Project Documents

Opportunities for more sustainable infrastructure and logistics of Hydrocarbons in the Caribbean:

The case of Trinidad and Tobago

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At the time of publication in October 2017 the Caribbean region was still reeling from the impacts of Hurricanes Irma and Maria which devastated several islands, with the full cost of long-term economic recovery still unclear. Aspects of this paper examine the opportunity to reduce power generation costs and ultimately improve socio-economic performance of the Caribbean region, and the findings herein do not account for the expected high costs of infrastructure restoration in the affected islands.

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Abstract

During the heyday of Trinidad and Tobago's natural gas industry, plans were afoot to export LNG to Jamaica and gas via pipeline to the Eastern Caribbean. In recent years T&T has been faced with gas supply shortages and both projects have been shelved. Despite this, Jamaica and Barbados have forged ahead to implement small-scale LNG solutions to combat the high costs and environmental issues associated imported fuel oil and diesel for power generation. However the rest of the Caribbean, in particular the CARICOM nations with their small demand, face challenges in implementing similar solutions, with the commerciality and cost of infrastructure being prohibitive to some extent.

This paper propose that natural gas is the fuel required for this urgent transition and that small-scale LNG from centralized hubs is the most viable option to gasify the Caribbean and improve its logistics. This paper also outlines the key policy and regulatory changes required, opportunities for financing, and presents cases studies of LNG implementation both in the Caribbean region and elsewhere, including project economics. The role of regional integration and particular CARICOM is examined in leading the charge – to bring the smaller countries together to consolidate volume demand, aid in policy implementation and access to international financing, and to develop commercial solutions which may include price concession within the common economic zone or leveraging of Venezuela's PetroCaribe. Furthermore CARICOM must leverage and influence supply out of Atlantic LNG in Trinidad, in particular via the Government and the National Gas Company of T&T.

1.0 Overview of the caribbean energy sector

1.1. Introduction

This paper aims to examine the opportunities for more sustainable infrastructure and logistics of hydrocarbons in the Caribbean, and in particular how valued added supply chains can reduce costs, improve access and create economies of scale and scope in support of inclusive development and structural change in the Caribbean. For this reason is important to firstly understand the unique challenges faced by Caribbean economies as it relates to energy, power generation and its link to growth and socio-economic development.

This section presents an overview of the Caribbean energy sector, and highlights the particular challenges faced by these developing states as a result of their dependence on imported fuels to meet domestic energy needs. Diesel and Fuel oil for use in power generation account for the majority of these imports, and are directly linked to both higher electricity tariffs, and higher per capita levels of greenhouse gas (GHG) emissions and air pollutants when compared to the rest of the world.

Map 1
Map of the Caribbean[1]

Source: European Parliamentary Research Service
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

The scope of this paper focusses on the 15 member states of the Caribbean Community (CARICOM), all of which, with the exception of Montserrat[2], form part of the Small Island Developing States (SIDS). The cases of the Dominican Republic and Puerto Rico are addressed separately in Section 3.3.

Table 1
Gross Domestic Product (GDP) and growth in CARICOM (sorted by growth)

Country	GDP (2016; current prices) *(in Billion US$)*	GDP per capita (current prices) *(in US$)*	Population *(millions)*	GDP Growth 2017 *(Percentage)*
Trinidad & Tobago	21.748	15 839	1.373	-2.3
Suriname	3.641	6 373	0.571	-0.2
Bahamas	9.172	24 631	0.372	1.4
Haiti	7.897	719	10.983	1.0
Jamaica	14.272	5 018	2.844	1.6
Barbados	4.759	16 938	0.281	1.5

[1] Montserrat, although an overseas British territory, is a member of CARICOM.
[2] Montserrat is a member of CARICOM but is not classified as a Small Island Developing State.

Table 1.0 (conclusion)

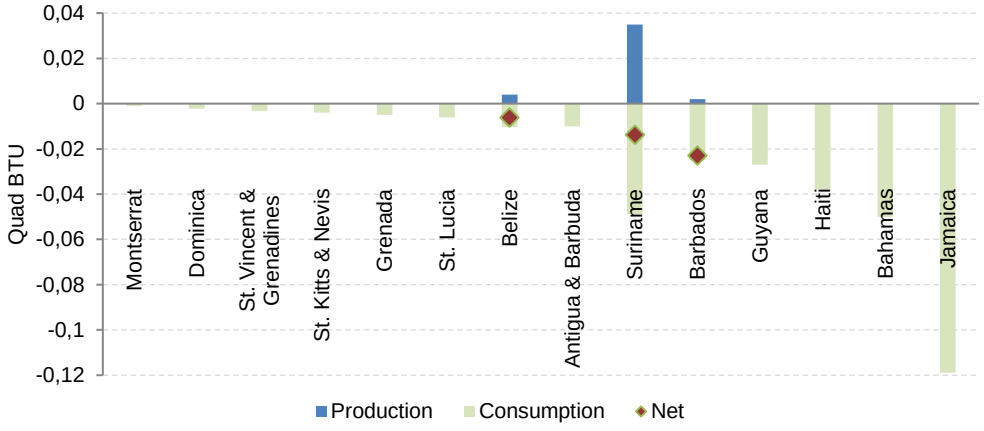
Country	GDP (2016; current prices) in Billion US$	GDP per capita (current prices) in US$	Population (millions)	GDP Growth 2017 (%)
St. Vincent & Grenadines	0.809	7 342	0.110	3.0
St. Lucia	1.428	8 135	0.176	1.5
Grenada	1.089	10 127	0.108	4.2
Antigua & Barbuda	1.454	15 932	0.091	5.0
Dominica	0.539	7 621	0.071	-3.0
Belize	1.829	4 724	0.387	3.2
Montserrat	0.063	13	0.005	3.7
Guyana	3.591	4 662	0.770	2.9
St. Kitts & Nevis	0.951	16 704	0.057	1.9

Source: IMF[3] (2017), ECLAC[4] (2016) & UN[5] (2014).

1.2. Primary Energy

With its well-developed oil and natural gas sector, Trinidad & Tobago (T&T) is the only net exporter of energy in CARICOM. The other 14 member states are net importers of energy, including Belize and Suriname despite their indigenous production. Such dependence on imported energy increases the vulnerability of these nations to oil and commodity price fluctuations, and put increased pressure on public debt and foreign exchange reserves.

Figure 1
CARICOM (excl. T&T at +0.73 Quad Btu)
Primary Energy Production & Consumption 2014



Source: US Energy Information Administration (EIA).

3 International Monetary Fund, World Economic Outlook Database, April 2017 (except Montserrat).
4 Economic Commission for Latin America & Caribbean, October 2017 (GDP growth rates, except Montserrat).
5 United Nations Data portal, 2014 (Montserrat indicators).

1.3. Power Generation

Power generation in CARICOM states is heavily reliant on imported diesel and fuel oil, with the exception of Trinidad & Tobago which generates 100% of its power from domestic natural gas production. Of the approximately 5.5 Giga-Watts (GW) of installed capacity in the region, 47% (or 2.6 GW) is linked to diesel and fuel oil. By excluding Trinidad and Tobago's 2 GW of installed power generations capacity from natural gas, CARICOM's remaining 2.5 GW of installed capacity would in fact comprise 75% diesel and fuel oil.

Table 2
Usage of Diesel / Fuel Oil in CARICOM

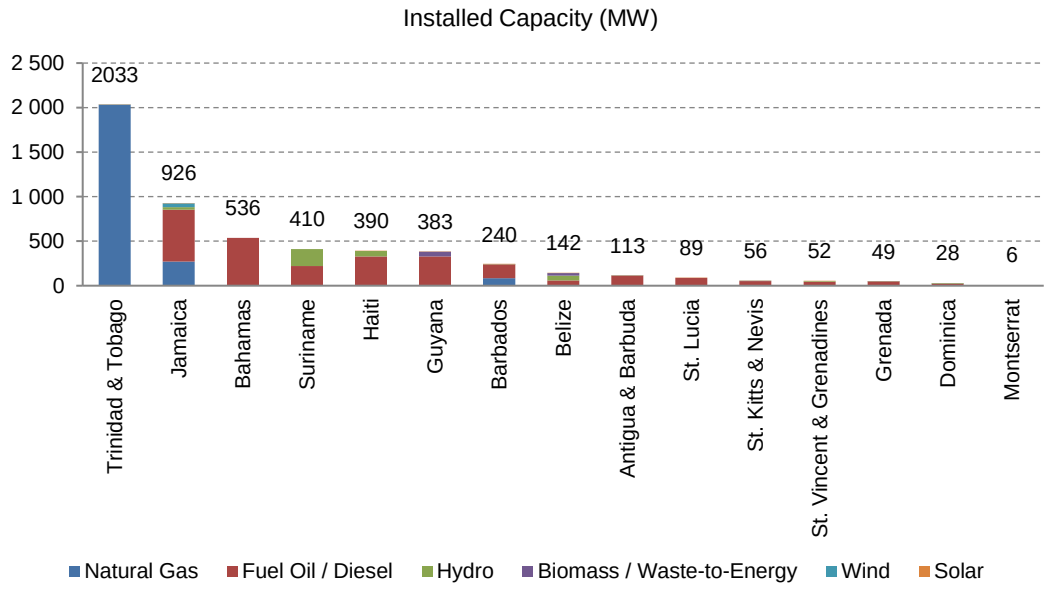
Region	Installed Power Generation Capacity (MW)	of which is Diesel/Fuel Oil (MW)	Percentage Diesel/ Fuel Oil
CARICOM	5 452	2 581	47
CARICOM (excluding T&T)	3 419	2 581	75

Source: Adapted / updated from C-SERMS[6] / Worldwatch Institute.

Both Barbados and Jamaica also have installed power generation capacity that utilizes natural gas, with the latter having imported its first shipment of Liquefied Natural Gas (LNG) for conversion to power by the 120 Mega-Watt (MW) Bogue Power Plant in Montego Bay in August 2016.

Hydroelectric power in Belize, Dominica, Haiti, Jamaica, St. Vincent and Suriname, accounts for six (6) percent of CARICOM's installed capacity, while other renewable sources such as Biomass / Waste-to-Energy, Solar and Wind make up less than three (3) percent of installed capacity.

Figure 2
Installed Power Generation Capacities in CARICOM



Source: Adapted / updated from C-SERMS/Worldwatch Institute.

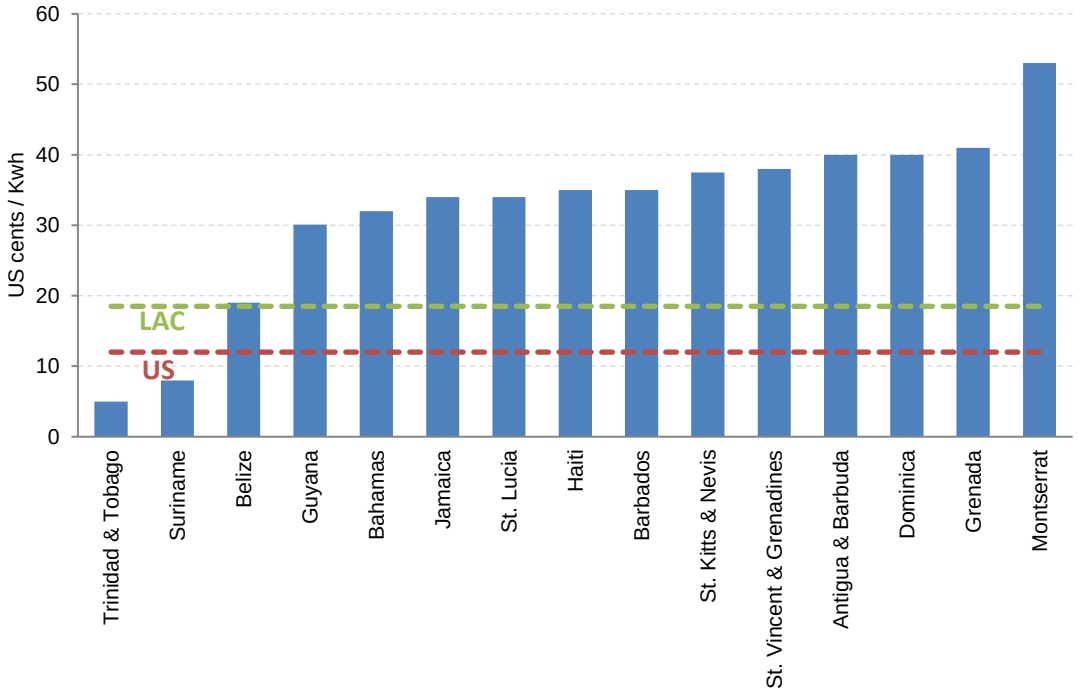
[6] C-SERMS is the "Caribbean Sustainable Energy Roadmap and Strategy" published by Worldwatch Institute, 2015.

The net forecast for power generation is set to grow across the region (including non-CARICOM countries), with a compounded annual growth rate of about 3.7% out to 2028 [Nexant, 2010].

1.4. Cost of electricity and socio-economic impact

Undoubtedly, imported diesel and fuel oil for power generation are directly correlated to high electricity prices. According to the Caribbean Electric Utility Services Corporation [CARILEC, 2012], residential electricity tariffs ranged from US$ 0.19 per kilowatt-hour (Kwh) in Belize to a high of US$ 0.53/Kwh in Monserrat in 2012[7]. In stark comparison, the subsidized tariff in T&T is approximately US$ 0.05/Kwh with the United States) at US$ 0.12/Kwh and the regional Latin America and Caribbean (LAC) average hovering around US$ 0.18/Kwh.

Figure 3
CARICOM Electricity Tariffs
(¢/Kwh)



Source: Adapted from CARILEC.

McIntyre, in a 2016 IMF Working Paper [McIntyre et al, 2016], has presented the macro-impact of high energy costs on the Caribbean economies, and has demonstrated how external and domestic balances have suffered in the last decade due to high oil prices. Nations who have a higher dependence on imported fuel oil and diesel are vulnerable to relatively higher rates of inflation and foreign exchange rate appreciation during oil price shocks, which ultimately impact growth, and have knock-on socio-economic effects. McIntyre goes further to conclude that high energy costs ultimately contribute to dampening competitiveness and potential growth of these Caribbean states that rely on imported fuel oil and diesel for power generation.

[7] Updated tariffs are available for select countries, but this 2012 report allows comparison among CARICOM members.

1.5. Where does the Caribbean go from here?

1.5.1. CARICOM Energy Policy

Caribbean leaders have long recognized the need to move away from such imported fuels, and as early as 2002 CARICOM began formulating a regional energy strategy, and a year later established an Energy Task Force who had the responsibility to draft a regional Energy Policy to address issues such as pricing, logistics and overall energy security. In March 2013, at the forty-first special meeting of the Council for Trade and Economic Development (COTED), CARICOM adopted an Energy Policy. The aim of this policy is to ensure that member states have access to modern, clean and reliable energy supplies at affordable and sustainable prices, and to facilitate the growth of internationally competitive regional industries towards achieving sustainable development of the Caribbean Community [CARICOM, 2013]. The policy encompassed both (a) the diversification of existing source of fuels as well as (b) the promotion of renewable sources of energy.

In 2015 at the Paris Climate Conference (COP21), the member states of CARICOM adopted the Paris Agreement on Climate Change which laid out the commitments for nations to limit their greenhouse-gas emissions and contain the impact of global warming. The agreement allows developing nations and SIDS (including CARICOM states) to access funding that would hasten the transition to green technologies to reduce emission, and it is doubly important for CARICOM as the island nations are the most susceptible to rising sea levels as a result of global warming. The impetus is now there, and CARICOM is well poised to move away from fuel oil and diesel in power generation, to cleaner and more sustainable fuels.

1.5.2. Future role of Natural Gas

The topic of whether and when Renewable Energy (e.g. Solar, Wind, Wave, Geothermal, etc.) would replace fossil fuels (Oil, Natural Gas and Coal) is a hotly debated one. While it is clear that the cost of implementation renewable energy technologies is coming down rapidly [Timmons et al, 2014], there is industry consensus that natural gas would have an important role to play as a 'bridging' fuel [Pierce, 2012]. The rate at which renewable energy phases out fossil fuels is a factor of global climate change targets, domestic energy policies, and the economics of investment away from traditional fossil fuel-based infrastructure.

The concept of a 'bridging' fuel is based on the fact that natural gas as a fossil fuel inherently emits significantly less greenhouse gases and atmospheric pollutants when compared to oil and coal. The expectation is that while renewable sources of energy will ultimately by the main source of energy in the long-term, it is in the medium-term that natural gas would be utilized to make a gradual step away from oil and coal.

The International Energy Agency predicts that demand for natural gas (when compared to 2014) would increase by 49% in 2040 in a New Policies[8] scenario, by 63% in 2040 in a Current Policies[9] scenario, and even by 14% in a decarbonisation[10] scenario (Table 3). Thus for Caribbean nations, while renewable energy will figure strongly in the power generation mix in the coming decade, natural gas will continue to grow and play a significant part in the energy system.

[8] New Policies Scenario reflects the way that governments, individually or collectively, see their energy sectors developing over the coming decades.

[9] Current Policies Scenario depicts a path for the global energy system shorn of the implementation of any new policies or measures beyond those already supported by specific implementing measures in place as of mid-2016.

[10] Decarbonisation (or 450) scenario has the objective of limiting the average global temperature increase in 2100 to 2 degrees Celsius above pre-industrial levels.

Table 3
World Primary Energy Demand by Fuel and Scenario
(Million tonnes of oil equivalent)

	2000	2014	New Policies 2025	New Policies 2040	Current Policies 2025	Current Policies 2040	450 Scenario 2025	450 Scenario 2040
Coal	2 316	3 926	3 955	4 140	4 361	5 327	3 175	2 000
Oil	3 669	4 266	4 577	4 775	4 751	5 402	4 169	3 326
Gas	2 071	2 893	3 390	4 313	3 508	4 718	3 292	3 301
Nuclear	676	662	888	1 181	865	1 032	960	1 590
Hydro	225	335	420	536	414	515	429	593
Bioenergy	1 026	1 421	1 633	1 883	1 619	1 834	1 733	2 310
Other Renewables	60	181	478	1 037	420	809	596	1 759
Total	10 042	13 684	15 340	17 866	15 937	19 636	14 355	14 878
Fossil-fuel share	*80%*	*81%*	*78%*	*74%*	*79%*	*79%*	*74%*	*58%*

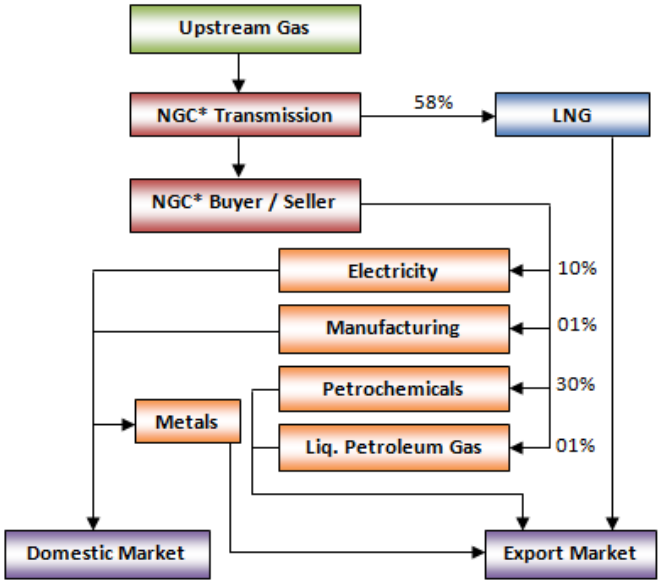
Source: International Energy Agency (IEA) World Energy Outlook, 2016.

2.0. Trinidad & Tobago energy sector

This section examines the history of the Trinidad and Tobago energy industry, including how the country transformed from an oil-based sector into a very successful natural gas-based sector, based on a monetization policy that sought to attract investment into petrochemicals and liquefied natural gas (LNG). If Trinidad is to be considered as a potential supply source of gas to meet the Caribbean's energy needs, then there are certain issues with respect to supply and policy that must be addressed, and these are explored in some detail here.

Additionally, an overview of the current gas infrastructure is presented, with possible options for future interconnection with Venezuela's vast reserves.

Diagram 1
Natural Gas Value Chain in Trinidad



Source: T&T Energy Chamber, 2011.
Note: NGC is the state-owned gas company.

2.1. The rise of Natural Gas

With a population of just over 1.3 million and Gross Domestic Product (GDP) of US$ 20.9 billion in 2016, the Republic of Trinidad and Tobago is ranked at number 38 globally according to the GDP per capita based on Purchasing Power Parity (PPP) [World Economic Outlook Database, 2016]. The economy is heavily energy-based, as this sector accounted for approximately 32% of nominal GDP in 2016, where a 59% of this value corresponds to Exploration and Production, followed by Petrochemical with a 15% and Refining (inlc. LNG) with 11% [CSO, 2017]. Additionally, in the recent years[11] the Energy sector represents as much as 34% of Government revenue [GoRTT, 2017].

The Energy Sector in Trinidad dates back as far as 1857 when the first oil well was drilled, with the first commercial discovery coming fifty years later in 1908. By the time Trinidad & Tobago gained Independence from Great Britain in 1962, local oil production had reached 133,000 Barrels of Oil per Day (BOPD) [Ministry of Energy, 1962], and the country boasted the largest oil refinery in the British Commonwealth, setting the stage for Trinidad's future industrialization and economic growth [Besson, 2009].

By the early 1970's, it was clear that the previous policy of "passive reliance on Foreign Direct Investment" which was adopted in the 1960's, was not working [Barclay, 2004]. The country was in the midst of a socio-economic crisis as evidenced by significant debt, negligible foreign reserves and high unemployment at the time. But due to the Arab oil embargo in 1973 which shot oil prices from US$ 3 to US$ 12 a barrel [Frum, 2000] Trinidad experienced a windfall income.

Using this cash, the Government now wisely adopted a policy where the focus was on job-creation and economic stimulation via the creation of downstream industries based on the use of natural gas as a feedstock [Williams, 2002]. By 1975 a Government task force had identified eight initiatives for using natural gas (Table 4) and later that year the National Gas Company was created to buy gas from the upstream producers and sell to the downstream plants.

Table 4
Gas Utilization Proposals and Implementation in 1970/80's

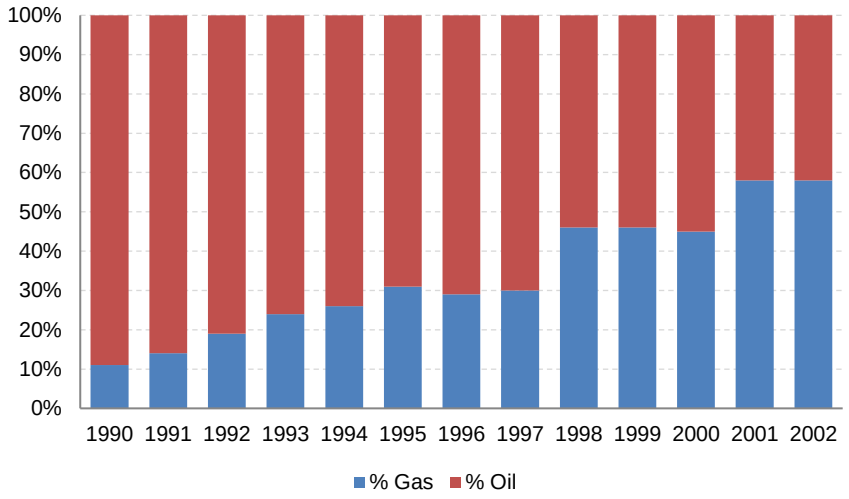
Utilization Proposal	Implemented 1970/80's
Power Generation (expansion)	Yes
Petroleum Refining (upgrade)	-
Aluminum Smelting	-
Iron & Steel	Yes
Ammonia & Urea	Yes
Methanol	Yes
Cement (expansion)	Yes
LNG	-

Source: NGC, 2013.

As further Ammonia and Methanol production capacity was added in 1990's, natural gas had begun to play a more significant role in the local economy. In 1999 the country commissioned its first Liquefaction Train (out of four) of the Atlantic Liquefied Natural Gas (Atlantic LNG) facility, and by 2001 gas had eclipsed oil as the primary revenue source for the country, bringing in 59% of Government's energy revenue (versus oil's 41%), including all taxes and energy-related payments [T&T Ministry of Finance, 2008].

[11] Energy revenue stood at 34% of Government revenue in 2014 but decreased sharply by 2016 (discussed later).

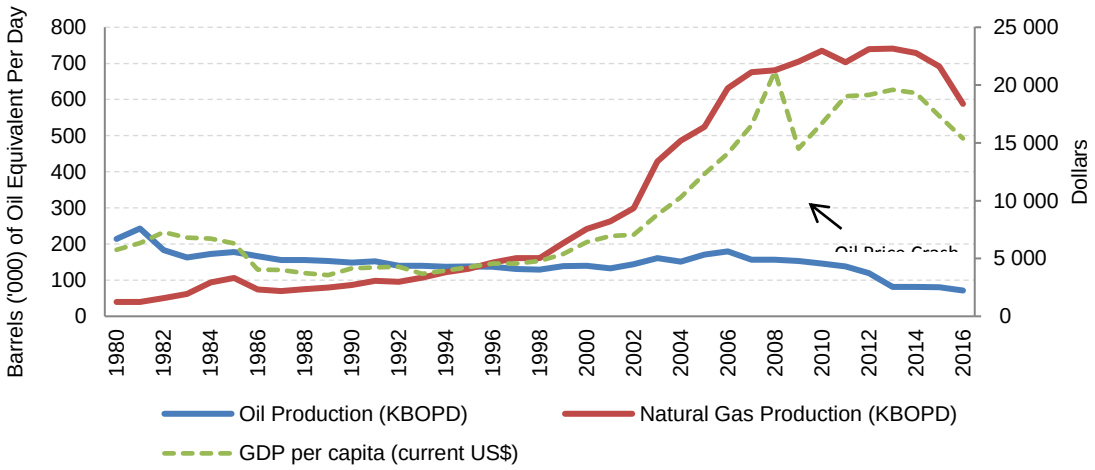
Figure 4
T&T revenue from Gas over-taking Oil in early 2000's
(Percentage)



Source: T&T Ministry of Finance Inland Revenue Division compiled by McGuire et al, 2008.

By the time the country commissioned the second and third Atlantic LNG Liquefaction Trains respectively in 2002 and 2003, annual gas production was 611 billion cubic feet (bcf) or approximately 300,000 barrels of oil equivalent per day (bopd). A mere four years later in 2007, with the fourth and final Liquefaction Train online, gas production had more than doubled to 1434 bcf in that year or 703,000 bopd. Oil production on the other hand however, never recovered its 1981 high of 243,000 bopd, and has since been steadily declining to 71,000 BOPD in 2016 (Figure 5).

Figure 5
Oil and Gas Production in Trinidad 1980 to 2016
(KOBPD) vs. GDP per capita (US$)

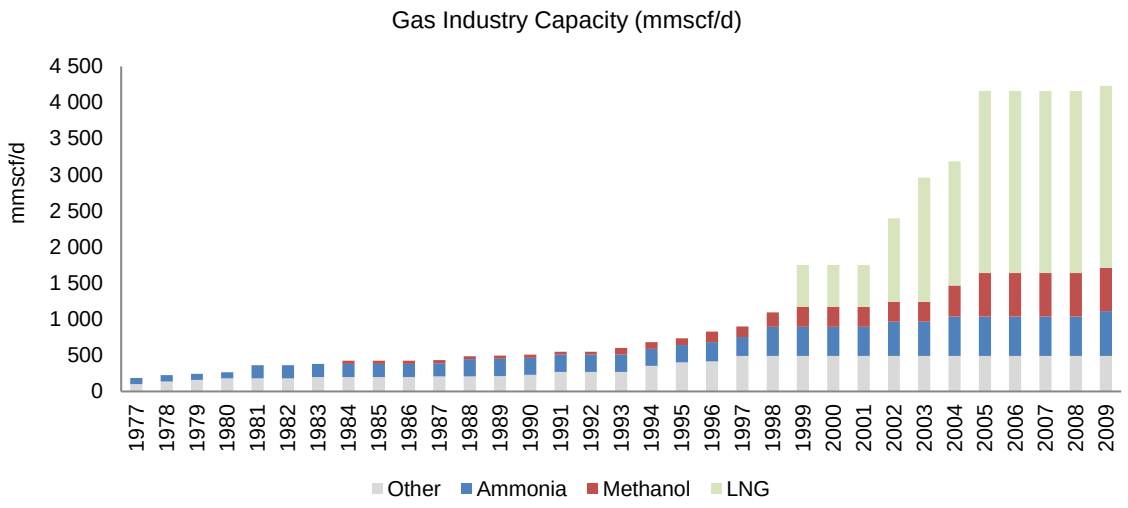


Source: US Energy Information Administration (EIA) and World Bank.

2.2. Current challenges

With the commissioning of several Ammonia and Methanol plants over the period 1996-2009, as well as the ramp up of the Atlantic LNG facility, the island's installed gas processing capacity grew to an impressive 4.2 bcf/day (Figure 6).

Figure 6
T&T Gas Industry Capacity
(Million standard cubic feet per day)

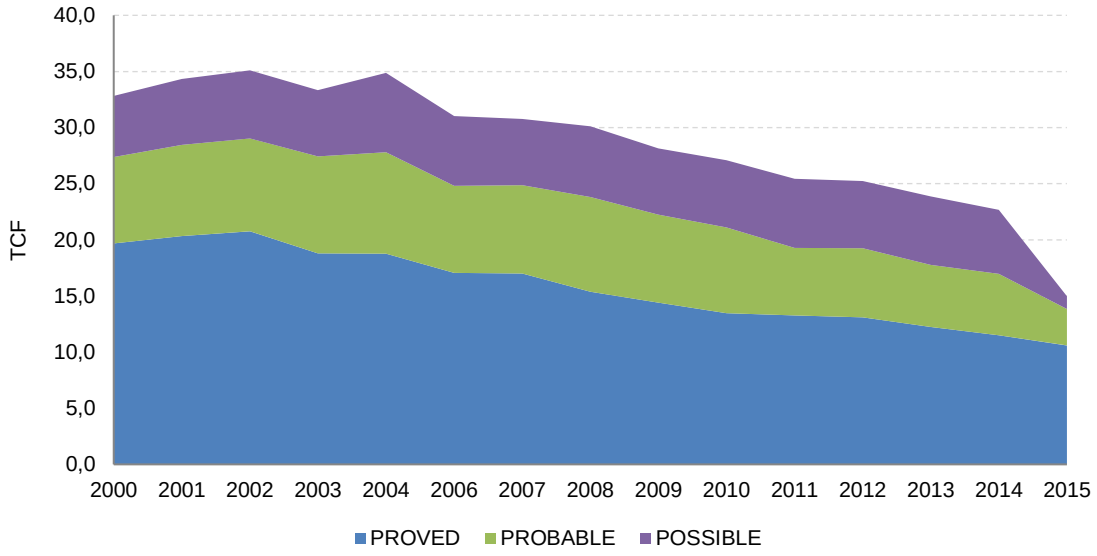


Source: Author compilation.

During the same period however, there was relative under-investment into upstream exploration and production which consequently resulted in a gas supply shortfall today. Trinidad's production was unable to sustain its installed processing capacity, and after gas production peaked in 2010 to match the 4.2 bcf/day installed capacity, it quickly fell to a low of 3.3 bcf/day in 2016.

The absence of upstream investment by the major energy companies to maintain this production plateau was linked to a lack of fiscal incentives by the Government [Pereira, 2017]. And despite some attempts to incentivize exploration and development via amended Production Sharing Contracts, the Government generally believed that it was not getting enough netback value from the gas value chain (in particular from gas exported as LNG) [Poy Wing, 2016], and therefore was understandably hesitant to provide further incentives including tax breaks and capital cost recovery to the Upstream.

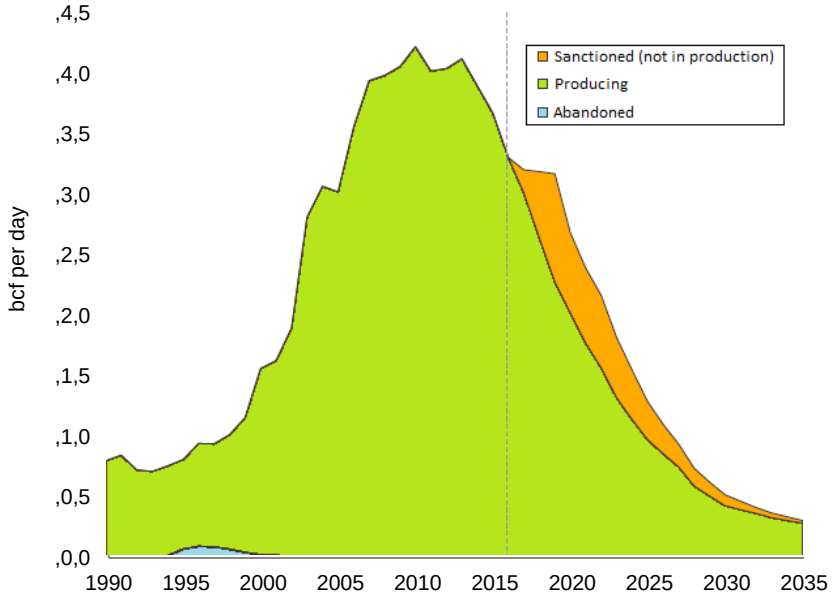
Figure 7
T&T Gas Reserves
(T&T 3P Reserves)



Source: Ryder Scott, 2016

In 2010, Trinidad has thus experienced phenomena known as "Peak Gas" production – the point at which the maximum rate of hydrocarbon extraction is reached, after which it is expected to enter terminal decline [Supersad, 2013]. More recently, it has been postulated that production from existing fields is forecasted to decline by an average of 14% over the period 2016 to 2030 [Rystad Energy, 2017]. This scenario assumes that no new production is brought online from development of discovered resources or exploration for new fields, as shown in Figure 8.

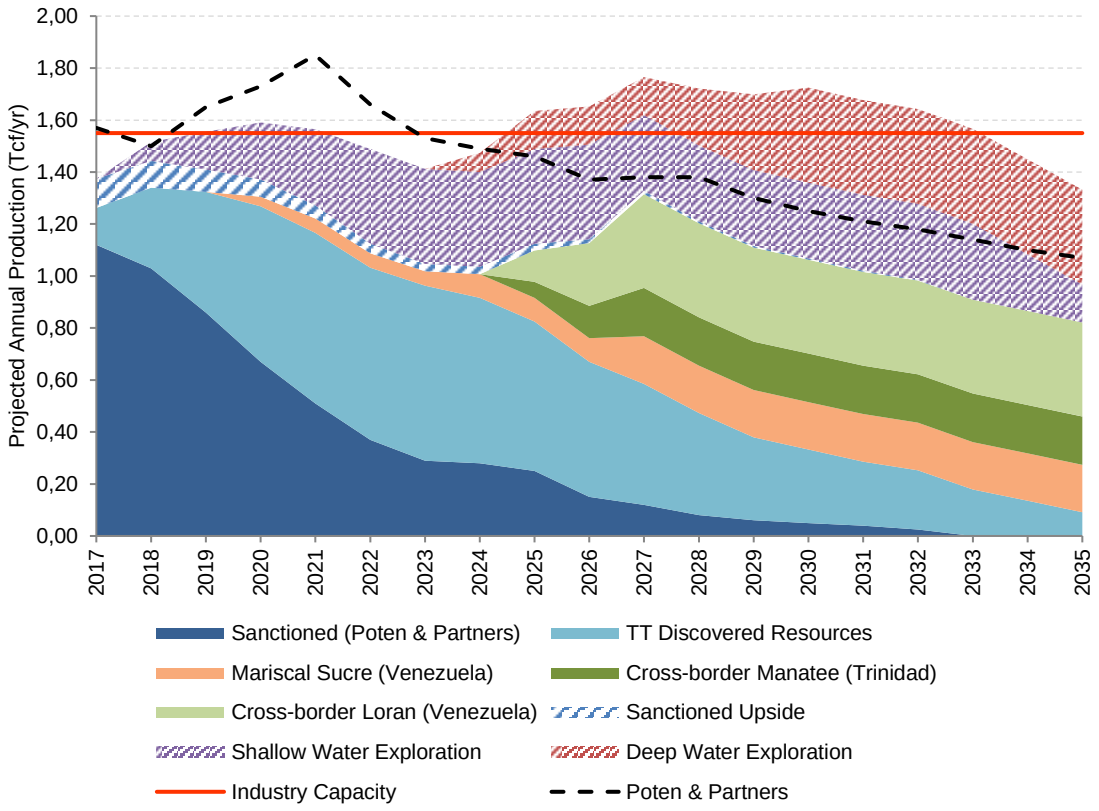
Figure 8
Projected decline in T&T Gas Production



Source: Rystad Energy, 2017.

Nevertheless, there remains a portfolio of production and supply opportunities for Trinidad, and the "terminal decline" could be manifested as either a sharp drop in production (production from sanctioned projects only) or a sustained plateau for the next 10-15 years (with further exploration success and development of Venezuelan resources). Both these cases are shown in Figure 9.

Figure 9
T&T Gas Production Forecast to 2035
(Trillion cubic feet per year)



Source: IHS, Wood Mackenzie, Ryder Scott & Poten and Partners.

2.3. Setting the stage for recovery

Due to the gas shortfalls in recent years, petrochemical plants and the Atlantic LNG facility have both been operating below their full capacity and in 2017 plans were announced by one Methanol company to mothball two of its existing plants [MHTL, 2017]. On the other hand, the state-owned National Gas Company (NGC), in its role as gas aggregator for the downstream market, is facing mounting legal claims for its contractual failure to supply gas to some petrochemical plants [Rowley, 2017]. Despite these challenges however, there are plans to commission[12] a 100 mmscf/day petrochemical plant in 2018 – which is projected to keep the industry's overall installed capacity roughly flat in the coming years at 1.8 bcf/day.

Not only did T&T feel the impact of reduction in supply to the petrochemical and LNG sectors (and consequently less Government tax revenue), but this also came at a period of depressed oil, natural gas and commodity prices following the collapse of global energy prices in 2014. In 2015 a new

[12] The Massy / Mitsubishi Di-Methyl Ether (DME) plant is expected to come online in 2018.

Government was elected, and after a series of engagements and negotiations with the large multinational energy companies operating in the country in 2016/7 (including drilling commitments and new domestic gas sales agreeemtns), there is renewed optimism in the sector today.

BPTT[13], the country's largest gas producer has brought the Trinidad Regional Onshore Compression (TROC) online and has begun production from its '*Juniper*' development as well as its '*Sercan*' development in partnership with EOG Resources[14]. Combined these projects are expected to deliver an additional 1 bcf/day by the end of 2017. BPTT also announced the sanction of the 590 mmscf/day *'Angelin'* development, with first production in 2019.

Additionally, Both BPTT and EOG Resources also signed new gas supply contracts with the NGC, and together with signals from Shell[15], it is expected that investment into the energy sector over the period 2017-2022 could be approximately US$ 10 billion [Energy Chamber, 2017].

2.4. Oil and Gas Infrastructure

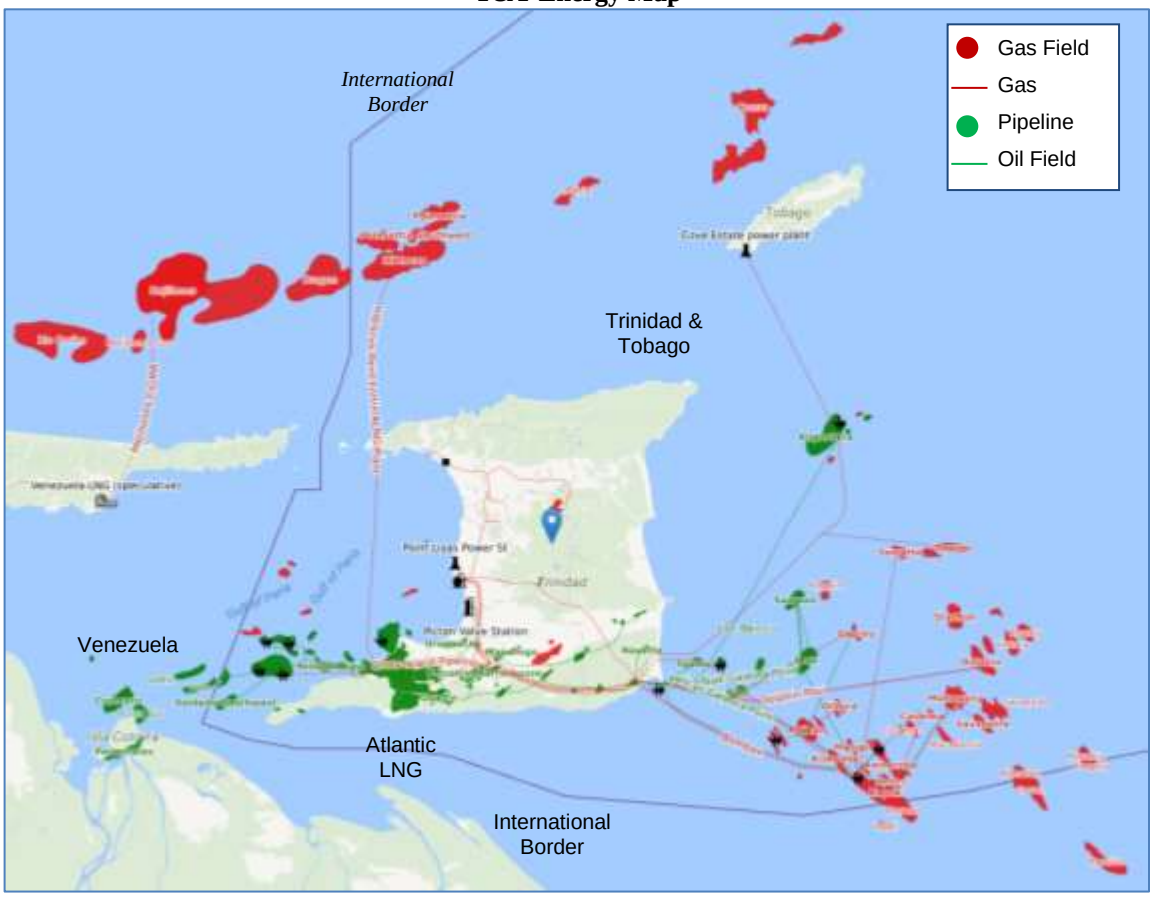
Trinidad has quite an integrated and robust network of both offshore & onshore pipelines and processing facilities which ensures adequate and flexible gas transportation to the industrial sector. Offshore pipelines to the east and southeast coast bring gas onshore at Beachfield, and then make its way through the onshore network to end users that include the Atlantic LNG facility, petrochemical plants and industrial estates, power generation plants and large manufacturers.

The gas transmission and distribution system has evolved to serve the growing industrial use in the 1970's (as previously seen in Figure 6). Most onshore pipelines are owned and operated by the National Gas Company of T&T (NGC), including the 56-inch diameter Cross Island Pipeline (CIP) that was commissioned in 2005. The CIP transports gas on behalf of suppliers into the Atlantic LNG facility and to the industrial estates in La Brea and Union in the southwest. At the time, it was the largest gas pipeline in the western hemisphere and cost approximately US$ 260 million at the time of commissioning.

The offshore operators such as BPTT, EOG Resources, Shell and BHP Billiton[16] also own and operate pipelines from their production facilities, which are eventually tied into the onshore network at Beachfield. The only exceptions however are Shell's 24-inch pipeline from its Hibiscus platform in the north that feeds the Atlantic LNG facility, and the recently commissioned (2012) 12-inch line from BHP Billiton's platform off the upper east coast to Columbus Point in Tobago.

[13] BPTT is 70% owned by British Petroleum (BP) and Spain's Repsol.
[14] EOG Resources is a US crude and natural gas Company.
[15] In 2016 British Gas T&T (BGTT) was acquired by Royal Dutch Shell.
[16] BHP Billiton is an Australian mining company that has significant oil and gas assets in Trinidad.

Map 2
T&T Energy Map



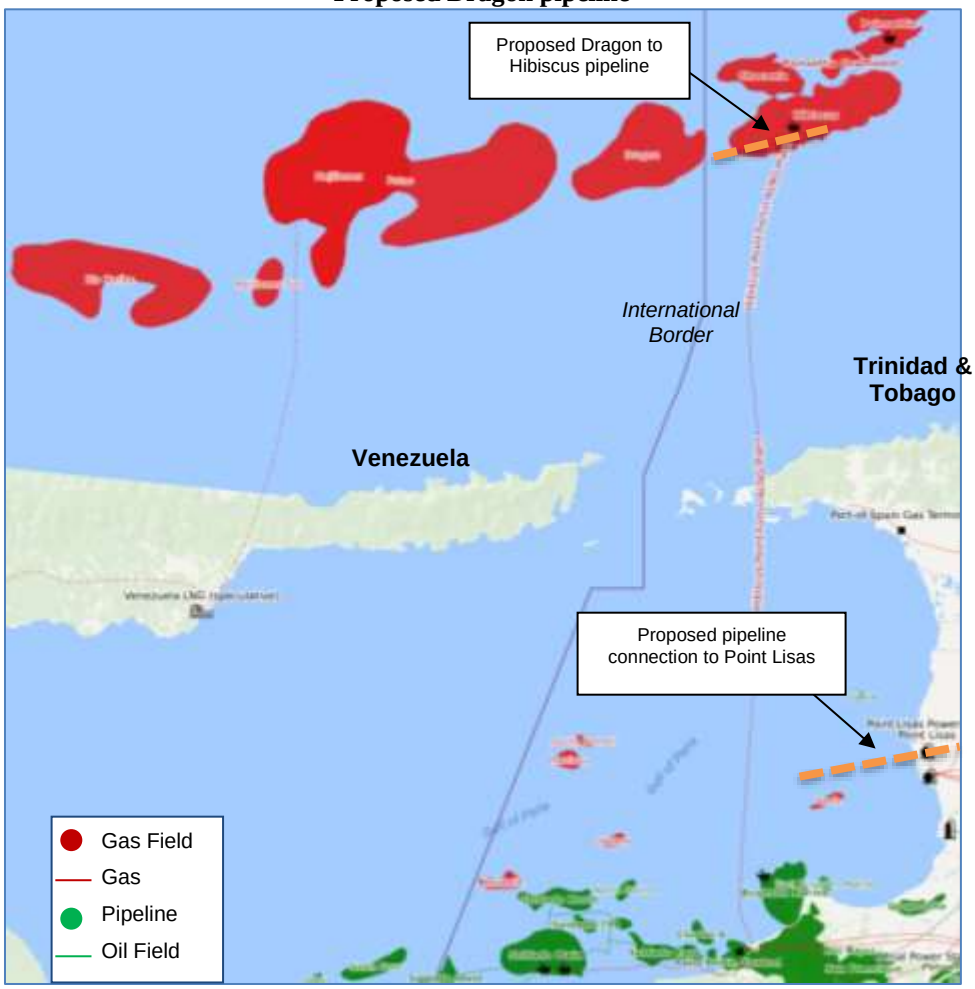
Source: Wood Mackenzie
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

2.4.1. Dragon field interconnection with Venezuela

In December 2016 the Government of the Republic of Trinidad and Tobago (GoRTT) and the Bolivarian Republic of Venezuela (GoVEN) signed an agreement to connect Venezuela's Dragon gas field to Trinidad. Faced with domestic shortages, GoRTT has been actively pursuing this project, and reported that first production from the Dragon field could be obtained during 2019 or 2020, and that the new 17 kilometre pipelines would be constructed from Dragon to Shell's Hibiscus platform [Imbert, 2017]. As Shell's pipeline from the Hibiscus platform runs only to Atlantic LNG, GoRTT also indicated that a separate pipeline would also be built at Point Lisas to supply gas for downstream Petrochemical industries (Map 3).

The Dragon field interconnection is seen as a significant political issue for both GoVEN and GoRTT. In the midst of a socio-economic crisis, Venezuela can demonstrate tangible steps that are being taken to bring in such much needed foreign exchange via the sale of its gas resources. On the other side, T&T is signalling decisive steps being taken to alleviate the current gas supply shortfalls.

Map 3
Proposed Dragon pipeline



Source: Author interpretation, Wood Mackenzie.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

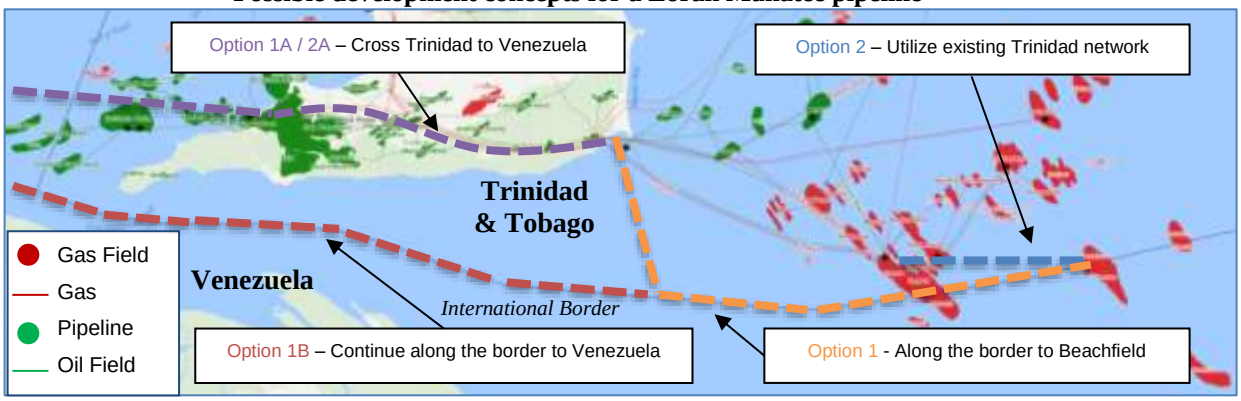
2.4.2. Cross-border Loran Manatee field

Discovered in 1983, Loran Manatee is a large gas field that straddles the south-eastern border between Venezuela and Trinidad, and is estimated to hold combined reserves of up to 10 trillion cubic feet (equivalent to about 7 years of production in Trinidad[17]). Negotiations started in 2003 with a Memorandum of Understanding (MOU) signed between GoVEN and GoRTT and although progress has been slow to date gas is expected to flow by 2022 [Oil & Gas Journal, 2017].

There are several factors that would influence how a pipeline from the Loran Manatee field would be developed. These include the technical limitations of the field, costs and financing, the Trinidadian offshore pipeline network (and its commercial limitations[18]), the relative demand for gas in Trinidad and Venezuela, and the geo-political impact of these gas reserves to both countries (Map 4).

[17] Trinidad has installed capacity to consume about 1.45 trillion cubic feet per year.
[18] No policy exists that allows open access to existing Trinidad infrastructure by third party suppliers.

Map 4
Possible development concepts for a Loran Manatee pipeline



Source: Author interpretation, Wood Mackenzie.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

2.5. Energy Sector Policy in T&T

2.5.1. The 2015 Gas Master Plan

In response to the worsening gas supply shortfalls and declining reserves (Figure 7), GoRTT contracted Poten & Partners in 2014 to prepare a 10-year Natural Gas Master Plan (GMP) in order to guide Government's strategic response for the local gas industry, aiming to maximize the benefits to the country and provide a basis for long-term management of the gas sub-sector. The GMP, which was delivered in September 2015 and then eventually laid in Parliament in June 2017, is expected to be the guiding document for GoRTT as it enters its next phase of contract renewals and negotiations with both the upstream producers and the downstream off-takers of gas. The major findings of the report are summarized in Table 5.

Table 5
Summary of Recommendations of the Gas Master Plan

Gas Supply in the Short-Term	Demand & Utilization	Secure the Long-Term
In the context of the current gas supply shortfall, the GMP recommends that GoRTT's focus should be to mobilize upstream production as quickly as possible to maintain a reliable plateau rate of 3.85 bcf/day. It is recommended that GoRTT adopt the following short-term strategies aimed at bringing unsanctioned projects (including small and marginal fields) into development: (i) realignment of unfavourable fiscal regulations to E&P companies, (ii) maximization of access to infrastructure (allowing multiple users) and (iii) flexibility to support projects on a case-by-case basis.	The GMP has concluded that petrochemicals (ammonia, and to a lesser extent methanol) provide a higher netback[19] to GoRTT than LNG under the current status quo, and some of the recommendations urge GoRTT to extract more value from existing LNG arrangements. A more extreme recommendation in the short-term is to deliberately redirect gas from LNG to other users of gas domestically, while in the longer-term the NGC could assume the role as gas aggregator nationally.	The GMP recommends that GoRTT lays the foundation to secure gas supply from 2025 onwards by focussing on the development of the Cross-border gas reserves with Venezuela and by creating the conditions to incentivize operators to unlock Deepwater potential.

Source: Author summary.

[19] Netback revenue is the net revenue from the sale of gas less the costs associated to bring it to market (per unit).

2.5.2. Downstream Refocus

More than a decade before the Poten & Partners 2015 Gas Master Plan, a similar study by Gaffney Cline and Associate (GCA) in 2001 began to prompt the discussion around maximization of value from the country's gas reserves. GCA's report indicated that there should be diversification of the portfolio of projects that use gas, including further LNG expansion and 'added-value' products (or secondary tier petrochemicals that used the primary feedstock of methanol and ammonia) [Williams, 2002]. Young Hoon and Furlonge postulated that going further downstream by producing secondary tier petrochemicals was in fact the best long-term option for the country [Young Hoon & Furlonge, 2001].

As the gas supply shortfall began to hit, the Minister of Finance articulated the position of the Government quite clearly, citing that methanol and ammonia are "only the first step downstream and can be stepping stones to products of higher value", and he cited the need to "go further downstream". This was supported by the former President of National Energy (NE), who stated that the generation of gas, methanol and LNG had already been passed, and that the downstream industry is entering a new phase of "value-added manufacturing" [Oil & Gas Journal, 2013].

The 2015 GMP also concluded that there is the opportunity to diversify along the petrochemical derivative chains for the existing products (methanol and ammonia), but cited the small size of the local market as a possible hindrance in creating an economy of scale that would be required for viability [Poten & Partners, 2015].

2.6. Gas Sector Regulation

"Regulation" can be loosely described as the full range of legal instruments by which governing institutions, at all levels of government, impose obligations or constraints on private sector behaviour [OECD, 1995]. In Trinidad and Tobago the Minister of the Ministry of Energy and Energy Industries (MEEI), principally via the Petroleum Act of 1969 (and a number of subsidiary regulations), has the authority to maintain appropriate regulatory control over the energy sector (which includes state- owned energy companies).

Construction and / or modification of any energy-based facility and associated infrastructures require the consent of the Minister. Furthermore, according to MEEI's regulatory manual, the objectives of the approval regime are to ensure that: (a) there is adherence to legislation, (b) operations are conducted in a safe and environmentally acceptable manner, (c) GoRTT's interests are justly derived and maximize and (d) facilities are properly engineered [MEEI, 2006].

Within MEEI in particular, the 'LNG and Gas Exports Division' is tasked with the creation of value along all aspects of the gas value chain, and to develop policies and strategies to maximize sustainable benefits to the citizens of T&T. This includes ensuring that infrastructure is optimally utilized, benchmarking of value is done in accordance with contractual arrangements, and supply and demand balance is maintained along the chain [MEEI, 2017].

The 2015 Gas Master Plan however concluded that, with the exception of the upstream exploration and production, the natural gas sector in T&T "is largely unregulated and left to function under a series of commercial arrangements". Due to current industry challenges and anticipated human resource constraints, the consultants went further to recommend that MEEI *not* attempt to establish an independent downstream regulator, but rather maintain its role in setting policy and establishing standards for industry performance [Poten & Partners, 2015].

2.6.1. LNG Pricing and issues of contention

As Poten & Partners' work on the Gas Master Plan was drawing to a close in 2015, GoRTT began turning its attention to the existing LNG marketing arrangements as it was purported that the current commercial arrangements were not working in the country's best interest. Not only did Poten & Partners claim that

netback revenue from LNG was lower than that of the petrochemical sector [Poten & Partners, 2015], but GoRTT was beginning to question previous contractual arrangements of upside sharing between the Atlantic LNG partners and GoRTT, imputing that such arrangements were not being honoured [Olivierre, 2016].

Although interventionist approaches were recommended by Poten & Partners to extract more value from the LNG chain (see Table 5), they also recognized that further analysis of existing contracts would have been needed to determine the extent of GoRTT's leverage to so intervene. Furthermore, they cited the risk of legal claims by LNG players should the status quo be disrupted. Today however, there has been a more conciliatory approach between the parties, with recent signals pointing to contract renewals as an opportunity for recalibration of the LNG industry – in particular the expiry of the Atlantic LNG Train 1 supply contract [T&T Guardian, 2017]. It has also been recommended that NGC act as an aggregator for all gas in the country, supplying both to the petrochemical market (which it currently does) and also to Atlantic LNG (which it does not).

2.6.2. The role of the NGC

The NGC was established in 1975 with a core role to purchase, transport and sell natural gas to the power generation and petrochemical sector. As a state-owned enterprise, it holds a monopoly on the domestic (non-export) market, but does not control supply into Atlantic LNG (controlled by the upstream gas producers with interest in the facility). Today the NGC's role has evolved, with a host of different interests which include upstream production, gas processing and LNG marketing among others.

With an objective of ensuring that maximum value is accrued from all gas-based industries (including petrochemicals and LNG), Poten & Partners recommends that the NGC performs the role of aggregator and transporter as a statutory body, so that gas trading and transportation functions are conducted according to clear rules, without the distraction of political and commercial agendas [Poten & Partners, 2015].

2.7. Competitiveness and Business Models

As expected with a mature hydrocarbon province such as Trinidad and Tobago, there have been a variety of business models that have evolved over time, and which have been successfully employed to monetize the nation's natural gas reserves. These models have ranged from privately owned and operated ventures (as is the case for most of the petrochemical plants), to fully or majority state-owned companies (as found in the gas processing or power generation sectors).

Outside of the relatively small power and gas processing sector however, GoRTT's participation in the midstream and downstream gas sector has been limited to but a few ventures – a minority shareholding in Atlantic LNG Trains 1 and 4 (10% and 11.1% respectively via the NGC) and majority shareholding in 2 of the early Ammonia plants. In recent years however GoRTT has signalled intent on value maximization as it captured majority shareholding of the island's profitable gas processing facility located in Point Lisas.

The accessibility and relative affordability of Trinidad's gas over the decades led to significant investment in the sector by numerous multinational firms, who leveraged their access to global commodity markets in order to run profitable ventures. However, investment has slowed considerably in recent years as energy and commodity prices have weakened, but more importantly, as the industry has been hit with gas supply shortfalls. GoRTT's response to this these challenges would be critical for the local economy, and hinges on its ability to maximize gas production and supply in the short-term.

And while the Build-Operate-Transfer (BOT) model has rarely been used in the gas sector, GoRTT has invited expressions of interest into a Waste-to-Energy facility [MEEI, 2017] via a BOT model, indicating that this approach may yet be deployed in the area of Renewable and Alternative Energy rather than in the conventional gas industry.

Table 6
Various business models in the T&T gas sector

Gives an overview of these business models, with an analysis and examples of how each has been applied in the Trinidad context.

Business Model	Description	Trinidad context	Examples
Private – Foreign Direct Investment (FDI)	An investment by a firm based in another country, either through expansion of an existing business or buying an existing operation.	A common model used in the petrochemical sector where large upfront capital investment is need. These companies usually have similar plants elsewhere in the world and have access to global markets for their products.	PCS Nitrogen – an Ammonia and Urea producer, and subsidiary of Canada's Potash Corporation of Saskatchewan Methanex (Titan Plant) – a Methanol producer, and subsidiary of Canada's Methanex Corporation Point Lisas Nitrogen Limited – an Ammonia producer, jointly owned by USA's Koch and CF Industries
Private – FDI with local Joint Venture (JV)	This is similar to Private FDI, but with local partnership.	This model has been recently used in the secondary tier petrochemical sector, and leverages the expertise and relationships of a large local player.	Caribbean Gas Chemicals Limited – a Methanol and Di-Methyl Ether producer (2018), owned by Japan's Mitsubishi Gas Chemicals and Trinidad's Massy Holdings
Private – Upstream player with Midstream or Downstream interest	Where an upstream gas producer also has interest in the downstream petrochemical sector.	Used by the major upstream players to 'hedge' or manage risk with commodity-linked prices and extract maximum value along the chain, or as a means to 'control' gas supply into their respective midstream or downstream interests.	Methanex (Atlas Plant) – a Methanol producer, owned by Canada's Methanex Corporation and upstream giant BPTT Caribbean Nitrogen Company – an Ammonia producer, owned by Switzerland's Proman, Germany's Ferrostaal, USA's Koch, and upstream producer EOG Resources Atlantic LNG (Trains 2 and 3) – a Liquefier of Natural Gas, owned by upstream giants BPTT and Shell

Table 6 (conclusion)

Business Model	Description	Trinidad context	Examples
Public / Private – FDI with Government	This is similar to Private FDI, but with Government presence through a state agency.	Used by Government to attract private sector financing and expertise, or in ventures where the state desires a strategic presence.	Tringen I & II – an Ammonia producer, owned 51% by the Government via National Enterprises Limited (NEL) and Norway's Norsk Hydro Atlantic LNG (Trains 1 and 4) – a Liquefier of Natural Gas, with minority shareholding by NGC Powergen – a power generator, owned 61% by GoRTT and 39% by Japan's Marubeni Corporation
State owned	Wholly owned by the Government.	A model utilized by the state for regulation or control, or where significant value resides in the chain. The state usually has significant expertise in these areas, typically acquired after years of participation. Some state owned enterprises have come out of previous partnerships with private companies.	National Gas Company – established initially as a gas transmission and distribution company Trinidad Generation Unlimited – a power generator, initially 40% owned by the Government, now 100% with subsequent acquisition of remaining interest from USA's AES Corporation Phoenix Park Gas Processors Limited – a gas processing, and natural gas fractionating and marketing company, where Government eventually acquired the interest of USA's Pan West Engineers & Constructors LLC (previously held by Conoco Phillips) Trinidad & Tobago Electricity Commission – sole distributor of electricity

Source: Author compilation.

3.0. Case studies of the Caribbean

This section looks into the policies, projects and gas infrastructure of selected Caribbean countries that made relative advancements with respect to introducing natural gas as a fuel into its energy mix in order to detect best practices and possible future course of actions to improve the hydrocarbons logistics. However, it is important to be in mind, that these are only recommendations based on the best practices detected and more deeper studies will be need before to have a regional plan.

Jamaica and Barbados, both members of CARICOM, have recently imported LNG for domestic use albeit in vastly different quantities (and hence via different modes of maritime transportation and logistics involved). The Dominican Republic and Puerto Rico, although not members of CARICOM, have long introduced into LNG from Trinidad by capitalizing on the larger economies of scale compared to the smaller islands of the Caribbean.

The case of Guyana is also explored as that country looks at monetization opportunities for gas that has potentially been found as part of recent offshore exploration campaigns, and as well Belize, who despite not having any gas infrastructure to date, has considered pipeline imports of natural gas for use in power generation.

The remaining countries in the Caribbean, including non-CARICOM small island states, have not had any infrastructure-related development that relates to natural gas, and face the unique challenge of having a high dependence on imported fuel oil and diesel for power generation, but with relatively smaller economies of scale. The options for these states are outlined in Section 6.5.

3.1. Jamaica

In 2009 the Government of Jamaica (GoJ) published its National Energy Policy 2009-2030 (NEP) with a vision to have a “diversified sector providing affordable and accessible energy… supported by an appropriate policy and regulatory framework…” [National Energy Policy, 2009]. One of the fundamental elements of this policy is to provide affordable energy to all consumers throughout the country, to ultimately create an energy sector that contributes to the international competitiveness of the productive sectors of the economy.

There NEP acknowledged that although energy diversification would involve moving from a total dependence on petroleum to a mix of other sources (including coal, petcoke[20], nuclear, renewables and biofuels), it is natural gas would be the field of choice in the short to medium term for power generation, and the country's alumina industry. The policy further articulates that "there will be a strengthening of existing multilateral, regional and bilateral partnerships…" and cites that it enjoys favourable relations with energy-rich countries in CARICOM (i.e. Trinidad), the Caribbean region (non-CARICOM) and other regions. Two key strategic actions coming out of this 2009 policy were to (i) establish an enable environment to encourage local and foreign financing of energy sector projects and (ii) develop a framework for the introduction of natural gas.

Jamaica's Parliament approved the NEP in November 2010 and by early 2012, with the aid of the international funding via the World Bank[21], the Ministry of Science, Technology, Energy and Mining (MSTEM) invited Expressions of Interest for the development of a legal and regulatory framework for the Jamaican gas sector. This report framework was delivered by consultants in 2013, and paved the way for the introduction of LNG in Jamaica in 2016.

3.1.1. The Jamaica LNG Project

Jamaica has been attempting to introduce gas as an alternative to fuel oil since the early 2000's, commencing with a Memorandum of Understanding (MOU) signed in 2004 with GoRTT aimed at developing a project with LNG supplied from Trinidad. The intent was to supply 1.1 million tonnes of LNG per year for 20 years, and included the construction of a re-gasification terminal in Jamaica. GoRTT also had plans to establish an aluminium smelting plant in Trinidad, and the intent of the MOU was to also trade Jamaica's alumina and bauxite production for Trinidad's LNG [Jamaica Information Service, 2004]. A Front-End Engineering and Design (FEED) study was completed in 2006 for an onshore LNG receiving, storage and regasification terminal, but the negotiations were suspended in 2006 as GoRTT cited lack of supply [UPI, 2009] (see Figure 7 where T&T reserves audit in 2006 demonstrative relative decline versus previous years).

The then Prime Minister of T&T suggested that Jamaica now engage Venezuela due to their large reserves of gas, and in 2007 GoJ and GoVEN signed an MOU for LNG supply to commence in 2009 [Oil & Gas Journal, 2007]. Venezuela itself had been attempting to get an LNG supply project off the ground, but this did not materialize and hence GoJ had to turn its focus elsewhere.

In 2009 there was an attempt to introduce an LNG Floating Storage Regasification Unit (FSRU) as the Petroleum Corporation of Jamaica (PCJ) issued a Request for Proposal (RFP) for the associated infrastructure to receive LNG (including harbour facilities and services), store, regasify and distribute the gas downstream [AF-Mercados and Pierce Atwood, 2013]. In June 2010 GoJ then approved the start of negotiations with an Exmar-led[22] consortium to provide an FSRU in the Port Esquivel area and construct a gas pipeline network. However the bid process was re-launched following allegations of corruption, and Samsung was selected in July 2012 to install the FSRU, although the effort stalled [Wood Mackenzie, 2017].

In November 2015 GoJ re-initiated the LNG project, and USA's New Fortress Energy (NFE) was awarded a contract to operate a floating LNG facility to supply the 120 MW Bogue Power Plant located in Montego Bay, which had to be converted to run on gas (instead of diesel) at a cost of US$ 22.5 million [Jamaica Observer, 2015]. The LNG receiving terminal itself cost US$ 750 million and the first shipment of LNG was delivered to Jamaica in August 2016. New Fortress Energy has chartered the Golar Arctic LNG vessel to be used as a Floating Storage Unit (FSU), and have also chartered the small

[20] Petcoke is a solid carbon material that resembles coal and is formed as a product of oil refining.
[21] The World Bank Group is one of the world's largest sources of funding and knowledge for developing countries.
[22] EXMAR is a maritime logistics company offering custom energy solutions.

6,500 cubic metre Coral Anthelia LNG vessel to be used as a shuttle from the FSU in Port Esquivel to the Bogue Plant on the north-eastern coast of the island (see Map 5).

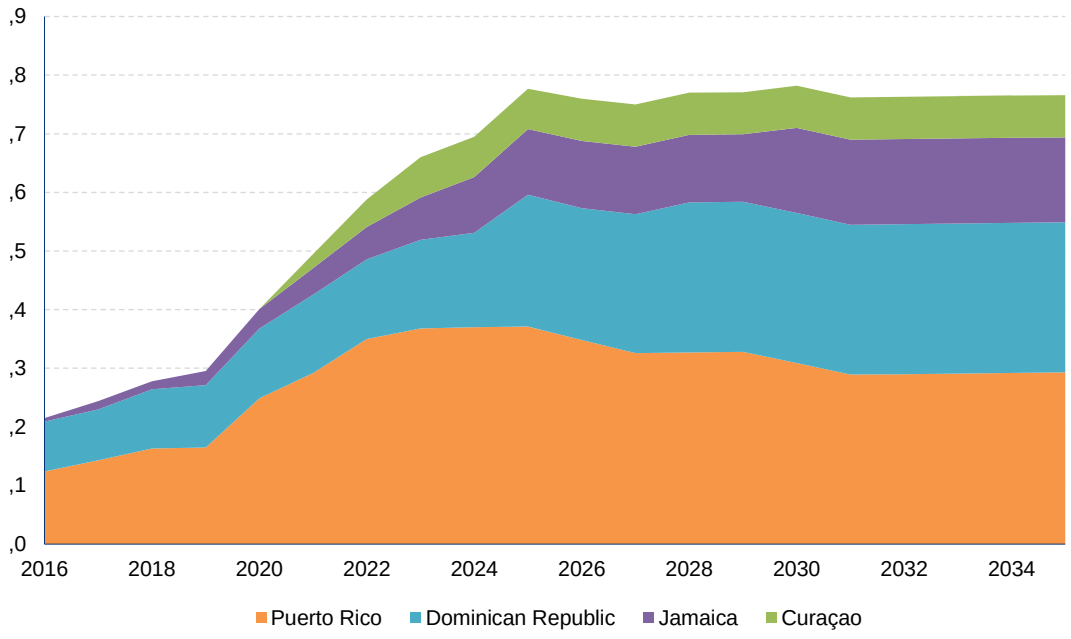
3.1.2. Gas-to-Power expansion and Development of an LNG Hub

In February 2017 and Engineering, Procurement and Construction (EPC) contract was signed by the South Jamaica Power Company (SJPC)[23] and a Spanish firm (TSK Group) for the turnkey construction of a 190 MW combined cycle[24] gas-fired plant at Old Harbour Bay at an estimated cost of US$ 330 million [Marubeni, 2017]. This plant is expected to start-up in early 2019, and the Jamaica Public Service Company[25] (JPS) have agreed a 20-year supply Gas Supply Agreement (GSA) with NFE, who will privately finance and develop the infrastructure necessary to deliver LNG to the plant.

In August 2017 the drive to convert from diesel and fuel oil to gas continued, as JPS signed a PPA with New Fortress South Power Holdings Limited, the latter of which will construct a 94 MW power plant on the site of the JAMALCO bauxite operations in Clarendon [Jamaica Observer, 2017].

With a naturally increasing demand for power, as well as its continued conversion from fuel oil and diesel to gas, demand for LNG is Jamaica is undoubtedly projected to grow (Figure 10). But Jamaica is not stopping here. The GoJ has on many times articulated its strategy to establish Jamaica as a "Caribbean energy hub", and aim to have the right infrastructure to leverage their proximity to their western Caribbean neighbours (Cuba, Haiti and the Dominican Republic) in order to supply LNG to these countries [Paulwell, 2015].

Figure 10
Future LNG growth for Caribbean countries in million metric tonnes per annum
(mmtpa)



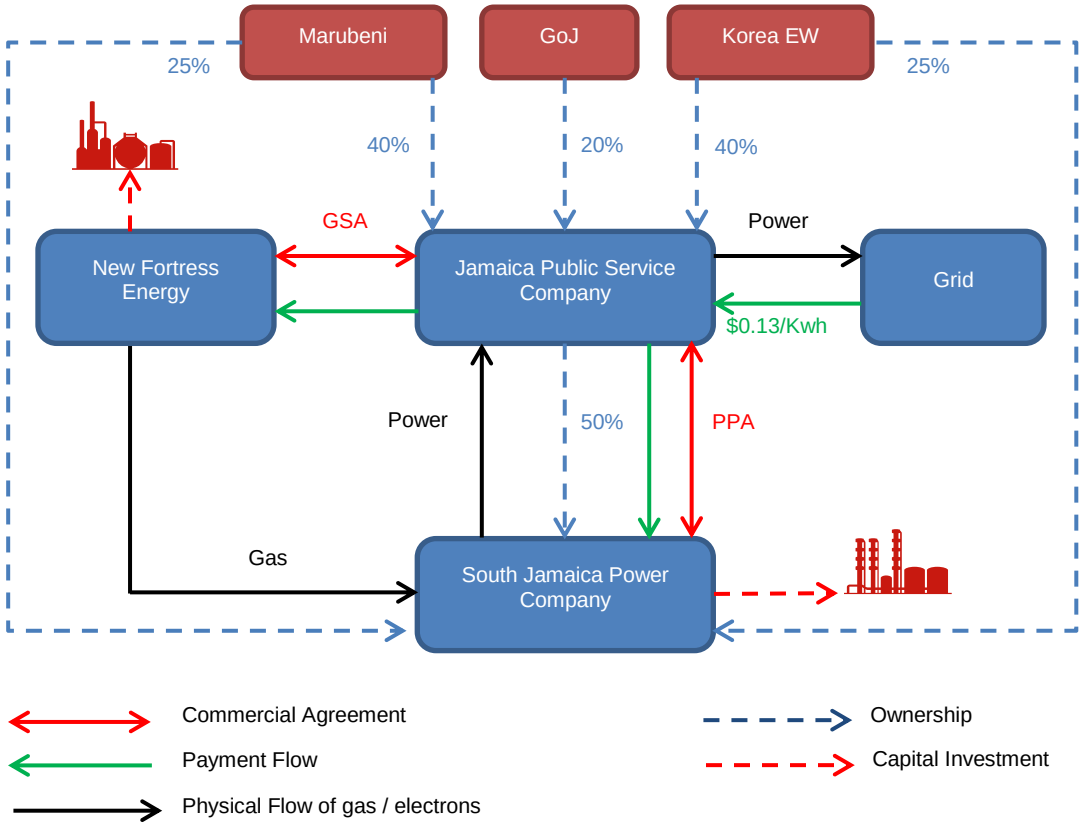
Source: Wood Mackenzie…

[23] SIPC is a subsidiary of the Jamaica Public Service Company.
[24] Combined cycle power plants are more efficient than older single cycle plants.
[25] JPS is a public-private joint venture responsible for Jamaica's power distribution, and owner of power plants.

3.1.3. Commercial Structure & Financing – Old Harbour Bay Power Plant

For the new 190 MW power plant at Old Harbour Bay, the JPS and its subsidiary have signed a 20-year power purchase agreement (PPA) under which the subsidiary will sell the power generated by the plant to the island's sole distributor of electricity. According to industry experts, the plant will be generating electricity at a tariff less than US$ 0.13/Kwh [Tomblin, 2017] (see Figure 3 for comparison with the current estimated tariff of US$ 0.31/Kwh), and estimated savings compared to the use of diesel would be approximately US$ 200 million annually [Theoc, 2017].

Diagram 2
Commercial Construct of Old Harbour Bay power plant



Source: Author compilation

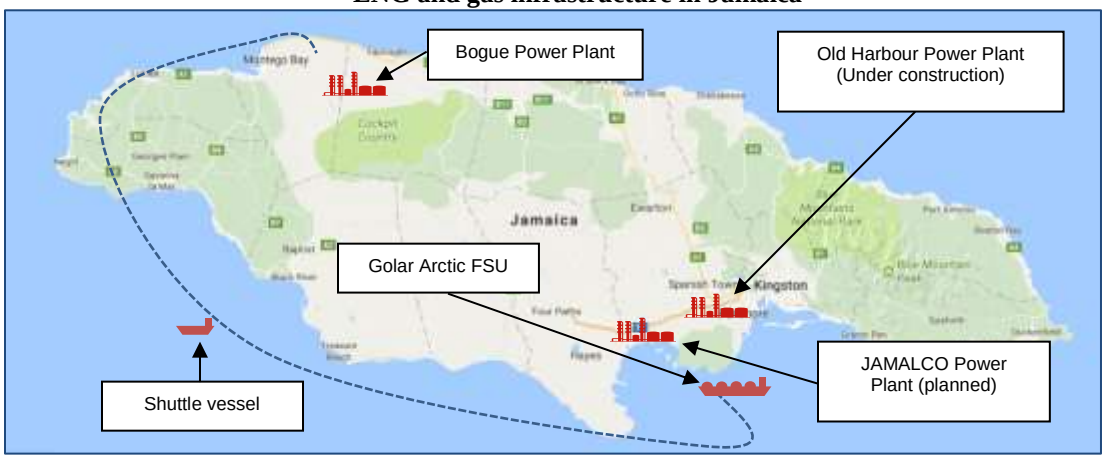
Of the US$ 330 million capital investment, US$ 230 million of this is funded via loans and bonds by syndicate of local banks and financial institutions led by National Commercial Bank (NCB) of Jamaica, which mature in 12 and 15 years respectively [Jamaica Gleaner, 2017]. It is reported as well that the financing structure also provides cash flow relief during construction and initial years of operation of the plant by delaying payments on principal during the earlier years of the facilities. The remaining approximately US$ 100 million would be equity-funded.

The 20-year Power Purchase Agreement between JPS and SJPC is structured commercially to facilitate the recovery of capital costs into the construction of the new plant, and provides a 'certainty of revenue' to SJPC who is taking on the capital risk. In this regard JPS would pay SJPC a tariff as an Independent Power Producer (IPP) either on a capacity basis (i.e. the ability to deliver power whether delivered or not) or on a rate basis (i.e. the actual energy delivered) or a combination of both.

Similarly the 20-year Gas Supply Agreement between JPS and New Fortress Energy also provides a cash-flow guarantee to the LNG supplier as it takes on the capital risk to construct the relevant infrastructure to deliver gas to SJPC.

Not taking into account any dividends remitted by SJPC to JPS as a 50% shareholder, JPS' revenue is derived from selling this power to consumers, and (according to the President of JPS), this tariff is US$ 0.13/Kwh and enables JPS to pay both SJPC via the PPA and New Fortress Energy via the GSA, and cover its own operating costs and margin. For comparison, the Energy Chamber of Trinidad and Tobago (ECTT) have estimated that T&T's real (non-subsided) cost of gas-fired power generation is about US$ 0.10/Kwh [ECTT, 2016], indicating that a selling price of US$ 0.13/Kwh does in fact provide a decent margin.

Map 5
LNG and gas infrastructure in Jamaica



Source: Author, Google Maps.
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3.2 Barbados

In 2007 the Government of Barbados (GoB) developed a draft Energy Policy that broadly addressed fossil fuels and renewables, and at the top of GoB's agenda was the promotion of offshore exploration. Several years later in 2010 a Sustainable Energy Framework was produced with the aid of the Inter-American Development Bank (IDB), and then followed by a Draft National Sustainable Energy Policy in 2013, which built on the 2007 vintage.

Today, the Interim Draft of National Energy Policy for Barbados 2017 to 2036 has been presented to GoB by a consultant, and it focuses on further facilitating economic and environmental sustainability through development of regulatory and legislative mechanisms to build on and support those that currently exist [Ince, 2017]. The policy makes specific reference to increasing the use of natural gas in the power generation sector, with the expectation that this fuel would account for 20% of power generation by 2036 as compared to the 0.2% today. The policy also recommends establishing an energy mix that promotes affordable energy prices, and also endorses a framework for the promotion of energy sector investment and financing.

3.2.1. The Gas journey in Barbados

Barbados has a little amount of indigenous natural gas production, coming as associated[26] gas from the mature onshore Woodbourne area. Total gas production from the Woodbourne field is less than 2 million standard cubic feet per day (mmscfd/d), all of which is piped to a nearby Liquefied Petroleum Gas (LPG) plant [Wood Mackenzie, 2017]. After shrinkage, a lesser volume remains to be sold into the domestic market (for comparison purposes, Trinidad has installed industry capacity of 4,200 mmscf/d).

In early April there was a shortfall of gas production and the Barbados National Oil Company (BNOC), who operates the Woodbourne area, imported 5 tank-loads ('Isotanks') of gas to meet needs of Barbados Light & Power's electricity-generating plant and nearby residential and commercial users. The Isotanks, which totalled a modest 8 mmscf were shipped from the American LNG Marketing liquefaction plant in Hialeah, Florida for prices that ranged between US$ 10 to $16 per million British thermal units ($/MMBtu). The Henry Hub spot trading price for natural gas in April 2016 was US$ 1.96/MMBtu [EIA, 2016], while the highest price that LNG from Trinidad had fetched for the first quarter of 2016 was US$ 6.70/MMBtu [T&T Guardian, 2016].

As expected, with one of the closest Caribbean islands to Trinidad having imported Isotanks of LNG at prices that were relatively high, there were many eyebrows being raised around the region. In June 2016 the Minister of Energy and Energy Industries of T&T responded to a public question as to why Trinidad did not supply LNG instead to Barbados, commenting that the Atlantic LNG facility was not set up to do small shipments, but that she has "instructed Atlantic LNG to look at the feasibility" [T&T Guardian, 2016].

In December 2016 GoB announced that it had secured a US$ 34 million loan from the IDB to facilitate, among other things, the implementation of a public-private partnership project to import and supply LNG for power generation [IDB, 2016]. The loan is for a 24-year term and will be financed by the IDB's Ordinary Capital resources with a 6.5 year grace period and a LIBOR-based[27] interest rate.

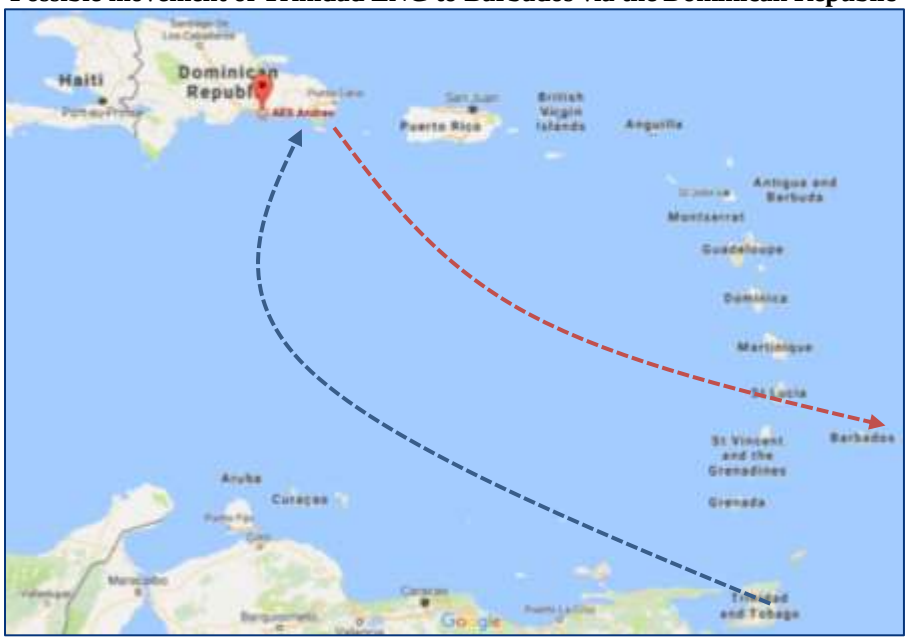
3.2.2. Long-term deal with the Dominican Republic

In May 2017 the energy group AES Dominicana signed an agreement with BNOC to supply LNG in Isotanks from its AES Andres LNG terminal in the Dominican Republic. The LNG would be loaded at a truck loading facility within the terminal, and then transported to vessels for shipping on to Barbados. This agreement between both parties actually is the first of its kind in the Caribbean, where one island supplies another, and reinforces AES' strategy to create an LNG distribution hub out of the Dominican Republic. AES also completed construction of a marine facility in early 2017 at cost of US 9 million, which consisted in adapting the existing LNG reception terminal into an export terminal for ships as small as 10,000 cubic meters [Dominican Today, 2017].

[26] Associated gas is gas coming out of a well that produces oil

[27] LIBOR is a benchmark rate for short-term loans, and is more flexible than a conventional fixed payment

Map 6
Possible movement of Trinidad LNG to Barbados via the Dominican Republic



Source: Author, Google Maps.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

There is some irony however, as AES Andres received LNG cargoes (in excess of 135,000 cubic metres) from Trinidad's Atlantic LNG Plant through a long-term Sale and Purchase Agreement (SPA). This LNG would have ordinarily been stored in a tank at AES' facility for use in the Dominican Republic, but with AES' strategy to distribute smaller cargoes these molecules could make their way back to Barbados in ISOTANKS. This round trip to Barbados would now take into account added shipping costs, boil-off[28] and regasification, logistics and administrative costs that effectively drive the unit cost of energy upwards versus if this same volume of LNG was supplied directly from Trinidad to Barbados. This paper looks at opportunities for small scale LNG from Trinidad in Section 5.2.5.

AES has also touted supplying the Bahamas with ISOTANKS [Hartnell, 2017], and the additional options for this country are explored in Section 5.4.

3.3. Dominican Republic and Puerto Rico

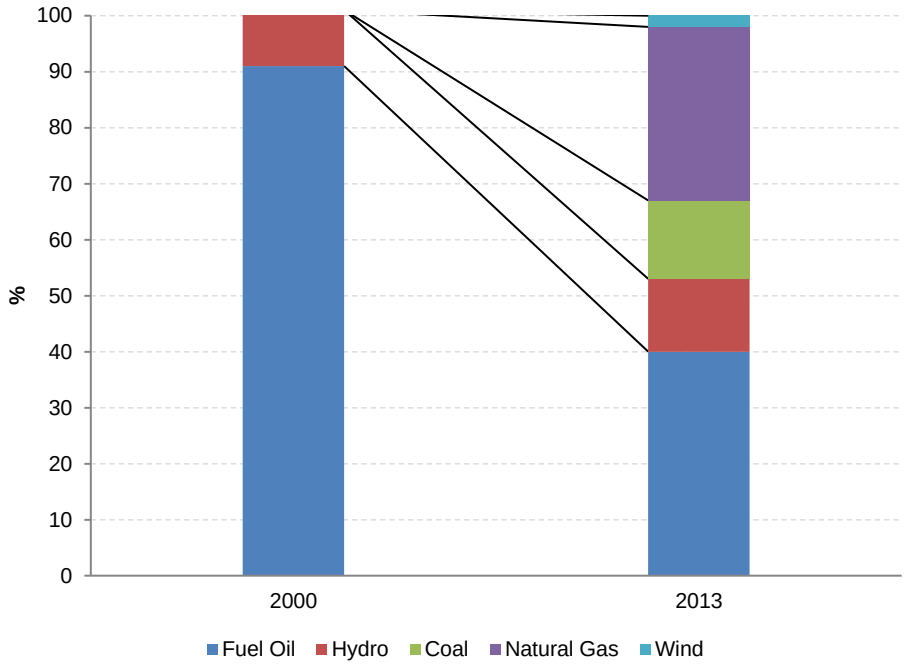
Although they are not members of CARICOM, the Dominican Republic, Cuba and Puerto Rico are island states (or in the case of Puerto Rico, a US territory) in the Caribbean who have faced similar energy challenges as the rest of the Caribbean.

[28] Boil off is natural evaporation of the liquid gas to vapour.

3.3.1. Dominican Republic

With a population of approximately 11 million, the Dominican Republic shares the island of Hispaniola with Haiti, another populous Caribbean country (and a member of CARICOM). Like many other Caribbean islands cover in this paper, the Dominican Republic had a high dependence on fuel oil to meet its power generation needs. In fact, 91% of the power generated in the Dominican Republic came from fuel oil [San Pablo, 2010], with this figure dropping to 40% by 2013 [Economist Intelligence Unit, 2013], and natural gas now accounted for 31% of the mix (Figure 11).

Figure 11
Growth of Natural Gas in the Dominican Republic



Source: Asociación Dominicana de la Industria Eléctrica (ADIE).

The phasing out of fuel oils via the introduction of natural gas has been a success story in the Dominican Republic. In 1999, a private firm (AES) invested in an LNG terminal, and two years later had supply contracts in place for 33.6 Tera BTUs per year, with commercial operations beginning in 2003 with the commissioning of a gas pipeline and supplying gas to power 550 MW of installed capacity.

AES' strategy of increasing the availability of natural gas to the Dominican Republic continued as it expanded supply to the Industrial, Commercial and Transport sectors, including the use of Compressed Natural Gas (CNG), and gas demand is projected to increase considerably (see Figure 10). Today, AES has expanded into reloading of this LNG to ISOTANKS (see Section 3.2.2) with an aim of becoming a distribution hub for the Caribbean. In fact, the Dominican Republic has probably beaten Jamaica in this race to become a distribution hub, not only in the western Caribbean as Jamaican strategy intended (see Section 3.1.2), but for the rest of the eastern Caribbean as well (to which the Dominican Republic is geographically closer than Jamaica.

3.3.2. Puerto Rico

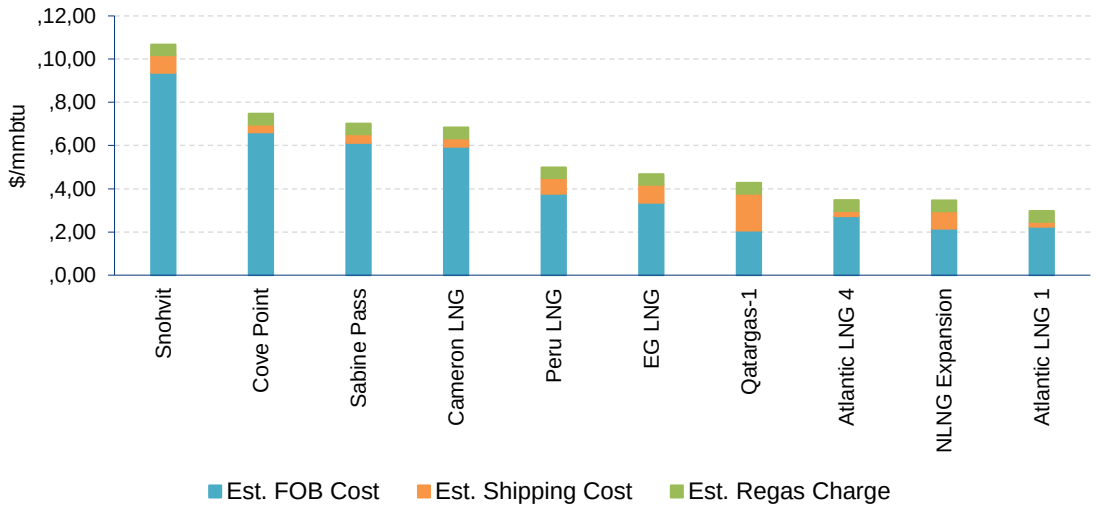
With no indigenous gas production, Puerto Rico relies on LNG imports for is gas supply. Consistent with the strategy of other Caribbean states, the Government of this unincorporated US territory is keen to increase the penetration of gas in the fuel fix, and ultimately reduce dependence on imported oil.

The Penuelas LNG regasification facility, which is linked to a 534 MW gas-fired power station and desalination plant, was commissioned in July 2000. This terminal was developed with a 22-year PPA signed in 1995 with EcoElectrica[29] and the state power company; with a concomitant long-term LNG supply contract between Engie[30] and EcoElectrica [Wood Mackenzie, 2017]. In 2012, Gas Natural Fenosa[31] signed a contract to supply another power plant on the island, and together with Engie, they accounted for the island's total supply of LNG.

What is important however is that Gas Natural Fenosa and Engie both are the current off-takers of LNG from Atlantic LNG's Train 1 in Trinidad, and with BPTT's gas supply contract to Train 1 expiring in 2018 [Poten & Partners, 2015], it could signal that new LNG supply contracts to Puerto Rico will soon have to be negotiated. Wood Mackenzie believes that there is no cheaper source of LNG than from Atlantic LNG Train 1 (see Figure 12), but recognize that current gas supply shortfall issues in Trinidad (see Section 2.2) could impact its ability to supply [Wood Mackenzie, 2017].

In 2014 Puerto Rico began imported ISOTANKS of LNG out of the US to meet the needs of the country. Demand for LNG in Puerto Rico is expected to grow from just over 1.2 million tonnes per annum (mmtpa) today, to about 3.5 mmtpa in 2022 (see Figure 12) as much of its 5000 MW of installed power generation capacity continues phasing out fuel oil and diesel.

Figure 12
Relative costs of LNG cargoes (2017) into Puerto Rico



Source: Wood Mackenzie, 2017.

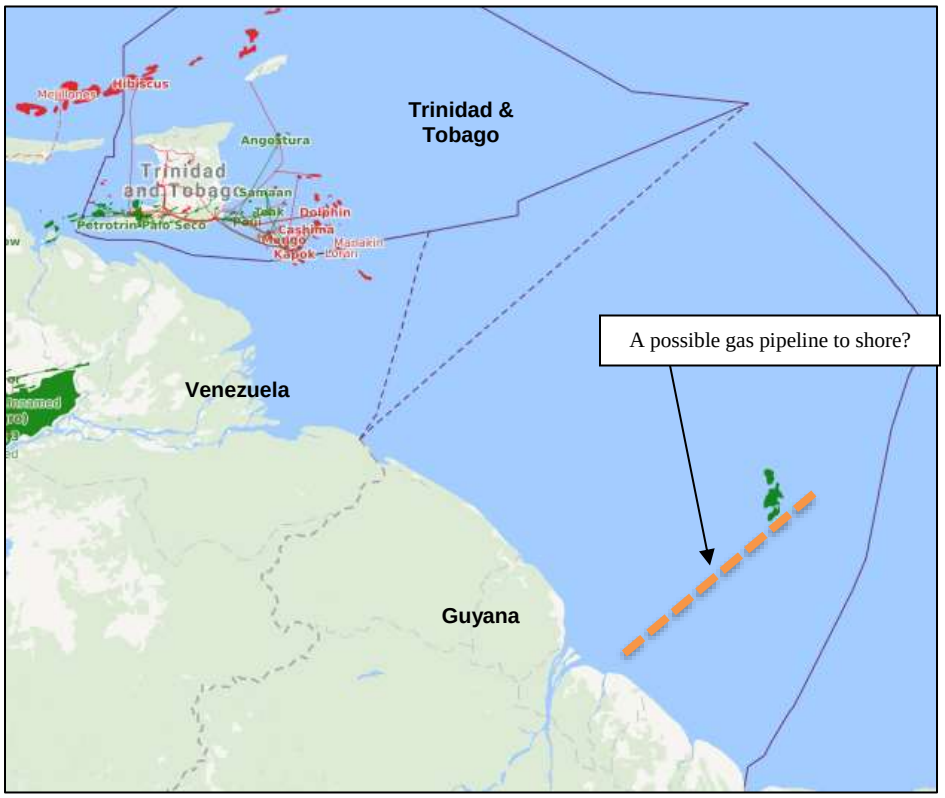
29 EcoElectrica is a Puerto Rican power generation company owned by Gas Natural SDG (47.5%), a subsidiary of Gas Natural Fenosa, Engie (35%) and others.
30 Engie is a headquartered in France, and is a major player in electricity, natural gas and energy Services.
31 Gas Natural Fenosa is a multinational integrated gas and power generation company, headquartered in Spain.

3.4. Guyana

Guyana is located on the north-eastern coast of the South American continent, and has a population of approximately 800,000 inhabitans. Up until recently, the country had not been considered a hydrocarbon bearing province and the Guyanese basin was very much under-explored. This changed with in 2015 with a significant 1.4 billion barrel oil discovery by Exxon Mobil[32] approximately 200 kilometres offshore in Liza field, with commercial production expected to commence in the year 2020.

Although there has been no public pronouncement on whether natural gas has also been found in commercial quantities, the Ministry of Public Infrastructure has commissioned a study on how best to transport natural gas from the Liza oil field to shore and to use it to fuel electricity generation [Patterson, 2017]. Any gas that is unable to reinjected, flared or consumed in the field will also need to be commercialized, which would present major costs since there is no nearby pipeline network or major gas market [Wood Mackenzie, 2017]. Map 7 puts this distance in perspective, comparing a potential gas pipeline from Liza to shore in Guyana with the existing pipeline network in Trinidad, the latter of which has a very well-established domestic and export gas industry.

Map 7
Possible Gas pipeline from the Liza field to shore



Source: Author interpretation, Wood Mackenzie
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

[32] Exxon Mobil is one of the world's largest energy companies, with headquarters in the US.

Due to the fact that no commercial gas discoveries have been announced, the distance and the lack of infrastructure and gas market mentioned earlier, it is unlikely that gas from Guyana's Liza field would be utilized for domestic power generation in Guyana in the short to medium term.

3.5. Belize

Belize is the only member of CARICOM that is located in Central America, and has an installed power generation capacity of approximately 142 MW to service its population of less than 400,000. Of this installed capacity, hydroelectric accounts for 38% (or about 54 MW), while approximately 20% (or about 28 MW) is linked to bagasse (biomass) from sugar processing – which totals 58% of installed power generation capacity from renewable sources[33] [CARICOM, 2015]. Due to its proximity to Mexico, Belize also has capacity to import 50 MW of electricity from Mexico's Federal Energy Commission (Comisión Federal de Energía, or CFE in Spanish) [Gischler et al, 2014].

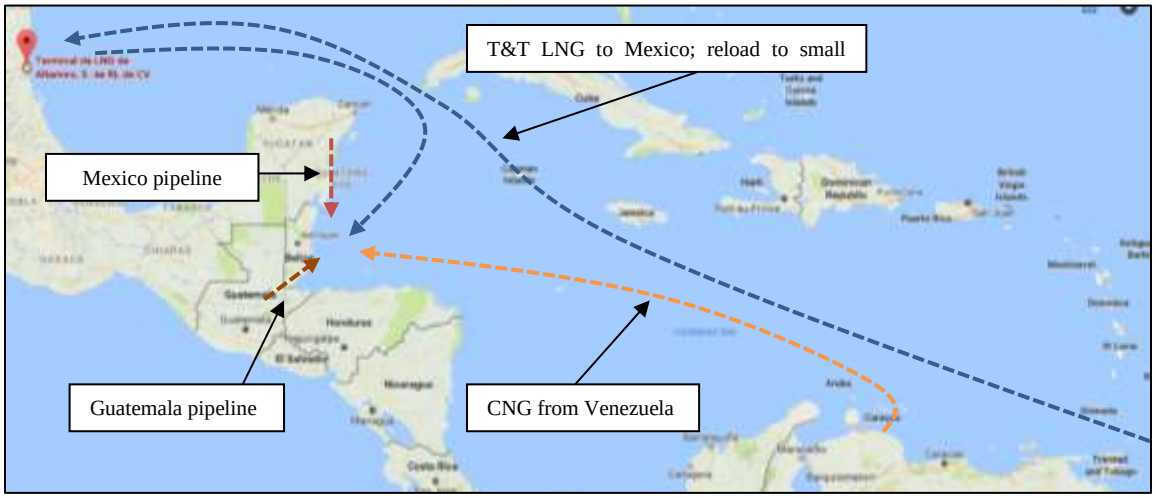
The Belize National Energy Policy of 2011 acknowledges that natural gas is an option to diversify its energy mix, and that there are indeed opportunities to access gas from the from within the Latin American and Caribbean to power at least a 25 MW baseload gas turbine operating at a plant capacity factor of 80% for the purposes of electricity generation [Tillett et al, 2012]. At the time, the options presented for supply of natural gas to Belize included yet-to-be-constructed pipelines from either Mexico or Guatemala, the latter of which had the intention of originating from Colombia via the 'Central American Gasification Project'.

Gas from Venezuela was also presented as an option via the Petro-Caribe agreement (see Section X.X), but there was recognition that Venezuela did not have (and still does not have) any LNG plants to enable export, and instead that it would have had to be done via Compressed Natural Gas (CNG) which was not economical given the small quantities expected and transport distance involved.

Tillett's work also concluded that LNG from Trinidad could be sourced at preferential prices, given the fact that Jamaica was attempting to do so at the time as part of CARICOM (see Section 3.1.1), but that Belize's small demand was too low to justify the cost of transportation and investment into a local LNG re-gasification terminal. He went further to state that any supply from Trinidad would therefore have to "be arranged as part of economically-sized shipments to Mexico and / or Central America as a whole" through a future LNG terminal in Mexico or another part of Central America.

[33] This also includes less than 1MW of solar as of 2015.

Map 8
Logistics Gas supply options to Belize outlined in the Energy Policy of 2011



Source: Author interpretation, Google Maps
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

4.0. Key success factors for gasification of the Caribbean

This section analyse the main elements and concepts required for successfully deploying natural gas in the Caribbean and improve the logistics integration. Firstly, the market demand is explored to determine whether there is the critical mass required to support the deployment of natural gas. Secondly, the enabling regulatory policies and frameworks are examined as they pertain to the importing countries. Thereafter, the supply-side opportunities and challenges are analysed, particularly in the context of Trinidad's gas supply shortfall, the possible role of CARICOM and the National Gas Company (NGC), and the potential impact of Venezuela's PetroCaribe.

The penultimate subsection investigates the economic and technical feasibility of LNG, including the evolution of small-scale LNG, the economic drivers, examples where small-scale solutions have been successfully deployed, and a look at small-scale logistics in practice. Finally, this section outlines some alternatives of how financing of these capital-intensive projects in the Caribbean.

4.1. Demand

Investment into to the monetization and distribution of natural gas has to be done with the certainty that a market exists for the gas. The upstream exploration and production companies in Trinidad (BPTT, Shell, EOG and BHP) shows that these companies have invested over the years in the development of gas fields because there the market for monetization exists in both the domestic (petrochemical sector) and the export (LNG) sector. In turn, the investors over recent decades into the petrochemical plants and the Atlantic LNG facility in Trinidad also needed assurance that there would be markets for their methanol, ammonia and LNG respectively.

This principle remains the same for the deployment of natural gas in the rest of the Caribbean. Investors into receiving facilities, storage tanks, regasification and pipeline infrastructure must be guaranteed that there will be sufficient demand that translates into revenue to cover the costs of investment and operating costs, as well as provide an acceptable rate of return.

Figure 10 published by Wood Mackenzie confirms the expected growth in the larger Caribbean territories that have already embraced LNG, namely Jamaica, Dominican Republic and Puerto Rico. With the rest of CARICOM set to grow (see Table 1 on GDP growth rates), it can be argued that these countries

could also expect similar trends in demand for LNG with the introduction of natural gas. The following subsections outline why such a demand growth for LNG in the region is justified.

4.1.1. Direct Demand – Power Generation Sector

In Section 1.3 it was established that 75% of CARICOM's power generation needs (excluding Trinidad & Tobago) are being met by fuel oil and diesel. As the region strives to move away from these imported sources of fuel and their substantially higher CO2 emissions, then this 75% (or roughly 2,500 MW of installed capacity) reflects the maximum potential market share available to natural gas. In reality though, how much of this would actually be replaced by natural gas versus renewables is a factor of individual Government and CARICOM regional policy (see Section 1.5.1). In addition, the electricity demand itself is inherently predicted to rise (see Section 1.3) with a regional compounded annual growth rate of 3.7% out to 2028, and thus the *size* of the available power generation market is also set to increase.

4.1.2. Indirect Demand

4.1.2.1. Manufacturing and Industrial Sector

Trinidad has been quite successful within CARICOM as a manufacturer and exporter of a wide range of products and commodities that can be found across the region. Its access to low cost electricity (albeit subsidized) has allowed the country to create a competitive advantage in the light manufacturing (e.g. foods, plastics, etc.) and industrial sector (steel, cement, etc.), and many of these goods are even exported outside of CARICOM.

Jamaica, who has in the past raised the issue of the imbalance of trade with Trinidad [Jamaica Observer, 2013] has only just begun its journey to lower-cost electricity via natural gas. It is thus expected that the lower cost of electricity would now enable the manufacturing industry in Jamaica to become more cost-competitive, further increasing the demand for power and hence more natural gas.

In fact, one Jamaican manufacturing company has already calculated anticipated savings of US$ 336,000 by switching to natural gas for power generation instead of fuel oil [Jamaica Gleaner, 2017], and thus it sets the stage for increased competitiveness, potential growth, and future natural gas demand. There has been similar sentiment regarding Jamaica's alumina and bauxite sectors as well, as even before the arrival of natural gas to its shores, Jamaica had predicted "expansion of the sector" by leveraging the cheaper fuel [GoJ, 2010].

It can thus be postulated that the manufacturing and industrial sectors of other Caribbean territories would grow with the introduction of cheaper and cleaner-burning natural gas, and thus serve to further increase the demand for this fuel.

4.1.2.2. Transportation Sector

Caribbean states have also, by virtue of the adoption of the Paris Agreement on Climate Change, agreed to reduction in CO2 emissions in the transportation sector. The introduction of natural gas into the countries would in fact enable and acceleration accomplishment of this goal by the use of Compressed Natural Gas (CNG) technology in road transport.

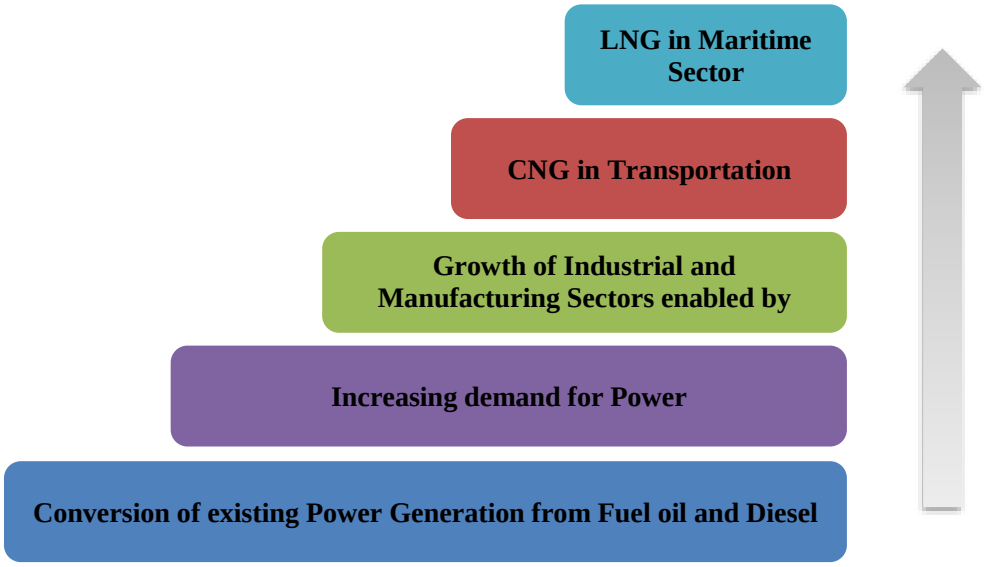
Trinidad has been a pioneer in this area, and via a subsidiary of its National Gas Company, it is currently constructing an extensive network of CNG fuel stations while offering incentives for owners of gasoline and diesel engine vehicles to switch to CNG. Thus it is anticipated that natural gas to CNG is set to grow in the coming years in Trinidad, and thus similar trends are to be expected when Caribbean territories open their doors to natural gas.

4.1.2.3. Maritime Sector

The Caribbean has due distinct advantages due to its geographic location in the maritime and shipping industry. Firstly, its tropical climate and beautiful beaches serve as an ideal destination for many cruise ships. Secondly, nestled perfectly between North and South America, and along the corridor to the Panama Canal that connects Europe and West Africa with Asia, the Caribbean is an ideally located outpost for the refuelling of cargo ships along the route.

Both of these maritime subsectors, namely the cruise ship industry and the cargo shipping industry have also begun a transition to LNG as their fuel of choice. By introducing LNG to some of these Caribbean territories, there is the added bonus that this fuel would not merely be constrained for domestic use, but rather it could help create and sustain niche maritime LNG industries, thereby creating further growth of natural gas in these markets.

Diagram 3
Building blocks of LNG demand in the Caribbean



Source: Author compilation.

4.2. Demand-side Regulatory and Policy Frameworks

Most Caribbean nations have a policy and regulatory framework that sets out the longer-term vision for that country's energy industry. Many of these policies make reference to energy efficiency and reliable infrastructure, but to varying extents. This subsection explores the essential policies and regulations that should be in place for Caribbean countries to facilitate the importation of natural gas. In 2016, Jamaica successfully followed through on the introduction of natural gas as outlined seven years earlier in their National Energy Policy of 2009 (NEP) for this reason, in the following section it will be used as to regional benchmark.

4.2.1. Energy Security and Diversification of the Fuel Mix

There is general consistency in policy across Caribbean states to improve their energy security by reducing its dependence on imported fuels, to increase the diversity of fuel sources, and to increase the contribution of indigenous fuels to the mix, namely via renewable energy. With respect to diversification of the fuel mix, Jamaica's National Energy Policy of 2009 (NEP) and Barbados' Interim Draft of National Energy Policy (IDNEP) both specifically mandate the introduction of natural gas. These clear directives on the introduction of natural gas are essential, and should be incorporated into the policies of all member states if not already so done.

CARICOM's Sustainable Energy Roadmap and Strategy of 2015 (C-SERMS) confirms that CARICOM states (as of that year, with the exception of Suriname) had specific targets related to the diversification of the energy mix through the addition of renewables [CARICOM, 2015]. It is recommended that national energy policies also contain specific targets for the relative contribution of natural gas to the energy mix.

4.2.1.1. CARICOM steer – not just Renewables

In CARICOM's Strategic Plan 2015 to 2019 there is objective achieve energy efficiency, diversification and cost reduction among member states as follows:

Box 1
CARICOM Strategy statement on Energy

Focused on optimizing existing assets, **reducing the high cost of energy inputs** (particularly in production) **through enhanced functional cooperation**, and development of alternative energy to meet CARICOM's target of 20% by 2017 for the contribution of renewable energy to the total electricity supply mix. Therefore this strategy will address energy efficiency across all sectors, development and use of renewable energy, legislative and market reform to allow for access of renewable energy to the electricity network, building awareness and capacity within Member States, and facilitating public private partnership in energy development and build on the CARICOM Energy Policy adopted in 2013.

Source: CARICOM, 2014.

However, as covered in Section 1.5.2, the transition to power generation from solely renewable sources in not an automatic and seamless one. Instead, natural gas would be required to 'bridge' this transition, and as such, the policy and strategy should include the need to for legislative and marker reform, building awareness and capacity, and facilitating public-private partnerships.

4.2.2. Facilitation of Foreign Direct Investment (FDI)

Although the economics of introducing natural gas are explored in Section 4.4.3, there is undoubtedly significant investment that is required across the region to facilitate the widespread deployment of this fuel that may require the participation of foreign investors. Thus, there must be policies in place that address the need to attract such foreign direct investment. Jamaica's NEP states the policy objective to

"establish necessary enabling environment to encourage local and foreign financing of energy sector projects."

FDI into the energy sector is also linked to economic stimulation via job creation. The immediate impact is seen during the construction phases as physical infrastructure needs to be laid, as well as later through the operation and maintenance of the facilities, including related services.

4.2.3. Environmental Commitments

Most Caribbean energy policy documents make reference to the need to reduce greenhouse gas emissions via the reduction and / or elimination of fossil fuels. These policies should now be reviewed and updated in line with the 2016 Paris Agreement on Climate Change to include specific targets on their respective plans and contributions to mitigate global warming. The Barbados IDNEP specifically recognizes natural gas as an "important bridge to the eventual complete removal of fossil fuels from Barbados' energy consumption."

It is important that policies also stipulate that the development on new energy projects will be implemented with minimal impact on the natural environment.

4.2.4. Increased Competitiveness of Domestic Industries

Policy objectives must also address the need to increase the competitiveness of domestic industry by leveraging access to cheaper and a more reliable supply of fuel. The NEP of Jamaica outlines a number of high-level goals of the policy, one of which is to ensure that Jamaica's energy supply is secure and sufficient to "support long-term economic and social development and environmental sustainability."

In Section 4.1.2 some of the indirect positive impacts on the competitiveness of various sectors are outlined, including the manufacturing, industrial, transport and maritime sectors. These are just but a few of the larger industries in the Caribbean, and similar progressive impacts can be expected on small businesses, tourism, food processing, etc.

Policies that link cheaper, cleaner and more reliable access to electricity, with the socio-economic development of the country, are likely to gain traction and wider acceptance than policies that do not explicitly make this connection. Going further, socio-economic development would impact literacy rates and quality of healthcare, while also contributing to reduction in child labour and gender imbalances (i.e. more women in the workforce earning equitable pay to men), all of which are pertinent issues in the developing nations of the Caribbean.

4.2.5. Education and Public Awareness

Energy policies of the Caribbean should also include an internally-focus education and public awareness campaign. For many countries in the Caribbean, the commercial introduction of natural gas will be a new phenomenon and consequently would require that Governments engage the community, business groups and other stakeholders.

Jamaica's NEP cites the need to "develop and implement a public education programme through the print media, television, radio and island wide meetings / seminars." It is expected that with a well-executed campaign to raise awareness (especially as it relates to energy pricing and the need to reduce greenhouse gas emissions), that natural gas can be seamlessly introduced into the energy mix and gain widespread public acceptance.

4.2.6. Knowledge Transfer and Local Content

It is essential that the developing nations of the Caribbean equip themselves in the longer-term with the skills to build and operate their own energy infrastructure. Apart from the expected economic gains associated with knowledge and technology transfer (by not having to expend already scarce foreign currency to pricey firms or highly paid consultants), the state's ability to manage its own energy industry promotes longer-term opportunities for domestic growth.

The Barbados IDNEP states the objective to "establish an effective system of knowledge transfer of higher order energy skills available in international institutions to local educational and vocational institutions".

Along similar lines, the development an adequate Local Content policy is necessary to maximize economic benefits to the local community, as well as setting the foundation for a sustainable energy services and support sector. Projects to introduce natural gas in Caribbean countries would typically by done in conjunction with large multinational firms, and it is imperative that these skills and expertise be passed on by the appropriate inclusion of local firms in various aspects of implementation and operation. Belize's National Energy Policy Framework (NEPF) robustly outlines measures to "maximize local benefit and local control of undertakings."

4.2.7. Address Regulatory Gaps

In changing the energy status quo there is the possibility that regulatory gaps may be exposed, and often responsibility for addressing these may lay across a number of different Ministries and state agencies. Thus it is important that Caribbean Governments clearly articulate, as a matter of energy policy, that the relevant agencies must collaborate to quickly resolve potential regulatory gaps.

Some of the regulatory issues that usually need to be addressed are permitting, procurement, ownership, financing, the role and participation of the state, determining which body provides oversight (and to what extent), the need for price regulation, and whether there need to be legislative change.

Jamaica's NEP has as one of its seven objectives, to "facilitate the removal of policy inconsistencies, and to provide a coherent policy and regulatory framework to facilitate competition in the energy supply system." The NEP also cites the aim to "provide integrated monitoring and enforcement of regulations, all overseen by agencies and organizations with the capacity and tools to guide the energy sector."

4.3. Supply-side Policy – Opportunities and Challenges of the regional integration

Section 4.2 covers some of the key policy positions that need to be adopted by Caribbean states desirous of introducing natural gas into its energy mix. This subsection analyse the sub regional dimension, outlines some hypothetical roles of CARICOM, PetroCaribe or other institutions in a potential regional plan to improve the logistics of hydrocarbon in the Caribbean in order to achieve a more sustainable development

4.3.2. The potential role of CARICOM

4.3.2.1. Lead the charge

The CARICOM organization could have an important role to play, as addressed in Section 4.1 most Caribbean states do not have the economy of scale to justify investment into a gas supply project. Thus CARICOM should take the lead in bringing everyone to the table to create this critical mass, and set up a sub-committee that deals exclusively the coordination and implementation of gas supply

throughout the region. Also, CARICOM could help to drive the implementation of a sustainable solution aimed at supplying natural gas throughout the region.

4.3.2.2. Concessionary CARICOM pricing

CARICOM came into being in 1973 with one of its four foundational pillars based on that of economic integration. The Common External Tariff (CET) was established and applied to commodities that were imported into the CARICOM region with the aim of protecting local manufacturers or suppliers of these commodities within CARICOM. Simply put, if the commodity is available locally within CARICOM, then it can move within the region without being subjected to import tariff, while extra-regional imports would be subjected to such tariffs.

Natural Gas is listed as a commodity that is exempted from import tariffs (CET) – meaning that any member state in CARICOM can import natural gas from outside the region without attracting additional duties.

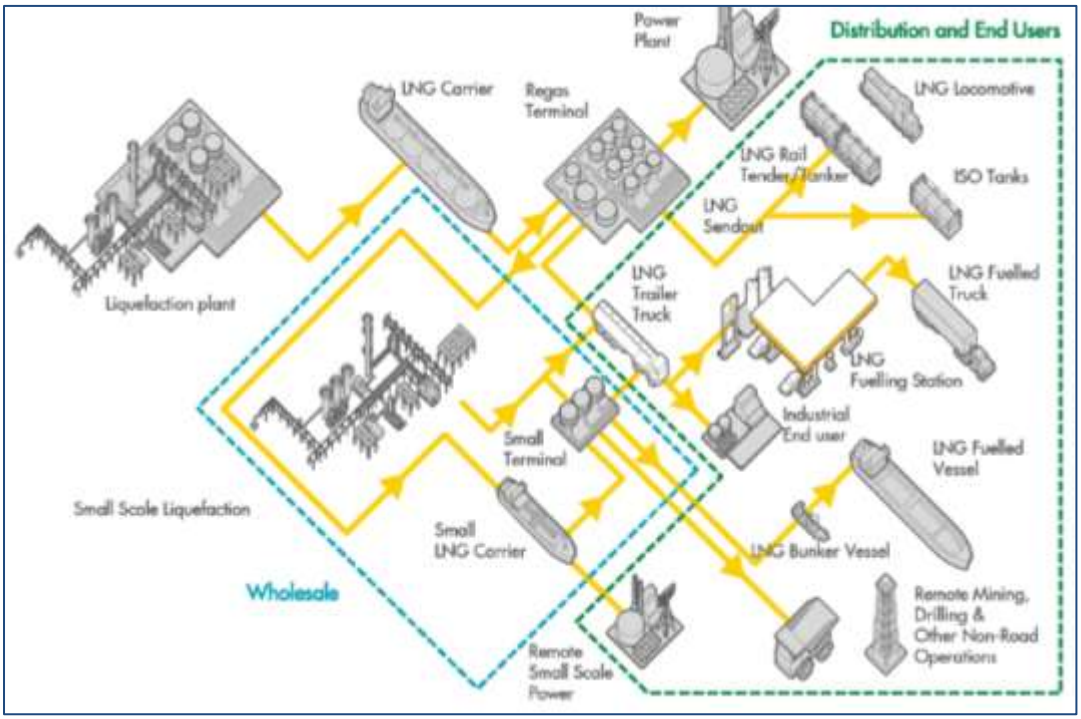
4.3.4. PetroCaribe

Formed in 2005, PetroCaribe is a Venezuela-inspired oil alliance with several Caribbean states, who can purchase oil on conditions of preferential payment. Most of the CARICOM members are subscribed to this agreement with the exception of Barbados, Montserrat and Trinidad (as an oil producer itself). In September 2017, Belize announced that it was suspending participation in PetroCaribe due to irregularity of supply from Venezuela that had knock-on logistics costs in Belize [Jamaica Observer, 2017]. Preferential financing for oil (and fuel oil and diesel) undoubtedly leads to some measure of dependency, and makes it even more difficult for some small island states to want themselves off as they attempt to diversify their energy mix.

Conceptually, PetroCaribe applies to any petroleum resource in Venezuela, and in May 2016 that country's President announced that Trinidad's gas infrastructure will be utilized to monetize the huge Venezuelan gas reserves. Since then, discussions between both Governments have accelerated and gas could flow from Venezuela to Trinidad as early as 2019 (see Section 2.4.1). This implies that some of Venezuela's gas would be monetized in Trinidad, and through some commercial mechanism Venezuela would (in theory) own physical molecules of LNG. As did with oil, Venezuela can now distribute this LNG under preferential terms to the nations that have subscribed to PetroCaribe, and could prove to be an essential lever in making LNG supply projects viable.

4.4. Feasibility and Logistics of LNG

Diagram 4
LNG Supply Chain



Source: IGU, 2015 (adapted from Shell).

4.4.1. Gas and LNG projects – safe and environmentally friendly

Natural gas has been in use for decades in many countries around the world, and while the risk of an explosion can be mitigated with proper engineering, operation and inspection programmes, there have been serious incidents. In the US, the American Gas Association (AGA) reports that pipeline incidents have declined approximately 50% over the past three decades as natural gas utilities continue to work to enhance safety, even though usage has risen over the period [AGA, 2015]. The LNG industry itself boasts a very strong safety records as LNG has been shipped since the 1960's without there ever being a significant spill, loss of cargo, or environmental incident.

Both natural gas and LNG projects can be implemented in environmentally-sensitive locations without detrimental impact. On Australia's tiny Curtis Island (a mere 6 square miles in area), there are 3 separate LNG plants amidst this delicate ecosystem, and LNG developers all had to follow a stringent environmental permitting process.

4.4.2. Small-scale LNG has emerged as the option for the Caribbean

4.4.2.1. Literature review

In a 2003 study that investigated the transportation of natural gas around the Caribbean, it was concluded that CNG or hydrates were both more cost effective than LNG or pipelines due to the prohibitively smaller demand of small island Caribbean states [Kromah et al, 2003].

Compressed Natural Gas (CNG) is a method of storing and transporting natural gas as a vapour under high pressure, where the gas is compressed to less than 1% of its original volume at atmospheric

pressure. LNG on the other hand requires a cryogenic (and relatively costlier) process to reduce the volume to less than 0.17% of its original volume at atmospheric pressure. Or in other words, for the same volume, LNG will deliver 6 times more energy than CNG, but with a higher storage cost.

In 2010 Nexant (consultants for the World Bank) analysed the economics of pipeline gas, CNG, conventional LNG as well as small-scale LNG for supply to the Caribbean islands [Nexant, 2010], and Table 7 summarizes these findings.

Table 7
Summary of gas supply options for the Caribbean in 2010

Option	Technical Issues	Economic Feasibility
Pipeline	No major technical issues.	High upfront capital cost but economics improved as more off-takers added. Analysis (retrospectively) does not account for potential supply shortages at the source (Trinidad).
CNG	Acknowledges that there are no commercial CNG marine transportation systems in operation worldwide, and that any CNG project would have to be a 'first of its kind'.	CNG was not feasible for the northern Caribbean, but was feasible for the eastern Caribbean over LNG options assuming that CNG was deployed from Trinidad.
Conventional LNG (>140,000 m^3)	No major technical issues.	Recognition that small demand in many territories would render this option economically unfeasible with the exception of Puerto Rico and the Dominican Republic (already established), Jamaica (retrospectively implemented), Martinique, Guadeloupe, Barbados and Cuba.
Small-scale LNG	No issues as technology involves smaller versions of more commonly used large facilities with proven track records.	Report revealed that it 'could be a viable option', but more detailed analysis was needed. Acknowledgement that small-scale LNG could be the solution for smaller islands.

Source: Nexant, 2010.

Several years later in 2013, the IDB published a detailed pre-feasibility study on the potential of natural gas as a fuel for power generation in the Caribbean [IDB, 2013]. It too examined the options of CNG, pipeline and LNG, and considered six potential gas supply sources – the US, Trinidad, Peru, Colombia, Venezuela and Mexico. In fact, of these six potential sources, the study ranked the US as the strongest option, followed by Trinidad only because of its relatively lower gas reserves when compared to the US. Amongst the group of six potential gas exporters, Trinidad was actually ranked as the option with the quickest potential to be implemented, and the one with the lowest political risk. The other main conclusions of this study are outlined in Table 8.

Table 8
Key findings of natural gas pre-feasibility study for the Caribbean in 2013

Key Finding	Description
LNG is the safest technology for the respective markets, although there is economic uncertainty around small-scale LNG.	The untested option of maritime CNG did not provide a cost advantage (compared to LNG) that justifies the risk. Despite this, there is some degree of economic uncertainty around the implementation small-scale LNG, and varying development concepts could increase costs further.
A pipeline option requires a large off-take market to be economically viable, but could be politically complex.	A regional pipeline is economically viable if there is a large market at the other end of the pipeline, and this has the added benefit of creating a cost-sharing mechanism for the smaller markets along the route. However this project would require considerable and sustained political support via many countries along the route, which increases complexity and risk.
Gas has a cost advantage over fuel oil, but small markets cannot stand by themselves.	All markets demonstrated cost benefits of gas over fuel oil, but small markets (as Dominica) are unable to sustain a gas-based solution on its own due to low volume. Thus various technologies and import configurations (including pooled demand) would have to be implemented.

Table 8 (conclusion)

Key Finding	Description
Securing a supply contract could be a challenge.	Project timelines and the appetite of an LNG trader / exporter to enter into a supply contract with importing Caribbean territories could potentially be difficult. This is because LNG traders are likely to already be tied into long-term contracts in more lucrative markets.
The first mover will have the main advantage in the Caribbean.	There is no huge advantage of one of the potential supply sources over the others, and the ability to supply into these small markets over other competitors would likely result in secure contracts with limited competition. Furthermore, countries like the US and Trinidad, with existing infrastructure, are best poised to capitalize.

Source: IDB, 2013.

4.4.2.2. Current developments versus previous studies

CNG versus LNG

Due to the anticipated small demand for LNG in the Caribbean islands, Kromah's 2003 study postulated that CNG was more viable than LNG because (at the time) there was no known small-scale LNG solution. Nexant in 2010 concluded that CNG was selectively feasible depending on the distance but acknowledged that CNG technology was untested. Nexant also cited the emergence of small-scale LNG technology but recognized that more studies were required. Several years later in 2013, the IDB pre-feasibility study concluded that LNG was the safest technology to be employed as CNG was still untested, but like Nexant in 2010, cited some degree of economic uncertainty regarding small-scale LNG.

Despite these earlier deliberations on the economics however, it was Jamaica and Barbados that implemented small-scale LNG solutions in 2016 – Jamaica via an FSU and shuttle vessel (see Section 3.1.1), and Barbados via ISOTANKS (see Section 3.2.1).

Pipelines

Both Nexant (in 2010) and the IDB (in 2013) examined the feasibility of pipeline gas supply throughout the Caribbean and concluded that it required a large final market and multiple off-takers along the route to be viable. Section 5.1 examines in detail the purported Eastern Caribbean Gas Pipeline (ECGP) from Trinidad, and concludes that this project is currently not viable.

Market Dynamics

All studies have recognized the issue that small Caribbean nations have in justifying investment into LNG infrastructure due to the small demand, and the IDB's 2013 pre-feasibility study also cited that entering into LNG supply contracts could be challenging for these countries. Section 6.2 identifies the role of CARICOM in creating a "pooled" demand (coming together as a group to create an economy of scale), and approaching supply negotiations as a unified region as opposed to individual nations.

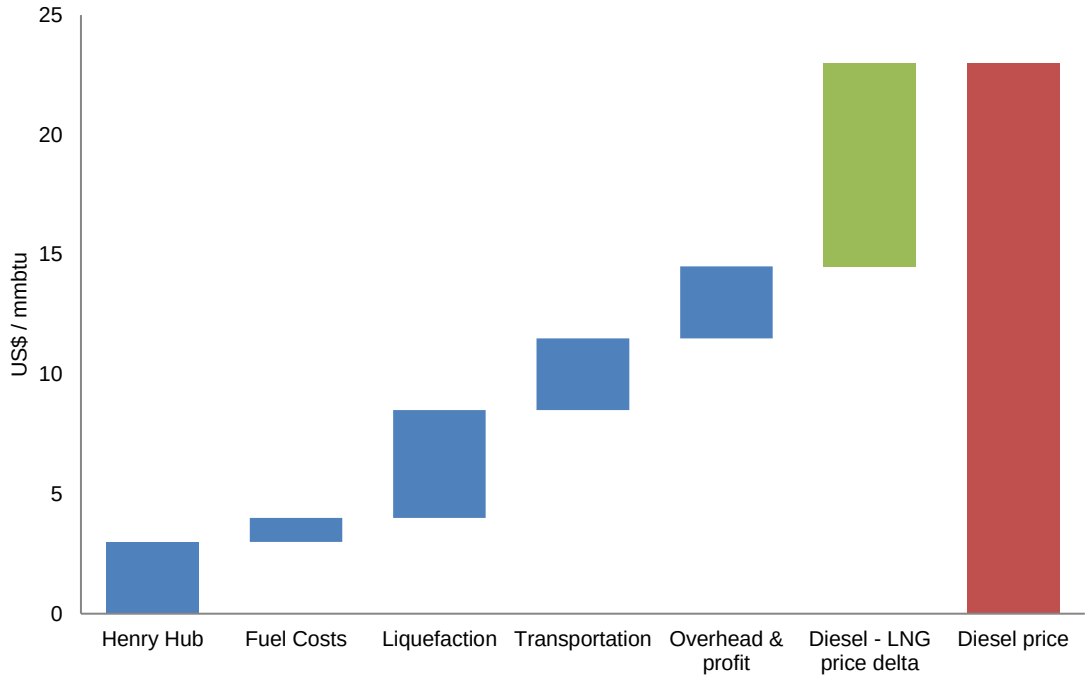
4.4.3. Economic drivers

The International Gas Union (IGU) in a 2015 report on small-scale LNG [IGU, 2015] sought to quantify the economic advantage that LNG has over other sources of energy, including to that of gas where pipeline infrastructure is absent. Figure 13 provides a sample comparison of the cost of small-scale LNG to diesel, and identifies a US$ 8.50 / MMBtu price advantage of small-scale LNG over diesel to the end customer, concluding that latter is 59% more expensive even when all of the costs along the value chain are incorporated.

This price delta has a substantial impact on the small economies of the Caribbean, and represents a significant opportunity to reduce fuel costs. In the cast of the 190MW Old Harbour Bay power plant in Jamaica, the use of small-scale LNG over diesel would result in savings of approximately

US$ 200 million per year (over the 20-year period) while the overall project was expected to have a capital cost of US$ 330 million (see Section 3.1.2).

Figure 13
Sample LNG Value Chain



Source: IGU, 2015.

4.4.4. Sample cases of implementation

4.4.4.1. Gibraltar

In 2016, multinational energy company Shell announced the construction of a small regasification unit that would receive, store and re-gasify the LNG arriving by ship for use in Gibraltar's adjacent gas-fired power plant, which has 6 generators each of 14MW [Shell, 2016]. The unit will also include a berth for a 7,500 m^3 small LNG carrier that will supply the LNG at night to 5 tanks each of 1,000 m^3 capacity, and it is expected that night-time operation would minimize disruption to the neighbouring port, airport and housing estates.

4.4.4.2. Indonesia

Indonesia, with its geography spread over many small and remote islands has proposed small-scale LNG solutions to meet its power needs. Wood Mackenzie has cited that the economics are improving as LNG prices decline, and that progress has been made through the construction of a small-scale LNG facility at Bali [Wood Mackenzie, 2016]. This Bali facility comprised an FSRU at a cost of US$ 100 million, and site, jetty & support facility for US$ 50 million, with the cost of LNG delivered to the 200MW power plant being US$ 4.60 / MMBtu (at 60% utilisation).

The entire Indonesia project covers approximately 85 natural gas power plants of varying size, ranging from 5MW to 450MW, with most of them below 40MW but clustered to other plants in close proximity, which allows for improved economic feasibility. Wood Mackenzie has projected that even though small-scale LNG facility costs are highly dependent on technology, size & actual throughput, costs could be as cheap as US $3.80 / MMBtu for a 250 MW power plant that is fed directly. On the

other end of the spectrum, for a 30 MW power plant served from a hub, costs could range up to US$ 11.50 / MMBtu.

In principle, small-scale LNG is economically viable as long as the total facility cost is lower than the diesel-LNG price differential.

4.4.5. LNG Logistics in Practice

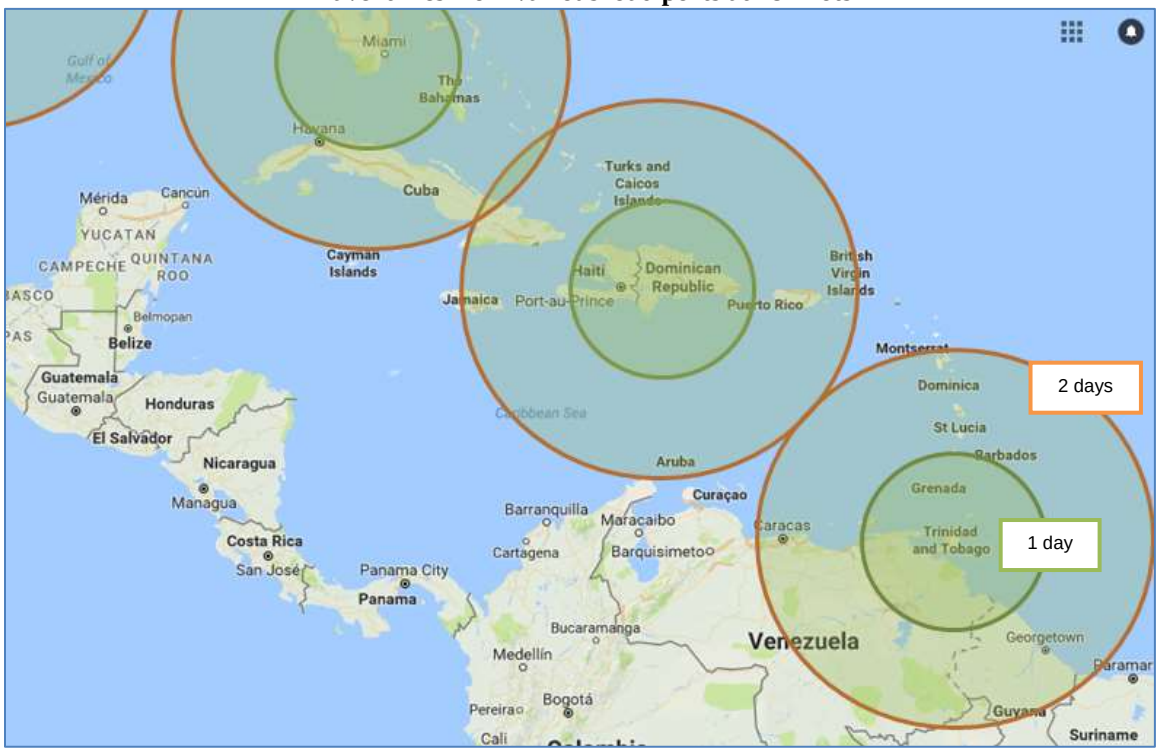
4.4.5.1. Shipping Distances

The distance from the source of the LNG facility to the end user is of key importance in the LNG value chain, and there are a couple factors that underscore the need for short transit distances for the viability of small-scale LNG.

Firstly, there is vaporization or 'boil-off' of a liquefied LNG cargo from the moment is loaded onto a transport vessel. While the tanks of these vessels are well-insulated, boil-off is unavoidable, and a longer voyage equates to more LNG being converted to gas and hence less final delivered cargo to the destination. This boil-off is usually valued at the delivered price and computed as part of the shipping cost. Thus longer distances have larger per unit shipping costs and deliver less LNG to the destination.

Secondly, a longer distance implies that the destination facility needs to hold more inventories, which increases the initial investment cost (into storage tanks) and the working capital cost, which could make small-scale facilities uneconomic.

Map 9
Travel times from various load ports at ~8 knots



Source: Author interpretation, Google Maps.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

4.4.5.2. Small-scale vessel and ISOTANKS

The industry typically defines a small-scale LNG carrier as any vessel up to 30,000 m^3 of capacity, and in operation today (for logistic and economic reasons), are a number of vessels that are equipped to carry multiple products as LNG, Ethylene and Liquefied Petroleum Gas (LPG). Vessels can either load cargo that will be fully discharged at the destination port, or can operate via 'milk runs', where some quantities of product are discharged along a particular route at multiple ports. In the Caribbean region, Jamaica's 120MW Bogue Power Plant is serviced by a 6,500 m^3 small-scale LNG vessel that loads LNG from an FSU.

Cryogenic ISOTANKS are typically either 20 or 40 feet in length, the latter of which holds up to 42 m^3 of LNG. These containers are filled at the LNG facility and trucked onto a barge or other cargo vessel and then transported via ocean to be offloaded at the destination. The mobility of these units allow them to act as intermediate storage, and full ISOTANKS are delivered and swapped for empties that have already been discharged. These containers are better suited (due to the smaller volume required) for smaller power generators and industrial clients.

4.5. Financing and Ownership

4.5.1. Caribbean Energy Thematic Fund

Analyses over the last decade and a half have demonstrated that infrastructural costs associated with the LNG industry have been prohibitive for the small nations of the Caribbean (see Section 4.4.2.1). In 2015, the then Prime Minister of Trinidad and Tobago suggested that a US$ 1 billion 'Caribbean Energy Thematic Fund' be established to assist CARICOM countries to achieve a "cleaner, more sustainable energy future", and had the strategic intent of establishing LNG as the primary fuel for power generation in the region.

The methodology proposed by the Prime Minister aimed to incorporate the private sector along with the Inter-American Development Bank (IADB), the Caribbean Development Bank (CDB), the World Bank, and the International Monetary Fund (IMF). With the change of Government in Trinidad later in 2015, it seems however that this proposal has lost momentum, and to date there has been no further developments.

4.5.2. Funding in Practice – Jamaica and Barbados

Notwithstanding the lack of progress on the Caribbean Energy Thematic Fund, both Jamaica and Barbados have forged ahead with LNG projects. In the case of Jamaica's Old Harbour Bay natural gas power plant, US$ 230 million has been raised via loans and bonds by syndicate of local banks and financial institutions led by National Commercial Bank (NCB). The loans and bonds mature in 12 and 15 years respectively, and the remaining approximately US$ 100 million on the project has been funded by private equity (see Section 3.1.3).

In December 2016 the Government of Barbados secured a US$ 34 million loan from the IDB to facilitate a public-private partnership project to import and supply LNG for power generation, and the term of the loan would run for 24 years. It would be financed by the IDB's Ordinary Capital resources with a 6.5 year grace period and a LIBOR-based interest rate (see Section 3.2.1).

Both of these models must be followed by the rest of the Caribbean as these nations aim to implement natural gas power generation plants to replace the existing diesel and fuel oil installed capacity. There is the added benefit that international agencies such as the IDB also provide access to a wealth of technical and commercial experience, and would aid in the implementation of the project, and knowledge-transfer to locals afterward.

Section 6.2 analyses the role that CARICOM must play in enabling a coordinated approach to the international lending agencies such as the IDB and World Bank, and Section 5.5 recommends that Governments must exercise their right to participate in the value chain and co-own infrastructure along with the private sector.

5.0. Regional solutions – opportunities and challenges in implementation

5.1. Eastern Caribbean Gas Pipeline (EGCP)

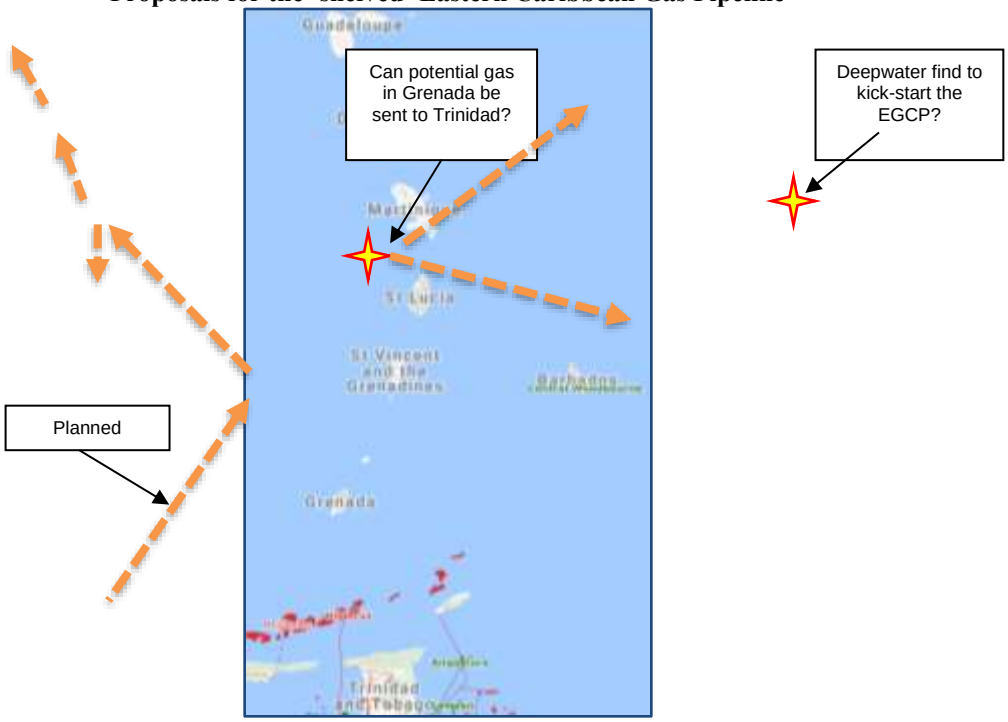
During Trinidad and Tobago's gas bonanza of the early 2000's, the Eastern Caribbean Gas Pipeline project was conceptualized. Announced by GoRTT in 2002, the initial aim was to send gas along from Trinidad (via Tobago's Cove Point) to seven countries in the eastern Caribbean which included Grenada, St. Vincent, Barbados, Martinique, St. Lucia, Guadeloupe and Dominica [Oil & Gas Journal, 2002]. The underlying intent was to supply gas to power to replace fuel oil and diesel, and the early pioneers cited the expectation that energy costs in these islands would be reduced by about 50% [Oil & Gas Journal, 2003].

By 2005, reports signalled that due to the small demand and geotechnical risks involved, both St Vincent and Grenada had been ruled out of the project [Gooding, 2005], and the revised scope envisioned an initial pipeline to Barbados from Tobago in 2006/7 and then interconnection with Guadeloupe in 2008/9 (see Map 10), with the entire project expected to cost US$ 550 million (in 2005).

The feasibility of the project hinged on the materiality of gas demand expected in the French islands of Guadeloupe and Martinique and (non-CARICOM), and which are geographically located to the north and south of Dominica respectively. The then president of the NGC confirmed that the French Government had not bought in the project, this was substantiated by the officials of the pipeline company who indicated that "significant hurdles remain" as commercial negotiations continued around inter-Governmental agreements covering issues such as transit rights, security, taxation and regulatory regime [Trinidad Express, 2005].

The Trinidad to Cove Point, Tobago pipeline was commissioned in 2012, and to date there has been no further development on the EGCP to head northwards to Barbados.

Map 10
Proposals for the 'shelved' Eastern Caribbean Gas Pipeline



Source: Author interpretation, Wood Mackenzie.
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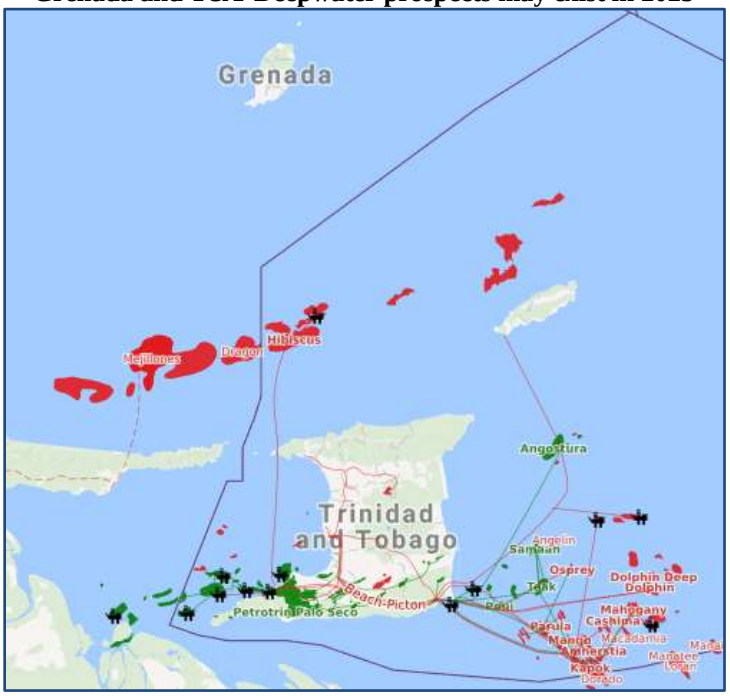
Map 11
Grenada and T&T Deepwater prospects may exist in 2025



Source: Author interpretation, Wood Mackenzie.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

5.1.1. Developments in Grenada

In July 2017 Grenada announced the drilling of an exploration well in its acreage off the south-western coast of the island in an area just north of where significant proven reserves have been found both in Trinidadian and Venezuelan waters (see Map 11) [Drilling Info, 2017]. While it is still too early to pronounce, any significant gas find could mean that a pipeline would be established southwards to the only available gas market – Trinidad, and infrastructure could also be established to take some of this gas back to shore in Grenada.

5.1.2. Trinidad Deepwater

In 2018 BHP Billiton plans to continue its deep-water exploration campaign, and this could include prospect in the northern licenced areas in Trinidad and Tobago. Should this campaign be successful, there is the potential that a significant gas find can lead to the resumption of discussions surrounding the EGCP, and whether it may be feasible to connect Barbados or Grenada.

5.1.3. Next Steps

The likelihood of the EGCP actually coming to fruition is very low, as the current gas supply shortfall in Trinidad takes priority. The country is currently working to boost upstream exploration, development and production to reverse the current 1 bcf/day shortage in the domestic and LNG markets (see Section 2.3). Even if Grenada and / or Trinidad northern deep-water prospects are successful, these greenfield[34] projects would take about 7 or 8 years to be fully developed, taking the timeline out to 2025 or 2026.

In the interim, Barbados has already inked a deal to import ISOTANKS of LNG from the Dominican Republic (see Section 3.2.2), and with advances in LNG logistics and technology, one may expect that pipeline gas from Trinidad cannot would not be able to compete with ISOTANKS by the middle of the next decade, unless of course some very significant gas reserves are found.

In any event, the Dragon gas interconnection project with Venezuela is giving the NGC and GoRTT sufficient experience in cross-border pipeline gas deals, as it is actually the first of its kind for the country. Gas from this development could flow as early as 2019 or 2020 (see Section 2.4.1), by which time GoRTT and NCG should be well poised to navigate the past commercial challenges of the EGCP should it come back on the table.

5.2. Atlantic LNG

5.2.1. Cost competitive yet commercially complex

Atlantic LNG, a 15 million metric tonne per annum (mmtpa) LNG plant was built at the nadir of the cost curve for similar scale LNG plants at the time, and is fully depreciated. Figure 12 summarizes how cargoes from Atlantic's Train 1 are the most cost competitive of all cargoes supplied into Puerto Rico. While it may make sense to capitalize on this relatively cheap LNG to supply the CARICOM market, it is not as commercially simple as it may seem.

The Trinidad & Tobago Gas Master Plan of 2015 reveals the commercial complexity of Atlantic LNG. There are four individual liquefaction Trains that operate under 3 separate companies, with different gas suppliers, ownership, commercial structures and off-take arrangements (see Table 9). Off-take arrangements are usually long-term and would typically have back-to-back commercial arrangements to deliver to specified customers. The net effect is that a decision cannot simply be made to deviate and send an LNG cargo to a 'new' destination, unless of course there was excess supply that

[34] Greenfield oil and gas projects are those in new areas without existing infrastructure.

resulted in the availability of a 'spot[35]' cargo, and with Trinidad's current gas supply shortfall, one can expect that such 'spot' cargoes are few and far between.

Table 9
Commercial Structure of Atlantic LNG

Train	Shareholding	Structure & Term	Gas Supply	Off-take
Train 1	Shell (46%), BP (34%), NGC (10%) and CIC[36] (10%)	'Merchant' model with the Train taking price risk; supply contract ends 2018	BP (100%)	Engie (60%) and Gas Natural Fenosa (40%)
Train 2 / Train 3	Shell (57.5%) and BP (42.5%)	'Pseudo-tolling' model where the Train buys gas and sells LNG with little volume / price risk; supply contracts end 2022 and 2023	BP (50%) and Shell (50%)	Shell (68%), Gas Natural Fenosa (21%) and Engie (11%)
			BP (75%) and Shell (25%)	Shell (74%), Naturgas Energia (26%) and BP (any excess)
Train 4	Shell (51.1%), BP (37.8%) and NGC (11.1%)	'Full tolling' where service is provided to Processing Entities with little volume / price risk; supply contracts end 2027	BP (71.1%) and Shell (28.9%)	Shell (51.1%), BP (37.8%) and NGC (11.1%)

Source: Poten & Partners, 2015.

5.2.2. Role of the state-owned gas company

In Section 2.6.2, the NGC was identified as an important stakeholder in any gas supply project on the island – both from its equity off-take in Atlantic LNG Train 4 and the fact that it has positioned the company to get into marketing and trading of commodities, such as LNG.

Additionally, the Gas Master Plan (GMP) of Trinidad recommends that the NGC takes a more active role in the aggregation of all the gas supply on the island, even gas that goes to LNG (and which is currently controlled directly by the upstream companies) (see Section 2.5.1). There is also scrutiny on the upcoming expiration of the supply contract to Atlantic LNG Train 1 in 2018 (see Section 2.6.1), of which NGC owns 10%, whether a new supply contract will be re-negotiated, and under what terms.

When all of these factors are considered together, it could mean that the NGC has the ability to leverage its shareholding not only in Atlantic LNG Train 4, but also in Train 1 during the upcoming negotiations to assure that (via some commercial solution) that a sliver of LNG volume is put aside to preferentially supply the small states in the Caribbean.

5.2.3. GoRTT dilemma

In the GMP, Poten & Partners indicated clearly that the Government of the Republic of Trinidad and Tobago (GoRTT), and by extension the country, was not deriving its best value from gas by sending it to LNG (see Section 2.6.1). It is unclear how GoRTT would respond if now approached with another LNG supply project (this time to small island states), especially where some commercial concessions may have to be given to ensure viability of the project.

However, the issue of low LNG netbacks to the country all arose out of long-term contracts. Given the opportunity to renegotiate, and in keeping with GoRTT's economic commitment to their Caribbean neighbours, it is likely that new commercial terms would allow GoRTT to still derive an acceptable return from LNG supply in the region.

5.2.4. Normal operations

Normal supply to EcoElectrica in Puerto Rico and AES in the Dominican Republic would nonetheless continue through the life of their supply contracts. However, it is recommended that some commercial

[35] Spot cargoes are sold on a short-term basis as opposed to long-term contracted supply.
[36] CIC is the China Investment Corporation.

solution be explored if indeed AES is utilizing Trinidadian LNG to reload into smaller vessels and / or ISOTANKS to supply the smaller states of the Caribbean.

It is unclear whether additional taxes and duties are accrued when this product passes from a CARICOM to a non-CARICOM member (Trinidad to the Dominican Republic), and then potentially back on to a CARICOM nation (e.g. Barbados). In this regard, an allowance should be made so that the end CARICOM receiver does not have to pay the inflated value that may potentially include taxes and duties by having to 'pass through' the Dominican Republic. This could serve as an interim measure while a more-sustainable LNG supply project is developed in Trinidad.

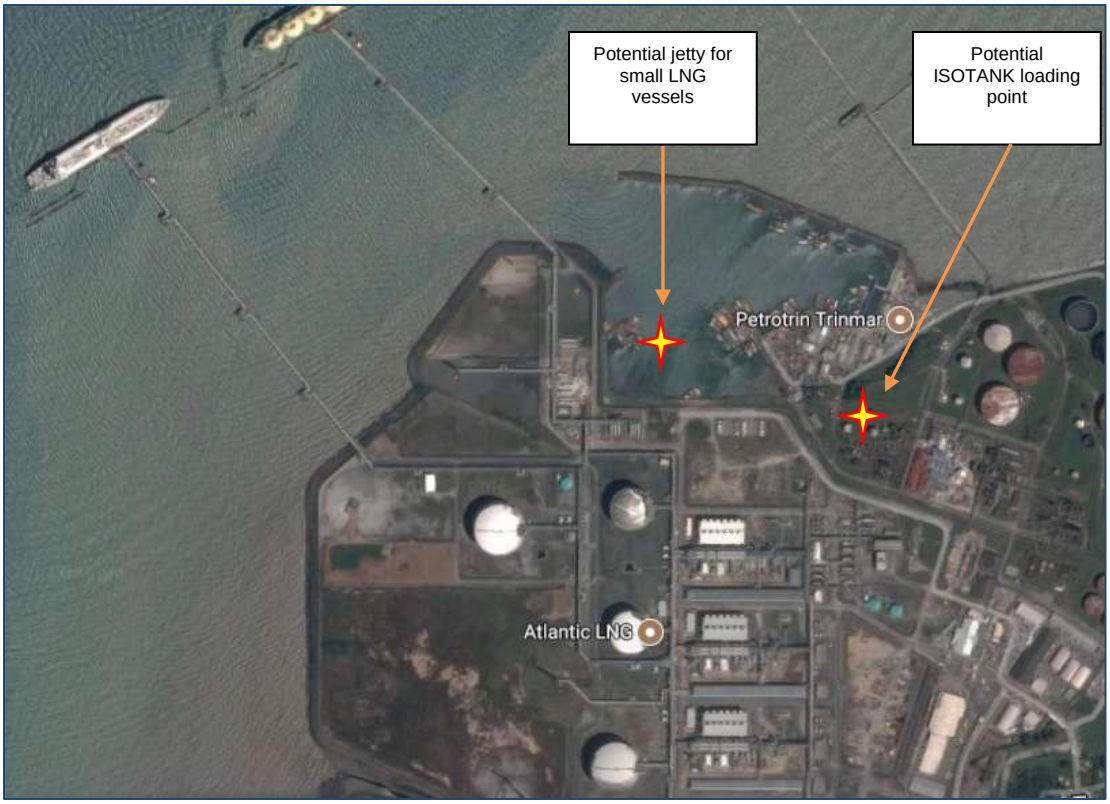
5.2.5. Innovations to enable small scale LNG from Atlantic LNG

It has been established that the Atlantic LNG facility produces very cost-competitive LNG when compared to its peer LNG plants. Leveraging this cost advantage it is possible for the facility to install the necessary infrastructure to enable the loading of small LNG vessels and / or ISOTANKS as reviewed in Section 4.4.5.2. In the Dominican Republic, AES has already implemented this infrastructure utilizing its single 160,000 cubic metre storage tank [AES, 2017]. Compare Atlantic LNG that has four tanks that correspond to a total storage of 540,000 cubic metres.

While the facility's existing dock may be incompatible for smaller vessels, the opportunity exists to utilize the smaller dock (for smaller LNG vessels or barges to transport ISOTANKS) located on a state- facility to the north-east of Atlantic LNG.

In Section 3.2.1 it was indicated that in 2016 the Minister of Energy and Energy Industries (MEEI) instructed Atlantic LNG to look at the feasibility of implementing small scale LNG. To date, there has been no public development on this, but for Atlantic LNG it could be a question whether it is worth navigating its own commercial complexity for such a small prize, especially given the gas supply (and revenue) shortfalls.

Map 12
Potential Small scale vessel and ISOTANK LNG at Atlantic LNG



Source: Author interpretation, Google Maps.

Nevertheless, tapping-off LNG from an existing production facility would require minimal infrastructure when compared to setting up a Greenfield, new small scale LNG option in Trinidad (see Section 5.3). Thus Atlantic LNG presents the most favourable infrastructure-based option to enable small scale LNG in the Caribbean, but would require the influencing of the NGC and GoRTT to enable a solution to overcome potential non-technical issues. These would include initial funding, how investment into a small scale infrastructure is recovered by the shareholders across the complex commercial structure, approval of commercial agreements, and how small scale LNG off-take is apportioned.

5.3. Small scale LNG from Trinidad not involving Atlantic LNG

In 2013 GoRTT gave approval for a subsidiary of the National Gas Company to enter into a Project Development Agreement with Gasfin[37] for the construction of a mid-scale LNG plant for the supply of LNG to the Caribbean called 'Caribbean LNG'. The scope involved a single LNG Train with the capacity of 0.5 mmtpa, with the possibility to scale up to 1.0 mmtpa with additional Trains based on demand growth in the Caribbean and Central American basin (compare Atlantic LNG with a capacity of 15 mmtpa).

Caribbean LNG's deal hinged on a 2011 supply agreement with Electricité de France (EdF), which is the power generation company on the French Caribbean islands of Martinique and Guadeloupe,

[37] Gasfin is a provider of mid-scale LNG infrastructure with its headquarters in Luxembourg.

for 400 ktpa of LNG [Platts, 2013]. By 2015 the PDA with GoRTT had still not been executed and Gasfin still expressed confidence that supply would commence in Q1 2019 [Energy Chamber, 2015].

With the current gas supply shortfall where Atlantic LNG and the downstream petrochemical sector are both undersupplied and underutilized, it is unlikely that a new LNG export project would be approved. Furthermore, the Gas Master Plan of 2015 has signalled clearly to GoRTT that LNG has not provided the best economic rent to the country versus the petrochemical sector (see Section 2.5.1), and even though new LNG projects (such as Gasfin's Caribbean LNG) would be subject to new commercial contracts, GoRTT's hesitance could be linked to unfavourable LNG experiences of the past.

In any event, should Caribbean LNG's supply start in 2019, it would have lost first mover advantage as Jamaica and Barbados have forged ahead with LNG solutions of their own, and with AES Andres in the Dominican Republic already having positioned itself as a supplier of small scale solutions in the Caribbean. Although Gasfin's initial supply was linked to Martinique and Guadeloupe initially, the economics of the project would have also considered expansion to supply the wider Caribbean, which meant lower unit capital and development costs. With the reducing likelihood of being able to supply these additional markets, the overall viability based on a single Train may become even more challenged.

Diagram 5
Caribbean LNG's projected supply opportunities

Source: Platts, 2013.

5.4. Geographic FSRU / FSU solution

A Floating Storage and Regasification Unit (FSRU) is a vessel which is capable of transporting, storing, and regasifying LNG, and is either purpose-built or converted from a conventional LNG transport vessel. FSRUs either requires an offshore terminal, which typically includes a buoy and connecting undersea pipelines to transport regasified LNG to shore, or an onshore dockside gas receiving terminal.

Compare a Floating Storage Unit (FSU) which does not have regasification capability, and is usually an LNG transport vessel that has been taken out of service for some time to provide LNG storage

only. The FSU is equipped to receive cargoes using the ship-to-ship transfer process, and also equipped to reload LNG onto smaller vessels. New Fortress Energy (NFE) has deployed an FSU in Jamaica to provide LNG for a new natural 120 MW gas power plant and the vessel is equipped with the capability to reload to smaller shuttles vessels.

This new plant in Montego Bay, together with another 190 MW plant planned for construction in Old Harbour, Jamaica has the critical mass to sustain its own 136,000 cubic metre FSU (see Section 3.1.2). Smaller nations of the Eastern Caribbean have a greater challenge as they do not have sufficient installed capacity on their own to each sustain an FSU should they begin their power-generation conversion to gas. However, the opportunity exists to replicate the Jamaica FSU model should these smaller nations be considered together.

Wärtsilä has calculated that 100 MW of natural gas power generation (taking into account plant efficiencies) would require approximately 1,022 cubic metres of LNG per day [Wärtsilä; 2013], and one month of inventory requires storage of approximately 30,000 cubic metres – less than 25% utilization of a typical FSU.

The aggregated installed fuel oil and diesel power-generation capacity of Antigua and Barbuda, Barbados, Grenada, Dominica, Montserrat, St. Lucia, St. Kitts and Nevis and St. Vincent and the Grenadines, is 526 MW (see Table 10). This 526 MW equates to 5,200 cubic metres of LNG per day, or 157,000 cubic metres per month should all this capacity be converted to natural gas – and is more aligned with the typical FSU volume. In practice though, a phased approach would assume that the move to natural gas for power-generation is gradual, and with the assumption that only 40% is migrated from fuel oil and diesel, a substantial 63,000 cubic metres is still required for these Eastern Caribbean countries on a monthly basis.

Similarly, the Bahamas with its 536 MW of fuel oil and diesel generation capacity, which equates to 5,300 cubic metres of LNG per day, or 160,000 cubic metres per month should all this capacity be converted to natural gas, is also in line with the typical FSU volume.

Table 10
FSU solutions for the Eastern Caribbean and the Bahamas

COUNTRY	Fuel Oil / Diesel Installed Capacity (MW)	Equivalent LNG (m^3/day)	LNG (m^3/month) based on the % conversion from Fuel Oil / Diesel Installed Capacity to Natural Gas				
			20%	40%	60%	80%	100%
Bahamas	536	5 318	31 910	63 820	95 731	127 641	159 551
Equivalent 160,000 m^3 FSUs required			0.20	0.40	0.60	0.80	1.00
Barbados	153	1 518	9 109	18 217	27 326	36 435	45 543
Antigua & Barbuda	112	1 113	6 680	13 359	20 039	26 719	33 398
St. Lucia	88	878	5 265	10 530	15 796	21 061	26 326
St. Kitts & Nevis	53	528	3 167	6 334	9 502	12 669	15 836
St. Vincent & Grenadines	46	455	2 733	5 465	8 198	10 930	13 663
Grenada	48	475	2 853	5 706	8 559	11 411	14 264
Dominica	20	199	1 196	2 392	3 588	4 784	5 980
Montserrat	6	55	327	655	982	1 310	1 637
Eastern Caribbean	526	5 222	31 330	62 659	93 989	125 319	156 648
Equivalent 160,000 m^3 FSUs required			0.20	0.39	0.59	0.78	0.98

Source: Author calculation.

The data in Table 10 demonstrates that FSUs in the Bahamas and the Eastern Caribbean are viable from a volume perspective – where the FSUs receives typical large LNG cargoes, stores them, and then reloads in onto a smaller shuttle vessel to feed the power generation needs of each island. The scope of this analysis only considers CARICOM countries, but the case for implementation is enhanced when one considers neighbouring non-CARICOM countries that can also benefit from these shared FSUs e.g. Anguilla, Martinique, Guadeloupe, Saint Martin / Sint Maarten, Saint Barthelemy, US and British Virgin islands in the Eastern Caribbean (see Map 13), and the Turks and Caicos near the Bahamas (see Map 14).

The success of this option however depends on the simultaneous introduction of small-scale natural gas power generation plants, LNG receiving terminals, inland storage and regasification facilities, and pipelines in each of these island territories. For the Eastern Caribbean for example, this would require the coalition of individual state agencies from each island to form a single coordinating body, who in turn engage private sector counterparty for LNG supply and infrastructure investment. It is assumed that these FSUs would be supplied out of Trinidad, with CARICOM concessions applied as necessary to meet the respective investment hurdle rates.

Map 13
Potential FSUs in the Eastern Caribbean and the Bahamas

Source: Author interpretation, Google Maps.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

Map 14
Potential FSUs in the Eastern Caribbean and the Bahamas

Source: Author interpretation, Google Maps.
Disclaimer: The boundaries and names shown on this map do not imply official endorsement or acceptance by the United Nations.

5.5. Setting up the Value Chain

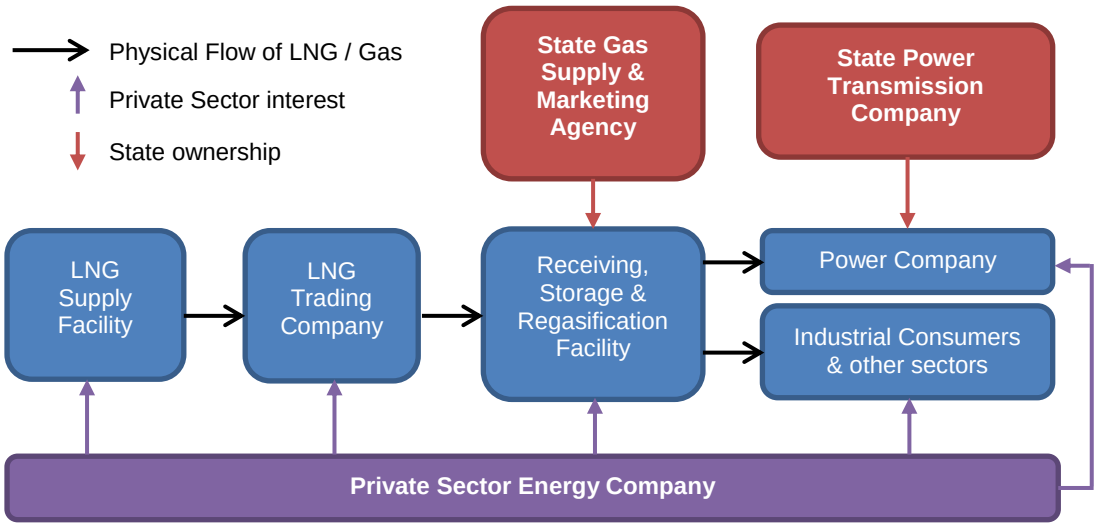
This section examines how the respective value chains could be set up in practice, and is premised on the successful gas monetization model in T&T, where the state-owned National Gas Company (NGC) is the aggregator for all gas supply domestically[38]. This gas supply and marketing organization sells gas to the power generation sector (either directly to the independent power producers or to the state power company), industrial customers and other gas-based industries / consumers.

Private sector energy companies usually have various commercial interests along the value the chain, from the LNG supply facility, to a trading company, to the end users such as power generation or industrial commodities. Fully integrated energy companies typically are present in each of the segments of the chain (see the Trinidad examples in Table 6). Thus, if there is a market for gas use in a particular territory, such private sector companies would be the likely investors into receiving, storage and regasification infrastructure, as did New Fortress Energy in Jamaica (see Section 3.1.1).

It is recommended that respective Governments also attempt to participate in this area of the value chain via a Joint Venture, with the aid of international funding to meet its equity capital as necessary (see Section 4.5). Such state participation allows balanced decision-making in the interest of the local stakeholders, enables future flexibility (as opposed to being locked into commercial arrangements with a single counterparty), builds local expertise, and creates commercial value for the State.

[38] NGC does not aggregate gas supply for export, although the Gas Master Plan recommends (see Section2.5.1).

Diagram 6
LNG Supply model and value chain



Source: Author interpretation, Google Maps.

Where the Receiving, Storage & Regasification facilities are concerned, there is typically (i) a terminal owner, (ii) a terminal operator and (iii) capacity holders. The terminal owners (as the name implies) own the terminal and hold a contract with the terminal operator, who in turn runs the terminal and has a back-to-back contract with the capacity holders. Capacity holders physically own the molecules of gas, and pay a handling fee to the terminal.

6.0. Conclusions and Recommendations

This paper sought to examine the opportunities for more sustainable infrastructure and logistics of hydrocarbons in the Caribbean, and in particular how valued added supply chains could reduce costs, improve access and create economies of scale and scope in support of inclusive development and structural change in the Caribbean.

The link was made between economic fragility of Caribbean nations and the dependence on higher-priced, imported diesel and fuel oil for power generation. Furthermore, it was demonstrated that there is a clear opportunity to move away from diesel and fuel oil, and to introduce the cheaper and cleaner option of natural gas via small-scale LNG.

LNG has traditionally been associated with large capital investments which are prohibitive for small volume Caribbean markets, but recent advancements by Jamaica and Barbados to implement small-scale LNG has demonstrated that the solution space is evolving. This paper concludes that the following elements are instrumental to enable the promulgation of LNG in the Caribbean:

- There must be sub-regional phased solutions that are driven by geography, market size and existing infrastructure.
- An economy of scale must be created by alignment of country policies, financing strategies and timelines for implementation – where CARICOM could have an important role lead or coordinator this process.
- Appropriate commercial considerations must be made, which includes the possibility of a concessionary pricing on intra-regional LNG.
- Trinidad and Tobago have a key role to play despite current domestic gas supply challenges.

6.1. Sub-regional Phased Solutions based on Geography, Market Size and Existing Infrastructure

It is recommended that Atlantic LNG in Trinidad be equipped to supply small-scale LNG via modification of its existing facilities. The primary destination would be the Eastern Caribbean, Suriname and Guyana, and for the Eastern Caribbean ISOTANKS can be initially utilized until the

combined demand can sustain small-scale vessels on a milk-run, and then ultimately its own FSU. In lieu of the readiness of Atlantic LNG, the Dominican Republic would continue to supply small-scale LNG out of the AES Andres facility.

The Dominican Republic (as it intends), should begin to supply the Bahamas with ISOTANKS and then small-scale vessels until, like the Eastern Caribbean, its own FSU can be sustained. Belize, on the Central American mainland, and Haiti should be supplied via ISOTANKS and then small-scale vessels by the Dominican Republic or Jamaica, the latter of whom intends to create its own supply hub.

Trinidad would continue to supply the Dominican Republic via conventional cargoes (greater than 135,000 m^3), but there should be the aim to introduce concessionary pricing (see Section 4.3.2.2) so that LNG redistributed to CARICOM nations enjoys the 'benefit' of having been dispatched from a fellow CARICOM nation.

6.2. CARICOM-led alignment on Policies, Financing Strategies and Timelines – an Economy of Scale

Throughout this paper it has been demonstrated that most nations in the Caribbean do not have the power generation demand or industry to sustain the importation on LNG on their own. In order to implement sustainable solutions, the countries must approach this opportunity collectively as their combined demand can create an economy of scale. CARICOM could take the lead in bringing its member states together, and to lead the formation of a single body or committee that handles all aspects of the implementation of LNG across the region.

A unified region would have the added advantage of approaching international agencies such as the IDB for support in developing and implementing supporting policy, enabling access to funding or even negotiating supply agreements with counterparties. There is also the added bonus that project development could be properly coordinated and phased, leading to further logistic and cost optimization. All of these tasks would be considerably more difficult should a single small nation attempt on its own.

6.3. Commercial Considerations

6.3.1. Concessionary Pricing

Some countries within the Caribbean basin are well-advanced in the importation, and in the case of the Dominican Republic, the redistribution of LNG. The Dominican Republic sources its LNG from Trinidad and, from the strategies outlined by the major player in that market (AES), LNG via small-scale vessels and ISOTANKS will continue to be redistributed across the region and will penetrate new markets that currently do not use natural gas. Recognizing that CARICOM nations would be importing LNG that originated from a fellow member state of CARICOM (Trinidad) and was merely transhipped and reloaded in the Dominican Republic, there must be some mechanism that facilitates the intended CARICOM objective of single-market economic integration.

A trade agreement currently exists between CARICOM and the Dominican Republic, and this should be leveraged to ensure that CARICOM nations that import small-scale LNG enjoy some benefit of having it originally shipped from Trinidad. This could take the form of a discount, tax rebate, improved credit, low interest financing or some other form of preserving and transferring value to the importing nation. It would require a suite of creative, back-to-back commercial arrangements that need to be coordinated and facilitated at a regional level.

6.3.2. Market Competition in the North Caribbean

It has been established that small-scale LNG solutions for the Caribbean will be driven by geographical considerations, but there are two countries in relatively close proximity to one another that each aim to be an LNG redistribution hub – the Dominican Republic and Jamaica. As the former is a bit further advanced in the journey in terms of infrastructure and experience, it could be argued that Jamaica would experience difficulty in establishing its hub. This however should not be discouraged, as competition would merely seek to drive final prices downwards, which would further benefit the importing nations of the Caribbean.

6.3.5. Customized Commercial solutions

It is important to recognize that even though there are some commercial proposals to enable small-scale LNG projects to progress within CARICOM, it does not necessarily equate to a broad-brushed approach. Just as CARICOM has subdivided the region into the Lesser Developed Countries (LDCs) and the More Developed Countries (MDCs) and applied varying Common External Tariffs on extra-regional importation (see Section 4.3.2.2) to both groups, so too can this approach be emulated for concessionary LNG pricing via CARICOM agreements or via PetroCaribe.

To ensure commercial value is created for the LNG supplier in an already small market, negotiations should seek to allow a fair return on project investment but still make LNG affordable to the importing nation. Supply projects to smaller islands would have an increased unit development cost, but to ensure that these nations are part of the LNG transition journey along with their larger neighbours, their concessions can be further adjusted to ensure that project hurdle rates are met, and the tiered concept of MDCs and LDCs can be employed.

In addition, the option of establishing a Caribbean LNG pricing index could be established (see Section 4.3.2.3).

6.4. Maximizing Trinidad's role

In the past, Trinidad's willingness to supply gas to the Eastern Caribbean via pipeline and to Jamaica via LNG has been articulated, but both failed to materialize due to signs that its own reserves to production ratio was dropping perilously low. Successive Governments in Trinidad have also committed to the CARICOM Single Market and Economy (CSME), for the creation of a single enlarged economic space through the removal of restrictions resulting in the free movement of goods, services, people, capital and technology. It is therefore important that Trinidad's past and present intent be fully leveraged to supply LNG to the Caribbean, but this will require a coordinated effort by the rest of CARICOM at a critical time when Trinidad is grappling with its own supply shortages.

Firstly, T&T has a wealth of experience in developing and financing energy projects. The Government-owned National Gas Company (NGC) and its business development subsidiary National Energy (NE), are actively marketing their services to a number of African nations who aim to develop their industries, and similar services can also be deployed by these agencies closer to home in the Caribbean. Additionally, the energy service sector in Trinidad is awash with competent firms whose expertise should also be leveraged in developing small-scale LNG in the rest of the Caribbean. Both the participation by state firms and private companies are facilitated by existing CARICOM policy that promotes the movement of people and services in the region.

Secondly, the T&T Government is also a player in the LNG value chain via the NGC's participation in Atlantic LNG. Though their shareholding of the facility is relatively small compared to BP and Shell, and despite the complexity, they do have ability to influence the facility to embark on installation of small-scale LNG loading infrastructure that can be used to service the Caribbean. From a commercial perspective as well, they currently own LNG off-take from Train 4, and with negotiations

underway for the renewal of the Train 1 supply contract in 2018, they could own additional off-take here. As a state agency, with the right Government policy agreed between T&T and CARICOM, some of this LNG could be used to supply the Caribbean.

6.5. Opportunities for the wider Caribbean region

Although the scope of this paper mainly focuses on CARICOM due to the integration and enabling policy that already exists, the other non-CARICOM nations and territories would all ultimately benefit from any coordinated regional approach, as this further enhances the economy of scale. For example Cuba, with its relatively larger land mass and population would gain from any solution deployed in the northern Caribbean, while non-Caribbean islands such as the Dutch or French territories can benefit in the Eastern Caribbean. Aruba, Bonaire and Curacao in the south-west could also be serviced from Trinidad, Jamaica or the Dominican Republic.

6.6. Areas for Future Work

To aid the implementation of small-scale LNG projects in the Caribbean, it is recommended that further work be done in the following areas:

Undertake a joint feasibility study between CARICOM and the Government of Trinidad and Tobago, and the NGC on the opportunity to implement small-scale LNG from Atlantic LNG in Point Fortin, Trinidad. This work should also an examination of how new commercial arrangements would fit into the existing commercial structure.

Establishment of a commercial committee to evaluate how price concessions and / or PetroCaribe (among other commercial considerations) would work in practice.

Perform a detailed study on the other Caribbean nations and overseas territories, and the ability to have a coordinated approach together with CARICOM.

Compare and contrast the Indonesian model of small-scale LNG and what learnings can be applied to the Caribbean.

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