SUGGESTED ENERGY TRANSITION POLICY

FOR

TRINIDAD AND TOBAGO

The Next 50 Years

June 30, 2021

Professor of Practice Andrew Jupiter

University of the West Indies

St. Augustine

Dr. Pedro van Meurs

Van Meurs Energy

INTRODUCTION

Trinidad and Tobago will be impacted significantly by international climate change policies. It is expected that after COP 26 various nations will intensify their efforts to achieve Net-Zero Carbon conditions by 2050 or 2060. Trinidad and Tobago is a major exporter of LNG, ammonia, methanol and fertilizers. The economy will therefore be severely negatively affected by these worldwide policies.

It is crucial that an optimal policy is defined and implemented to lead the country through the energy transition over the next four decades. The well being and wealth of the next generation depends on the success of this policy.

Yet, so far such a policy has not been developed, although the country has committed to its contribution under the Paris Agreement, while the Government has various established strategies and plans with respect to oil and gas, renewable energy and power generation.

This document is meant to be an initial contribution to a discussion about this matter.

The authors have prepared this report at their own initiative and are not financed or sponsored by any party. The reason for the report is for us to celebrate 50 years of our services in the petroleum industry with a look at the next 50 years.

INTERNATIONAL FRAMEWORK

A wide variety of entities and companies have made forecasts of possible scenarios of the world energy developments for the next twenty or thirty years. For the purpose of this report the estimates of the International Energy Agency ("IEA") will be used.

They published recently a remarkable report called *"Net Zero by 2050 – A Roadmap for the Global Energy Sector"* (the "Roadmap")[i]. This report describes a scenario how the world can actually reach a condition of net zero carbon emissions by 2050. "Net Zero" means that whatever emissions would still take place in 2050 would be offset by carbon capture and storage ("CCS") or other methods.

This scenario is radically different from the usual IEA Stated Policies Scenario ("STEPS")[ii], which is the forecast based on the current policies of the various countries. Under STEPS the world emits 34 Gigatons of CO2 in 2020 and this will slightly grow to 36 Gigatons by 2050. Based on this scenario the global temperature rise will be 2.7 degrees Celsius by 2100.

Under the STEPS scenario oil demand will increase from 98 million barrels per day ("mb/d") in 2019 to about 104 mb/d in 2030 and thereafter stabilize at this level. Gas demand will increase from 138 Tcf per year in 2020 to 201 Tcf by 2050.

Total CO_2 emissions will not increase strongly because at the same time coal demand will decline significantly and renewable energy will become a major contributor to satisfying energy demand.

Under the Roadmap the oil demand will decline to about 24 mb/d, but about two/thirds of this will be for non-energy use. Gas demand will decline to about 60 Tcf, but about three/quarters of this will be subject to CCS. The remaining emissions will be offset by other means, such as the generation of electricity based on biomass with CCS.

It is impossible to estimate how successful the world will be in achieving the goals of the Roadmap. It should be noted that nations representing 70% of the world GDP have committed to achieving Net-Zero Carbon by 2050 or 2060. However, there is considerable skepticism whether these commitments can be achieved. Russia, India, Indonesia, Saudi Arabia and most developing countries have made no such commitments.

For the purposes of setting a transition policy it is therefore assumed that world will achieve the Net-Zero objective about halfway between STEPS and the Roadmap. This means in 2050 the world demand for oil will be 64 md/d and for gas 130 Tcf per year.

In the case of oil, it can be assumed that low-cost OPEC producers will be able to largely maintain their current production, which means OPEC may produce as much as 30 mb/d. The decline in production will therefore be mostly come from non-OPEC countries.

Yet, it is precisely the non-OPEC countries which have been rather active in promoting exploration and production with licensing rounds during 2020 and 2021 (such as the UK, Norway and Suriname). Non-OPEC countries want to benefit from the full development of their petroleum potential before it is too late to do so. Therefore, active promotion of acreage can be expected to continue. World over-supply conditions will be the result. This in turn will result in downward pressure on price. The oil price in 2050 can be expected to be in the range of $ 30 to $ 40 per barrel (in constant 2021$).

The intense competition for investment among non-OPEC countries during the next three decades will result in a lowering of the government take. The world average is 60% today. This can be expected to drop to 50% or even 40% by 2050.

Russia and Qatar intend to enter strongly the LNG markets in the coming decade. This means LNG markets will remain highly competitive under this scenario.

There are other important international trends that will significantly impact on the energy transition in Trinidad and Tobago.

The most important trend is that the cost of producing solar and wind energy is rapidly declining. This is due to advances in technology and scale up of industrial production.

The lowest cost solar Power Purchase Agreement ("PPA") this year was in Saudi Arabia for 1.04 cents/kWh[iii]. Depending on climate conditions solar power can be expected to be supplied for PPA's in the range of 0.8 – 6 cents/KWh by 2030 (2021$), on average about 2.5 cents/kWh and these costs will decline further towards 2050.

This means that solar energy can now be supplied at costs that are well below the costs of the most efficient new combined cycle natural gas plants (assuming a relatively low gas price).

The lowest onshore wind PPA in the world came in at 1.43 cents/kWh recently in Texas. By 2030 onshore wind can be expected to be supplied at 1 – 6 cents per kWh in 2030 (2021$), on average about 3.5 cents/kWh. Offshore wind can be expected at 4 – 10 cents/kWh, on average 5 cents/kWh. These costs can again be expected to reduce further towards 2050.

Another important trend is the electrification of the transport sector. It is expected that by 2025 electric vehicles ("EVs") will be cheaper to buy, operate and maintain than cars based on internal combustion engines ("ICE"). Many car manufacturers are therefore moving into EVs. General Motors will only produce EVs after 2035[iv] and Honda after 2040.

The Roadmap assumes only EVs after 2035. However, again it is likely that some ICE cars will continue to be produced after that. Trinidad and Tobago depends for its vehicles on imports, so it will be difficult to purchase ICE cars after 2040. Therefore, it can be assumed that by 2050 at least 70% of the vehicles in Trinidad and Tobago will be EVs, although it is beneficial to have a higher percentage as will be discussed below. This in turn will require a significant expansion of the electricity generation capacity.

It is important to note that the world is engaged in massive R&D related to energy transition. Breakthroughs in technologies could dramatically change the future outlook. Inventions that bring the cost of green hydrogen ("green" means produced entirely based on renewable resources) below $ 1 per kg, would dramatically change world gas markets. Similarly, low cost green ammonia discoveries would change the ammonia markets.

A recent example of such R&D[v] is the discovery of zero-carbon ammonia synthesis made by Australian researchers of the UNSW School of Chemical Engineering and Sydney University. This synthesis does not require fossil fuels, does not emit CO2 and can be produced at room temperature on a small scale. This would permit farmers to produce their own fertilizers, if this scientific discovery would translate in commercial operations.

The fact that the European Union and other countries will undertake major efforts at achieving Net Zero Carbon conditions, will be an incentive to avoid "carbon leakage"; which is importing energy intensive goods from other countries that have more relaxed policies. The EU is working on a carbon border adjustment mechanism ("CBAM")[vi] whereby duties will be charged on such products. If such policies become widespread among OECD and other countries the export of gas-based industry products from Trinidad and Tobago may be negatively affected.

Trinidad and Tobago may be faced in the next ten years with a situation whereby most of their gas-based export products will be taxed on imports under the CBAM concept by a variety of countries, severely hampering further exports.

Other political developments are also important. It is assumed that relations with Venezuela will normalize and that joint development of transborder gas fields will be possible. It is also assumed that Iran will rejoin normal international relations and thereby become an important oil and LNG exporter.

ENERGY RESOURCES OF TRINIDAD AND TOBAGO

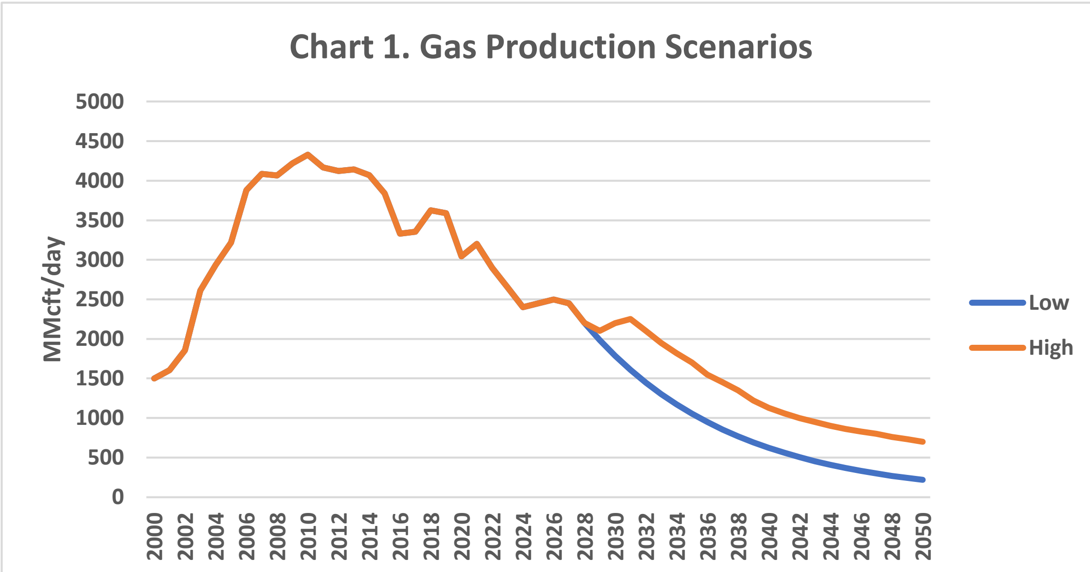
Trinidad and Tobago is rich in energy resources. However, the ultimate recoverable potential of oil and gas is subject to some considerable uncertainty. Following is a discussion of the various resources.

Natural Gas. As of 2020 the Ryder Scott natural gas reserves audit reported proved gas reserves were reported at 10.7 Tcf. Some additional possible fields are scheduled to come on stream during the next few years, which would increase the reserves. It is assumed that by 2025 the cross-border fields Loran/Matanee with Venezuela on the Trinidad side can be developed by Shell as the operator.

From then onwards a low estimate is that production would decline by about 10% per year, down to about 200 MMcft/day by 2050 as displayed in Chart 1. The total cumulative production over the thirty years from 2021 to 2050 would be 14.1 Tcf.

A high estimate is that deep water gas production from BHP operated fields or new fields as a result of the bid round, can be brought on stream by about 2030. This could be associated or non-associated gas from various fields at a production level of about 500 MMcft/day in addition to the low estimate. This would result in about 700 MMcft/day by 2050 and a total cumulative production over the thirty years of about 18.3 Tcf.

It should be noted that the development of most non-associated gas fields in deep water may be uneconomic due to possible low gas prices beyond 2030.



Oil and Condensates. MEEI announced previously that based on an audit of Netherlands Sewell and Associates, the following crude oil reserves were identified: Proved – 220 million barrels, Probable – 100 million barrels and Possible – 135 million barrels.

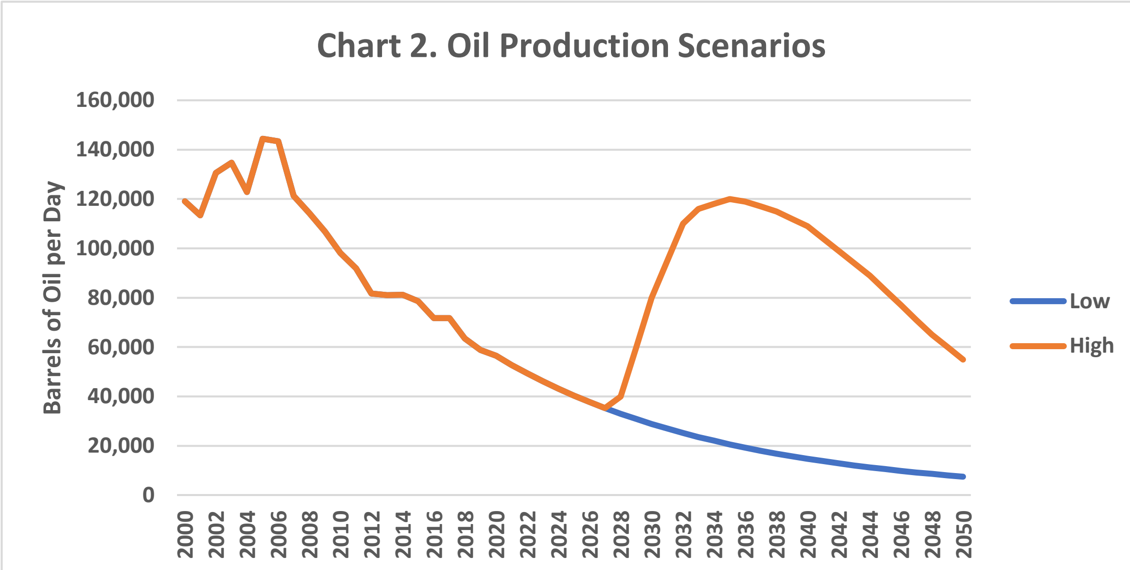
Using the appropriate risk factors for probable and possible reserves, this would result in an ongoing declining production of about 6.5% per year. Production in the year 2050 would be 7,500 bopd and the cumulative production over 30 years would be 257 million barrels.

In addition, 3.2 billion barrels of un-risked prospective resources were identified, largely in deep water.

At this time there is still considerable uncertainty about possible deep water developments, due to the fact that exploratory drilling has been limited and so far no major deep water discoveries have been made. The recent dry hole of the BHP Broadside well indicates that the risk factor for the prospective resource estimate is high.

Chart 2 shows the deep water production estimation based on a 1:4 success rate. It would add by 2030 about 100,000 bopd from several fields, which would start to decline towards 2050 resulting in a total production in the country of 55,000 bopd; about the same level as today. Cumulative oil production during the thirty years would be 880 million barrels. This is probably an optimistic scenario and there is a possibility that only dry wells will be drilled in the deep water blocks.

However, some further small shallow water oil discoveries may also add some modest production after 2030 or earlier.



Solar energy. The solar energy irradiance in Trinidad and Tobago is attractive. The Global Horizontal Irradiance ("GHI") is measured as the solar capacity in kWh per year on a square meter. The typical GHI for most of Trinidad is about 2000 kWh. The SW part of Tobago has 2200 kWh and the East and South Coast of Trinidad have about 2100 GHI.

This compares to 2700 kWh in the best areas in the world, such as Northern Chile, but is far better than Germany, for instance, with 1100 kWh (Yet, Berlin requires large buildings to have solar panel rooftops).

Furthermore, Trinidad and Tobago has a climate variation with drier months early in the year, but compared to other areas in the world the solar irradiance is rather evenly spread out over the year.

Wind energy. The wind energy capacity is measured as the wind speed in meters per second (m/s). Onshore most of Trinidad the wind speed is a relatively poor 4 – 5 meters per second. Some relatively small areas have wind speeds over 7 m/s, such as the NE tip of Tobago and some isolated locations on the North Coast of Trinidad.

Offshore winds are generally acceptable over 7 m/s off the North and South Coast of Trinidad and surrounding Tobago. The shallow waters off the South Coast of Trinidad may offer some low-cost opportunities.

The best areas in the world, such as the North Sea or offshore Aruba have 10 m/s.

Biomass. Trinidad and Tobago no longer has large scale agricultural enterprises that produce sugar or other products for export. Nor is there a large forestry industry. Therefore, there does not seem to be a significant opportunity for electricity production based on biomass.

Renewables and Hydrogen. From a world competitive point of view, Trinidad and Tobago will be able to produce solar and offshore wind energy at reasonable average costs and for any amount required for local use, providing a sound basis for energy transition.

The country will not be able to compete with some ultra-low-cost renewable countries such as Australia, Oman, Mauritania or Chile[vii] for the large-scale production of hydrogen for exports. However, some small-scale hydrogen operations for local use and small scale exports may become economic.

OVERALL STRATEGY OF OIL AND GAS DEVELOPMENT

The Roadmap indicates that it is no longer necessary for Governments to offer new acreage for oil and gas exploration, since under the Net Zero – 2050 scenario, all world oil and gas resources that are required have already been found. Some nations, such as France, Denmark and New Zealand are actually following this policy.

However, the most oil and gas producing nations are doing the exact opposite.

During 2020 and 2021 bid rounds were held or new contracts were signed in Norway, the UK, Austria, Australia (Queensland), various states and the federal government of the United States, emirates of the UAE, Russia, China, Timor Leste, Malaysia, Argentina, Brazil, Colombia, Suriname, Uruguay, Syria, Oman, Liberia, Botswana and Zimbabwe. Nigeria is about to pass their Petroleum Industry Bill with precisely the objective to accelerate oil and gas production. Colombia just launched their 2021 bid round.

In fact, there is a sense that it is important to accelerate oil and gas exploration since oil and gas production may soon no longer be viable. Acceleration will ensure that the nation benefits to the maximum extent possible from the remaining oil and gas potential before it is too late.

Pavel Zavalny, the head of the energy committee of the Russian Parliament, crystallized this policy as follows[viii]: *"Everything that can be produced should be produced as long as there is still demand to sell it".*

The IEA report recognizes that their recommendations will have devastating consequences for oil and gas producer economies. The IEA report[ix] concludes on page 176 that producer economies *"are likely to struggle to finance essential spending at current levels. This could have knock-on effects for social stability, …".*

In other words, it is recognized that a worldwide strategy to combat climate change will impact very negatively on nations such as Trinidad and Tobago. It therefore seems fully justified that these nations focus primarily on saving their nations first before trying to save the world.

Nevertheless, where energy transition results in economic benefits, such benefits should be fully realized. Also, the overall transition process should be based on placing the nation in the strongest possible economic position once the world achieves Net Zero Carbon conditions.

This is part of the framework for the following discussion.

NET ZERO DATE FOR TRINIDAD AND TOBAGO

Given the fact that the oil and gas resources of Trinidad and Tobago can be expected to be largely exhausted by 2060, it would not be an heroic policy to join China and Brazil in targeting the year 2060 as the year in which Trinidad and Tobago hopes to achieve Net Zero Carbon.

Even if Trinidad and Tobago manages to keep their gas-based industries going based on imported natural gas from Guyana or Venezuela, the world can be expected to buy only "green" or "blue" ammonia and methanol at that time ("blue" means the production of ammonia with the carbon capture and storage of CO2).

Therefore, it can be recommended that Trinidad and Tobago officially adopts 2060 as the Net Zero target date. This would be a beneficial matter to establish during the next COP 26 meeting.

This definition would also give substantial guidance to the overall transition policies that Trinidad and Tobago might follow.

FISCAL AND OTHER TERMS FOR OIL AND GAS

Fiscal Terms for Natural Gas. The dramatic long-term future decline of anticipated natural gas production and the huge importance of the gas-based industries for Trinidad and Tobago make it imperative to promote the production of natural gas relentlessly.

Trinidad and Tobago has established a minimum royalty of 12.5%, which needs to be paid under any circumstance. This royalty is a payment that is deducted for determining the profit oil or profit gas share under PSCs.

The proposed overall cost limit of 80% for the deep water bid round is attractive from an international perspective. It can be recommended that this 80% is determined on the basis of the total production. This means that the profit share remaining after the deduction of the royalty and maximum costs would be 7.5%. This would be subject to the sharing of the profit gas and profit oil. Of course, as costs are being recovered and become less than 80%, the profit share goes up correspondingly.

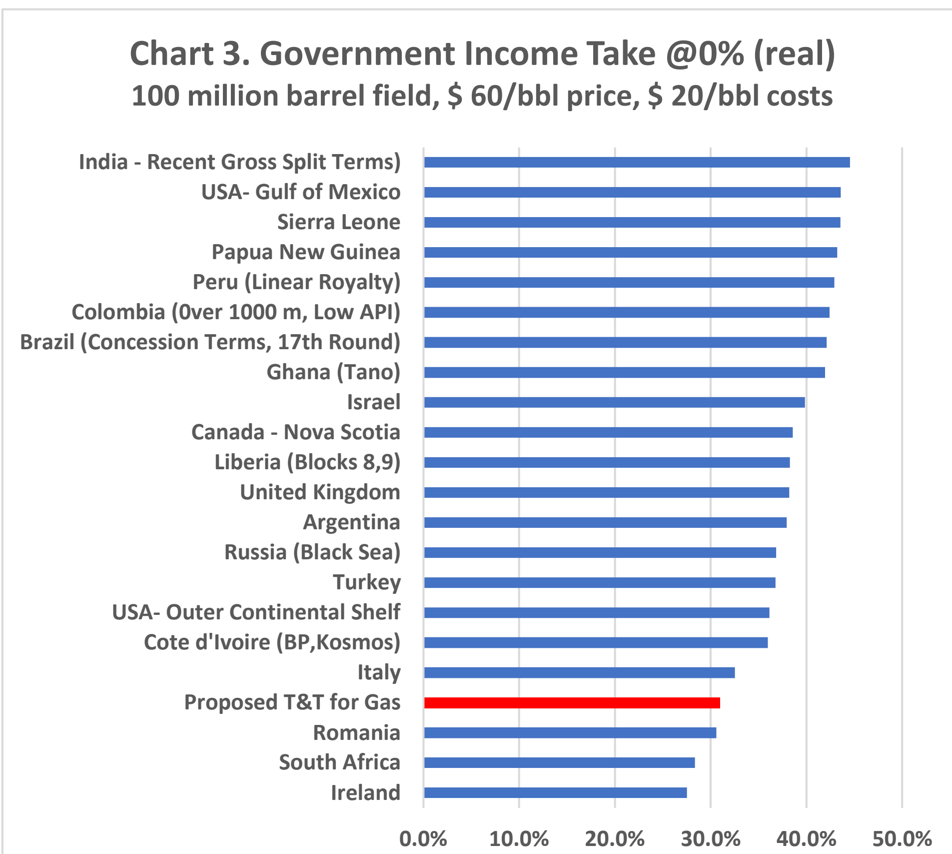
For the anticipated deep water competitive bid round, it can be recommended that the profit gas share be fixed at 15%; which means it should not be subject to production level and price variation. It should not be a bid variable. A maximum opportunity should be created to make deep water gas economic, even if this may result in some exceptional cases in a "gas windfall profit". The focus should be on promoting gas production.

Such a level of profit gas would create an overall government take of about 31% under conditions of an 33.3% cost/price ratio (for instance at costs of $ 1 per Mcf and a gas price of $ 3 per Mcf).

Chart 3 shows the typical level of government take for a cost/price ratio of 33.3% for oil. Gas would usually have a somewhat lower government take than oil, in particular gas that is used domestically. Therefore, this level is reasonable.

Chart 3 shows the typical undiscounted and un-risked government income take on a real basis for oil of these countries. The government take is ranging from 27% to 45% for typical deep water terms (government participation is not included in this chart, only direct government income). These countries include the United States, the UK, Canada (Nova Scotia), Argentina, Brazil (Concession Terms), Colombia, India, Israel, Romania, Russia (Black Sea), Turkey, Ghana, Cote d'Ivoire, Sierra Leone, Liberia and South Africa. Of course, there are countries with a higher government take (such as Suriname, Egypt, Norway or Malaysia), but there is no evidence that the offshore geology of Trinidad and Tobago is better than or equal to such countries.

Even under this system it is likely that in many cases non-associated gas fields will not be economic due to low gas prices.



Fiscal Terms for Oil. As indicated earlier, the main option for the country to increase oil production are possible attractive oil discoveries in deep water. Given the international framework discussed above, it is indeed essential to have the planned deep water competitive bid round as soon as possible.

It is important to target fiscal crude oil terms correctly, because significant licensing activity can be expected from other countries and acreage is available that in some cases may be more attractive than deep water offshore Trinidad and Tobago.

The only model PSC available is so far the 2014 model on the MEEI website. It seems that a different model may be used for the bid round. The fiscal information provided on the official PowerPoint is limited and consist only of one slide (slide 36).

However, based on this information a number of comments can be made.

In general, the exploration phase should not be burdened with excessive fiscal charges. Given the possible high geological risk, such charges affect the overall fully risked economics negatively.

The concept of a signature bonus is very negative and therefore this concept should not be applied. During the bid process, the focus should be on the work program and the profit oil share.

Article 21.1 of the 2014 model PSC contains a wide variety of charges during the exploration period. Many of these charges should be eliminated.

The scheme of the 2014 model of making the profit oil share to government a function of the level of production and price can be recommended, since it ensures that government receives a fair share under favorable circumstances. However, the scheme needs to be adjusted to provide increased protection for investors under the circumstances to be expected during the next thirty years. This means, there should be more emphasis to permit companies to survive under low prices and high costs.

If pre-bid minimum terms are being set for the profit oil share, it should preferably not be higher than 25%, creating a competitive government take of about 39% (compared with Chart 3). Companies can then bid upwards for the different price and production classes.

It is indicated in the MEEI PowerPoint, that the PSC terms override other fiscal provisions in case of conflict. This is important since MEEI needs to ensure the payment of taxes out of the profit share to Government. Under a government take of 31% or 39%, the profit share to Government will not be sufficient to pay these taxes.

A recommendation is for the government to introduce “leaky ring fences” in the deep water blocks bid. This would be a very significant incentive. This means that as soon as a discovery is slated for production, further exploration in different blocks can be recovered for production sharing purposes from the revenues of such discovery. This would strongly encourage follow-up exploration. This means that the profit oil and profit gas shares have to be determined per company, so companies involved in different blocks are being treated in a comparable manner.

Other terms. The duration proposed for the PSC is problematical. After a commercial discovery the PSC can be extended for a period of 25 years from the effective date. This means PSCs that would start in 2022 would terminate in 2047.

In case there is still commercial production ongoing in the PSC, it will not be possible to have an attractive bid round in 2047 for the extension of the PSC, with the world going to Net Zero by 2050. Nor are these favorable conditions for renegotiation of the PSC. It can therefore be suggested that instead an automatic 10-year renewal be granted, to properly complete the related production. If required, a further renewal can be granted afterwards, taking into consideration the target of Net Zero by 2060.

OVERALL ECONOMIC FORECAST

Population Growth. The current population of Trinidad and Tobago is about 1.39 million people. The fertility rate is a relatively low 1.70[x]. As a result, the population is not expected to grow strongly in the next decade and may reach 1.45 million by 2035. After that, it can be expected that the population will start to decline. By 2050 the population level may be about the same as today, but the average age of the population will be older and may drop to 1.2 million by 2070.

Economic Growth. The IMF estimates[xi] that the GDP per capita (PPP) by 2021 of Trinidad and Tobago will be US $ 25,883. Given the sharp decline of the expected natural gas production and the related government revenues, it will be difficult to achieve significant economic growth per capita over the next 30 years. Economic growth may rekindle after the petroleum production becomes minimal and production decline has no longer a negative effect on yearly economic growth.

The level of economic growth depends to a large degree on government policies.

If successive governments would let the economy slide with the decline of the oil and gas production, the GDP per capita (PPP) in 2050 may decline to $ 18,000 and due to the weak position of the economy at that time recover to $ 22,000 by 2070. This means the public of Trinidad and Tobago would be less wealthy in 2070 than they are today and over time there would have been a significant loss of jobs.

If, on the other hand, successive governments would be successful in attracting large scale investment to restructure the economy during energy transition, the GDP per capita (PPP) may actually continue to grow and reach $ 35,000 by 2050 and $ 56,000 by 2070. At that time the public of Trinidad and Tobago would be richer than in most European nations today and a large number of high quality jobs would have been created.

The implementation of successful energy transition policies is therefore of huge importance for the next generation(s).

RESTRUCTURING OF THE POWER SECTOR

Key to any energy transition strategy is the restructuring of the power sector.

Future Electricity Demand. The Trinidad & Tobago Electricity Commission ("T&TEC") is in charge of coordination and distribution of electricity. The power is produced by Independent Power Producers ("IPPs") with separate plants of various sizes.

The total installed capacity is 2608 MW. However, actual peak power use is only about 1400 MW. Total electricity consumption is 10,300 GWh (10.3 billion kWh).

Essentially 100% of the population has access to electricity.

The growth of the electricity demand can be expected to be modest. Even a growth of 35% in GDP over the next thirty years would require less growth of electricity demand, probably about 20%. However, the introduction of EVs would result in a significant increase in electricity use. In total the peak power requirements in 2050 can be predicted to be below the capacity that is already installed. Therefore, new capacity will not be required, other than for possible replacement of plants that need to be abandoned for operational purposes.

Current Subsidized Tariffs. The tariffs for electricity vary depending on the type of customer. Rates were established in 2009 and have not been adjusted since. Based on current US$ exchange rates, the residential tariff per kWh is determined based on the level of consumption about every 60 days. It is $ 0.039 for the first 400 kWh, $ 0.048 per kWh for the next 600 kWh and over this level $ 0.056. The commercial rate is $ 0.062 for any amount. These tariffs are in addition to certain fixed charges.

The industrial tariffs are based on a combination of capacity charges and usage charges for a variety of industrial users depending on size.

The electricity tariffs are well below typical international rates based on fully commercial conditions.

All electricity generation is based on natural gas and the gas price to utilities is subsidized about $ 1/MMBtu. This is significantly below the gas prices charged to other parties and international market conditions.

Trinidad and Tobago has so far been following the policies of most other oil and/or gas exporting countries of subsidizing energy prices to their populations. This is indeed a rather effective policy of sharing the petroleum wealth with the population. These policies are immensely popular and therefore once such policies are established it is politically extremely difficult to abandon them.

The problem with these policies is that they result in wasteful energy use.

The Government of Trinidad and Tobago is aware of these issues. The Regulated Industries Commission ("RIC") is deliberating on increases in electric tariffs and most likely will determine such in 2021/2022.

Current Framework and Renewables. It will not be possible to economically develop the renewable resources of Trinidad and Tobago for the purpose of electricity generation against a gas price of about $ 1/MMBtu, even assuming inefficient power plants.

Renewables would primarily compete against the cost of fuel and other operating costs of already operating plants, because no new installed capacity is required.

Without significant change in current policies, the introduction of renewable energy is uneconomic in this framework.

The long-term consequences of not developing the renewable resources could be disastrous, since the current gas-based electrical generation capacity will become useless when natural gas production becomes insufficient and the country would not have prepared for the eventual large-scale change-over to renewables.

The government is aware of the need to develop renewables and an initial relationship has been entered into with Shell-BP for the creation of 130 MW of renewable power[xii].

Current National Electricity Policy. The best statement of the national policy of Trinidad and Tobago can be found in the document supporting the Intended Nationally Determined Contribution ("INDC") under the Paris Agreement[xiii], which states:

"Trinidad and Tobago already produces all of its electricity from natural gas and is working towards achieving greater efficiency through combined cycle generation at all its power plants. This sector should therefore be at the edge of low carbon emissions with renewable energy being the next stage for reducing emissions even further."

The fact that Trinidad and Tobago already produces all of its electricity from natural gas is indeed an important statement in a worldwide context whereby many countries (USA, China, etc.) still use coal as an important source for electricity generation.

The policy shows the anticipated sequence: first promote increased efficiency of power generation and next promote renewable resources. This seems indeed a rational sequence. Nevertheless, the National Climate Change Policy adopted by the country does not show detail of the time line and suggested specific measures to achieve this overall goal.

Implementing the National Electricity Policy – Step 1. Conceptually, the first step is simple: stop subsidizing energy. Natural gas delivered to IPPs should be competitively priced. Tariffs to residential, commercial and industrial customers should be adjusted upward accordingly to permit IPPs to have profitable operations.

The competitive natural gas price would be low compared to gas prices in Europe or Asia and therefore electricity tariffs would still be low compared to international conditions, but not excessively low.

Assuming the first step would succeed, what would be the next step?

Implementing the National Electricity Policy – Step 2. Apart from implementing the 130 MW renewable energy agreement, there is indeed no panic to rush into utility scale renewables. A waiting period of 5 years before the next major renewable utility scale investment would be made, maybe beneficial for a number of reasons.

Firstly, the increase in tariffs will encourage energy efficiency. Customers will become more careful using electricity. This may slow down electricity demand and the waiting period would permit to analyze the trends.

Secondly, higher electricity tariffs may encourage home owners and businesses to start installing their own residential or commercial solar panels. This should be furthermore encouraged with the creation of feed-in tariffs, so excess solar can be sold back to the grid. It is beneficial to see for a few years how such private investments in solar energy would work out.

Thirdly, the program of improving efficiency in power generation would receive a strong impetus with the increased costs of natural gas, and it is beneficial to see how moving into combined cycle generation progresses. It can be recommended to consider whether special tax incentives can be created to increase the interest in such investments.

Finally, anyway, it is expected that the cost of solar energy will further decline. So, nothing is economically lost waiting for a few years.

The waiting period would also permit to monitor other issues, such as the introduction of EVs in Trinidad and Tobago and the response to the proposed improved fiscal terms for deep water.

Also, it can be recommended to do a detailed offshore wind survey in order to better plan a strategy for the eventual production of offshore wind energy and to define the respective license areas.

Implementing the National Electricity Policy – Step 3. As part of the overall policy to achieve Net Zero by 2060, it can be recommended that by 2050 all power generation should be based on renewables. Therefore, the third step is to move gradually to this objective in three phases, as follows:

- The priority should be to develop utility scale solar energy from 2025 onwards, which is relatively low cost as explained above.
- Next, would be the development of somewhat higher cost offshore wind energy, and
- Finally, the development of utility scale renewable energy storage to be able to produce 100% renewable electricity on a 24/7 basis by 2050.

As will be discussed below, the conversion of the power sector by 2050 is important, since priority of natural gas use should be given to methanol plants and cement industries, since these industries have few other options, but to use natural gas.

The transformation of the power sector should be part of a national strategy, in which the long-term interest should override possible short term economic considerations through legislation or by other means. This would make the introduction of carbon taxes not necessary, that would otherwise be required.

By 2025 it should be possible to install utility scale solar for less than 4 cents per kWh. The country may introduce variable electricity tariffs with lower tariffs during the day when low cost solar is available. This would promote the optimal use of solar energy.

Offshore wind would be introduced somewhere between 2030 and 2035 depending on the results of the offshore wind survey. An important R&D development for offshore wind is the creation of larger turbines that can benefit from the higher wind velocities at greater height.

An example is the recent Vestas 15 MW turbine[xiv] which has a swept area of 43,000 m2 and a production capacity of 80 GWh per year. Its rotor diameter is 236 meter and the cut-in wind speed is 3m/s. By 2030 there might be even larger turbines that can operate at lower costs; such as 5 cents per KWh or less.

As will be discussed below, offshore wind may be attractive to develop earlier as part of an overall green hydrogen or green ammonia scheme.

Major energy storage may be required from 2040 or 2045 onwards. With respect to renewable energy storage, an important development is the use of Electric Vehicles as backup for energy storage. With at least 70% of the vehicles EVs by 2050 and assuming variable power tariffs, owners of EVs may find it attractive to use their vehicles for energy storage. This means utility scale storage requirements by 2045 may actually be modest.

A huge amount of R&D is taking place to lower cost of energy storage. For instance, the US Department of Energy[xv] has published a roadmap to achieve low-cost storage by 2030, called "Energy Storage Grand Challenge". With respect to utility scale long term storage the goal is to achieve a cost by 2030 of 5 cents kWh. This is for a 100MW-10 hour storage system. A wide variety of R&D storage systems is supported by the program. It might therefore be that by 2040 the cost of renewable energy storage will be relatively modest; for instance, 4 cents per KWh.

RESTRUCTURING THE OTHER SECTORS

A variety of policies is required for the other sectors.

Electric Vehicles ("EVs"). Given the fact that there is ample power generating capacity, the incremental costs of producing electricity, even based on competitive natural gas prices, is remarkably low. Therefore, it is beneficial for Trinidad and Tobago to promote the use of EVs based on nationally produced low-cost electricity, instead of importing high-cost petroleum products, such as gasoline and diesel. Also, typical driving distances on the islands are well below the range of current EVs.

Assuming Step 1 is successful and electricity is no longer subsidized, it can be recommended to promote the use of EVs. A successful way of doing this would be to follow the example of Norway, which has one of the highest uses of EVs. Norway achieved this objective by making the purchase and import of EVs exempt from VAT. Trinidad and Tobago could do the same.

As the power sector moves gradually to renewable energy, the EVs would increasingly contribute to lowering CO2 emissions. The goal would be to have 100% of the road transport electric by 2060 based on 100% renewable energy (or based on hydrogen in some cases).

Electric Planes and Taxis. Electric planes and air taxis are increasingly being considered.

Vertical Aerospace, UK, has pre-orders for 1000 aircrafts from American Airlines, Virgin Atlantic and others for its air taxi, VA-X4[xvi]. This is a 4 person aircraft plus pilot that can take off vertically like a helicopter but flies like a plane at 200 miles per hour over a maximum distance of 100 miles. It is totally electric and carbon free.

Such air taxis seem just about ideal to fly between Piarco Airport and hotels or other locations on Tobago. VAT exemption for purchasing such electric air taxis should be introduced.

For larger distances hydrogen planes are now being planned, among others, by Airbus.

Ferries Based on Renewables. The ferries operating between Trinidad and Tobago could be converted within 15 years to the use of renewable energy. Ferries could operate on electricity and on hydrogen. Also, green methanol is being considered as a possible marine fuel. Ellen, an electric ferry in Denmark[xvii] currently can transport up to 30 cars between islands. Switch Maritime in California is building the first 70-foot hydrogen fuel cell ferry for the Bay area.

Cement. Cement industries are difficult to convert to renewable energy. It is therefore, that this industry should have priority in terms of supplies of natural gas relative to other sectors. Internationally, considerable research is being done as to how to convert this industry to renewables. Therefore, eventually the country may benefit from such international developments. Alternatively, carbon capture and storage ("CCS") may have to be introduced.

Gas based industries and LNG exports. The gas-based industries relate to ammonia, methanol, fertilizer and melamine production. The fertilizer and melamine production depend in turn on ammonia production.

Depending on the development of the natural gas production, the international ammonia market and policies of ammonia importing nations, Trinidad and Tobago may find it necessary to convert to the production of "blue" ammonia, which is ammonia production with CCS of the emitted CO2.

Trinidad and Tobago has already considerable experience in CO2 injection and storage related to the enhanced oil recovery ("EOR") in particular reservoirs[xviii]. Further EOR opportunities are being evaluated and appear possible. However, even without the possibility of EOR, the injection of CO2 for climate change reasons is amply possible in the country. If it is beneficial to move to blue ammonia production, there are no major technical obstacles to such a scheme.

As described earlier, the future LNG markets can be expected to be highly competitive.

However, it can be expected that LNG exports and gas-based industry production will gradually decline over the next twenty years, subject to the possible development of a green ammonia industry, to be discussed below.

The level of LNG exports would primarily depend on the level of gas production and the future production of ammonia and methanol. Assuming current ammonia and methanol would not decline, LNG exports would terminate around 2035.

In principle, the gas-based industries could be supplied with imported gas from Guyana and Venezuela, depending on gas pricing and international market conditions for ammonia and methanol. However, Guyana is determined to land associated natural gas from their large oil fields with priority in country and has already selected the site for the relevant infrastructure. Therefore, this scheme is questionable. In case of gas imports, they would be most likely from Venezuela.

Refining. It can be expected that within a few years international oil production will start to decline. This means the world will have to deal with an ongoing structural over-capacity of refining operations. Furthermore, unless there are major discoveries in deep water, local oil production will continue to decline. This is not an attractive environment to rekindle refining operations that were recently closed.

CARBON TAXES

Most economists, as well as the World Bank, would recommend the introduction of carbon taxes as part of an overall climate change policy.

Given the fact that it may be difficult enough to move Trinidad and Tobago out of subsidized electricity, this seems a “bridge too far” as part of the energy transition policy. Anyway, the expected rapid decline of natural gas and oil production will force the country out of fossil fuels over time.

The proposed legislative policy with respect to the transformation of the power sector would make the introduction of carbon taxes not necessary.

An important matter is, however, the international development of CBAM policies. If major duties would be introduced in OECD countries with respect to import of gas-based products from Trinidad and Tobago, it would be better to pay carbon taxes to Trinidad and Tobago than duties to foreign governments.

POSSIBLE NEW INDUSTRIES

Green Hydrogen. Green hydrogen can be produced based on renewable energy and water electrolysis. Currently, the production of green hydrogen is not yet economic. However, it is believed that prior to 2030, the costs of green hydrogen production can be brought down to $ 2/kg, which would make green hydrogen economic[xix].

The main costs of green hydrogen are the electrolysers and the cost of renewable energy. The economics of hydrogen production depends on the efficient and longest possible use per day of the electrolysers.

Therefore, ideally stable and low-cost renewable energy is required. The joint development of wind and solar energy, to create the maximum daily availability of renewable energy, is beneficial. Alternatively, possible cheap storage methods can be introduced for solar energy.

In principle a solar + wind + green hydrogen project would be possible. As indicated above, the costs of renewable energy can be expected to be about average for Trinidad and Tobago and therefore the country would have difficulty competing with the ultra-low-cost renewable countries (Chile, Australia, Oman, etc.) for large scale hydrogen exports. Nevertheless, the cost of transporting hydrogen by liquid hydrogen carriers is relatively expensive. Therefore, Trinidad and Tobago may be able to competitively produce green hydrogen for local use and for the Caribbean market.

Possible local use of green hydrogen in Trinidad and Tobago may be important in several sectors. In case hydrogen planes develop in the future, the country would be able to supply the hydrogen. NewGen Energy[xx] is already planning to produce green hydrogen for delivery to ammonia plants.

The development of green hydrogen should be strongly promoted, preferably with tax incentives.

Green Ammonia. Having already in place a large ammonia industry and industries using ammonia derivatives, may place Trinidad and Tobago in a competitive position to migrate from a gas-based ammonia industry to a green ammonia industry. The production processes of gas-based ammonia and green ammonia are very different. However, associated activities, such as storage and transport would be the same. Therefore, there might be commercial potential for solar + wind + green hydrogen + green ammonia projects.

Green ammonia projects are already taking place. In Spain, Iberdrola and Fertiberia are investing in a plant which will produce a total of 0.2 million tons ammonia per year based on 100 MW solar, 20 MWh storage and 20 MW electrolysis[xxi]. The CIP group in Denmark will built a 1000 MW green ammonia plant based on offshore wind in Esbjerg. In Saudi Arabia[xxii], ACWA, Air Products and NEOM have teamed up to produce the largest green hydrogen project to date; a $ 5 billion investment in a plant that will produce 650 tons of hydrogen per day as well as 1.2 million tons per year of green ammonia, based on solar and wind energy.

Therefore, green ammonia could be the key to long term survival of the current ammonia and ammonia derivatives industries in Trinidad and Tobago. The life of LNG exports could be extended if green ammonia could be started during the next ten years in order to replace regular ammonia production.

Also, the development of green ammonia should be strongly promoted, possibly with tax incentives.

Green Methanol. The production of green methanol based on green hydrogen would also be a possibility. However, in this case access to large volumes of low cost CO2 would be a problem. In the post Net Zero world the logical combination is to combine power plants based on urban waste or biomass with methanol plants using the CO2 produced.

One such methanol plant is already under construction in Sweden[xxiii] slated to produce 50,000 tons of methanol per year, based on a district heating plant of Oevik Energi combined with green hydrogen produced by Liquid Wind. The methanol will be used for marine transport in vessels converted to use methanol.

It may be somewhat of a long shot to expect such a combination in Trinidad and Tobago. Therefore, natural gas should preferably be allocated with priority to methanol plants to ensure their longest possible survival. Nevertheless, if somehow green methanol could be produced, it would be a fuel of choice for marine shipping, with a good bunkering location close to the Panama Canal.

It should be noted that methanol is a considerably cleaner fuel for marine transport than low sulphur fuel oil. Therefore, in the near term the introduction of methanol (green or not) is beneficial.

Carbon Capture and Storage with direct CO2 capture from the air ("Direct Air Capture", "DAC"). Direct capture of CO2 from the air for underground storage is still somewhat of an uncertain concept. Since CO2 is only a small percentage of the air (412 ppm today), it is very costly to capture and separate it. Cost estimates vary between $ 100 and $ 1000 per ton CO2; well in excess of current carbon tax levels.

Nevertheless, a variety of companies are working on the concept. For instance, a one million ton CO2 plant based on DAC is planned to start in 2026 in Scotland[xxiv]. The investors are Carbon Engineering and Storegga. The CO2 will be injected off the Scottish coast in depleted petroleum formations. It should be noted that Trinidad and Tobago would have been a much better location for this project due to the cheaper reinjection potential.

Given the experience and possibilities related to CO2 underground storage in Trinidad and Tobago, the country may be in a good position to benefit from other similar projects.

Green Synthetic fuels. Assuming Trinidad and Tobago will be able to establish commercial green hydrogen production, the next step would be to produce synthetic fuels. In particular, synthetic jet fuel, as alternative to hydrogen, may be in strong demand in the future. Some initial synthetic jet fuel production is already taking place. The Klesch Group[xxv], operating the Heide oil refinery in Northern Germany, is perfecting this process based on hydrogen from local wind farms. Lufthansa committed to use this synthetic fuel for 5% in their jet fuel consumption within 5 years.

ENERGY TRANSITION POLICIES FOR TRINIDAD AND TOBAGO

In summary, the following policies are critical for a successful energy transition in Trinidad and Tobago:

1. The year 2060 should be adopted to achieve Net-Zero carbon conditions in the country.
2. By 2050 all power generation should be based on renewables.
3. As the production of natural gas declines, priority should be given for use by methanol plants and cement industries.
4. Subsidization of electricity should stop and electricity tariffs should be adjusted upward.
5. A national strategy for gradual transformation of the power sector should be backed up by possible legislation to overcome short term economic considerations.
6. The planned 130 MW renewables should be followed through.
7. VAT exemption should be given for the purchase of electric vehicles and air taxis.
8. Special tax benefits could be considered for the promotion of combined cycle gas plants.
9. Deep water gas development should be based on a fixed gas profit share of 15%, while the minimum oil profit share should not exceed 25%.
10. Deep water PSCs should be renewed automatically upon their termination.

11. Preferably, a variable daily electricity tariff should be introduced to promote solar energy.
12. A detailed survey of offshore wind should be carried out to determine license areas.
13. A standby capability should be maintained with respect to CCS in case international developments require the export of blue ammonia.
14. The development of green hydrogen and green ammonia should be strongly promoted with tax incentives.
15. There is no need to introduce carbon taxes, unless international CBAM developments make this necessary.

ENERGY TRANSITION TIMELINE

The future is highly uncertain. Results of R&D could dramatically impact on forecasts with unknown and unpredictable results. Nevertheless, based on current understandings of technological developments the following transition timeline would be a possibility for Trinidad and Tobago:

2022 - The Government would adopt elimination of subsidization of electricity prices, VAT exemption would be established for EVs and electric air taxis, fiscal tax incentives would be provided for combined cycle gas plants and green hydrogen and green ammonia production, the initial 130 MW renewables would continue to be implemented, the deep water oil and gas bid round would start, feed in tariffs would be established for private solar generation and during COP 26 T&T would commit to be Net Zero carbon neutral by 2060 and 100% renewables for electricity generation by 2050.

2025 – T&TEC would commit to start development of 20% renewables for electricity production. Licence areas for offshore wind would be established.

2030 – T&TEC would commit to the development of 40% renewables, an offshore bid round for wind energy would be held and wind energy production would start soon afterwards, the first commitments would be made to invest in green hydrogen and green ammonia production, EVs would become 20% of the imports, the first electric air taxis would operate. Daily variable electricity tariffs would be introduced.

2035 – Exports of LNG would terminate (assuming gas would be used for ammonia and methanol production). Fertilizers and melamine would be produced based on green or blue ammonia in order to avoid CBAM levies. The ferries between Trinidad and Tobago would be electric or operate on hydrogen or other renewable marine fuel.

2040 – Large utility scale renewable energy storage projects would be undertaken. T&T would commit to 70% renewables. All ammonia exports would be based on green hydrogen. EVs would be 50% of all imports. T&T would fuel large distance aircraft at Piarco airport with locally produced hydrogen.

2045 – T&TEC would commit to develop 100% renewables. First large-scale DAC project would be initiated based on credits against international carbon taxes. T&T would export significant volumes of green hydrogen to Caribbean countries.

2050 - All electricity production would be based on production of renewables. Gas use would be restricted to methanol plants and cement industries with some CCS offsets. EVs would consist of 70% of imports. All local air transport would be electric. T&T would start to export synthetic jet fuel.

2060 - T&T would achieve Net Zero Carbon. All imported vehicles would be EVs. All oil and gas production would stop (or alternatively small remaining production would be offset with CCS). Methanol production would cease. Cement would be based on hydrogen and/or renewable methane (methane produced based on renewable energy). T&T would be a large green ammonia exporter to world markets and green hydrogen and synthetic fuels exporter to the Caribbean. T&T would have large DAC operations.

2070 - Population of T&T would be 1.2 million people. As a result of the successful implementation of the transition policies, GDP per capita (PPP) would be $ 35,000 by 2050 and $ 56,000 by 2070 and many high quality jobs would be created.

WHAT IF?

What if successive governments of Trinidad and Tobago do not implement an aggressive energy transition policy?

What if the country sleep-walks toward 2050 in the mistaken belief that somehow oil and gas production will continue to support cheap electricity, substantial government budgets and large exports of LNG, ammonia, methanol and fertilizers?

The most important conclusion of this report is that Trinidad and Tobago does **NOT** have a competitive advantage in producing renewable energy. Ultra-low-cost solar and wind are in available in other countries. Reasonable solar cost exists in most of the tropics and subtropics. Attractive wind conditions exist in many of the temperate zones. Cheap biomass can be produced by most large agricultural exporters. Large DAC projects can be created in all nations with depleted oil and gas reservoirs or basalts or peridotites that absorb CO2.

Therefore, renewable methane, green hydrogen, green ammonia, green methanol, green fertilizers, green synthetic fuels and DAC projects will be produced in the countries that are most aggressive and successful in attracting the large scale private investments required for energy transition.

If Trinidad and Tobago does not implement such policies, it will wake up in 2050 to discover that (as an example):

- The methanol and cement industries have to close for lack of natural gas,
- Electricity production has to initiate a massive conversion to renewables, at significant costs at a time the country can no longer afford it,
- The USA imports green ammonia and fertilizers from Puerto Rico because the USA protected this industry with CBAM levies against ammonia and fertilizer imports from Trinidad and Tobago and therefore the ammonia and fertilizer industries in T&T closed down in 2040,
- The Dominican Republic has cornered the Caribbean green hydrogen market,
- Barbados is the hub for hydrogen supplies for large distance aircraft,
- Large DAC projects have been implemented in Peru, Texas, Scotland, Iceland[xxvi], Oman[xxvii] and Malaysia, but not in T&T,
- Colombia is the main exporter of synthetic jet fuels in the region based on the excellent solar potential of La Guajira,
- The GDP per capita of Trinidad and Tobago is down to $ 18,000,
- The economic prospects for 2070 are grim because the country has not established competitive industries based on renewables and has not prepared its human resource base to be successful in the Net-Zero world. The per capita GDP in 2070 may be at best $ 22,000 and many jobs would be lost.

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BIOGRAPHIES

Professor Andrew Jupiter. Professor Andrew Jupiter is the Coordinator of the Petroleum Studies Unit and directly oversees the MSc Petroleum Engineering, and MSc and Postgraduate Diploma in Petroleum Engineering and Management programmes at The University of the West Indies (UWI).

Professor Andrew Jupiter received a BSc in Natural Sciences and a Postgraduate Diploma in Petroleum Engineering from The UWI and also holds a Masters of Engineering Degree in Mineral Engineering Management from The Pennsylvania State University.

He was the recipient of the Chaconia Medal (Gold) in 2016 (Public Service). He was appointed as Distinguished Fellow in 2013 and Professor of Practice by The UWI. He is the holder of the Methanol Holdings Trinidad Limited (MHTL) Dennis Patrick Chair in Petroleum Engineering.

Professor Andrew Jupiter was the Permanent Secretary of the Ministry of Energy and Energy Industries Trinidad and Tobago from 1998 to 2004. He was also President of National Energy Corporation of Trinidad and Tobago Limited (NEC) from 2009 to 2012. Professor Andrew Jupiter has held the position of Director on various State Boards.

He was one of fifty (50) public servants to be honoured at the Outstanding Public Service Awards Ceremony and Gala by the Government of Trinidad and Tobago for the country's golden 50th year anniversary of independence. He is a member of the Society of Petroleum Engineers, Fellow of the Energy Institute, Fellow of the Institute of Materials, Minerals and Mining (FIMMM), and a member of the Association of International Petroleum Negotiators. Professor Andrew Jupiter is married to Dr Clarise McMillan-Jupiter.

Dr. Pedro van Meurs and Van Meurs Energy (VME). Dr. Pedro van Meurs received his Ph.D. *cum laude* from the State University of Utrecht in 1970. From 1970 to 1973 he was Chief of the International Petroleum Developments Division, Department of Energy, Mines and Resources, Federal Government of Canada.

Since 1974 Dr. van Meurs and Van Meurs Energy have provided petroleum consulting services to governments of 90 different jurisdictions, including Alaska, Alberta, Bangladesh, Bolivia, the Canadian Western Arctic, China, Gabon, Guatemala, Kuwait, Mexico, Newfoundland, Oman, Pakistan, Peru, Russia, Thailand and Trinidad and Tobago. Dr. van Meurs is currently lead advisor on the Nigerian Petroleum Industry Bill.

VME has the largest and most comprehensive world petroleum fiscal comparative analysis data base consisting of 790 fiscal systems in 169 countries and territories, featuring extensive sensitivity analysis capabilities on field size, costs and prices.

During the last 40 years Dr. van Meurs has provided highly regarded courses in fiscal systems various times per year for 20 – 40 participants per course on an open access basis, currently through London Petro Academy in London, UK, as well as on an in-house basis for governments and companies. During the COVID epidemic the course are provided on a virtual basis.

Dr. van Meurs has assisted as expert witness for governments and companies in 9 arbitration cases.