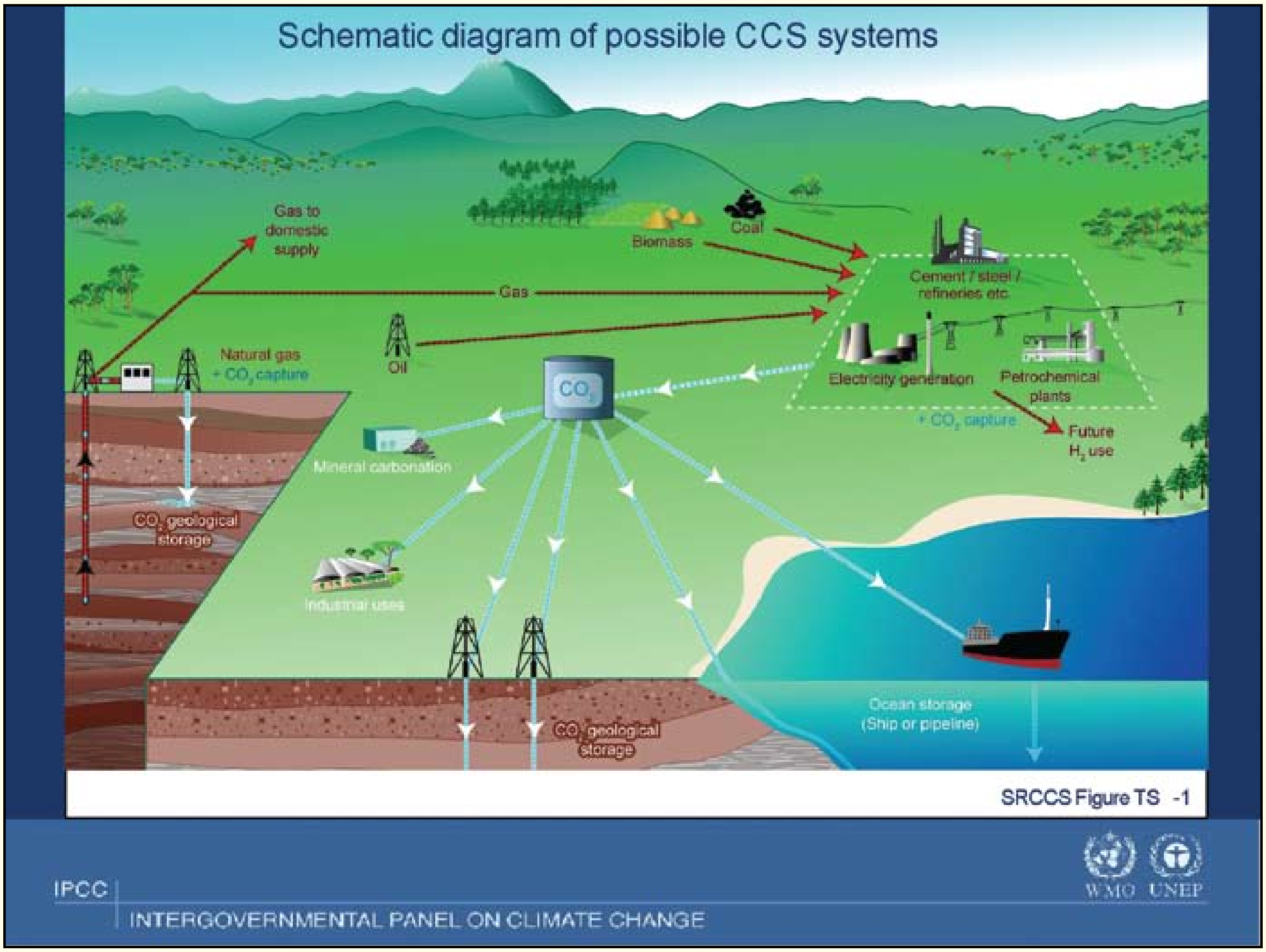


Figure 5: Carbon Capture and Sequestration Systems



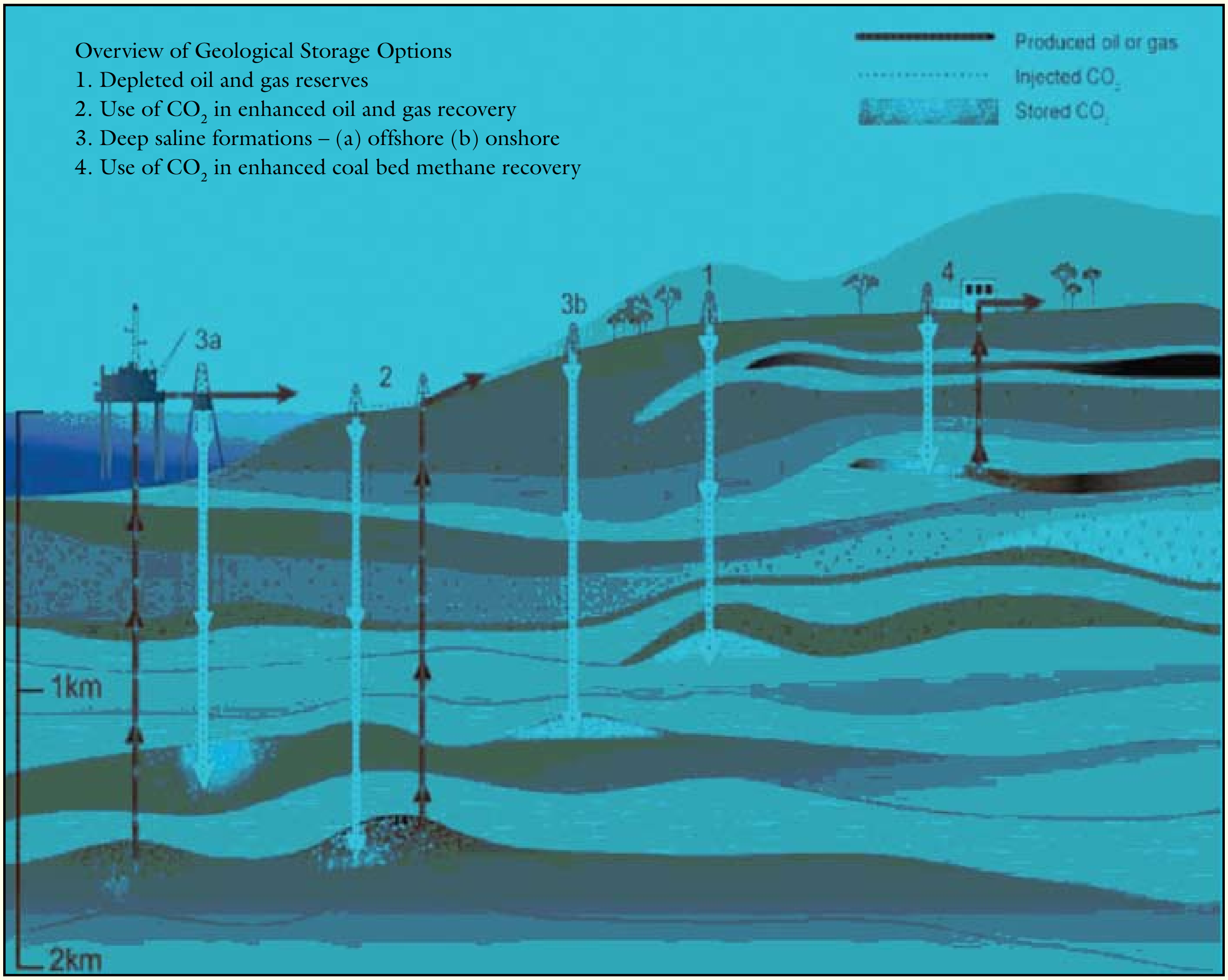
Source: IPCC, 2005.

To facilitate both transport and storage, the captured CO_2 gas is typically compressed to a high density at the capture facility

Carbon Capture and Sequestration (CCS) requires the use of technology to collect and concentrate the carbon dioxide produced from industrial and energy-related operations, transports it to a suitable storage location and then stores it away from the atmosphere for a long period of time (IPCC, 2005).

Figure 5 illustrates the three main components of the CCS process: capture, transport and storage. All three components are found in industrial operations today, although mostly not for the purpose of CO_2 storage. The capture step involves separating carbon dioxide from other gaseous products. The transport step may be required to carry captured carbon dioxide to a suitable storage site located at a distance from the carbon dioxide source. To facilitate both transport and storage, the captured CO_2 gas is typically compressed to a high density at the capture facility. Potential Storage methods for the CCS process include injection into the underground geological formations, injection into the ocean or industrial fixation in inorganic carbonates. Carbon capture is already used in several industrial applications. These

Figure 6: Geological Storage Options



Source: IPCC, 2005

technologies are used in the manufacture of fertilizers and petroleum refinery operations

4.1 Geological Sequestration

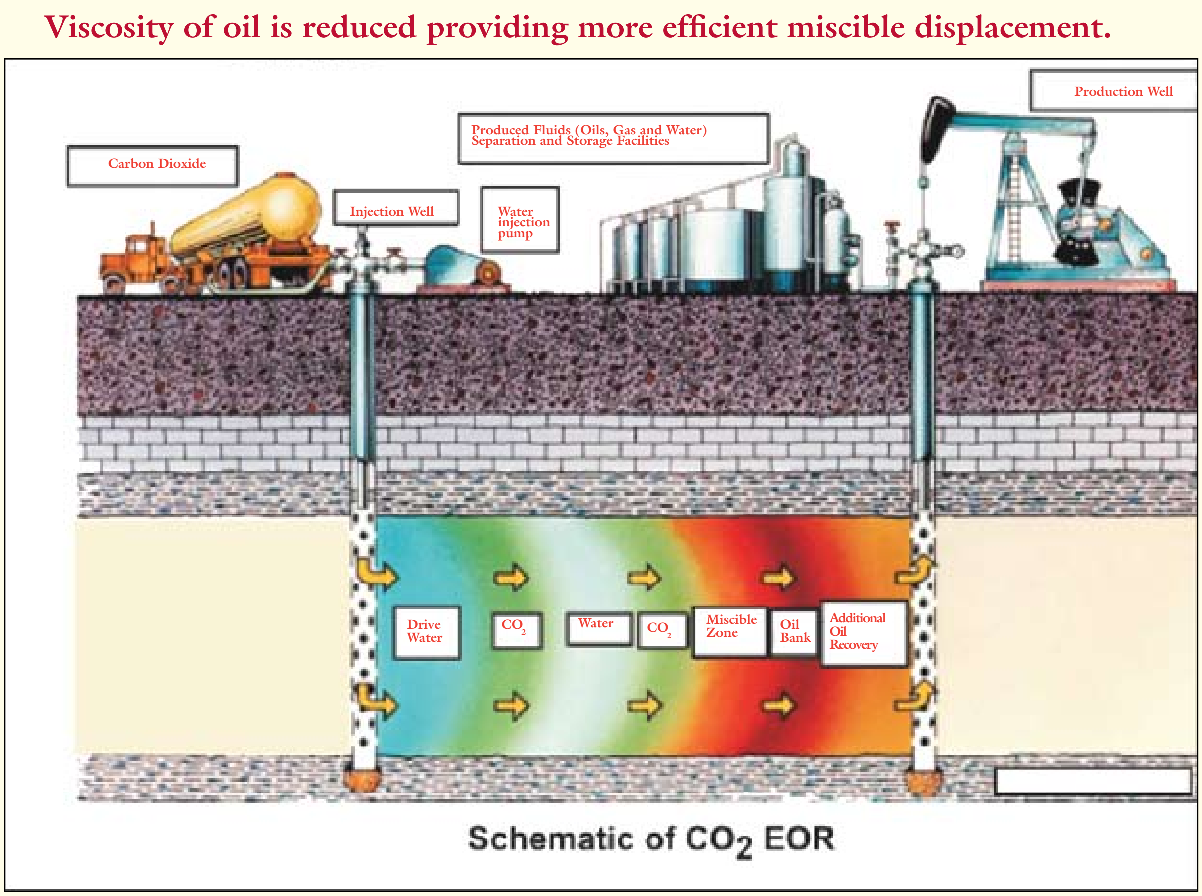
Following the capture process, carbon dioxide needs to be stored so that it will not be released into the atmosphere. Geological sequestration involves the storage of carbon dioxide in large physical structures, such as disused oil fields or other formations, such as oil reservoirs, unmineable coal seams, saline formations, and shale formations with high organic content. The options for geological storage are illustrated in Figure 6.

4.2 Enhanced Oil Recovery (EOR)

The injection of CO_2 gas into depleted underground oil reservoirs is referred to as Enhanced Oil Recovery (EOR) (Fig. 7 refers). Under conditions of high pressure, the carbon dioxide and oil become completely miscible, leading to enhanced oil recovery, conferring

The term carbon sequestration refers to the capture and long-term storage of carbon in forests and soils or in the oceans

Figure 7: Schematic of Carbon Dioxide Enhanced Oil Recovery



Source: US Department of Energy, 2008.

added economic benefits to the use of this technology.

One method of EOR, carbon dioxide flooding (CO_2 EOR), has the potential to not only increase the yield of depleted fields, but also to sequester carbon dioxide that would normally be released into the atmosphere.

Carbon dioxide has been injected into declining oil fields for more than 30 years to increase oil recovery. This option is attractive because the CO_2 storage costs are offset by the sale of additional oil that is recovered. Further benefits are the existing infrastructure and the geophysical and geological information about the oil field that is available from the oil exploration. All oil fields have a geological barrier preventing upward migration of oil. It is supposed that these geological barriers will also be sufficient as long-term barriers to contain the injected CO_2.

Identified possible limitations to the use of this technology are the many ‘leak’ opportunities provided by old oil wells, the need for very high pressures (about 80 times air pressure) and low temperatures (below about 20° Celsius) to keep the CO_2 liquefied (only practical very deep underneath the sea) and the conversion of CO_2 into acids which can damage the geological barrier and well casings. Other disadvantages of old oil fields are their geographic distribution and their limited capacity.

The major limitation to the use of this technology however, is that when the enhanced oil is recovered and combusted, the once “sequestered” carbon dioxide is ultimately released into the atmosphere. The application of this technology can be considered therefore as a mechanism which delays the release of stored carbon dioxide through the process of miscibility.

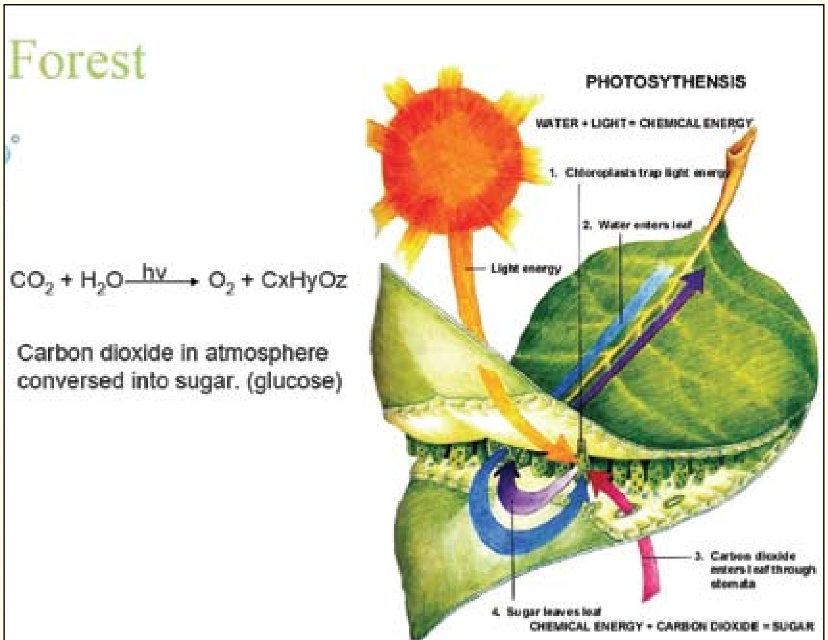
4.3 Ocean Sequestration

Oceans absorb, release, and store large amounts of CO_2 from the atmosphere. There are two approaches whereby oceanic carbon sequestration takes advantage of the oceans’ natural processes. One approach is to enhance the productivity of ocean biological systems (e.g. algae) through fertilization, whilst the other entails direct injection of carbon dioxide into the ocean. Experiments carried out in moderate to deep waters (350-3,600m) indicate that the liquid CO_2 reacts to form solid CO_2 clathrate hydrates, which gradually dissolve in the surrounding waters. (US Department of Energy (DOE), 2007)

This method however, has potentially dangerous environmental consequences. The carbon dioxide reacts with the water to form carbonic acid, H_2CO^3, most of which, (as much as 99%) remains as dissolved molecular CO_2. (US Department of Energy (DOE), 2007)

The equilibrium would no doubt be quite different under the high pressure conditions in the deep ocean. The resulting environmental effects on benthic life forms of the bathypelagic, abyssopelagic and hadopelagic zones are unknown. Even though life appears to be rather sparse in the deep ocean basins, energy and chemical effects in these deep basins could have far-reaching implications. Further research is required to define the extent of the potential impacts of this method of carbon sequestration. (US Department of Energy (DOE), 2007)

Figure 8: Biological Fixation of Carbon Dioxide



Source : US Department of Energy, 2007

4.4 Vegetation and Soil Sequestration

Biological sequestration is a form of indirect sequestration whereby ecosystems such as forests, agricultural lands and wetlands, are maintained, enhanced, or engineered, to increase their ability to store carbon. Agriculture can sequester carbon when organic matter accumulates in the soil, or above-ground woody biomass acts as a permanent sink or is used as an energy source that substitute for fossil fuels (Powell et al., 2002). Plants, through the process of photosynthesis (Figure 8 refers), absorb carbon dioxide from the atmosphere and convert it into cellulose through a series of complex biochemical reactions and processes. Forest type vegetation plays a major role in carbon sequestration through the process of photosynthesis. In this regard, forests are considered a major and significant carbon sink which literally “sucks” carbon dioxide from the atmosphere and converts it to cellulose where the carbon is “sequestered” in the woody biomass of trees.

Forest sink enhancement is crucial to carbon sequestration and can be grouped into several different categories including:

- Maintaining or increasing forest area through reduction of deforestation and degradation, and through reforestation;
- Maintaining or increasing the stand-level carbon density (tonnes of carbon per hectare) through the reduction of forest degradation and through planting, site preparation, tree improvement , fertilization and other appropriate silviculture techniques
- Maintaining or increasing the landscape-level carbon density using forest conservation, longer forest rotations, fire management, and protection against insects.

4.4.1 Forest as a Natural CO_2 Sink – A Review of the Literature

Research has shown (Brown et al., 1996) that tropical forests can sequester significant amounts of carbon through conservation of primary forests, conservation of biodiversity,

Current land use data indicates that there may not be enough parcels of land available to establish new forests for the purpose of carbon sequestration

good harvesting techniques and through the establishment of forest plantations, as trees in the tropics grow at a much faster rate than in any other geographical region. Typical sequestration rates for reforestation, in tonnes of carbon per hectare of forest per year according to geoclimatic conditions, are in the order of 0.8 to 2.4 tonnes for arctic forests, 0.7 to 7.5 tonnes for temperate regions and 3.2 to 10 tonnes for the Tropics (Brown et. al., 1996). Studies have also shown (Muora-Costa 1996), that carbon sequestration potential is specific to floral species, site and management involved, and is therefore very variable. With respect to species-specific carbon sequestration rates, studies were undertaken to assess carbon sequestration potential of tropical species in China, Indonesia, Costa Rica and Australia. In Costa Rica, native forest plantations from nine to 14 years old sequestered carbon at a rate of 1.2 to 10 tonnes per hectare per year, whereas in Panama 20-year-old teak plantations of Tectona Grandis averaged 5.22 tonnes per hectare annually (Kraenzel et al. 2003).

There is a dearth of available literature on species-specific rates of carbon sequestration for tropical forest species. Successful implementation of environmental carbon sink enhancement programmes locally shall therefore be contingent upon research to identify appropriate and optimal sequestration floral species for this type of project. It is imperative therefore, that research to identify the carbon sequestration potential of Trinidad's native forest species be conducted.

Forests serve many environmental functions aside from carbon mitigation. Natural forests with various stages of stand development, including old-growth forests with snags and fallen logs, provide diverse habitats necessary for biodiversity (Harris, 1984; Franklin and Spies, 1991).

Preserving forests conserves water resources and prevents flooding. By reducing runoff, forests control erosion

Table 2: Trinidad & Tobago Forest Resources

	Trinidad	Tobago	Total	%
Total Land Area (ha)	482,500	30,500	512,800	100
Total Forested Area	232,093	15,907	248,000	48.4

Source : (Chalmers, 1992 cited by the Ministry of Agriculture Land and Marine Resources Annual Forest Resources Report, 2004/2005).

Table 3. Forest type, Area (hectares) and Location

Indigenous Forest Types	Trinidad % Cover	Tobago % Cover	Trinidad Area Hectares	Tobago Area Hectares	Trinidad Location
Evergreen seasonal	39.9		98,190		NE and SE
Semi-evergreen seasonal	5.7		13,928		Southern extremes
Deciduous seasonal	1.5		3,617		Western northern range
Dry Evergreen	0.2		495		East coast
Seasonal Montane	0.4		926		Northern Range
Montane	8.8	0.6	21,619	Main Ridge	Northern Range
Swamp	6.8	60.5	16,731	Coastal	Coastal
Secondary	6.8	6.5	16,631	Main Ridges	Widely Distributed
Plantation (Teak, Pines, Mixed, Hardwoods)	8.44		20,735		
Other Areas	21.51	32.4	52,859		

Source : (Chalmers, 1992 cited by the Ministry of Agriculture Land and Marine Resources Annual Forest Resources Report, 2004/2005).

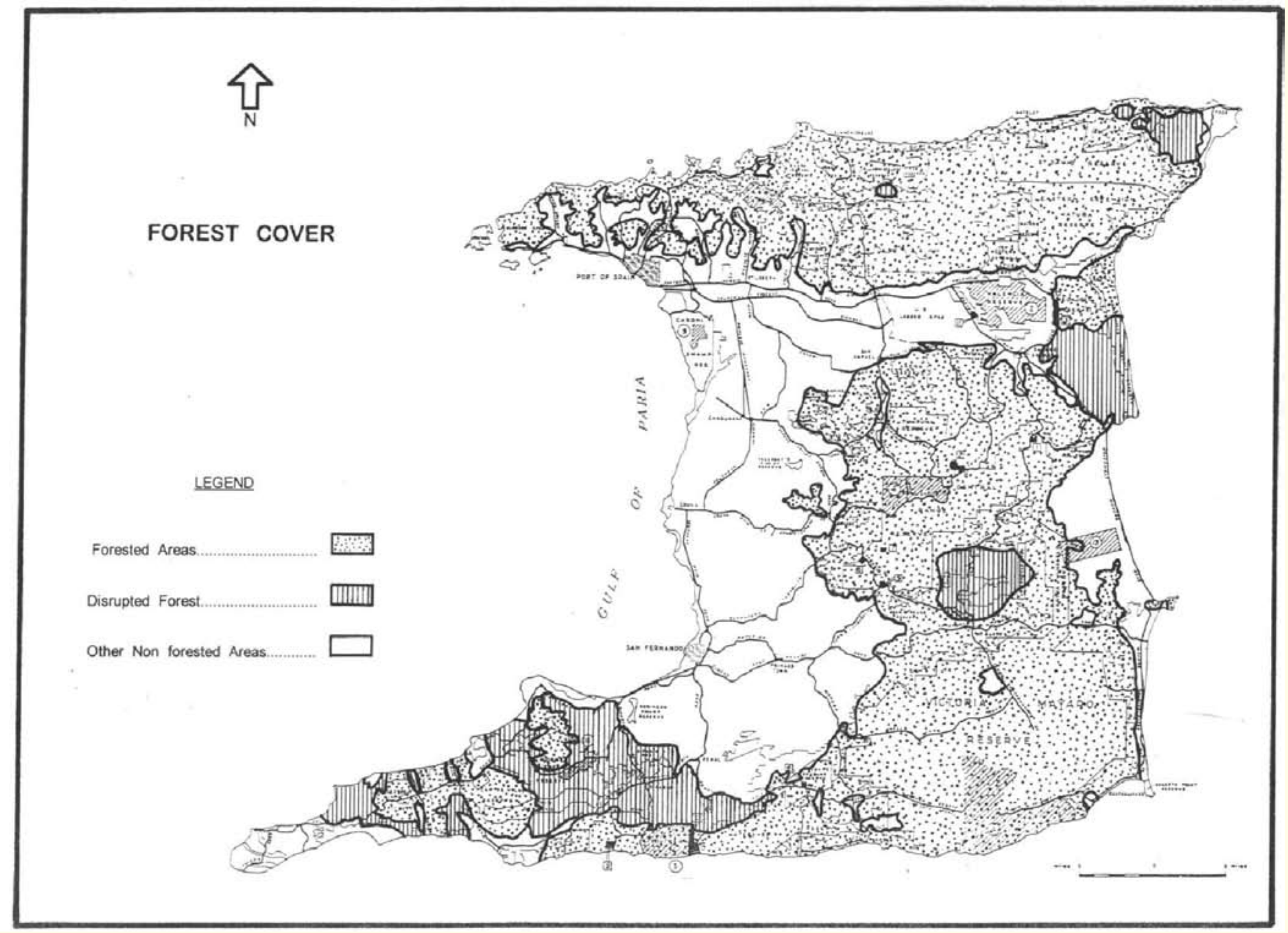
and salinity. Consequently, maintaining forest cover can reduce siltation of rivers, protecting fisheries (Chomitz and Kumari, 1996).

Of the 482,500 hectares of land which comprises the Island of Trinidad, approximately 232,093 hectares (Table 2 refers), or 48% was under forest cover in 1992 (Chalmers, 1992 cited by the Ministry of Agriculture Land and Marine Resources Annual Forest Resources Report, 2004/2005). The clearing of forests for various developmental purposes may have subsequently reduced total forest cover. Current land use data indicates that there may not be enough parcels of land available to establish new forests for the purpose of carbon sequestration. However, opportunities exist for the use of degraded forest lands, which were once forested (Table 3 and Figure 9 refer) or previously under sugar-cane cultivation, to be reforested or biologically enhanced for this purpose.

5.0 NGC's Reforestation Programme

Mindful of the increasing rates of production and emission of GHGs from the local energy, petrochemical and manufacturing sector, NGC has recognised the need to sequester

Figure 9: Trinidad, Forest Cover



Source: Ministry of Agriculture Land and Marine Resources, Forestry Division (FRIM), 2001.

carbon post-carbon dioxide emissions. In keeping therefore with NGC's "No Net Loss" Forest Policy, the company embarked on a reforestation programme in July of 2005 to offset the forest cover removed during three major projects.

Approximately 100 hectares of forest were cleared to accommodate the CIPP and BUD (85 ha CIPP and 15 ha BUD) projects, and approximately 200 hectares of primary and secondary forest were cleared to facilitate the construction of the Union Industrial Estate.

NGC has therefore embarked on a 10- year ex situ reforestation programme aimed at rehabilitating 105 hectares of

Successful implementation of environmental carbon sink enhancement programmes locally shall therefore be contingent upon research to identify appropriate and optimal sequestration floral species for this type of project

critically degraded forest within a 2.5km radius of the CIPP and BUD project sites, as well as 210 hectares of similarly degraded forest in the Morne L'Enfer Forest Reserve, La Brea, a total of 315 hectares.

During Phase I of the programme (August 2005 to August 2007), 38.8 hectares was planted, exceeding the 35 hectares earmarked for reforestation under the CIPP & BUD Reforestation Programme, while 11 hectares was planted in the Morne L'Enfer Forest Reserve.

Field audits indicate survival rates well above the 80% rate established by the Forestry Division as an indicator of a successful reforestation project. Over the next three years, NGC will be planting the remaining 265 hectares. The 50.0 hectares planted during Phase I of the programme will be maintained and protected from loss by fire until such time as they are viable.

CONCLUSION

Opportunities undoubtedly exist for the implementation of programmes to enhance natural terrestrial carbon dioxide sequestration sinks in order to achieve a two-fold objective of attaining a long-term reduction in greenhouse gas production and emission while maintaining and enhancing our nation's biodiversity.

Policies set to guide carbon dioxide sequestration should include several approaches to control the emissions. Regardless of the quantity of carbon sequestered, a good strategy should entail several different sequestration options. This would ensure environmental benefits in conjunction with the desired end results. For instance, carbon dioxide in enhanced oil recovery, a method of geological sequestration can be used in tandem with reforestation, a terrestrial approach, to produce a collective carbon dioxide abatement strategy.

The use of forest sinks is particularly attractive, since no new technologies need to be developed. Also, in addition to carbon dioxide emission abatement, Trinidad and Tobago will enjoy ecological benefits including increased forest cover, reduced run-off, increased recharge of aquifers, reduced flooding and increased precipitation. Research is needed, however, to adequately tailor forest sink enhancement programmes that result in the optimum rate of carbon dioxide sequestration per hectare. To assess the effectiveness of forest sink enhancement in offsetting carbon dioxide emissions in Trinidad, the carbon sequestration ability of our native tree species must be quantified.

The continued impact of the oil and gas industry on our natural landscape provides a strong rationale for the involvement of energy stakeholders to harmonize and synchronize industry efforts to reduce industrial carbon dioxide emissions and enhance natural carbon dioxide sequestering sinks.

The use of forest sinks is particularly attractive, since no new technologies need to be developed. Also, in addition to carbon dioxide emission abatement, Trinidad and Tobago will enjoy, ecological benefits including increased forest cover, reduced run-off, increased recharge of aquifers, reduced flooding and increased precipitation

POTENTIAL FOR BIOCHEMICAL PRODUCTS FROM NATURAL GAS IN TRINIDAD AND TOBAGO

By VERNON PALTOO PhD
Team Leader – Business Development, National Energy Corporation

Trinidad and Tobago is a major global supplier of primary petrochemicals such as ammonia and methanol. In recent times the State has indicated its desire to diversify the natural gas processing sector into a variety of products with significant added-value. One such project that is currently being developed is the production of single cell protein (SCP) via fermentation of natural gas or methanol.

Work is currently in progress to establish a pilot plant to manufacture single cell protein using proprietary technology from UNIBIO of Denmark at the University of Trinidad and Tobago. This project is being sponsored by the National Energy Corporation of Trinidad and Tobago Limited (NEC) and Evolving Technologies and Enterprise Development Company Limited (e TecK).

Single cell proteins produced in this manner are currently used for the manufacture of animal food, such as fish meal. However there are substantial possibilities for the development of other markets such as animal feed for poultry, pigs, cows, dogs, and cats. Future applications include possible use as a protein additive for human consumption. Potential industrial applications include the manufacture of paints, glues and adhesives.

In a 2008 report by Global Industry Analysts (GIA), it is estimated that the market for protein ingredients will exceed US$18 billion by 2010. Europe is the largest protein ingredient market and is expected to cross US$10 billion by 2010. On the other hand, the United States is the fastest growing market with a projected annual growth rate of 7.6%. Currently most of the protein ingredients originate primarily from animals with 69% of the supply. However, the demand for protein from plant material is expected to increase by 8% annually within the next five years due to perceived health benefits. This will have the effect of putting additional constraints on the global food production capacity, which has been under pressure in recent times to increase output due to growing populations and use of food to produce alternative sources of energy.

In this context, the pilot plant project in Trinidad and Tobago would hope to lay the foundation for the future development of increased food production, as well as alternative non-traditional and high value uses of the country's hydrocarbon resources.

"Currently most of the protein ingredients originate primarily from animals with 69% of the supply. However, the demand for protein from plant material is expected to increase by 8% annually within the next five years due to perceived health benefits. This will have the effect of putting additional constraints on the global food production capacity, which has been under pressure in recent times to increase output due to growing populations and use of food to produce alternative sources of energy."

Process for Production of Single Cell Protein (SCP)

The process for the manufacture of single cell protein is well established. Essentially the process involves the use of a methanotrophic bacterium in water for the fermentation of a mixture of methanol, ammonia, and oxygen to produce single cell protein. Alternatively, natural gas can be used instead of methanol as the primary substrate for fermentation. In the proposed project for Trinidad and Tobago, the fermentation process would use the M102 bacterium in a patented U-loop reactor owned by UNIBIO of Denmark. The process essentially has five stages to manufacture a finished product.

These steps are illustrated in Figure 1 and include the following:

- Fermentation
- Centrifuging
- Ultra-filtration
- Heat treatment
- Drying

The finished product is a non-dusty agglomerate that is reddish brown and free-flowing (Figure 2). It could be defined as a protein-rich biomass produced by a microbial culture with natural gas as the sole carbon and energy source. This definition is very important for regulatory approvals to use the product as a food, since it can be considered strictly an additive from this perspective.

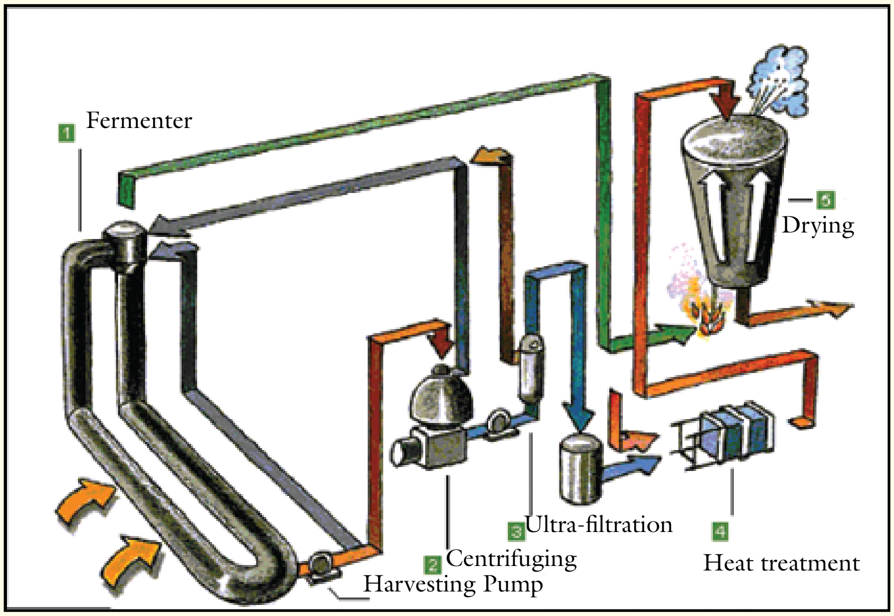


Figure 1: Single Cell Protein Manufacturing Process (Diagram courtesy UNIBIO)

Potential Applications

Feedstuff for Animals

SCP can be used as an essential source of amino acids, and when mixed with other low protein feedstuff, will make an excellent feedstuff for animals such as pigs, poultry, cows, fish, dogs, cats, etc. Many animals cannot survive on proteins from vegetables alone, as the number of different amino acids is too small. This results in increased sickness, as well as deaths. It is therefore important to mix the feed with other sources of protein such as those from milk, fish, soya, potatoes, blood, etc. However these sources are not always desirable since bone and blood meal can cause Mad Cow Disease. Plants are generally deficient in the amino acids methionine and lysine, which are essential for survival. This is why large-scale feeding of fish on an exclusive diet of soya based product is fatal.

Human Consumption

Proteins are necessary for humans to live and survive. SCP can add quality and physical profile to food and enter the market as a protein additive. In order to lower prices of food products and maintain a high amino acid content in a healthy product, SCP can be mixed into soups, sausages, bread, sauces and other foods. Sport drinks of protein mixed with chocolate, vanilla or strawberry are good examples of applications which currently use soya or potato protein, and has a low amino acid profile. However, in order to be used for human consumption, SCP will have to undergo a heating process to remove nucleic acids which causes kidney problems in long-living animals and in humans. Additonally regulatory approvals will be required from governments in targeted markets. It this regard, SCP can be marketed as an engineered food without genetical modification.

Figure 2: SCP Finished Product

Industry

Proteins are used in the industrial manufacture of adhesives, glues and paints.

Market Outlook

The primary market for SCP would be as a substitute or additive for fish feed and poultry feed. It takes five tonnes of fish to make one tonne of fish meal. Industrial manufacture of fish meal is also an expensive process since the fish must be cleaned and decontaminated from pollutants such as dioxins. Furthermore harvesting fish for producing fishmeal has led to over-fishing and depletion of resources, which has caused fish meal supply to decline and prices to rise substantially in the last few years. Figure 3 shows how fishmeal supply has declined in the last few years, while Figure 4 illustrates the rise in fishmeal prices from an average of US$600/MT in 2002-2005 to over US$1200/MT in 2007.

The potential market for single cell proteins is very large because globally there is now a shortfall in the supply of proteins. Worldwide, the consumption of protein is estimated at the following (Figure 5):

- Animal Feedstuff
  51,000,000 tpy
- Human Consumption
  50,500,000 tpy
- Substitution of Casein in Paints
  5,000,000 tpy
- Substitution of Casein in Adhesives
  5,000,000 tpy

The average 2006 prices of the proteins, which SCP will target to replace, are as follows (Figure 6):

- Fish Meal Protein
  US$1.15 per kg
- Soya Protein
  US$1.20 per kg
- Potato Protein
  US$1.05 per kg
- Milk Protein
  US$2.10 – 3.50 per kg
- Blood and Bone Protein
  US$2.50 per kg

Figure 5: Segments of Global Market for SCP

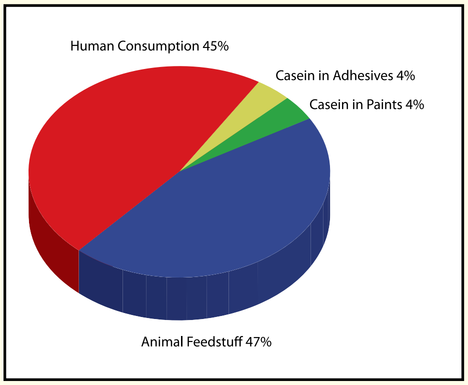


Figure 3: Global Fishmeal Supply Market

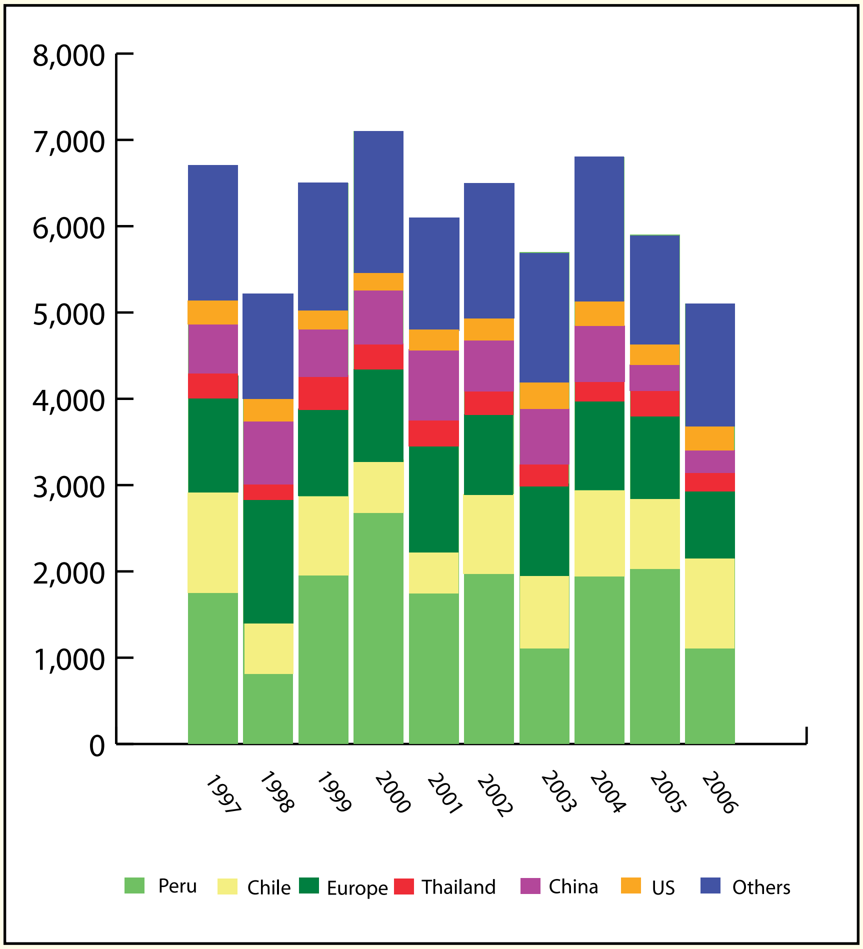
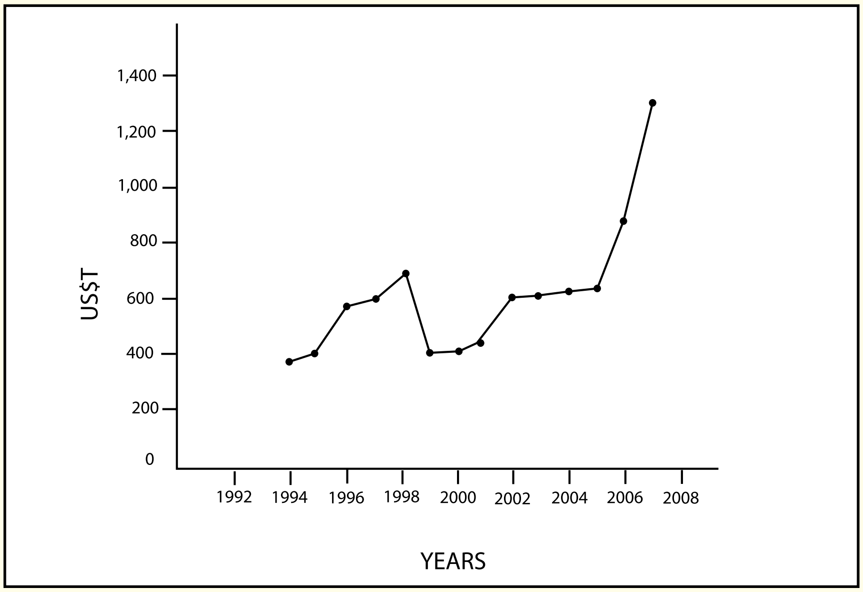


Figure 4: Historical Fish Meal Prices



In this case of future protein sales for industrial applications, current prices are US$5.00 to US$6.00 per kg. If the product is eventually approved for human consumption, prices would then range from US$4.00 to US$6.00 per kg.

A Commercial SCP Industry in Trinidad and Tobago

The current pilot plant project for the manufacture of SCP which is underway at UTT's Point Lisas Campus will set the stage for the development of a possible full commercial facility. A potential commercial SCP facility could produce anywhere from 50,000 tpy to 200,000 tpy of product depending on the configuration. It should be noted that a commercial plant will require substantially less natural gas to use as a substrate than what is consumed as feedstock in a traditional petrochemical plant. Land and utility requirements are also much fewer than for traditional and conventional gas processing plants.

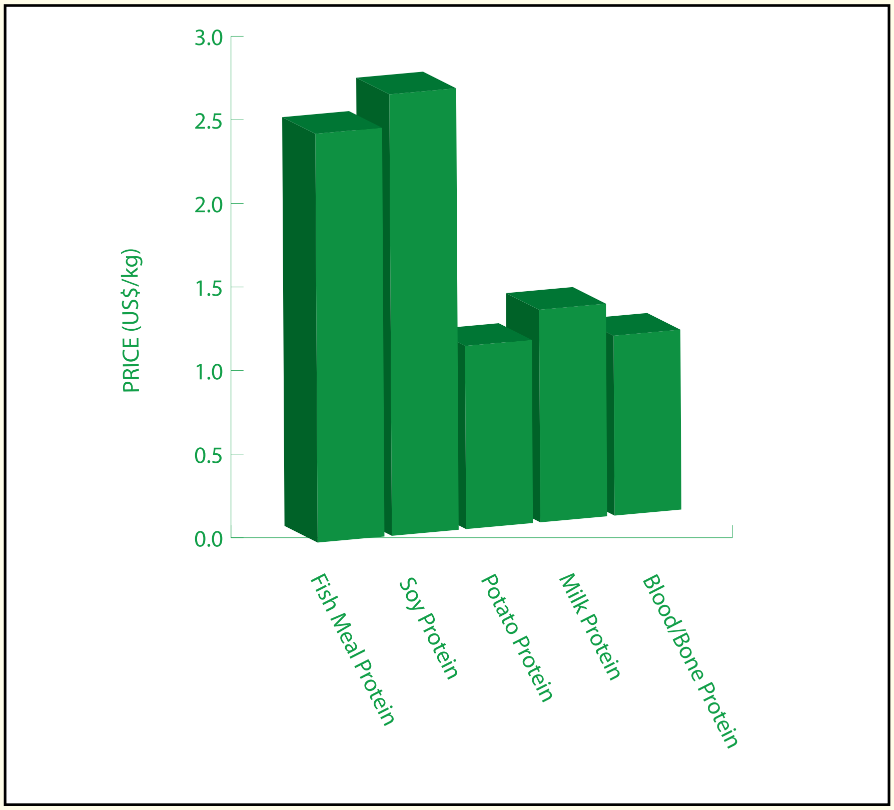


Figure 6: Sample Prices of Protein Products

Implications for Trinindad and Tobago

Downstream Processing

There is scope for this project to establish large downstream agro-processing industries such as very large poultry farms, fish farms or prawn farms. The potential to be a leading compound feed exporter will also be available. From such industries, there will be generation of sustainable employment and development of high added value sectors.

Development of Biotechnology Sector

Implementation of this project will allow the country to begin development of the biotechnology industry, which is considered to be a worldwide high-growth sector. Again, this will be a departure from traditional petrochemicals and metal processing.

Cooperation with local Universities

The transfer of technology and capabilities to local universities will create an opportunity for biotechnology engineers and scientists to develop in this country. There will be an opportunity to develop other segments of the biochemical processing industry, especially in areas such as fermentation. Also further research and development in the single cell protein production process or in potential downstream projects can be done in conjunction with other local institutions.

Further Expansion and Local Ownership

Since the project does not require substantial resources for implementation, it is fairly easy for expansion with new plants in which there could be local participation or investment.

The bio-processing industry is in its infancy in Trinidad and Tobago. The pilot plant programme at the University of Trinidad and Tobago is the first step in establishing a new long-term growth industry in Trinidad and Tobago. These SCP manufacturing plants do not require substantial resources in terms of gas usage, utilities or land. Furthermore, according to the Food and Agricultural Organization of the United Nations (FAO), "Single Cell Protein (SCP) has the potential to be developed into a very large source of supplemental protein that could be used in livestock feeding." Therefore, if this pilot plant project develops into a commercial enterprise, it will go a long way in the country's efforts to diversify the natural gas sector, as well as contribute to building a knowledge-based society.

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Beachfield Slug Catcher

BUD Works Completed

On April 25, NGC formally marked the closing of works at the Beachfield Upstream Development project with a ceremony at the Abyssinia Facilities, Guayaguayare. At the event, feature speaker Senator, the Honourable Conrad Enill, Minister of Energy and Energy Industries described the new facility as the hub of the gas transmission business in Trinidad and Tobago and noted that the transmission system was the seventh largest in the Western hemisphere.

Constructed at a cost of US$225m, the BUD project required the construction of a new slugcatcher facility and a 66-kilometre pipeline from bpTT's Cassia B to Rustville, Guayaguayare (an historical site of the oil industry in Trinidad and Tobago where some of the country's oldest wells were drilled in the area in 1902).

Senator Conrad Enill, Minister of Energy and Energy Industries

The new pipeline is capable of transporting 600 million standard cubic feet per day (MMscf/d) which increases the overall capacity of the NGC transmission system to 2,000 MMscf/d of natural gas. The slugcatcher separates 5,000 barrels of condensate per day. The expansion of the gas transmission network and the increased capacity offered by the pipeline is expected to meet increased demand for gas at the Point Lisas estate through 2012.

The BUD facility is overseen by a team of technicians working in two crews that operate the facility 24/7. NGC is completing construction on a 28-room facility that will meet the accommodation and recreation needs of the employees, who work seven days in residence and seven days off.

The new facility required the removal of some forested acreage, but NGC has undertaken a reforestation exercise of an equivalent or greater number of hectares under the guidance of the Forestry Division.

Phoenix Park Valve Station is being upgraded.

Phoenix Park Valve Station Upgrade

Upgrade works to the existing Phoenix Park Valve Station will double throughput from the facility from the current capacity of 1.6 billion standard cubic feet per day (Bcf/d) to 3.0 Bcf/d by 2012.

The Valve Station removes liquids from the gas flowing through NGC's pipeline system and routes the gas to Phoenix Park Gas Processors Limited (PPGPL) for processing and distribution to customers. PPGPL provides dry natural gas to NGC's customers after it has separated the propane, butane and natural gasoline from the liquids extracted from the pipeline supply.

The expanded valve station facility will include a number of key improvements, including a new above-ground slug-catcher with a capacity of 40,000 bbl, a new flare system, condensate storage vessels with state-of-the-art loading arms and a diesel storage tank among other improvements.

Detailed designs by Worley Parsons Trinidad Limited (WPTL), the project engineering contractor, are 95 per cent complete. Components for the slugcatcher have been delivered to the laydown yard. The tendering process for the project will be completed by July. Electrical and instrumentation designs by WPTL have been submitted to NGC and are under review.

Contracts for the fabrication and supply of the flare system, condensate storage vessels and Wet Gas Bypass Separator have been awarded and fabrication design drawings are in progress. WeldFab Ltd is the contractor for the construction of the condensate storage, knockout drums and diesel tanks. The flare system, which will include a 150-foot flare stack, is being supplied by John Zink of Oklahoma, USA. Delivery of the flare system is expected by March 2008. Twenty-two work packages for goods and services are in various stages of procurement and piling and foundation works by Gordon Winter Company Ltd, a local contractor, will proceed on the site between June and November 2008.

Pipeline Loop to Ring Main during construction.

Pipeline Loop to Ring Main

Construction work on the 36-inch-diameter Pipeline Loop to Ring Main project is nearing completion. The project, which commenced in July 2007, improves distribution of natural gas from the Phoenix Park Intermediate Station and plants on the Pt Lisas Industrial Estate. The line has been successfully 'tied in' at the manifold of the Intermediate Station, and the in-service welding on the Estate's supply line has been completed. Final civil works on the project include fencing, painting of above-ground sections of pipe and the construction of foundation slabs. The connection has been successfully hydro tested and will be reviewed by the Certified Verification Agent at the end of July.

NEO/Tobago Pipeline

Approvals have been granted for the largest project that NGC has undertaken to date. The estimated cost for the project is anticipated to be over US$500M. This project scheduled to be completed by January 2010, entails the construction of new pipeline infrastructure off the northeast coast of Trinidad that connects onto the existing network in the southeast of the island. The pipelines to be constructed are the 36-inch-diameter North Eastern Offshore (NEO) pipeline, and a 12-inch-diameter Tobago pipeline. Also to be constructed are the Tobago gas receiving facilities which will be able to process up to 60MMscf/d with the capability for future expansion up to 120MMscf/d.

The NEO pipeline comprises a 58-mile/94-km line with offshore and onshore segments, while the Tobago pipeline is a 33-mile/54-km, 12-inch-diameter marine line. Both projects entail the construction of a line that will run for 145.6km offshore and 6 miles/9.6km overland, connecting the Mayaro Bay Regulator Station, the BUD/ slugcatcher with BHP Billiton's Gas Platform before proceeding to Tobago's Cove Industrial Estate.

Front End Engineering Design has been completed and detailed engineering design has started. NGC will proceed with procuring the pipe to mitigate potential cost escalations in the volatile steel markets, as well as some items that require long lead time for production.

Tender packages for the acquisition of 60,000 tonnes of pipe for the project will be issued in June for award in July. Concrete coating of the pipe will be done at Labidco's laydown yards, using the same techniques that were developed for the BUD project. Two additional Engineering Procurement Installation and Commissioning contracts will be awarded by August/September for the pipelines and the Tobago gas receiving facility.

Liquid Fuels Pipeline Underway

Contractor Kellogg, Brown & Root has been engaged to design the new Liquid Fuels system and this aspect of the project is 40 per cent complete. The contractor has submitted specifications for the required pipe and the procurement work on this aspect will begin via e-tendering in June.

The original scope of the project has been expanded to include a loading facility at Petrotrin. The Liquid Fuels pipeline will transport 1.6 million gallons of refined distillates per day along 8-inch-diameter steel lines. The products to be transported will include unleaded super and unleaded premium gasoline, diesel oil and jet fuel. Topographic survey work is complete, and the optimal path, balancing access and safety considerations have been agreed on. The line will run north from Petrotrin along the highway following the existing 16 inch-diameter's Right of Way for the most part. At the Caroni Swamp, the line will veer eastwards for some distance and then northwards to the Frederick Settlement Industrial Estate where a loading facility is to be constructed on 22 acres of land.

From the Frederick Settlement Industrial Estate an 11-km line will run to Piarco routing south alongside the Petrotrin line before turning east to the Southern Main Road, north to the Caroni South Bank Road and then northeast just before Kelly Village, before turning north again to Piarco. The Caroni Loading Facility at the Frederick Settlement Industrial Estate will replace the NP Loading Facility at Sea Lots, and in tandem with the Petrotrin Loading Facility, will have the capacity to service the entire country.

The new Liquid Fuels line will improve the security of the nation's fuel supply, eliminate emissions from loading facilities, reduce the costs associated with automobile and jet fuel handling and reduce tank wagon traffic on the roads. Det Norske Veritas (DNV) has been contracted as a Certified Verification Agent and will work directly with the Ministry of Energy and Energy Industries to ensure that the system is fit for purpose and use. DNV performed the same role on the Cross-Island Pipeline Project. Subject to necessary clearances and approvals, construction is expected to begin in the third quarter of the year with commissioning in the third quarter, 2009.

Government Campus Plaza, Richmond Street

Construction on this new main, originally planned to commence in April 2008 will now begin June 23, 2008 and is expected to be completed by end of July 2008.

The works involve the installation of a 50mm-diameter tie-in valve, metering facility and 50mm/152mm-diameter gas main by a combination of open-cut and horizontal directional drilling.

Tamana InTech Park Gas Main

Certificate of Environmental Clearance (CEC) was obtained. Drawings for tender are 90% complete and tender packages for construction are being prepared. Procurement of materials is in progress, as steel pipe has been delivered. Construction works are expected to begin in October.

Pipeline to Diamond Vale

CEC has been received. Contract for the procurement of pipe was awarded. Drawings are 90% complete. Work is expected to begin Q4 2008 and completed by year end. The majority of works will involve horizontal directional drilling in order to avoid obstruction of the roadway and traffic delays.

Service Main and Metering Facility at Beetham Estate

Construction of the service main and metering facility at Beetham Estate has been completed and commissioned to upgrade the gas supply to our customer, NP Pouchet Service Station.

Replacement Distribution Main to Longdenville

An Environmental Impact Assessment is being conducted on behalf of NGC by Consultant ECO Engineering towards attainment of a CEC. Detailed designs are also being undertaken towards tendering for construction services and procurement of materials. Subject to CEC approval, work is expected to begin Q4, 2008.

Pt Lisas South and East

The Pt Lisas South and East Industrial Estate project is on schedule. A traffic study, field data for base mapping and proposals for the location of 50 fully serviced two-hectare plots for light industries are in progress. Preliminary works on roads, drainage, utilities and waste management are also underway. The final submission of a CEC application to the Environmental Management Authority, incorporating all review amendments was passed in April for further processing. Final CEC clearance is anticipated by August 2008.

Based on the traffic study, the Ministry of Works has requested that one of the main feeder roads to the Estate, Rivulet Road, be converted to a dual lane roadway to minimize traffic congestion at peak times. A proposed overpass will also be constructed on the Southern Main Road at the intersection of the corridor access road and the Southern Main Road. This overpass will also be a dual-lane roadway. Specific changes have also been requested on the Indian Trail Overpass, the Couva Interchange and the roundabout at the intersection of the Southern Main Road. While these works are not in the original scope, the Ministry of Works is requesting that NEC undertake detailed designs to ensure that external road works required to serve the project do not impact on existing traffic flows.

Pt Lisas South and East Port Facility

Saipem's contract for detailed design and construction is proceeding on schedule. The contractor has mobilized a local office and staff. Pre-construction work is in progress and conceptual designs have been completed. Final designs are in progress and under review. Dredging and reclamation planning is well advanced.

An EIA study has been submitted, and amendments in response to the EMA's review are being addressed. A CEC is anticipated by July 2008.

Field bathymetric and geotechnical work have been completed, and geosynthetic fabric for soil improvement is already stored on site. NEC is managing this project in strict adherence to the requirements of the Environmental Management Authority and is subject to its review of planned procedures.

Oropouche West Bank

The Oropouche Bank Reclamation Project was approved in January 2006 as a site for a new industrial estate by the Government. The project, with a scope of works that encompasses hydrodynamic modelling, mapping, dredging and reclamation methodology, will be best served by a single provider for design services in order to prepare an effective EIA. In February, the Italian firm Technital was awarded a contract for the design and the company is presently mobilizing for the project.

UIE UPDATES

Alutrint Site

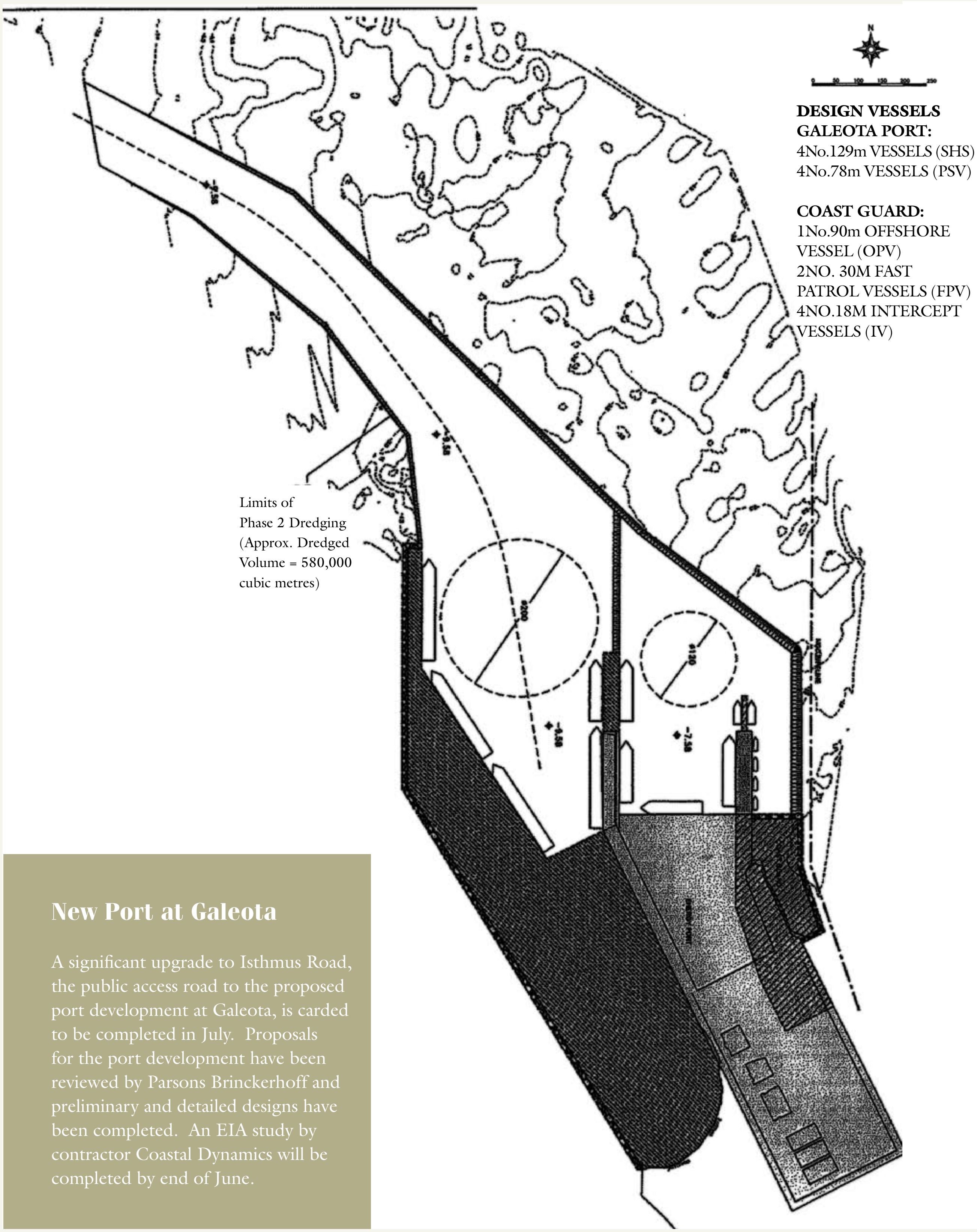
Work continues at the main site north of the Vessigny River with a view to completion by June 2008. Five oil wells in the area were abandoned and the well heads cut to the required elevation in May. Dynamic Compaction testing has been completed, and the site is being prepared for larger scale works with the construction of an access road and the clearing of a lay down area on the site. WASA has completed connection work for construction works on the proposed aluminium plant.

Power Plant and Syn Gas Site

T&TEC requested an access road to the substation site. LABIDCO has invited tenders for the construction of this road. Tenders were received and are being evaluated. It is anticipated that a contract will be awarded in mid-June.

Petrochemical Sites

Two short-term leases have been approved, one for WASA, to establish a pipe storage yard to supply works in the area, and another for Bredero Shaw to execute a pipe coating contract. Compliance with CEC approvals is constantly monitored via fortnightly audits of projects at the estate.



New Port at Galeota

A significant upgrade to Isthmus Road, the public access road to the proposed port development at Galeota, is carded to be completed in July. Proposals for the port development have been reviewed by Parsons Brinckerhoff and preliminary and detailed designs have been completed. An EIA study by contractor Coastal Dynamics will be completed by end of June.

Fabrication Yard

Labidco Operations

The first shipment of cargo for the Alutrint Smelter project arrived on the MV *Fu Kang Shan* on May 11 and was discharged in three days at the La Brea port facilities.

The cargo of construction equipment and steel consisted of 1,478 pieces of break bulk cargo totalling 5,801.073 revenue tonnes and three containers. Labidco managed the berthing and unberthing of the vessel and the supply of stevedores for the discharge of the cargo.

Fabrication Yard Operations

Trinidad Offshore Fabricators (TOFCO) will ship out the Savonetta platform, the company's fourth project for bpTT at the end of August 2008.

Materials for the fabrication of Poinsettia platform for British Gas are being received. This project is particularly notable for the size of its topsides. It is the largest offshore platform to be constructed at the TOFCO facility. Poinsettia is scheduled for shipping in mid-September 2008.

Works are in progress on the Toucan platform for EOG Resources, the third platform in construction at La Brea.

Alutrint Plans for Smelter Expansion

The proposed Alutrint aluminum smelter plant is being planned with a production capacity of 125,000 tonnes per annum, but the company has announced that the plant layout allows for expansion that will double its output. Alutrint has notified the EMA of the possibility of expansion, and will seek the necessary approvals if the project moves beyond its approved scope. The EMA has given approval for the establishment of a buffer zone between the factory's operations area and the surrounding community on the north, east and west boundaries of the plant. The China National Machinery and Equipment Import and Export Corporation will manage the construction of the smelter and is currently mobilizing its resources in Trinidad and Tobago pending the official commencement of construction on the project.

one moment please

to reflect on the beauty that surrounds us here in Trinidad and Tobago

ST GILES ISLANDS – HEAVEN'S ISLET: Tobago is often called paradise. And just off of its northeast coast is a separated slice of that paradise. In the photograph St. Giles Islands stand sentry to the vast waters of the Caribbean, ethereal under the sun's rays. The main island and its outlying rocks are farther north than any other point in Trinidad and Tobago. Dense with forest, the main island is unsuitable for human habitation, but unseen beneath its mossy green depths are thriving colonies of some of the region's most exotic birds. And hidden beneath the charged blue waters is one of Trinidad and Tobago's most stunning aquatic environments, a diving haven.

Heaven for birds, heaven for fish and from a tall spot on Tobago's north coast road, St Giles Islands look like a tiny piece of heaven itself.
– *Photograph by Christine Punnett*

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