Diagnosis of Generation in Latin America & the Caribbean: Jamaica

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General Context:

Utility power systems of the Latin American and Caribbean Region (LAC) tend to be large hierarchical systems which have inefficiencies and depend on integrated generation, transmission, and distribution systems to serve customers. Such systems are also typically thermal plants using fossil fuels though there is some trending towards more renewable distributed generation sources. Contrasting with this traditional large centralized generation model is an alternate model of distributed generation, where increasing numbers of customers generating power locally on a smaller scale, feeding into the grid network and delivering power over shorter distances, at lower voltages (distribution) and utilizing available renewable energy sources. This transformation is influenced by the national mandates for cleaner fuels, unbundling of centralized and vertically integrated utilities, greater energy security especially related to the use of indigenous resources, and the economics of incremental generation expansion. As a Caribbean island, Jamaica is also influenced by the reasons for and outcomes of these trends.

In this changing energy environment, it is necessary to diagnose the current state of conventional generation and distributed generation in Jamaica, the technologies used, the sources of energy and the trend towards distributed generation.

Specific Objectives:

The specific objectives determined for this analysis are as follows:

a. Analyze the generation expansion plans of Jamaica, considering conventional and distributed generation, current status of generation systems, the technology used, and their sources of generation and growth prospects.
b. Classify by type, the technology used and the production and generation model of the current generation sector as well as that which will be implemented in the future.
c. Evaluate the status of conventional generation and distribution set utilization.
d. Make projections about the trend of proliferation of distributed generation and implementation feasibility in Jamaica.
e. Investigate and propose new conventional and distributed generation technologies.
f. Conduct economic evaluation for the implementation of new efficient conventional and distributed generation technologies in Jamaica.

Jamaica's Energy Scenario:

National Energy Mix:

In 2011 imported fossil/petroleum fuels accounted for 95% of Jamaica's overall energy mix (21.2 million barrels in 2011) and renewable resources accounted for approximately 3% of the total national energy mix (heat, power, motive and other). Most of the renewable sources came from wind, hydro, fuelwood, bagasse, solar and ethanol (used in the transportation sector). The electricity sector consumed the largest volume of petroleum amounting to 6,529,445 bbls (30.8%) for the generation of power mostly from old and inefficient generation plants. Approximately 5.6% of the electricity supply mix came from renewable sources for power generation namely hydro, wind and a smaller amount from biomass for both heat and power in 2008.

The Jamaica's National Energy Policy (JNEP) 2009 – 2030 as the central guiding policy, is therefore built around a vision which states that Jamaica will have a *"modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework"*.

Socio Economic:

Under a contracting real Gross Domestic Product (GDP) of 2.7% in 2009 there remains a need to maintain Jamaica's commitment to sustainable development programmes and climate change issues, implementation of a state driven program of energy conservation and efficiency, and the addition of more a more sustainable energy mix focused on alternative energy.

As much as 75% of foreign exchange earned has been spent on imported crudes and petroleum fuel and this amounts to more than 15% of Gross Domestic Product. The volatility in oil prices has also contributed significantly to high electricity costs as most plants are oil fired thus energy substitution using renewables and distributed generation will directly aid in improving the Jamaican economy and the electricity sector long-term.

Regarding electricity charges, Jamaica's residential, commercial and industrial electricity prices are among the highest in the Latin American and Caribbean (LAC) Region. This partly because 95% of electricity generation uses the more expensive petroleum fuel for generation. The cost of fuel and IPP charges which is approximately 2/3 of the electricity charge to the consumer is a pass through item and electricity delivered has been sold for approximately US$ 0.25/kWh in 2013. Service charges and tax are then added for a total charge amounting to US$ 0.40 – 0.42/kWh. This is further compounded by high total system losses of 23% (9.9 % technical losses and 13.0 % non-technical loses by electricity theft - 2009 data). The economic impact on the society from this fossil fuel generation is exacerbated by the necessary periodic increases in its tariff rates for central generation. The combination of global oil prices, pass through fuel charges, and generation and transmission inefficiencies makes electricity an expensive energy option for the average Jamaican household and especially for citizens in a low socio-economic grouping. The overall price of electricity is however expected to decrease by 20 – 30 % in 2015 following the addition of 6.3 MW of hydro at the Maggoty

Hydro Power site and 360 MW of new LNG powered generation is added to the mix. Generation (only) is expected to approach around 13 – 15 ¢/kWh.

Electricity Generation Sector:

Jamaica Public Service Company Ltd is the dominant player in generation approximately 588 megawatts (MW) or over 66% of the total current generation capacity, some of which comes from renewable energy. By 2011, annual electricity generation alone from renewable energy sources accounted for approximately 5.6 % of total system generation with contributions of 3.5% and 2.1 % from hydro and wind respectively. Three hundred megawatts (300 MW) of this capacity has been provided by independent power producers (IPP) who sell power to JPS via power purchase agreements (PPA) for delivery unto the grid. These IPPs are Jamaica Energy Partners (JEP) = 124 MW; Jamaica Private Power Company (JPPC) = 60 MW; Wigton Wind Farm Limited = 38.7 MW; and Jamalco (bauxite company) = 11 MW. The utility recently added 3 MW of wind from its own generation and has a total of 21.3 MW of hydropower from previous generation plus some refurbished plants.

The gross peak demand to date is 614 MW (and gross generating capacity of 920 MW) but is projected to grow at an average rate of 3.8% per annum over a twenty year (20) year planning horizon (2010 to 2029). Over the next 20 years, approximately 1,400 MW of new fossil fuel power plant capacity will have to be constructed in Jamaica including distributed generation systems, to meet the projected demand for electricity and approximately 800 MW of this new capacity needs to be constructed in the coming decade.

JPS has an extensive transmission and distribution system which includes approximately 400 km of 138 kV lines and nearly 800 km of 69 kV lines. The system consists of twelve (12) 138/69 kV inter-bus transformers with a total capacity of 798 MVA and fifty-three (53) 69 kV transformers (total capacity of 1,026 MVA) which supplies the primary distribution system at 24 kV, 13.8 kV and 12 kV. The coverage of the overall electricity infrastructure of 14,000 km for transmission and distribution results in over 95% electrification of the country. Total system losses inclusive of technical and non-technical losses declined from 23% in 2009 to an average of 22.3% in 2011.

The key legal and regulatory framework governing various aspects of the Jamaican power market are contained in and regulated by the following:

- The OUR Act 1995 (as amended).
- The Electric Lighting Act.
- JPS's Amended and Restated All-Island Electric License, 2011.
- OUR's Regulatory Policy on Guidelines for the addition of Generating Capacity to the Public Electricity Supply System: June 2006 (Document # Ele 2005/08.1).
- Generation Expansion Plan 2010.

Under the policy, legal and regulatory framework, with the objective of meeting new generation demand, Jamaica's rapidly changing generation landscape in the past decade will now include the following initiatives:

1. Request for Proposal for 480 MW of new generation from LNG.
2. Procurement process for base load capacity for 360 MW new fossil fuel generations.
3. Development of a wheeling legislative framework.
4. Government and utility efforts to reduce electricity prices.
5. Development of a Net Billing policy and regulations.
6. Consultations on the upgrade and unbundling of the grid network and grid network failures (2013/2015).
7. Request for proposals for new 115 MW renewable energy generations.
8. Three separate bids for hydropower feasibility studies.
9. Addition of 6.3 MW of hydropower by the utility.
10. Applied capacity additions of up to 25 MW as unsolicited bids generated from renewable sources.
11. Two LNG supply and infrastructure bid rounds.
12. Addition of 65 MW of new fossil fuel generation by West Kingston Power Partners.
13. Addition of 3 MW wind generation by the utility (JPS).
14. Addition of 18 MW of wind generation by Wigton Wind Farm Ltd.

In this evolving environment, new generation as centralized or distributed generation may be added in one of three (3) modes;

- New conventional technologies.
- New renewable energy technologies.
- New cogeneration technologies.

Distributed Generation:

In the last decade, technological innovations and a changing economic and regulatory environment has resulted in a positive and rapidly growing trend of distributed generation growth. There are 5 major factors that contribute to this evolution:

1. Electricity market liberalization allowing independent generation.
2. Increased customer demand for high reliability for electricity supplies, lower costs and price volatility.
3. Developments in distributed generation technologies and associated power electronics for smarter grids.
4. Constraints on the construction of new generation, transmission, and distribution lines.
5. Environmental concerns about climate change.

Distributed generation in Jamaica will be defined as privately owned (residential, commercial or industrial) generation units with a **maximum capacity of 10 MW**, located at the point of consumption, which are **neither centrally planned nor dispatched by the control of the utility** (i.e. on-grid as available). Such systems should be capable of connecting to the primary distribution network at 24 kV, 13.8 kV and 12 kV or on the consumer side of the meter only for the purpose of supplying power to other nearby facilities of the generator or to use the grid as a backup or storage option. Independent off-grid systems are included in the definition.

Distributed generation will be treated as non-specific to any particular energy source or technology and may be prime, firm, dispatchable or intermittent power.

Distributed generation should also be considered distinct from the primary revenue earning objectives of independent power producers (IPP).

Modern distributed generation technologies include the following:

● Primary Target Market
○ Secondary Target Market

	Residential	Commercial	Industrial	Grid-distributed	Portable Power	Transportation	Typical Unit Size Range (installation size can be larger)
Microturbines		●	●	●	○	○	25 - 300 kW
Reciprocating Engines		●	●	●	●	●	5 kW - 50 MW
Low-Temperature Fuel Cells	●	●	○	●	○	●	2 - 250 kW
High-Temperature Fuel Cells		●	●	●	○		100 kW - 3 MW
Fuel Cell/Gas Turbine Hybrids		○	○	●			250 kW - 20 MW
Small Gas Turbines			●	●			500 kW - 5 MW
Photovoltaics	●	○	○	●			1 - 500 kW
Wind Power	○			●			50 kW - 2 MW
Biomass Power			●	●			250 kW - 50 MW

Solar - Photovoltaic (PV):

In Jamaica the most prolific distributed generation option is solar photovoltaic (PV) technology for small to large-scale power generation requirements. Jamaica is well placed to exploit solar energy resources having superior and steady solar irradiation as much as 5.7 kWh/m^2/d. PV is modular and scalable; low maintenance; easily integrated into the existing electrical wiring; has access to new low interest financing; supported by a recent Net Billing Policy and broader Energy Policy; and supported by a rapid growth in the practitioner/installer market and high price of electricity.

Small-scale onsite grid-tied generation projects for households and businesses (< 1 kW to 100 kW) has been the fastest growing segment of this market and will continue to proliferate rapidly under the Net Billing programme. An estimated capacity of > 400 kW of residential PV and in excess of 1,000 kW of Commercial PV has been installed, making up < 1% of the country's annual energy demand from solar energy. Larger projects such as a 1 MW photovoltaic project in St. Catherine, > 2 MW in the broiler industry and an undetermined capacity for the National Water Commission could come on stream by 2015.

Wind:

Wigton Wind Farm Ltd was Jamaica's first commercial scale wind park with an initial capacity of 20.7 MW (23 NegMicon x 900 kW) which later expanded to 38.7 MW (9 Vesta x 2 MW). In 2010 JPS added 3 MW (4 UNISON U50 x 750 kW) wind power to its generation complement. Power from these wind resources are dispatched from the central grid control center.

Capacities of smaller distributed generation from small wind turbines around < 10 kW has also increased at both the residential and commercial levels. For example Digicel (telecommunications sector) has installed 3 Sky Stream 3.7 model (3 x 1.8 kW) wind turbines on the roof of its new headquarters as part of its energy efficiency and green objectives. Approximately 50 kW of small grid-tied wind systems have been installed and possibly 20 kW at commercial sites. Generally however distribute generation using small wind turbines have not been successful due to insufficient wind regimes onsite.

Biomass:

Biogas production from biodigesters on farms may have some future applications by utilizing small internal combustion engines with capacities from 100 kW to 3 MW. A 100-m^3 biodigester fed by domestic waste and animal manure is in operation at the St. John Bosco Boys Home in Manchester, implemented at a cost of US$ 14,200 and produces over 50 m^3 of gas per day (equivalent of about 300 kWh). The gas supplies cookers, stoves, water heaters and brooders and some electricity. There is however little interest in replicating this use of biogas for electricity at this time.

MicroGrids:

Modern gated communities in Jamaica could theoretically benefit from micro-grids driven by waste heat and shared distribution cables as developers are promoting renewable energy technologies for power, water heating and backup generators within the community. At this time however there is no legislation supporting shared micro-grids and the utility has the exclusive license for distributing and transmitting electricity in the island whether on their infrastructure or other new infrastructure.

Fuel Cell:

Whereas these technologies are advanced and particularly solid oxide fuel cells (SOFC), they are not yet ready for wide commercialization in a Jamaican energy market. The durability and reliability of fuel cells has not been tested due to less than 10 years of operation, and high capital cost, makes other proven technologies such as solar PV and wind more favourable as distributed generation systems. Jamaica has also not yet secured natural gas fuel for power generation, and the solid waste disposal sites are not designed to capture landfill gas (as a substitute), however liquefied petroleum gas could be a viable fuel substitute.

Fuel cells are not likely to be considered in the near-term landscape for Jamaica distributed power systems.

Micro Turbines:

Micro-turbine systems may be 30 – 500 kW and are fuelled by cleaner low carbon fuels such as natural gas, landfill gas, hydrogen, propane or diesel. Such systems may be technically suitable for small Jamaican firms which have heat and power demands however Jamaica has not yet developed a natural gas pipeline infrastructure (possibly by 2016). Clean replacement fuels could include propane from the established LPG trade.

Though there are no know systems in Jamaica there has been small interest in the systems.

Stirling Engines:

The Stirling engines are external combustion engines which utilize a sealed system with air, helium, or hydrogen as working fluids to drive two (2) pistons (alphas configuration). The engine works by the process of heating and cooling the cylinders. By using solar as the heat source, parabolic concentrators focus solar radiation unto the Stirling engine receiver to drive the pistons.

The Stirling engine will not have meaningful application in Jamaica at this time as solar PV systems are smaller and occupy less space, are more convenient to mount (e.g. as part of roofing or on roofs) and cost less to install and operate than required by solar dishes. In the future Stirling solar dish systems may be applicable for solar farms due to their modular characteristics.

Reciprocating Engines:

Reciprocating engines is a proven technology and makes up the largest share of the current small power generation market due to their small size (5 kW – 5 MW), low unit costs, and useful thermal output for combined heat and power applications. For convenience modern small reciprocating engines are sold as pre-engineered and pre-commissioned standard packages with power electronics. The most promising markets for reciprocating engines are on-site generation at commercial, industrial, and hotel facilities.

Reciprocating engines are either spark ignition (SI) typically fueled by gasoline or natural gas; or compression ignition (CI), typically fueled by diesel oil or heavy fuel oil. Fuel Flexibility is being added to generator systems where natural gas-fired engines are to be adapted to handle biogas, renewables, propane and hydrogen, as well as dual fuel capabilities to meet more stringent environmental standards.

Commercial applications currently use small reciprocating engines <1 MW for prime load service (100% demands; 80 – 85% of operation time) for both electricity demand and hot water or back up power, including the hotel, bauxite and sugar industries. Systems of 1 – 1.5 MW are being marketed in Jamaica for commercial operations and academic institutions as back-up power or partial loads to reduce electricity costs to operations.

<u>New Conventional Generation:</u>

Conventional Fossil Fuel Fired Generators:

Besides the need to obtain lower electricity costs and diversify the fuel base, there is an urgent need to replace some of the old generation sets. Current power generation technologies, plants include:

- Oil-Fired Steam (Conventional - Power only).
- Combustion Turbines (Aero-derivative and Industrial).
- Slow Speed Diesel.
- Medium Speed Diesel (Power only).
- Oil-Fired Steam (Co-generation).
- Combined Cycle Gas Turbine (Oil-fired).
- Medium Speed Diesel (Co-generation).
- Run of River Hydro.
- Wind Turbine (HAWT).
- Solar (Photovoltaic).

The most recent addition was 66 MW medium speed diesel power plant by Jamaica Energy Partners (JEP) in Kingston.

A transition from oil fired plants to coal and natural gas have been contemplated for central generation by the Government of Jamaica to reduce electricity costs by around US$ 0.10 per kWh for all utility customers. The business-as-usual strategy with the continued proliferation of petroleum based fuels is also not sustainable and unresponsive to the National Energy Policy objectives.

Approximately 800 MW of capacity needs to be constructed in the coming decade (2010 – 2020). The OUR's Generation Expansion Plan 2010 recommends the commissioning of 360 MW (3 x 120 MW) of Natural Gas-fired combined cycle capacity in 2014; 292 MW will be for displacement of aged, inefficient capacity and the remainder for demand growth requirements.

Nevertheless, natural gas remains a compelling option with its environmental advantages over coal. Many of the plants currently in the generation market can switch fuels to natural gas and thereby reduce generation costs without stranding assets. The levelised capital cost of coal is approximately 4 times the capital cost of a conventional natural gas combined cycle plant (US $65.8 /MWh, versus US $17.5 /MWh).

Smaller distributed generation systems (1 – 2 MW each) using more conventional fossil fuels in medium-speed reciprocating diesel or heavy fuel oil (HFO) engines are expected to be implemented by the private sector as they seek to reduce their electricity cost which can be as high as 30% of total operational costs.

Conventional Renewable Generation:

Not all the renewables are commercially viable at this time. Biomass and hydro are considered dispatchable renewable energy technologies, as such, they can be contracted to supply firm capacity to grid. Others are intermittent in their power delivery.

Anaerobic digestion has already been employed extensively in Jamaica, with over 200 functional digesters in operation, generally on farms but this is not suitable for commercial generation operations unless large resources can be extracted such as:

- Power generation from an expanded Soapberry wastewater facility in St. Catherine, Savannah-la-Mar and Montego Bay.
- Anaerobic digestion with community gas piping / power generation at Richmond (St. Ann) and other housing schemes.

Waste to energy from the Riverton waste disposal site in St. Catherine and the Retirement site in St. James is a long-contemplated possibility, made especially attractive due to public outcry over atmospheric pollution from frequent fires. Generation projects from municipal solid wastes only could have capacities of 5 MW and would be centrally dispatched. While this is technically feasible, there are regulatory challenges and a tipping fee has to be negotiated in favour of the generator for success.

Hydroelectric technology is the most mature of the commercially exploited renewable energy technologies. Approximately 56.1 MW of potential run-of-the river plants over 11 sites now have completed feasibility studies. The current 6.3 MW expansion by JPS may reflect the earliest expansion of hydropower.

Nuclear:

Jamaica with no prior technical expertise in nuclear power generation or in nuclear waste disposal. Also the implementation of a commercial nuclear power plant may take about 15 years.

It is unlikely that nuclear power will be deployed in Jamaica within the next decade, and if so, not for distributed generation.

Economic Analysis:

Most new reciprocating diesel engines or gas turbine technology will be almost twice as efficient as the oldest block of power (292 MW) on the JPS grid. By simply changing to the newer technologies using the existing fuel, Jamaica can realize a 20% reduction in the cost of energy. The switch to natural gas in the form of LNG is also proposed as a critical component in the long-term reduction in electricity cost. Migrating to LNG, will realize another 5% reduction.

TECHNOLOGY	MINIMUM ECONOMIC CAPACITY FOR GRID SCALE	COSTS	IMPLEMENTATION TIMELINE
COMBINE-CYCLE GAS TURBINE	> 70 MW	Project cost US$ 2.2 M per MW; cost of energy US$ 0.16162/ kWh.	24 to 36 months.
DUAL FUEL RECIPROCATING COMBINED CYCLE GAS TURBINE	>20 MW	CAPEX US$ 1.9 M/MW; cost of energy US$ 0.15567/ kWh	18 to 24 months.
COAL	> 50 MW	CAPEX US$ 3.5 M/MW; cost of energy < US$0.115/ kWh.	4 to 6 years
PETCOKE	> 50 MW	CAPEX US$ 3 M/MW; cost of energy US$ 0.10165/ kWh.	3 to 4 year.
WIND	> 1 MW	CAPEX US$ 3.5 M/MW; OPEX Cost US$ 0.039/ kWh; cost of energy US$ 0.1433/	18 to 24 months.

		kWh.	
BIOMASS	> 5 MW	CAPEX US$ 2.5 M/MW; OPEX Cost US$ 0.06 per kWh; cost of energy US$ 0.174/ kWh.	18 to 24 months.
SOLAR	> 1 MW	CAPEX US$ 2.9 M/ MW; OPEX US$ 0.189 cents/kWh.	< 12 months.
HYDRO	> 1 MW	CAPEX US$ 3.5 - 6 M/MW; OPEX < US$ 0.09/kWh; cost of energy US$ 0.11/ kWh.	4 to 6 years.
WTE	> 1 MW	Capital cost US$ 3.5 M/MW; OPEX US$ 0.05/kWh; cost of energy US$ 0.18/ kWh.	24 to 36 months.

Opportunities:

The Generation Expansion Plans objective states:

"The generation expansion plan is largely influenced by the need for new and more efficient generating capacity to reliably meet system demand at least economic cost. The plan is also an integral part of an overall strategy to reduce energy cost and Jamaica's dependence on imported liquid based fossil fuels. As such the plan aims to support the implementation of the National Energy Policy 2009 - 2030, focusing on: (1) increasing the contribution of renewable energy (wind, solar, hydro and biomass) in electricity generation; (2) effecting fuel diversification through the development of the natural gas industry".

The single **most important opportunity for distributed generation proliferation is the unbundling and liberalization of the generation market.**

Under the Amended and Restated All-Island Electric Licence 2011, self-generation using a distributed generation option is permitted, according to Condition 2: Clause 4 of the License, which states, *"that no firm or corporation or the Government of Jamaica or other entity or person shall be prevented from providing a service for its or his own exclusive use".* Also under its Clause 12 "Electricity Power Wheeling" would be permitted. This clause allows self-generators to supply their own facilities across the distribution lines and gain the economic benefits of reducing their electricity cost from the grid through self-supply.

Another significant policy, legal and economic instrument for small renewable energy generation (<100 kW), is the Net Billing Policy and accompanying Standard Offer Contract. Output cannot exceed 10 kW (AC) output for residential facilities, or 100 kW (AC) for commercial facilities. Under the Net Billing Policy, the generator can also sell excess power to the utility at wholesale or retail cost, an agreed tariff equivalent to the short-run avoided cost (fuel) as stipulated by the Regulator. The programme allocation is currently 2% of peak (around 12 MW). This amounts to less than 1.5% of total generation capacity. The Net Billing Standard Offer Contract Program is therefore intended to support greater use of renewable sources of energy in Jamaica from distributed generation sources (solar and wind).

A further opportunity exists for distributed generators in the megawatt scale which is through Excess (Dumped) Energy Policy. Independent generators (from conventional or renewable sources) that provide energy to satisfy a part or their full energy needs may from time to time be allowed to sell to the national grid. The Regulator will allow for this type of transaction through a standardized PPA from JPS. The Jamaica Broilers Group Ltd and Jamalco are beneficiaries.

<u>Summary:</u>

There is a rapidly growing trend favouring distribution generation technologies mostly from renewable intermittent contributions. Current and future policy, legislative changes and financing will support the growing distribution generation market. Distributed generation in the Jamaican generation market (self-generation < 10 MW is at an early stage of development as the generation market was previously an established electrical monopoly under law. The National Energy Policy and other significant policy measures and legislative changes have successfully opened up the generation market to include independent power providers, followed by the allowance for private generators to benefit economically and also to reduce onsite electricity costs via Net Billing. Though Net Billing is potentially the most significant policy initiative driving a rapid growth in distributed generation from solar PV (as much as 100 kW at some sites), the price of electricity for businesses and residential customers is also a current driving mechanism for addition of distributed generation sets. Solar PV is likely to be the fastest growing distributed generation option for the next decade.

If power wheeling is eventually implemented, it may catalyze the progressive liberalization of generation and the grid will be modernized sufficiently to allowing companies to send their power over the utility's central grid to their other facilities.

The trend toward distributed generation from renewables is primarily demonstrated by private solar installations, followed in numbers and impact by private wind installations. Both are facilitated by strong positive natural resource bases. Fossil fuel distributed generation is expressed primarily as standby diesel fired generation. Generators may range from tens of kW to a few MW. Some of them sell power to the grid as available via a "dumped power" agreement at a discounted rate to the utility.

Newer mico-generation technologies are largely not applied in Jamaica but may become the next evolution of the distributed generation trend. Some have not yet emerged as commercially proven, while other technologies are fully deployed for use in other countries but may have higher costs when compared with traditional generation options and therefore are implemented under special conditions or used to meet specific customized objectives. Micro-reciprocating engines are already in use but it is likely that newer technologies such as micro turbines will eventually be utilized in Jamaica however perhaps not in the near-term. More innovative and complex technologies such as fuel cells would likely follow. Some technologies such as fuel-cells and some micro-turbines will also experience a delay in proliferation until Jamaica has natural gas delivered and infrastructure installed.

Considering the convenience and numerous benefits of distributed generation for private onsite generation, the grid and for incremental addition to the national generation sources, the favourable trend of proliferation will continue and should be encouraged. The current legislation and policies will continue to facilitate this positive change however other mechanisms including implementation of wheeling, financial incentives and the supply of natural gas will be critical for the next significant change in the trend towards increasing application of small-decentralized distributed generation.

"Diagnosis of Generation in Latin America & the Caribbean (Jamaica)"

1. BACKGROUND:

Utility power systems of the Latin American and Caribbean Region (LAC) tend to be large hierarchical systems which have inefficiencies and depend on integrated generation, transmission and distribution systems to serve customers. Such systems are also typically thermal plants using fossil fuels though there is some trending towards more renewable distributed generation sources. Contrasting with this traditional large centralized generation model is an alternate model of more localized customers generating power on a smaller scale, feeding into the grid network and delivering power over shorter distances, at lower voltages (distribution) and utilizing available renewable energy sources. The transformation is influenced by the national mandates for cleaner fuels, unbundling of centralized and vertically integrated utilities, greater energy security especially related to the use of indigenous resources, and the economics of incremental generation expansion. As a Caribbean island, Jamaica is also influenced by the reasons and outcomes for these trends.

In this changing energy environment, it is necessary to diagnose the current state of conventional generation and distributed generation in Jamaica, the technologies used, the sources of energy and the trend towards distributed generation. In light of this evolving model for generation, transmission and distribution of power, OLADE intends to make a diagnosis of the generation models, sources of energy being used, and the technologies used for current and future conventional and distributed generation in Jamaican.

1.1 Specific Objectives:

The specific objectives determined for this analysis are as follows:

g. Analyze the generation expansion plans of Jamaica, considering conventional and distributed generation, current status of generation systems, the technology used and their sources of generation and growth prospects.
h. Classify by type, the technology used and the production and generation model of the current generation sector as well as that which will be implemented in the future.
i. Evaluate the status of conventional generation and distribution set utilization.
j. Make projections about the trend of proliferation of distributed generation and implementation feasibility in Jamaica.

k. Investigate and propose new conventional and distributed generation technologies.
l. Conduct economic evaluation for the implementation of new efficient conventional and distributed generation technologies in Jamaica.

1.2 Situation Analysis – Global Context.

World electricity demand is projected to double between 2000 and 2030, growing at an annual rate of 2.4% to 2.8% (see Table 1) concomitant with a global carbon dioxide emissions increase from power plants forecast to grow by about two-thirds from 2005-2030 (China and India accounting for nearly 60% of this rise)[1]. This electricity growth will outpace the increase in consumption of other energy sources for end-use including natural gas, coal or petroleum. Electricity demand growth is projected to be strongest in developing countries, where demand will climb by over 4% per year over the projection period, more than tripling by 2030. Consequently, the developing countries' share of global electricity demand will jump from 27% in 2000 to 43% in 2030 (US EIA, 2011).

Table 1: Electric Balance* Worldwide 2000 – 2030.

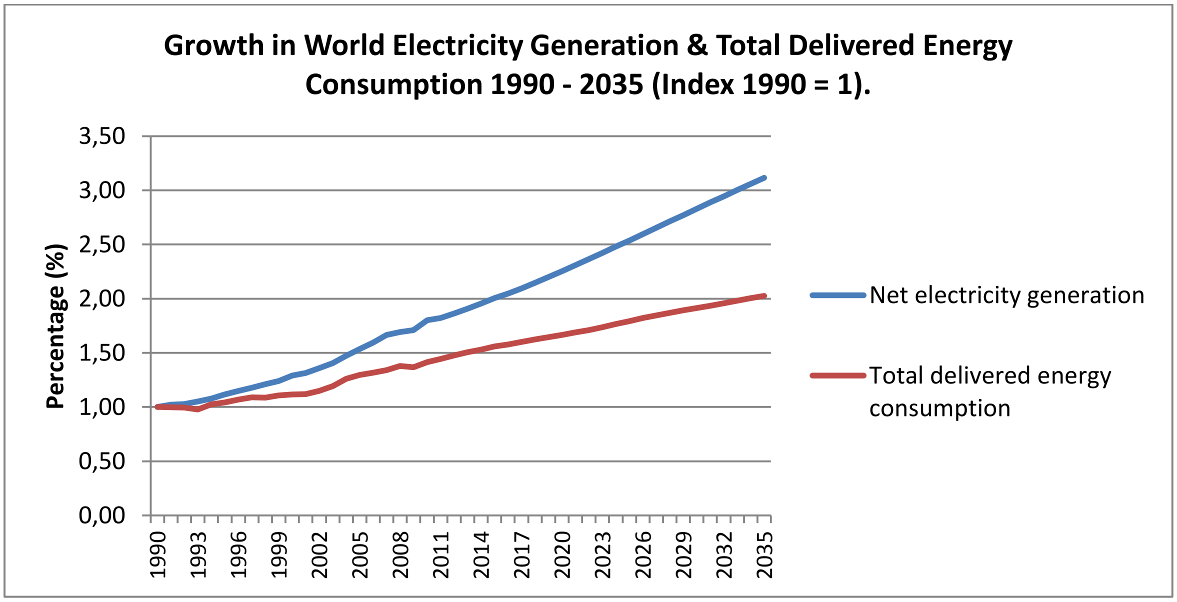
	2000	2010	2020	2030	Average Annual Growth 2000 - 2030 (%)
Gross Generation (TWh)	**15,626**	**20,340**	**25,966**	**32,001**	**2.4**
Coal	5,989	7,143	9,075	11,590	2.2
Oil	1,241	1,348	1,371	1,326	0.2
Gas	2,676	4,947	7,696	9,923	4.5
Hydrogen-fuel Cells	-	-	15	349	n.a.
Nuclear	2,586	2,889	2,758	2,697	0.1
Hydro	2,650	3,188	3,800	4,259	1.6
Other Renewables	249	521	863	1,381	5.9
Own Use & Losses(Mtoe)	235	304	388	476	2

**Includes transport, agriculture & non-specified use of electricity.*

Source: International Atomic Agency.

[1] http://www.davy.ie/content/pubarticles/renewableenergynov2007.pdf

Figure 1: Growth in World Electricity Generation and Total Delivered Energy Consumption 1990 – 2035 (Index 1990 = 1)



Source: US Energy Information Administration, 2011 (US EIA).

The US EIA notes that the mix of primary fuels for power generation has changed significantly over the past four decades. The next three decades will see a pronounced shift in the generation-fuel mix in favour of gas and away from coal (currently the most widely used fuel worldwide). Coal while being the fuel most widely used for electricity generation at 40 % of world electricity supply (2008), will decline in its share to 37 % by 2023 driven by national policies and international mandates to limit green house gas emissions. Generation from nuclear power is expected to rise, and natural-gas-fired generation is expected to have the greatest increase among fossil fuel options. The use of oil for electricity generation has been declining since the mid-1970s, when oil prices rose sharply and it's use for electricity is expected to continue declining with elevated prices, volatility issues and environmental mandates. The demand for oil will be about 90.6 million barrels per day (mmbd) for 2013 (International Energy Agency - 2012) and will have higher prices. IEA forecasts an average West Texas Intermediate (WTI) price of US$108/barrel for 2013 and US$110 in 2014 which is important as the Caribbean and Latin America apply this benchmark for crude pricing. Brent Crude is expected to decline to US$110/barrel (IEA).

Table 2: Crude Oil & Natural Gas Prices May 2013 (Bloomberg April 2013)

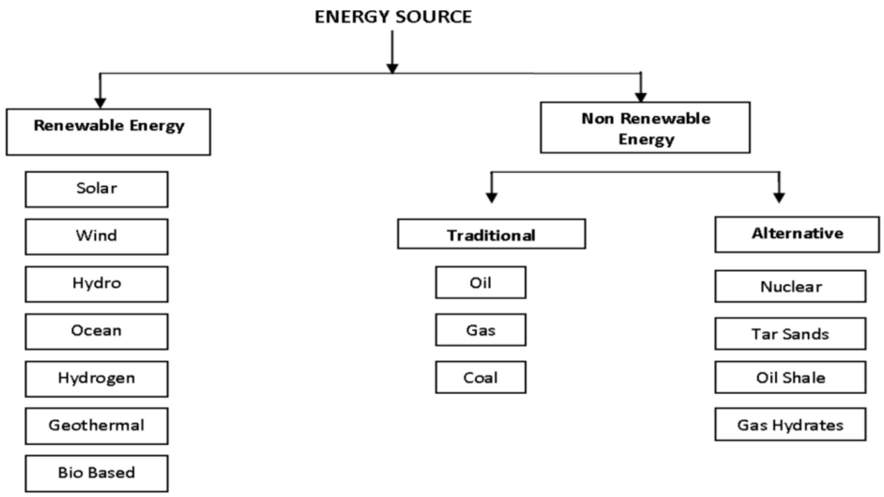
Commodity	Units	Price	Change	% Change	Contract	Time(ET)
Crude Oil (WTI)	USD/bbl.	92.70	-0.56	-0.60%	May 13	17:15:00
Crude Oil (Brent)	USD/bbl.	104.12	-2.22	-2.09%	May 13	18:00:00
NYMEX Natural Gas	USD/MMBtu	4.13	+0.18	+4.51%	May 13	17:15:00

Caribbean nations will need to diversify away from crude oil as the cost of crude in the near future will be affected by the embargo on Iran by western super powers, flexibility of Saudi Arabia to deliver more crude, shale oil production in the USA, threats of war between USA and South Korea, upheavals in Palestine and successes in LAC. More recently the death of President Hugo Chavez of Venezuela and upcoming elections, raise concerns around the continuity of the PetroCaribe oil facility which has buffered the Caribbean islands from the volatility of the oil market.

For the purpose of new generation many countries are considering cleaner generation options which will reduce the further generation of greenhouse gases (GHG), reduce other environmental impacts such as oil spills, and are in line with effluent and ground water quality standards. Interest is rapidly growing in the development of alternatives to fossil fuels—specifically, nuclear power and renewable energy sources. Corporate pressures for compliance with higher international performance standards will also be a driving force for cleaner power generation options. Jamaica is also constrained by these global targets and is aiming at achieving a diversified, low carbon energy economy.

The following represents the main traditional and emergent energy sources considered for power generation globally.

Figure 2: Traditional and Emergent Energy Sources for Power



The main areas of growth for renewables in power generation applications in 2009 included notably grid-connected solar photovoltaic applications (53%), wind power (32%), solar water heating (21% for electricity replacement), geothermal power (4%) and hydropower (3%). The remaining 19% was for biofuels in the transportation sector. Ultimately in 2011 renewable energy sources delivered 20 % of global electricity supply and by 2011 renewables comprised as much as a ¼ of the global power capacity from all sources of power – renewable, conventional and alternative power sources. The total renewable sources providing power capacity worldwide amounted to 1,320 GW[2].

At the international level it could be surmised that four (4) main global driving forces created the growth in renewable energy uptake and a trend towards more distributed generation applications.

- National energy policies which encouraged renewable energy technologies.
- Business models which diversified away from conventional business options which were impacted by the global down turn.
- Increase in investment flows (equaling US$5 billion in 2009 and US$2 billion in 2008) from public-sector, development banks and multilateral funding agencies.
- Government injected "green stimulus" efforts to resuscitate the business sector, public sector and their economies starting late 2008.

There is therefore a case for facilitating fuel diversification however a transformation to diverse options has been delayed. In the Caribbean with a relatively small energy market (population of 7 million), most countries of the Caribbean are net energy importers (except Trinidad and Tobago) with the power sector being the largest energy consumer (capacity of approx. 7,377 MW and gross generation of approximately 22.4 million GWh in 2009). Most rely predominantly on imported diesel and heavy fuel oil for power generation (approximately 93% oil and 5% gas) which is a significant energy security issue. In spite of this dependence some utilities consider that the use of oil for power

2 REN21 - Renewables 2011 Global Status Report.

generation is still economically the best option taking into account the utilities' installed base load generation and capital costs involved (*Carilec Position Paper on Energy Policy – January 2008*). Utilities of the Caribbean also consider that fuel diversification requires significant planning timelines and accurate price forecasting which conflicts with urgency in the majority of cases to retire/replace old units and add new generation in the near term. Future pricing for some natural gas options appears expensive and economies of scale may not be achieved based on small volume off-take and ongoing oil price increases (*Carilec Position Paper on Energy Policy – January 2008*). Other options such as coal has significant environmental constraints and are most feasible using larger scale power plants on larger islands potentially causing another energy security issues, that of proportionately lower diversity and a high dependence on such new coal plants. Most Caribbean islands are too small for present nuclear power technology and smaller more modular systems will be commercially proven around 2020. In addition the recent nuclear disaster in at Fukushima Daiichi, Japan has resurrected fears about nuclear safety and the consequences on a small island,

Continuing with oil would however present significant disadvantages for almost all Caribbean States in terms of:

- Uncertainty and volatility of oil prices with the looming risk of future oil price shocks.
- Lack of large economies of scale for gains in oil purchases.
- Threats of oil shortages.
- Burden of oil purchases on foreign currency reserves.
- More restrictive emissions benchmark standards.
- Continuous adjustment of fuel surcharges on kWh prices with changes in oil pricing, which negatively impacts consumers and the image of the electric utilities.

Presently, only around 2 - 3% of electricity based energy demand is met with the use of renewable energy sources in the Region with an ever-increasing Regional average electricity consumption growth rate of 2.70% in 2009[3]. Renewable energy resources could potentially provide 10% and as much as 60% of total energy demand or higher percentages for electricity only (example Nevis if geothermal is included) for the national energy mix with wind and solar power being the likely resources to significantly increase the renewable proportion in the mix.

And finally at the national level sovereign states were transitioning to renewable energy technologies driven by increasing political support, social pressures, corporate imperatives, and financial support (a €168 billion sector)[4] to achieve a clean environmental agenda. At the national policy level, governments encourage non-fossil options as an acceptable path towards achieving greater energy security. At the generation and transmission and distribution market levels, utilities are not yet assertive to add renewable generation for cost reasons and a preference for base load

[3] Caribbean Association of Electric Utilities - CARILEC 2010.
[4] http://www.davy.ie/content/pubarticles/renewableenergynov2007.pdf

dispatchable resources. Nevertheless this is the overarching environment in which distributed renewable generation finds significant value.

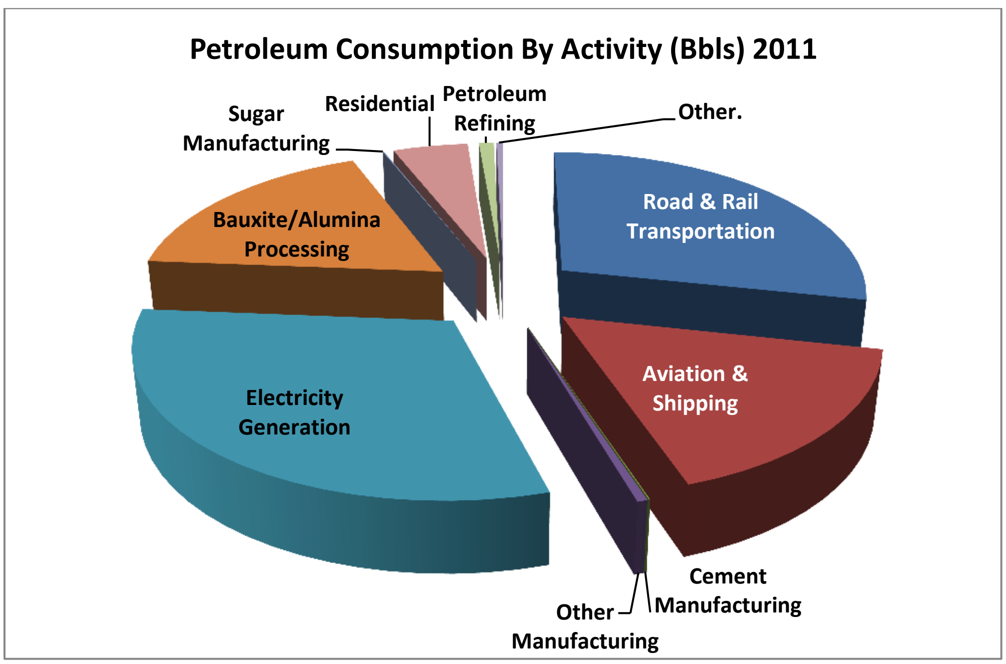
1.3 JAMAICA'S ENERGY SCENARIO:

1.3.1 Jamaica's National Energy Mix

In 2008 the rapid increase in oil prices set new benchmarks for crude and have exacerbated the impacts of imported fuels and the oil bill on Jamaica's economic development. In 2008 when oil prices approached $150/bbl Jamaica's oil bill reached a historic US$ 2.7 billion even though the Nation's crude consumption remained around 60,000 barrels of oil per day (petroleum importation in 2008 was approximately 29.1 million barrels and 20.5 million barrels in 2010).

Of the total volume of petroleum imported, the electricity sector consumed the largest volume (30.8% or 6,529,445 bbls) for the generation of power. Local road and rail transportation was the second largest category of consumer utilizing 28% of the total imports or 6,012,476 bbls. Bauxite and alumina processing was the third largest consumers of petroleum for heat and power at 18% or 3,752,927 bbls of oil. The last significant category of petroleum consumers was shipping and aviation at almost 17% (3,513,596 bbls) see Figure below.

Figure 3: Petroleum Consumption by Activity 2011.



Source: Energy Economics and Planning Unit, Energy Division, Ministry of Science, Technology, Energy & Mining, 2012.

The energy demand in the bauxite and alumina industry in Jamaica has historically influenced a high-energy intensity index of 15,400 (EII = BTU/$US 1 unit of output) for Jamaica when compared with most developing countries. The bauxite sector has determined that survival of the sector require greater energy efficiency and fuel diversification away from oil to natural gas or coal as the necessary strategy to reduce inefficiency and energy cost.

In 2008/2009 imported fossil/petroleum fuels accounted for 91% of the overall energy mix (or 22.1 million barrels in 2009[5]), while renewable resources accounted for approximately 9% (electricity and other demands). Approximately 5% of the electricity supply mix came from renewable sources for power generation namely 4% from hydro, 1% from wind and a smaller amount from biomass for both heat and power[6] in 2008. By 2010, the oil import bill declined to approximately US$ 1.67 billion with the decline in oil prices however by 2011 imported fossil/petroleum fuels accounted for a higher proportion of the energy mix. Petroleum rose to 95% of Jamaica's overall energy mix (though a smaller volume of 21.2 million barrels in 2011[7] not including lubricants and asphalt which are non-energy products) at a cost of US$ 2.24 billion. In 2011 renewable resources accounted for approximately 3% of the total national energy mix (see table below). Most of the renewable sources came from wind, hydro, fuelwood, bagasse, solar and ethanol (used in the transportation sector)[8].

Table 3: Jamaica's National Energy Mix (2011)

SOURCE	BOE	BOE	% MIX
Petroleum Imports		21,214,652	**95.3**
Coal Import		327,000	**1.5**
Renewables			
Hydro	*94,000*		
Wind	*57,000*		
Charcoal	*n/a*		
Bagasse	*570,000*		
Fuelwood	*n/a*		
		721,000	**3.2**
GRAND TOTAL		**22,262,652**	**100.0**

[5] Ministry of Energy and Mining, Oil Import Statistics, 2009
[6] Jamaica National Energy Policy 2009 - 2010.
[7] Ministry of Science Technology, Energy and Mining, Oil Import Statistics, 2012.
[8] Renewable Energy Policy 2009

Source: Energy Economics & Planning Unit, Energy Division, Ministry of Science, Technology, Energy & Mining, 2012.

Of this renewable energy content the sources were 13% from hydropower, 7.9% wind and 79% from bagasse[9].

Table 4: Renewable Energy Contribution to National Energy Mix

RENEWABLES	BOE	%
Hydro	*94,000*	13.0
Wind	*57,000*	7.9
Charcoal	*n/a*	
Bagasse	*570,000*	79.1
Fuelwood	*n/a*	
GRAND TOTAL	**721,000**	**100.0**

Source: Energy Economics and Planning Unit, Energy Division, Ministry of Science, Technology, Energy & Mining, 2012.

In 2011, annual electricity generation alone from renewable energy sources accounted for approximately 5.6 % of total system generation with contributions of 3.5% and 2.1 % from hydro and wind respectively[10]. By the time of this statistic, both JPS and Wigton Wind farm Ltd added 3 MW and 18 MW of wind power respectively.

Table 5: Jamaica's National Energy Sources to the Grid (2011)

SOURCE	MW	MWH	% ENERGY
JPS & IPPS (Fossil Fuels)	920	4,136,847	**94.5**
Cement Company (Coal)	n/a		
JPS Hydro	21.3	*152,000*	**3.5**
JPS & Wigton Wind Farm	41.5	*91,000*	**2.1**
Solar PV	n/a	*n/a*	
Sugar Industry – Bagasse	n/a	*n/a*	
GRAND TOTAL	**982.8**	**4,379,847**	**100.0**

[9] Source: Energy Economics and Planning Unit, Energy Division, Ministry of Science, Technology, Energy & Mining, 2012.

[10] Office of Utilities Regulation, RFP Document for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis. Document No. ELE2012003_RFP002

Source: Energy Economics and Planning Unit, Energy Division, Ministry of Science, Technology, Energy & Mining, 2012.

Since 2012 Jamaica Energy Partners (JEP) added 65 MW of Heavy Fuel Oil, Medium Speed Diesel generation to the grid through its West Kingston Power Producers Ltd (WKPP), increasing its share from 124 MW (74 MW + 50 MW) 184 MW. Both JEP and WKPP combined constitute 20 % of the generation market and second largest source of power in Jamaica. Between this new generation source and the continuity of the high proportion of imported fossil fuels, Jamaica's national energy security has been further compromised over the years in sheer volume and financially especially during the period in which the international petroleum market price increased by as much as US$ 150/bbl.

JPS projects however that between the addition of new hydropower (6.3 MW) and the Request for Proposal (RfP) for 115 MW of commercial scale renewable projects, that Jamaica will be able to achieve 10% capacity on the grid from renewable from relatively low cost renewable energy power[11].

1.3.2 Jamaica's Socio-Economic Context:

The Jamaican economy recorded a contraction in real Gross Domestic Product (GDP), of 2.7% in 2009 with the Goods-Producing and Services Industries contracting by 8.5% and 0.6%, respectively. The sectors recording growth were Agriculture 12.1%; Electricity and Water Supply 2.2%; Finance and Insurance 0.8%; and Hotels &Restaurants 1.4% (add 2011 ESSJ data). Jamaica's commitment to sustainable development programmes and climate change issues remained prominent even in the face of this economic downturn. Some of the efforts included the implementation of a state driven program of energy conservation and efficiency methods which was reflected in a decline in per capita consumption of energy. In addition, there was a move towards a more sustainable energy mix evidenced by greater focus on alternative energy.

As much as 75% of foreign exchange earned has been spent on imported crudes and petroleum fuel and this amounts to more than 15% of Gross Domestic Product. The volatility in oil prices has also negatively impacted variables such as inflation, Gross Domestic Product (GDP), employment, the trade balance, and the fiscal deficit and ultimately has contributed significantly to high electricity costs. Thus, a reduction of the amount of fossil fuel imported through energy substitution using renewables and distributed generation will directly aid in improving the Jamaican economy and the ability of the Government to plan for the long term.

Regarding electricity charges, Jamaica's residential, commercial and industrial electricity prices are among the highest in the Latin American and Caribbean (LAC) Region[12]. This partly because 95% of electricity generation uses the more expensive

[11] JPS Annual Report 2011

[12] Generation and Distribution of Electricity in Jamaica: A regional comparison of Performance Indicators. Jamaica Productivity Center 2011.

petroleum fuel for generation. The cost of fuel which is approximately 2/3 of the electricity charge to the consumer is a pass through item and electricity delivered has been sold on average from US$ 0.2508/kWh in 2007 to as much as US$ 0.3586/KWh in 2008 for residential consumption and >US$ 0.40/kWh for commercial in 2012. This is further compounded by high total system losses of 23%, 9.9 % technical losses and 13.0 % non-technical loses – electricity theft (2009 data). The economic impact on the society from this fossil fuel generation is exacerbated by the necessary periodic increases in its tariff rates. The combination of global oil prices, pass through fuel charges, and generation and transmission inefficiencies makes electricity an expensive energy option for the average Jamaican household. For citizens in a low socio-economic grouping and inelastic discretionary spending, the options have been towards unaffordable modern, clean, and safe energy options and the greater use of energy options such as kerosene and charcoal for cooking and kerosene and candles for lighting among the poorest in society. The high cost of electricity also encourages the unsustainable and dangerous practice of electricity theft using unsafe "throw up" lines or meter tampering by less than 1% of their total customer base (575,762 in 2011). JPS has spent US$ 25 million in 2010 and 2011[13] and approximately US$ 30 million in 2012/2013 to reduce this loss. Electricity theft is estimated at approximately 119,715 MWh from total JPS generation and purchases on the grid. The efforts of JPS to reduce non-technical losses have marginally reduced the level of losses from 23 % to 22.3% by 2011.

The overall price of electricity is expected to decrease by 20 – 30 % in 2015 following the addition of 6.3 MW of hydro at the Maggoty Hydro Power site and 360 MW of new LNG powered generation is added to the mix. Generation (only) is expected to be around 13 – 15 ¢/kWh.

1.3.3 Jamaica's Electricity Sector – Generation, Transmission and Distribution:

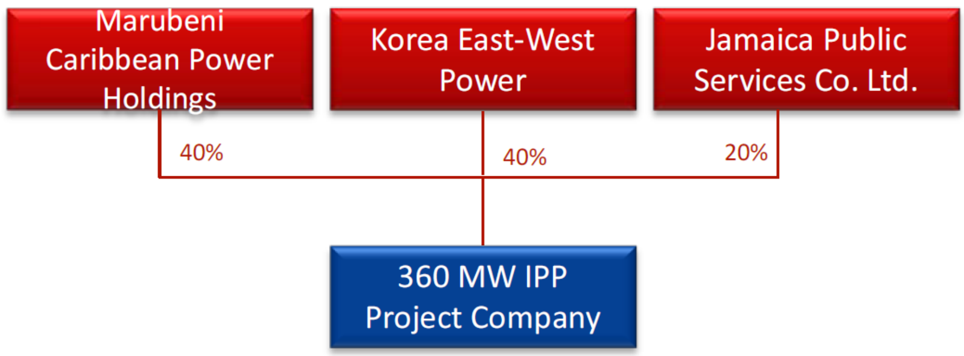
1.3.3.1 Generation Sector:

The electricity utility company - Jamaica Public Service Company Ltd (JPS) is a vertically integrated company, the Jamaica Public Service Company Limited (JPS) that owns the transmission and distribution grid and is the main supplier of power (65.9% of the national grid) to a population of over 2.7 million. JPS was privatized by the GOJ in 2001 at which time 80% of the common equity was sold to Mirant JPSCo (Barbados) SRL (Mirant), an energy company having its principal office in Georgia, United States of America. The GOJ retained a 20% shareholding in JPS. On August 9, 2007 Marubeni Caribbean Power Holdings, Inc., a wholly owned subsidiary of Marubeni Corporation of Japan, purchased Mirant's majority shares in JPS. On March 4, 2009 Marubeni transferred 50% of its shares in Marubeni Caribbean Power Holdings Inc. to Abu Dhabi National Energy Company (TAQA) of the United Arab Emirates. TAQA has announced its decision to withdraw from the Marubeni TAQA Caribbean partnership in the first quarter of 2011. With the withdrawal of TAQA, 40% of the shares of Maurubeni were sold to Korea East-West Power Company. The current 3 primary shareholders are; the Government of Jamaica with

[13] JPS Annual Report 2011.

19.9% shareholding, Korea East-West Power Company Ltd and Marubeni Caribbean Power Holdings, Inc. hold 40% each and the remainder is held by individual shareholders[14] [15] (see figure of JPS structure below).

Figure 5: Structure of Jamaica Public Service Company



Currently the electricity utility competes with other generations has "*the right together with other outside person(s) to compete for the right to develop new generation capacity*" under the legislative framework, the All Island Electric Licence, 2001 and policies to generate, transmit, distribute and supply electricity for public and private purposes in all parts of the Island of Jamaica and *has "the exclusive right to transmit, distribute and supply electricity throughout Jamaica for a period of 20 years"*[16] (see section on Legislative Framework). After the third year of the license, generation was no longer exclusive to JPS and as such, the company now has "

At the end of 2009, JPS had a customer base of 575,762 including residential, commercial and industrial consumers. The gross peak demand to date is 618 MW and the average system load factor is approximately 66%. JPS supplies this demand from a functional firm system capacity of approximately 920 MW of which approximately 300 MW is provided by Independent Power Producers (IPPs) (see table below for generation capacities). The full complement of JPS production capacity consists of eighteen (18) thermal power generating units located at four (4) sites (Rockfort, Hunts Bay, Bogue and Old Harbour), eight (8) hydro plants independently sited across the island and a small wind plant (3MW) at Munro in the south central part of the island[17]. There are also a number of self-

[14] www.jpsco.com
[15] Office of Utilities Regulation, RFP Document for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis. Document No. ELE2012003_RFP002.
[16] Jamaica Public Service Company Limited All-Island Electricity License, 2001.
[17] Office of Utilities Regulation, RFP Document for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis. Document No. ELE2012003_RFP002.

producers of electricity in the country, with the largest being the bauxite alumina companies and the sugar refineries.

Of the 588 MW of capacity owned by JPS 292 MW of its base-load capacity is over thirty-three (33) years old and represents some of the most inefficient plants on the system. The existing oil-fired steam plants have aged considerably. Over the years a number of turbines and boilers have been refurbished. However, the average age of the steam plants is 37 years. At Old Harbour the four steam units are over 35 years old, despite their rehabilitation over the years, their operating parameters at present indicate that all these units have surpassed their useful economic life.

The previous exclusivity in the license for generation was considered by potential generators to be a barrier for the economic introduction of new generation to the grid, and more so for renewable power generation. Since the opening up of the generation market, other generators now contribute to the grid. Jamaica Public Service Company Ltd is still the dominant player as it retains over 66% of the total current generation capacity of approximately 588 megawatts (MW) some of which comes from renewable energy; 300 MW of this capacity has been provided by independent power producers (IPP) who sell power to JPS via power purchase agreements (PPA) for delivery unto the grid[18]. These IPPs are Jamaica Energy Partners (JEP) = 124 MW; Jamaica Private Power Company (JPPC) = 60 MW; Wigton Wind Farm Limited = 38.7 MW; and Jamalco (bauxite company) = 11 MW[19]. The utility recently added 3 MW of wind from its own generation and has a total of 21.3 MW of hydropower from previous generation plus some refurbished plants.

Commercial scale renewable energy plants and smaller systems have become more important in the Jamaican electricity mix. Based on the performance up to the end of 2010, approximately 12 – 15% of total annual system generation (net) came from renewable sources (approximately 4% from hydro, 5% from wind and the remainder from biomass [sugar industry] and small PV installations). Up until 2009, there were two grid interconnected wind farms in Jamaica. The larger wind farm - Wigton Wind farm is near to the center of the island currently has an installed capacity of 23 x 0.9 MW turbines or 20.7 MW and supplied approximately 58.6 GWh of energy to the grid in that year.[20] Wigton Wind Farm Ltd. has already expanded its existing generating facility of 20.7 MW by an additional 18 MW. The expected average annual energy production from this additional capacity exported to the grid will be 37.0 GWh. The other (smaller) wind facility was the Munro College a single wind turbine with installed capacity of 225 kW, which supplied energy to the grid based on availability. The Utility has also expanded wind power delivery by 3 MW at this site anticipating approximately 10.5 GWh/yr delivery to the grid. Seven (8) small run-of-the-river hydro plants located at different sites over the country had an aggregated installed capacity of 21.4 MW with a combined annual energy generation averaging 117 GWh over the period 1990 to 2009. This will be

[18] Office of Utilities Regulation Generation Expansion Plan 2010
[19] http://www.myjpsco.com/about_us/renewables.php
[20] Office of Utilities Regulation Generation Expansion Plan 2010.

increased by 6.4 MW or 26 GWh/yr. Photovoltaic (PV) systems and small domestic and residential wind power systems are proliferating rapidly on private homes and more recently businesses however, the actual numbers are not known.

There is an estimated 20,000 solar water heating units mainly on private homes but also on the roofs of hospitals, commercial buildings, and residential strata complexes. There are also an undetermined number of small residential and commercial installations of wind and solar PV (PV estimated at approximately 1,200 watts of capacity to date)[21]

In order to realize Jamaica's renewable potential, the Government of Jamaica has utilized the national energy policy and a national vision plan to encourage the further development of indigenous renewable energy resources with the Goal of increasing the percentage of renewables in the energy mix[22]. The potential for new grid connected renewable and fossil fuel projects are summarized in the Tables below.

Table 6: Potential for Electricity Generation Using Renewable (Jamaica)

Potential Electricity Generation (MW)			
Hydro	**Wind**	**Biomass**	**Solar**
> 80 MW	> 60 MW	>100 MW	>2 MW

Table 7: Summary of Current and Future Electricity Sources.

	Supply of Firm Capacity.	Supply of Energy Only.	Proposals for New Renewable Energy.
Jamaica Private Power Co. Ltd.	61 MW (Slow Speed Diesel)		

[21] IBC Energy Summit, October 2011, Trinidad and Tobago - David Barrett – ENBAR Consulting and Keron Niles - University of Otago, Dunedin, New Zealand.

[22] Office of Utilities Regulation Generation Expansion Plan 2010

Jamaica Energy Partners.	124 MW (Medium Speed Diesel)		
JAMALCO	11 MW (Oil Fired Steam)		
West Kingston Power Plant	65.5 MW (Medium Speed Diesel)		
Wigton Wind Farm Ltd	-	38.7 MW (Wind).	
Jamaica Broilers Group Ltd.	-	2 MW (Diesel as available)	
Munroe Wind farm (JPS)	-	3 MW (Wind)	6.37 MW (Hydropower).

Figure 6: Location of JPS Power Plants.

(Source: http://www.jpsco.com)

Table 8: Generation Market (2011)

	NET GENERATION (MWh)	CAPACITY (MW)	CAPACITY (%)
JPS POWER GENERATION	***2,736,100.00***		

STEAM & SLOW SPEED GENERATORS	**1,583,387.00**		
Hunts Bay (Steam-HFO)		68.5	
Old Harbour (Steam-HFO)		221.50	
Rockfort (Slow Speed-Diesel/HFO)		36.00	
			36.5%
GAS TURBINES			
Hunt's Bay (#2 Diesel/ADO)	**179,914.00**	54.00	
COMBINED CYCLE GAS TURBINE			
Bogue (#2 Diesel/ADO)	**810,212.00**	183.50	
			26.6%
HYDRO	**152,087.00**	21.5	**2.4%**
WIND		3	**0.34%**
TOTAL JPS	**2,736,100.00**	**588**	**66%**
PRIVATE POWER PURCHASES	***1,506,879.00***		
Jamaica Energy Partners (Medium Speed Diesel/HFO)		184.36	
ALCOA (HFO)		11	
Jamaica Broilers Group Ltd (Cogeneration/HFO)		12.1	
Jamaica Private Power Company (Slow Speed Diesel/HFO)		60	
			30%
Wigton Wind Farm Ltd (Wind)		38.7	**4%**
TOTAL IPPs	**1,506,879.00**	**306.16**	**34%**

TOTAL NET GENERATION	**4,338,579.00**	**894.16**	**100%**

(Source: JPS 2011/2012)

JPS' tariff regime is currently set at five (5) year intervals based on a Performance Based Rate-Making Mechanism (PBRM) with OUR oversight. The last tariff review was effected in October 2009.

Despite the addition or renewable energy generating plants, there is still a high dependence on fossil fuels (96%) which emphasizes the need to diversify away from oil-fired plants. In an attempt to address this unsustainable demand of imported petroleum fuel, the Government of Jamaica (GOJ) through the National Energy Policy (2009 – 2030) has promulgated several long-term strategies; chief among them is energy diversification defined as follows:

"*Energy diversification will involve moving from an almost total dependence on petroleum to other sources, including natural gas, coal, petcoke, nuclear, and renewable energy such as solar, wind, and bio-fuels. In the short to medium term, natural gas would be the fuel of choice for generation of electricity and the production of alumina*".

By diversification of the nations fuel mix (for electricity) GoJ will be able to reduce the exposure and energy insecurity associated with petroleum for energy production while simultaneously improving the security of the country's energy supply using range of alternative fuels including renewable indigenous sources. The GoJ has stated that liquefied Natural Gas (LNG) will be the alternative and transitional fuel of choice for near-term generation and efforts have been made to secure supply and infrastructure for the reception, and re-gasification of LNG; and storage and distribution of natural gas for utilization in the electricity and bauxite sector in the coming years.

At the end of 2011, JPS had a customer base of 575,762 including residential (513,970), small commercial and industrial consumers (61,401), large commercial and industrial (145) and others (246). Approximately 89% are residential consumers, responsible for approximately 33% of the energy sales. Small commercial and industrial customers made up 10.7% of the Company's customer base and consumed 44.7% of the energy sales and large commercial and industrial customers constituted only 0.03% of the customer base while consuming 19% of the energy sales. The remaining customer base is 0.04% of the total, and consumed 3% of total billed energy see (table below).

Table 9: Jamaica Public Service Company Ltd - Customer Statistics (2011)

CONSUMER CATEGORY	NUMBER	% TOTAL	ENERGY SALES (MWh)	% ENERGY SALES
RESIDENTIAL	513,970	89.3	1,064,535	33.1
SMALL COMMERCIAL & INDUSTRIAL	61,401	10.7	1,437,283	44.7
LARGE COMMERCIAL & INDUSTRIAL	145	0.03	615,041	19.1
OTHER	246	0.04	99,131	3.1
GRAND TOTALS	**575,762**	**100.0**	**3,215,990**	**100.0**

Source: JPS Annual Report 2011.

The gross peak demand to date is 614 MW (and capacity of 920 MW) and is projected to grow at an average rate of 3.8% per annum over the twenty year (20) year planning horizon (2010 to 2029). Over the next 20 years, approximately 1,400 MW of new fossil fuel power plant capacity will have to be constructed in Jamaica; to meet the projected demand for electricity and approximately 800 MW of this new capacity needs to be constructed in the coming decade, highlighting the urgency of the issue. This considers a maximum Loss of Load Probability (LOLP) of two (2) days per year (0.55%), which equates to 48 hours per annum, was used as the reliability constraint. This condition provides the grid operator with the allowance to take out a single large unit (68 MW) for planned maintenance and have a fault outage on another and still maintain adequate supply to customers[23].

Approximately 220 MW of the installed capacity is located in Kingston (Capital City) which is less than the peak demand of approximately 341 MW. The balance of power is imported from other parishes[24].

1.3.4 Demand Forecast

Under the base demand forecast, peak demand, which is the main driver for new generating capacity, is projected to grow at an average rate of 3.8% per annum over the twenty year (20) year planning horizon (2010 to 2029). Net peak demand expected for 2010 was 625.8 MW with the peak occurring during the summer period.

A gross system peak of approximately 627.5 MW has been achieved year-to-date. Net generation forecast projects growth at an average rate of 4.0 % per annum over the period 2010 to 2029[25]. It should also be noted that based on the expected growth in system demand (MW), forced outage rates and maintenance schedule of the existing

23 Office of Utilities Regulation Generation Expansion Plan 2010 ELE2010007_REP001.
24 EIA for the Proposed Jamaica Energy Partners 60 MW West Kingston Power Plants at Industrial Terrace, Kingston. Jamaica. CL Environmental, 2009.
25 Office of Utilities Regulation Generation Expansion Plan 2010 ELE2010007_REP001.

generating units, there may be critical periods between 2010 and 2013 where the system's reliability is compromised.

1.3.5 Transmission and Distribution:

JPS has an extensive island wide transmission and distribution system (see Figure below)

Figure 7: JPS Island-wide Transmission & Distribution System.

(Source: http://www.jpsco.com)

JPS has an extensive transmission and distribution system which includes approximately 400 km of 138 kV lines and nearly 800 km of 69 kV lines. The system consists of twelve (12) 138/69 kV inter-bus transformers with a total capacity of 798 MVA and fifty-three (53) 69 kV transformers (total capacity of 1,026 MVA) which supplies the primary distribution system at 24 kV, 13.8 kV and 12 kV. The coverage of the overall electricity infrastructure of 14,000 km for transmission and distribution results in over 95% electrification of the country. Total system losses inclusive of technical and non-technical declined from 23% in 2009 to an average of 22.3% in 2011[26].

Overall, the JPS transmission network is divided into 3 power islands based on major generation and demand centers as in the table below;

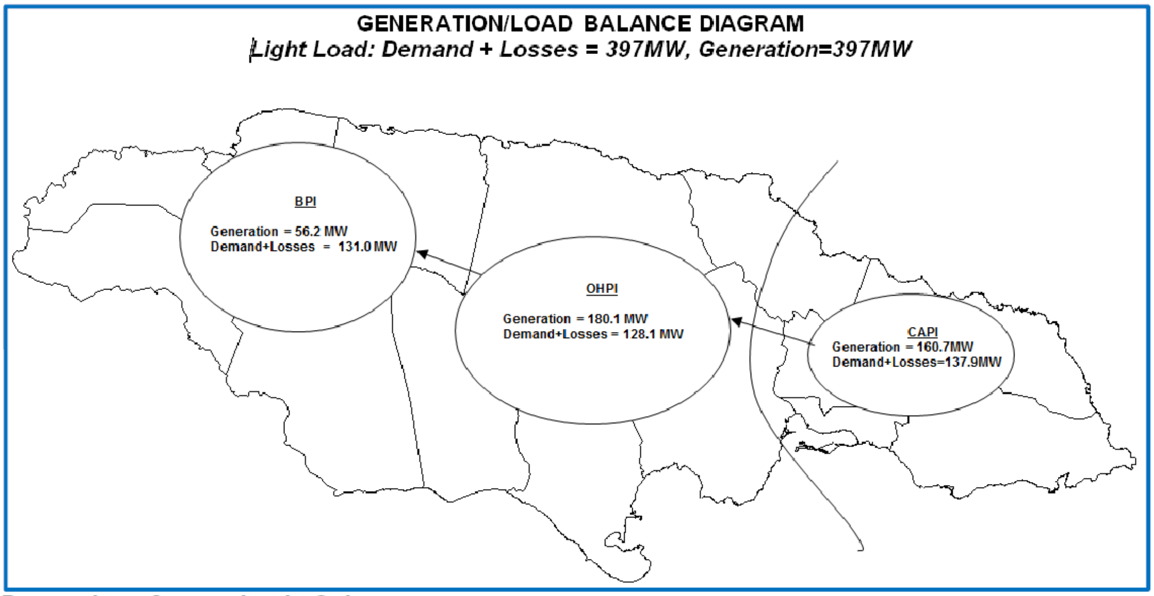
[26] Office of Utilities Regulation - Generation Expansion Plan 2010. ELE2010007_REP001.

Table 10: JPS Transmission Network Power Islands.

Subsystem	Generation (MW)	Demand + Losses (MW)	Difference (MW)
Corporate Area Power Island (CAPI) SOUTH-EASTERN	160.7	137.9	+ 22.8
Old Harbour Power Island (OHPI) SOUTH-CENTRAL	180.1	128.1	+ 52
Bogue Power Island (BPI) NORTH-WESTERN	56.2	131.0	-74.8
TOTAL	397.0	397.0	0.0

(Source: JPS Power System Integrity Investigation System Shutdown of August 5, 2012. OUR Doc: ELE2013001_REP001)

Figure 8: Generation Load Balance Diagram



Demand vs. Generation in Subsystems
BPI - Bogue Power Island; OHPI - Old Harbour Power Island; CAPI - Corporate Area Power Island

(Source: JPS Power System Integrity Investigation System Shutdown of August 5, 2012. OUR Doc: ELE2013001_REP001).

1.4 Jamaica's Energy Policy Outcomes:

The Jamaica's National Energy Policy (JNEP) 2009 – 2030 is built around a vision which states that Jamaica will have a "modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework". The strategic vision is supported by seven Goals for the energy sector as follows:

Goal 1: Jamaicans use energy wisely and aggressively pursue opportunities for conservation and efficiency.

Goal 2: Jamaica has a modernized and expanded energy infrastructure that enhances energy generation capacity and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis.

Goal 3: Jamaica realizes its energy resource potential through the development of renewable energy sources and enhances its international competitiveness and energy security whilst reducing its carbon footprint.

Goal 4: Jamaica's energy supply is secure and sufficient to support long-term economic and social development and environmental sustainability.

Goal 5: Jamaica has a well-defined and established governance, institutional, legal and regulatory framework for the energy sector that facilitates stakeholder involvement and engagement.

Goal 6: Government ministries and agencies are model/leaders in energy conservation and environmental stewardship in Jamaica.

Goal 7: Jamaica's industry structures embrace eco-efficiency for advancing international competitiveness and move towards building a green economy.

Jamaica's national developmental plan to 2030 "Vision 2030" supports the objectives of the JNEP and states that "Jamaica will create a **modern, efficient, diversified** and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security that contributes to international competitiveness throughout all the productive sectors of the Jamaican economy. **By 2030, no less than 20 per cent of our energy supply will come from renewable sources**"[27].

With these two central expressions of the national policy on energy, Jamaica's electricity sector is being transformed through two main areas of focus; fuel diversification and generation plant modernization through a transition from oil to natural gas; and the accelerated addition of indigenous commercial scale renewable energy resources for power.

1.4.1 Fuel Diversification and Generation Modernization:

Specific to generation, the JNEP recommends a number of strategies and key actions as Jamaica's generation approaches Year-2030. Selected strategies include;

- Implement least economic cost solutions for the supply of energy, including source, conversion and distribution options.
- Through a competitive basis, retire the old generation plants and replace them with modern plants to improve the conversion efficiency.
- Establish a system to identify and replace old and inefficient units/plants with more fuel-efficient and cost efficient technologies and plants.
- Establish a combined cycle capacity to replace old and inefficient units/plants with more fuel-efficient and cost efficient technologies and plants.
- Implement appropriate energy distribution and transmission systems.
- Unbundle generation and transmission & distribution creating an energy efficient electricity structure.
- Unbundle existing vertically integrated industry structures and establish and implement common carrier and common access principles, where demonstrated to be technically and economically feasible.
- Facilitate greater energy efficiency and lower energy costs in the bauxite and alumina industry and in the manufacturing sector.
- Review and complete rural electrification programme including use of alternative energy sources.

[27] Vision 2030 Jamaica, National Development Plan. Planning Institute of Jamaica 2009.

Under Goal #2, the modernization of the electricity infrastructure is critical and seeks to incorporate effective protocols for replacing old and inefficient generating plants and a transition to cleaner and energy-efficient plants specifically from oil-fired to natural gas power plants. Vision 2030 suggests that in this regard, the range of fuel diversification options for the energy sector includes natural gas, coal, petcoke and renewable energy resources such as solar energy, biofuels and wind. Modernization will also include an improvement in the distribution system. These are to occur in a liberalized energy industry that promotes competition governed by appropriate regulations.

Since 2001 the GoJ has sought natural gas as an alternative fuel to lessen Jamaica's high dependency on oil products and exposure to price volatility in the international oil markets. Fuel diversification is one of the main objectives of the National Energy Policy 2009 – 2030 which states that as part of the diversification strategy *"In the short to medium term, natural gas would be the fuel of choice for generation of electricity and production of Alumina"* and to meet the growing demand for power. The initial demand for LNG was approximately 0.8 million tonnes of LNG per year, with future demand projected at 2.5 million tonnes per year by the end of the decade. The first gas was intended to be used for firm generation capacity.

The first significant effort at the transition to natural gas was a Memorandum of Understanding (MOU) in 2004 between the GOJ and the Government of Trinidad and Tobago (GovTT) to cooperate on the development of an LNG project in Jamaica based on LNG supplied from Trinidad. However the negotiations were suspended in late 2006 as there was no consensus between the two island States on the applicability of the Treaty of Chaguaramas for the supply of gas (as LNG) at discounted prices to Jamaica, no agreement on the actual price offered for the sale of LNG and inadequate supplies as stated by the GovTT.

From this effort a Front End Engineering and Design (FEED) study was completed by Mustang Engineering in 2006 for an onshore LNG receiving, storage and regasification terminal located at Port Esquivel in St. Catherine, south central Jamaica. In 2009, the GOJ renewed its efforts to pursue LNG as the preferred primary fuel diversification option under the JNEP this time with a focus on the LNG Floating Storage Regasification Unit (FSRU) technology. The technology was considered to be adequately mature, lower in costs and would require a shorter implementation timeframe compared to an onshore terminal concept. On this basis a RFP was issued in November 2009 for FSRU infrastructure, gas pipeline network and natural gas supply. This initial tender process was aborted and a new tender was issued in 2011 but the process was again aborted in 2012 as a competitive final delivery price (especially for the bauxite sector) would not be obtained after all costs for infrastructure, supply and other costs were added. The successful bidder for the construction of the LNG FSRU at the time was Samsung C&T Corporation of Korea, and there were six submissions for the long-term supply of LNG for which there were no successful bidders.

This modernization by fuel diversification was also to facilitate a transformation in the generation sector including the conversion of old conventional oil fired plants to gas, the addition of new gas plants and generation systems conversion to achieve more efficient generation plants, and to increase generation to meet growing power demand[28]. In 2010, the Office of Utilities Regulations (OUR) placed a Request for Proposals (RfP) for new generating capacity of up to 480 MW (net) base-loads to the national grid on a Build Own and Operate Basis (BOO). This new capacity was intended for the replacement of approximately 292 MW of aging JPS plants which were to be retired, with the remainder of the generation supply to provide for projected load growth[29]. Simultaneously, gas would be introduced into the generation market. The plants would sign a 20-year PPA with Jamaica Public Service Company Limited (JPS), and be commissioned in two tranches: first stage plant (360 MW) was scheduled to start up in 2014 and the second stage plant (120 MW) was scheduled to start up in 2016[30].

The bauxite industry was also seeking to convert from heavy fuel oil (HFO) to gas fired plants to achieve greater energy efficiencies and improved financial viability. At the same time a component of the upgrade programme at Petrojam Refinery was intended to apply coking technologies to produce petcoke for JPS as an alternative fuel to oil by 2012. JPS would use the petcoke as an alternative fuel at a new 220 MW power plant to be developed at its Hunts Bay location close to the upgraded refinery to cut transportation costs.

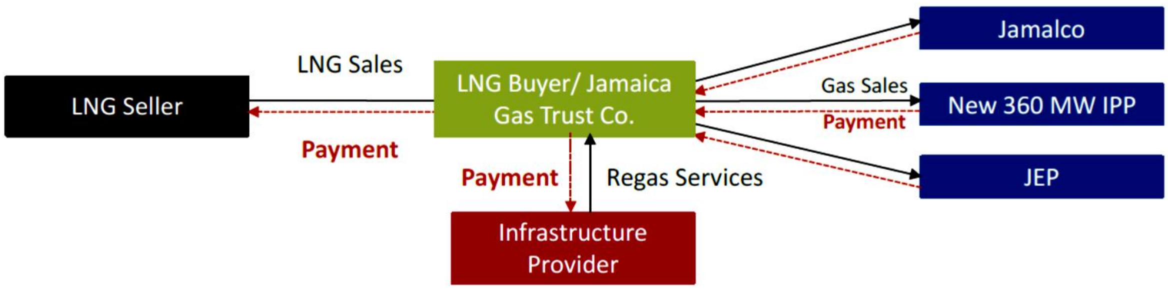
The first phase of the Jamaica LNG Project was therefore focused on three key power generators: Jamalco (bauxite/alumina producer in which Alcoa is the majority owner) Jamaica Public Service Company Ltd. (JPS) and Jamaica Energy Partners (JEP).

Table 11: Phase 1 Firm Demand for LNG.

END USER – LNG PHASE 1 DEMAND	POTENTIAL LNG DEMAND (tpa)
JAMALCO (Bauxite and Alumina producers)	320,000
JAMAICA ENERGY PARTNERS (Operating 2 X IPP power barges of 125 MW)[31].	140,000
JPS (New 360 MW IPP to be started up in 2014)	370,000
TOTAL	830,000

[28] Successive Governments have declared LNG as the preferred fuel.
[29] Office of Utilities Regulation - RFP Document for Supply of up to 480 MW Base-Load Generating Capacity Document No. ELE2010006_RFP001REV001. 2010.
[30] Government of Jamaica RFP for a Liquefied Natural Gas (LNG) Floating Storage & Regasification Terminal, August 31, 2011 and Information Memorandum - Government of Jamaica - Procurement of Liquefied Natural Gas (LNG). August 31, 2011).
[31] JEP has since added 65 MW with West Kingston Power Producers Ltd.

Figure 9: Jamaica LNG-SPV Ownership Structure



As part of the GOJ's fuel diversification strategy, the GOJ anticipates that the LNG fuel switching initiative will have the opportunity to generate substantial carbon credits under the Kyoto Protocol, or its successor agreements. It was anticipated that any bidder to the LNG tender would support the Clean Development Mechanism (CDM) compliance of the projects, support the feasibility of this initiative, and assure maximum benefit for the Jamaican economy as a whole, to be accounted in the evaluation of the bid submissions per Section III, Evaluation and Qualification Criteria[32]. This is in keeping with the objectives of the National Carbon Trading Policy (draft) Goal #4 *("A diversified emission trading sector with established linkages across the economy")*[33] which states;

Objective 1: Promote the development and commercialization of projects in the renewable energy sector.

Objective 2: Promote the development and commercialization of forestry-related projects.

Objective 3: Promote the development of Energy Efficiency projects.

Objective 4: Promote the development of Waste Management project.

The generation projects of focus under the Carbon Trading Policy Goal #4 and which may have access to CDM opportunities include:

- Energy efficiency.
- Renewable energy (wind, solar, bagasse co-generation, landfill gas recovery, biofuels).
- Use of alternative fuels (e.g. LNG, LPG, CNG).
- Waste-to-energy (biogas, methane etc.).

[32] Bidding Documents Issued On: August 31, 2011 for Procurement of Liquefied Natural Gas (LNG) Floating Storage & Regasification Terminal Icb: 2011/L002. Project: Jamaica LNG Project Procuring Entity: Government of Jamaica, On Behalf Of the Jamaica Gas Trust.
[33] National Carbon Trading (Sub)Policy (Draft), 2010

The benefits of incorporating carbon trading into future generation projects include:

- Transitioning towards a less carbon intensive economy (shift to a gas generation with smaller organic molecules) which uses more renewable sources of energy.
- Facilitating the renewal and operational improvements of important infrastructure such as power stations.

1.4.2 Developing Commercial Scale Renewable Generation Systems:

Under JNEP Goal 2 to modernize and transform the electricity sector and Goal 3 the second focus are applied to develop Jamaica's renewable energy resource potential for international competitiveness and energy security whilst reducing its carbon footprint for the electricity sector. The National Energy Policy 2009-2030 and Vision 2030 Jamaica explicitly underscores the importance of developing the renewable energy sector. The National Energy Policy has established targets for renewable energy; 11% by 2012, 12.5% by 2015 and 20% by 2030 (see table below).

Table 12: Renewable Energy Targets

INDICATOR	2009	2012	2015	2030
Percentage Renewables in Energy Mix.	8%	11%	12.5%	20%
Percentage Diversification of Energy Supply.	9%	11%	33%	70%

(Source: National Renewable Energy Policy 2010 – 2030).

In addition, the policy framework for achieving these targets and developing an efficient and more environmentally benign sector is further strengthened by the development of five sub-policies (drafts), namely the National Renewable Energy Policy, National Energy from Waste Policy, Biofuels Policy, Energy Conservation and Efficiency Policy and Trading of Carbon Credits Policy. In keeping with this emphasis in 2009, the Government undertook a three-year planning project to provide viable options for coping with the worldwide energy crisis including activities relating to wind mapping, and a determination of commercial generation opportunities for solar, hydropower, waste to energy and biomass[34].

Some of the proposed renewable projects for the short to medium term – (2009 to 2012) include:

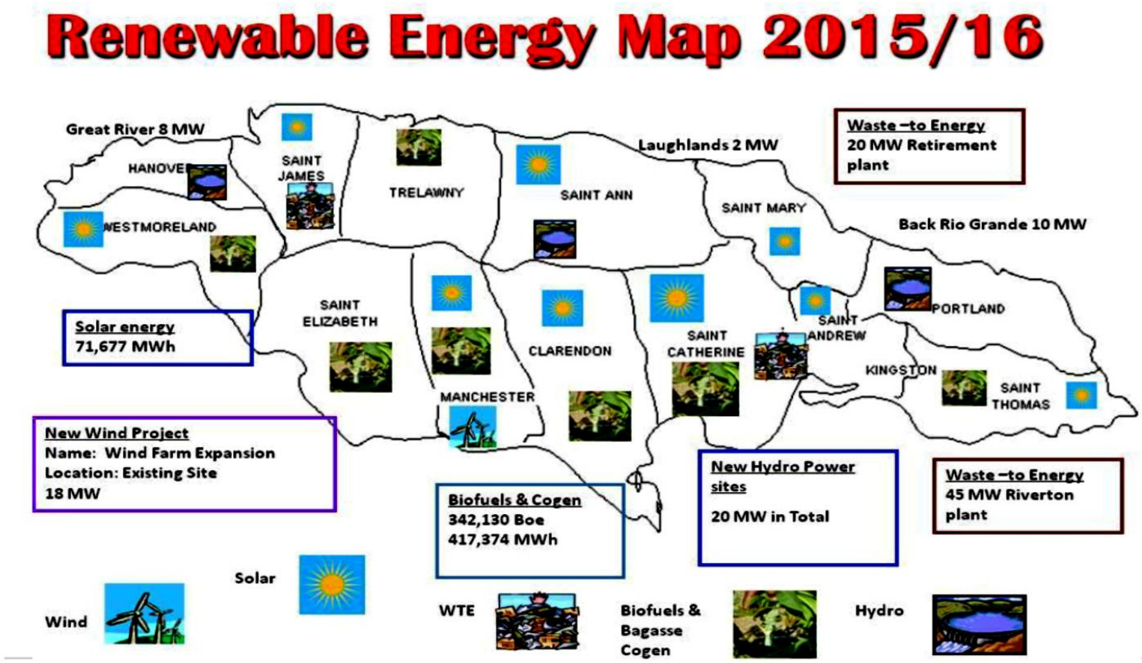
- Energy from Waste (landfill gas, agro-industry, municipal solid waste to energy).

[34] Planning Institute of Jamaica Economic and Social Survey 2009.

- RfP for 115 MW base load and energy only commercial scale renewable energy supply (>15 kW to 115 MW). These are expected to include WTE, biomass cogeneration, solar, wind, and hydro plants.
- Net Billing and accompanying Standard Offer Contract for energy only capacity of ≤100 kW (primarily solar and wind interests).
- Unsolicited bids for capacity of >100 kW but < 15 MW (all renewable).

The energy map below highlights the various renewable energy projects and programmes that are expected to be in place by 2015/16 when the percentage of renewable in the energy mix should be over 12%.

Figure 10: Proposed Renewable Energy Generation Projects by 2015/2016.



Source: National Renewable Energy (Sub) Policy 2010.

1.4.2.1 Renewable Energy Sub-Policy:

Goal 3 of the Renewable Energy Sub-Policy focuses on improvements and investments in the electricity grid towards the development of a modernized transmission network, including improved grid access for producers of electricity from renewable energy sources. At this time renewable energy sources on the grid include wind 2% (38.7 MW Wigton Wind Farm Ltd and 3 MW JPS), Hydro 5% (23 MW JPS) and solar < 1%[35]. Bagasse is used to generate power for the sugar factories and refineries but they are net importers of electricity from the grid.

[35] National Renewable Energy Policy DRAFT – August 26, 2010.

The Renewable Energy Sub-Policy, Goal 3 utilizes legal, regulatory and institutional provisions to remove barriers to the integration of renewable energy sources on the grid[36]. Significant opportunities for grid access to date include the GoJ Net Billing Policy and related Standard Offer Contracts (pilot and assessment period of 2 years beginning May 2012) with a cap of 2% of the peak demand (approximately 12.8 MW) and a RfP for the addition of 115 MW of renewable energy to the national grid. Bids for the RfP will be received in June 2013.

Table 13: Proposed Policy Incentives for Encouraging Renewable Energy Generation to the Grid.

AREA FOR RENEWABLE ENERGY (RE) DEVELOPMENT FOCUS.	FINANCIAL MEASURES	NON-FINANCIAL MEASURES
Research and Development, Demonstration and Innovation.	• Subsidies, grants. • (Zero) low interest loans.	Technical cooperation
Investments	• Investment subsidies. • Subsidies for switching to RE or replacement of older technologies to RE. • (Zero) low interest loans. • Favorable Tax mechanisms.	Negotiated agreements between generators and GoJ.
Production	• Feed in tariffs (FiT). • Favorable tax mechanisms.	Quota obligations on generation.
Consumption	• Tax advantage on the consumption of RE.	Quota obligation on consumption.

(Source: National Renewable Energy (Sub) Policy 2010 – 2030).

1.4.2.2 Net Billing and the Standard Offer Contract (Generation <100 kW).

The Government has set a target of 15% of total generation from renewable energy sources by 2015. The Regulator (OUR), which is responsible for the addition of generating capacity to the grid, has reserved a block of capacity for renewable sources, one portion of which should be in the category of 100 kW or less. The generator falls into two categories;

- Non residential entity - refers to a Qualified Entity (QE) which is a company Or Other Business Entity whose Qualified Facility (QF) has a nameplate capacity of less than or equal to 100 kW.
- Residential entity - refers to a QE who is an individual whose QF has a nameplate capacity of less than or equal to 10 kW.

[36] National Renewable Energy Policy DRAFT – August 26, 2010.

This small capacity pay back policy (Net Billing policy) has been critical in supporting access to the grid by small-distributed generation set, which previously faced a barrier to access by the vertically integrated utility which also is the monopoly on the transmission and distribution grid. Conventionally the utility was focused on adding base load, dispatchable generation only, and had a low appetite for small-scale renewable generation. The utility also stated that multiple small generators would cause grid instability. Net metering[37] was not supported by the utility and Regulator which opined that net metering does not consider the capital or maintenance cost for maintaining transmission and distribution systems. As such the Net Billing policy restricted QFs that sell electricity to JPS under the Net Billing Program to the prevailing short run avoided cost of generation (fuel costs not incurred/or avoided by the Utility), plus a premium of up to 15% at this time. This revenue is approximately 2/3 of the full electricity price to the consumer. The program seeks to encourage electricity production by small intermittent sources of renewable energy of 100 kW or less, via a simple contract arrangement with the Utility (Standard offer Contract – SOC). These installations will require supplemental power from the JPS on a day to day basis and will on occasion have excess electricity, which can be sold to the utility as long as the Gross System Output does not exceed 10 kW (AC) output for residential facilities, or 100 kW (AC) for the residential and commercial facilities. Therefore before Net Billing there was little interest for self-generation or distributed generation by entities in the instance where generation systems would eventually waste excess power as there was no off take. Without Net Billing, the payback period and initial infrastructure costs were prohibitive for most commercial and residential entities. The added justification of revenues in the form of a tariff (based on short run avoided costs to the utility) facilitated the approvals of bank financing and budget allocations within firms and for residents.

Under the Energy Ministry's policy mandate the Regulator approved the mechanisms for a Net Billing pilot project in 2012. Under Net Billing the domestic and commercial entities which are serviced by JPS are permitted to generate their own electricity and sell excess generation to the utility's power grid. Since the All Island Electricity Licenses does not allow generators to sell excess generation to other parties, then whereas Net Billing provides access to the grid for generation expansion, it does not necessarily encourage competition with the utility in the generation market and retail aspects of the system.

The current pilot programme supports all renewable sources and technologies of an intermittent nature however to date most projects have proposed to generate electricity from solar photovoltaic (PV) though there is consideration for wind also. The contact terms and conditions are for 5 years and may be reviewed every 5 years in keeping with the programme's experience and policy guidelines of the OUR. At the end of the pilot phase which there will be an assessment of the programme which will lead to modifications to similar future programmes arising from this assessment. As of April 2013

[37] Net metering involving one electrical meter, provides the small generator with tariffs equal to the retail price of electricity where the full price of electricity sold is also the purchase price to the generator; whereas Net Billing requiring 2 electrical meters only provides for the avoided cost of fuel plus a renewable energy premium paid to the generator.

there are forty applicants with Net Billing Licenses; an additional thirty three (33) applications for licensees are in process and ten (10) QE's which have signed contracts with the utility.

The revenues from the Net Billing Standard Offer Contract Program has encouraged the expansion of small additional renewable generation in Jamaica however the impact on the national grid is not significant as the programme allocation is currently 2% of peak (around 12 MW). This amounts to less than 1.5% of total generation capacity. The utility has indicated its willingness to tolerate 5% of the peak demand from intermittent/not-guaranteed power on the grid (solar and wind) to avoid additional expenditure on standby base load capacity for conditions of low or no generation. Nevertheless small initiatives such as Net Billing can improve energy security, reduce foreign exchange flight, diversify the energy base and when distributed at nodes across the grid can improve grid quality/reliability.

1.4.2.3 Hydropower

The GoJ anticipates that the Renewable Energy Policy, Energy from Waste Policy and overarching National Energy Policy will encourage new renewable energy projects in the near future. The GoJ has therefore undertaken a number of efforts to increase the use of hydropower in Jamaica as part of the GoJ's policy mandate to increase the use of renewable energy resources to 12.5 % by 2015, 15 % by 2020 and 20% by 2030. Since 2008, the government owned Petroleum Corporation of Jamaica (PCJ) aimed to form joint ventures to develop small hydropower projects including itself or its subsidiary, Wigton Wind Farm Ltd., domestic and strategic foreign investors. However no joint ventures have emerged.

This effort eventually gave way to the Energy Ministry's pursuit of an Energy Security and Efficiency Enhancement Project (funded by the World Bank) in 2011. Through Expressions of Interest (EoI) consultants were invited to provide technical assistance for promotion and development of cost-effective small hydropower projects in Jamaica, and capacity building for PCJ. This effort was not completed. However by mid-2011 another EoI sought to secure a consultant to perform pre-feasibility and feasibility studies of five hydro sites (with previously assessed capacities), Rio Cobre (1 MW), Morgan's River (2.3 MW), Mahogany Vale (2.5 MW), Negro River (1 MW), and Martha Brae River (4.8 MW) funded by the International Bank for Reconstruction and Development (IBRD). Work was to include desktop/bench studies, hydrological assessments, preliminary site investigations, and financial and environmental analyses. It was expected that once the viability of a site was established at the pre-feasibility level, the consultant would prepare a feasibility study of each small hydro project proposed. During the selection period however PCJ lost its exclusive right to develop all renewable energy resources in Jamaica[38], which changed the project mandate and scope significantly and thus the project would be

[38] The Senate unanimously approved an Act of Parliament called "the Petroleum of Corporation of Jamaica (Extension of Functions) (Amendment) Order", removing the PCJ's exclusive right to exploit and develop renewable resources in Jamaica (October 2012). http://www.jamaicaobserver.com/pfversion/Parliament-liberalises-renewable-energy_12711113#ixzz2PNmU4PH6.

retendered in mid-2013 under the new status of PCJ. This exclusive right was felt to be a barrier to the development of renewable by local and foreign direct investments in renewables while PCJ itself was experiencing challenges in securing funding or making budgetary allocations in a tight fiscal space.

PCJ intends also to promote private direct investment in three small hydro projects for which feasibility studies have been completed, Great River, Laughlands, and Back Rio Grande and by 2012 to begin feasibility studies in 2012 of run-of-river hydro sites on 10 other rivers.

If these efforts materialize, a significant amount of new baseload renewable energy generation will be added to the grid with a generation expansion of as much as 10 MW commercially[39]. Such projects would have a guaranteed access to the grid as the utility supports hydropower generation.

1.4.2.4 Waste to Energy (WTE) Sub-Policy – Municipal Solid Waste.

The National Energy from Waste (EfW) Policy has four (4) Goals which, when achieved together, is expected to realize the vision of Jamaica becoming the regional leader in providing affordable and clean energy from waste contributing to a sustainable future. With regard to this current policy analysis the two relevant Goals are Goals #1 and 2:

Goal 1: Jamaica develops an energy-from-waste sector as part of its renewable energy sector, leading to the achievement of the targets set for renewables in the country's energy mix to 2030.

Goal 2: Jamaica builds its energy-from-waste sector on modern technologies that are environmentally-friendly, producing a clean reliable renewable source of energy.

Goal 3: Jamaica creates partnerships between the energy sector and the waste management and agriculture sectors to facilitate the continuous streams of waste into the energy from waste.

Goal 4: Jamaica has well-defined governance, institutional, legal and regulatory framework for the generation of energy from waste.

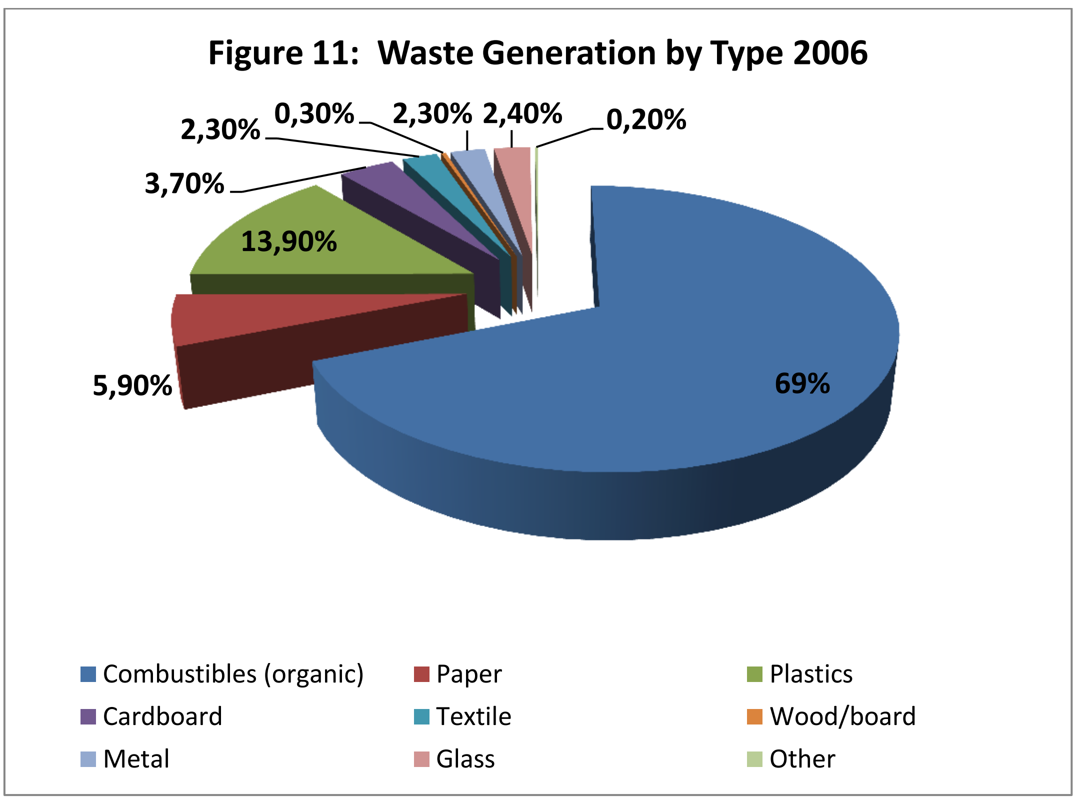
An economic feasibility analysis was conducted in 1995-1996 for the use of 300 tonnes per day (approximately 366,837 kg per day of residential wastes) or 109,500 tonnes per year of municipal solid waste at the Riverton City (Kingston) site to generate energy. Currently Riverton receives approximately 60% of the municipal solid waste generated in Jamaica (estimates of 300 truckloads per day). This waste stream includes combustibles of plastics, wood, garden waste, trees, paper, textiles, and food with an estimated heating value of 3,254,131 MJ per day (or > 8.87 MJ per kg per day) (see table and figure below).

[39] Other references exist for gross technical potentials of 25 – 30 MW of hydropower but this will be constrained by geology and terrain of the riverine systems; competing environmental and social water demands and financing.

Table 14: Waste Generation by Type 2006.

Type of Waste	Percentage	Volume (Tonnes)
Combustibles (organic)	69%	1,010,094.80
Paper	5.90%	86,370.50
Plastics	13.90%	203,482.90
Cardboard	3.70%	54,164.50
Textile	2.30%	33,669.80
Wood/board	0.30%	4,391.70
Metal	2.30%	33,669.80
Glass	2.40%	35,133.70
Other	0.20%	2,927.80
TOTALS	**100%**	**1,463,905.50**

(Source: National Energy from Waste Sub-Policy, 2010).



(Source: National energy from Waste Sub-Policy, 2010).

The requirements for this consideration is that the waste had a minimum calorific value of 5 MJ per kg; moisture content of < 50%; and the combustible portion of the waste should not be < 50% which makes heat for recovery from this municipal waste at Riverton City feasible (see table of calorific values below).

Table 15: Heating Values of Residential Waste Disposed, Riverton City

Items	Lower End (MJ/kg)	Quantity Disposed (kg/dy)	Total heating Values (MJ/dy)
Plastics	22.7	44020	999254
Wood/Board	15	36684	550260
Garden Waste, Trees	4.8	110051	528245
Paper/Cardboard	12.2	40352	492294
Textiles	16.1	29347	472487
Food	4.12	51357	211591
Totals	**12.49**	**311,811**	**3,254,131**

(Source: Presentation by M. Kiswani, PhD to the EfW PWG on May 26, 2010)

It was further estimated that 269,698 MWh could be generated annually with a thermal efficiency of about 25% with about 9 MW available for export to the national grid.

In 2009 a Memorandum of Understanding (MOU) was signed between the Petroleum Corporation of Jamaica (PCJ) and Cambridge Project Development Inc. and its partners to build and operate two (2) waste-to-energy plants to generate up to 65 MW of electricity from 1.3 Million tonnes annually at the Riverton solid waste deposit sites in Kingston from eight (8) solid waste disposal sites, (a 45 MW [358 GWh/yr] facility on the eastern side of the landfill and 20 MW facility [141 GWh/yr]). The Retirement Landfill site in St. James was also to be included over the planned period. The plants were to be operated over a 20-year period as a joint venture agreement between Cambridge and PCJ. It was estimated that the annual savings in fossil fuel could be 700,000 barrels or US$ 60 million (at that time). The necessary agreements to operate the plant were in place in March 2010. The negotiations however failed while attempting to confirm financing for the project.

It is anticipated that 2 WTE projects will be submitted in the current RfP for 115 MW of renewable energy generation based on an OUR pre-bid consultation meeting in January 2013 in Kingston where at least 3 firm interests were registered.

WTE projects would be guaranteed grid access both under the RfP as external to an RfP as it provides base load generation while resolving some challenges of fires at the disposal sites, employment, new generation requirements, and management of waste disposal.

1.4.2.5 Waste to Energy (WTE) Sub-Policy Methane Recovery.

Methane recovery from energy is also believed to be possible from Riverton as the volume of methane available for recovery is estimated at 200 L/kg of refuse over a period of 30 years. With an estimated methane recovery rate during the first 5 years of 1,040,250 m^3 per year and the estimated conversion of $3.6 \times 10^6 J = 1$ kWh, the energy produced could serve over 3,300 homes (Model: Emcon Associates-Henry 1989 study, Model: Zsuzsa- Hungarian – biogas). Before there is any opportunity however, the waste disposal site would have to be converted to a covered landfill to trap the methane. This is not in the near horizon.

However, a detailed viability study has not been done considering methane recovery.

1.4.2.6 Waste to Energy (WTE) Sub-Policy Bagasse Cogeneration

Sugar industry waste (bagasse) has been used during the cane harvesting seasons in the Jamaican sugar factories using cogeneration or trigeneration technologies (heat, power and mechanical). Approximately 600,000 tonnes of bagasse - equivalent to about 940,000 barrels of oil (value of US$ 37.5 million/annum in 2003) has been used for cogeneration in Jamaican sugar factories. It is estimated that excess electricity of approximately 300 GWh per year would be available on the grid with bagasse combustion alone, resulting in about 68 MW of available capacity. In the past more efficient cogeneration systems at the factories were able to deliver power to the grid, but has since discontinued grid supply as the equipment has aged and are overdue for retirement.

The sugar factories and refineries are currently net consumers of electricity from the grid; however the interest to facilitate bagasse cogeneration with coal/bagasse or fuelwood bagasse remains of national interest for expansion of the national generation capacity.

1.4.2.7 Other Renewables

Though the policies and regulations do not currently consider a mandatory Renewable Portfolio Standard (RPS) for electricity supply from renewable energy by the utility, Jamaica Public Service Co. currently operates eight small hydro projects totaling 21.4 MW. Studies have indicated there is a gross technical potential for about 11 additional hydro projects totaling 25 to 30 MW (also see section above on hydropower). JPS has also implemented a 3 MW wind farm in 2010 consisting of 4 x 750 kW gearless UNISON U50 turbines with 50 m towers and 25 m blades.

Further to this JPS is constructing a new hydropower plant in Maggoty St. Elizabeth (south central Jamaica) to expand hydro by 6.3-MW. The new plant will utilize 2 turbines.

1.4.2.8 Request for Proposals to Build, Own, Operate 115 MW of renewable Energy Generation Plants.

Based on the projected system configuration for 2015 in conjunction with the JNEP, 115 MW capacity from renewable energy sources is required to be commissioned by 2015 (see table below).

Table 16: Projected Renewable Generation Requirements.

	Additional Renewable Energy Generation (MWh) Yr-2015	Renewable Energy Capacity (MW) Yr-2015
Firm Capacity (RE)	212,084	37
Energy Only (RE)	204,872	78
Total RE	416,956	115

Source: OUR, RFP for 115 MW of Electricity Generation Capacity from RE on BOO Basis (2012)

In 2012, the Office of Utilities Regulation (OUR) issued a Request for Proposal (RFP) for new generation from plants of varying configurations greater than 100 kW and up to 115 MW of renewable energy firm capacity and energy (only) electricity generation to the national grid on a Build Own and Operate (BOO) basis. This is in fulfillment of the National Energy Policy and National Renewable Energy Sub-Policy's mandate for fuel diversification and the development of the country's renewable energy sources as two of its main objectives and vision of having 12.5% electrical energy from renewable energy sources by 2015[40].

The successful renewable energy generation system bids have a guaranteed connection to the grid and will be limited by a maximum tariff rate set by the OUR and specific to the types of renewables as follows:-

- Bagasse 15.16 US cents /kWh.

[40] Office of Utilities Regulation, RFP Document for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis. Document No. ELE2012003_RFP002

- Hydro-Power 11.13 US cents/kWh.
- Waste –to-Energy 14.88 US cents /kWh.
- Wind 13.36 US cents/kWh.
- Utility Scale PV 26.73 US cents/kWh.

Based on a pre-bid meeting in January 2013 OUR stated that proposals which offer lower tariffs, firm capacity and base load would be given preference over energy only proposals. This is due to the effort by the GoJ and the utility to reduce retail electricity prices downward from US 40¢/kWh and there is an urgent need to replace old generation as the useful generation life of most JPS plants have been exceeded and system failure is anticipated between 2013 and 2015. Discussions between various interested parties and queries sent to OUR subsequent to that meeting suggest that hydropower and waste to energy projects may be tendered. Further to this an initial analysis of the OUR RFP for energy only generation of 78 MW with 204,872 MWH/pa anticipates that a split between wind and PV of approximately 2 to 1, i.e. about 50 MW of wind and 25 MW of PV may occur. However some solar proposals were already withdrawn due to the maximum tariff offered under the RfP and the OUR's preference for lowers evaluated economic cost (as provided under the Generation Least Cost Expansion Plan), base load and firm capacity.

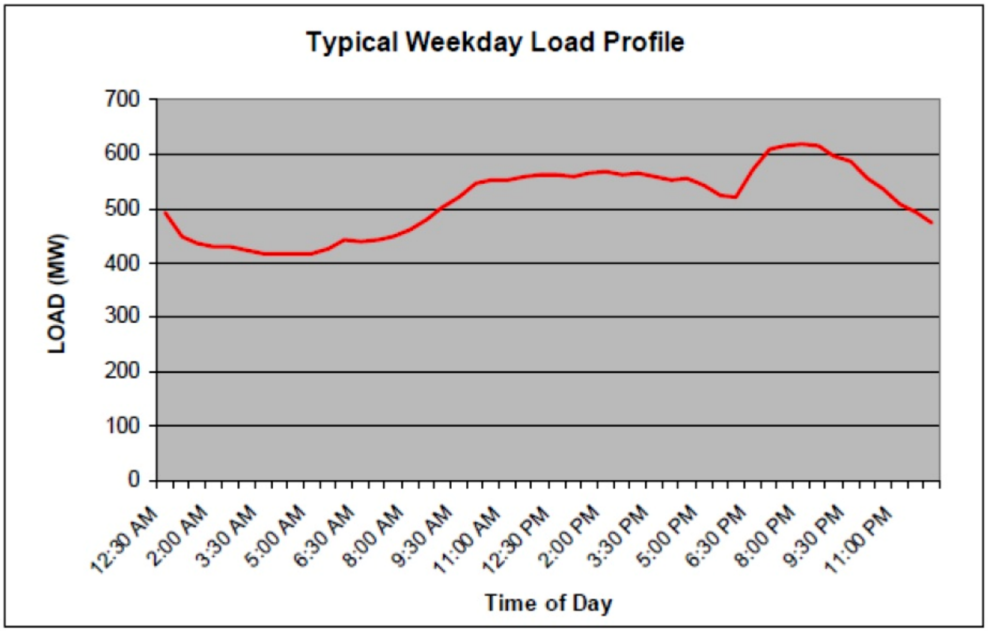
The deadline for submission of proposals is June 2013 and it is expected that construction will begin by Quarter 3 - 2014 and commissioning by Quarter 3 of 2015. Success of the RfP will facilitate the acceleration of expansion of generation capacity in the near-term by the addition of distributed generation sets and renewable energy technologies to the national grid.

1.4.2.9 Wheeling Legislation

The attempt to draft a wheeling legislation is a significant step towards the addition of renewable energy and fossil fuel distributed generation (DG) to the national energy mix and provide grid access to large commercial entities. Distributed generation as defined by the US Department of Energy (US DOE) refers to locating modular type electricity generators close to the point of consumption, can significantly reduce the load at the distribution level of the transmission and distribution grid. Another critical benefit of commercial scale DG systems is that some of the renewable energy technologies such as PV can provide a very close match of power supply to the consumer demand for electricity on weekdays between 11:00 am and 5:00 pm with less energy loss on the grid lines than with other alternatives.

Figure 12: Typical Weekday Load Profile for Jamaica Grid System.

Typical Weekday Load profile for Jamaica's power system



(Source: Generation Expansion Plan, OUR 2010.)

While the central generation stations provide most of the power for the T&D system distributed generation sources can meet the peaks of local feeder lines or major customers, providing some stability to the overall grid and reducing the demands on the generation systems at the utilities central generation stations. In this way DG support electricity grid performance and can delay the need to upgrade grid infrastructure. Wheeling can allow from time to time additional generation to balance the network, provide top up/standby electricity supplies in the event that self-generators are unable to supply all of their own consumption requirements ("Ancillary Services") for the preservation of the integrity of the network through the control of voltage and frequency and the avoidance of demand/generation imbalances.

Wheeling in particular will promote greater competition in the electricity sector (due to the commercial scale generation) and provide more options with regards to sources of electricity to consumers including renewable energy distributed generation sources (see other benefits in table below).

Table 17: Benefits of Distributed Generation Power Technologies

BENEFITS	PV	WIND	HYDRO	GAS - MICRO GENERATORS/	FUEL CELLS

				TURBINES	
1. Avoided Energy Loss In T&D Network/Grid.	✓	✓	✓	✓	✓
2. Modular - Incremental Changes (+/-) to Match Demand.	✓	✓	✗	✓	✓
3. Modular – Less Capital Investment in Unproductive Generation.	✓	✓	✗	✓	✗
4. Clean, Quiet Operation, Low Environmental Impacts.	✓	✓	✓	✗	✓
5. Potential to Release Transmission Assets for Increased Wheeling Capacity.	✓	✓	✓	✓	✓
6. Greater Market Independence & Consumer Choice.	✓	✓	✓	✓	✓
7. Avoided Fuel Transportation & Storage.	✓	✓	✓	✗	✓
8. Reduced O&M Cost to Utility.	✓	✓	✓	✓	✓
9. Capacity to Match Daytime Peak Demand.	✓	✓	✓	✓	✓
10. Capacity to Match Nighttime Peak Demand.			✓	✓	✓
11. Avoided/Differed T&D Line & Substation Upgrades.	✓	✓	✓	✓	✗

12. Faster Permitting than T&D Line Upgrades.	✓	✓	✓	✓	✗
13. Enhanced Power Quality and Reliability on T&D Grid.	✓	✓	✓	✓	✓
14. Potential Secondary Cash Flow to Consumers.	✓	✓	✓	✓	✓
15. Off-grid Supply Options.	✓	✓	✓	✓	✓
16. Dispatchable.	✗	✗	✓	✓	✓

(Source: US Department of Energy September /National renewable Energy Laboratory-National Center for Photovoltaics [enhanced], 1999)

Under Section 4(3) of the OUR Act it is the regulator which should "*undertake such measures as it considers necessary or desirable to:*

a) *encourage competition in the provision of prescribed utility services;*
b) *protect the interests of consumers in relation to the supply of a prescribed utility service;*
c) *encourage the development and use of indigenous resources; and*
d) *promote and encourage the development of modern and efficient utility services…*"

The benefits of wheeling have not been exercised in Jamaica before 2013 as the governing legislation did not provide a mechanism for access and use of the grid except by the owner of the assets and rights – the utility. Condition 2(4) of the "Jamaica Public Service Company Ltd Amended and Restated All-Island Electric License 2011", (*All-Island Electric License*) states –"*The Licensee shall have the exclusive right to provide service within the framework of an All-Island Electric Licence and the All-Island Electrical System. The exclusive right specified herein shall be as follows:*

a) *In the first three years from the effective date of this Licence [March 30, 2001], the Licensee shall have the exclusive right to develop new generation capacity. Upon the expiry of this period the Licensee shall have the right together with other outside person(s) to compete for the right to develop new generation capacity.*
b) *The Licensee shall have the exclusive right to transmit, distribute and supply electricity throughout Jamaica from the effective date of this license (that is March 30, 2001) until 2027.*

Provided that no firm or corporation or the Government of Jamaica or other entity or person shall be prevented from providing a service for its or his own exclusive use".

As such whereas the competition for generation of electricity could be carried out by several players in the industry, JPS, the sole owner of the national grid, alone had exclusive right to access the grid island-wide until 2027. This has historically created a significant barrier to the implementation of both small and commercial grade renewable energy generation projects as the economics[41] for such projects are significantly enhanced with grid access and generation revenues, therefore facilitating commercial feasibility.

Notwithstanding Condition 2(4) which also allows an entity to provide service for its own use and notwithstanding Condition 12 of the License which mandates JPS to provide open access to self-generators to the island-wide grid on such terms and conditions as are approved by the OUR, neither terms nor charges were prepared for action prior to 2011.

Condition 12 provides:

1. *"The Licensee shall implement Electric Power Wheeling Services in accordance with such terms and conditions as approved by the Office."*

2. *The Licensee shall prepare its charges for use of the System or top-up or standby supplies, including but not limited to Electric Power Wheeling service, on a basis which is cost reflective and consistent with tariffs and Price Controls as approved by the Office". With regards to Electric Power Wheeling, the charges for this service shall additionally be guided by the results of a cost of service study conducted by the Licensee, which results shall be submitted to the Office for approval. The cost of service study shall be conducted within twelve (12) months of the date hereof* [August 19, 2011]."

Consequent to Condition 12, an *"Electricity Wheeling Methodologies Consultation Document"* was submitted to OUR from JPS at the end of 2012. The study proposing wheeling charges based on a cost of service study conducted by JPS, is incomplete however will provide data for wheeling tariffs for approval[42] including transmission and distribution network access fees in order to guide the development of an appropriate wheeling framework. Further the OUR intends to develop this regulatory wheeling framework with rules/guidelines to ensure the efficient operation of transactions related to the use of the national transmission and distribution grid by self-generators in the transportation of electricity from power production sites to consumption points where demand and supply are not co-located.

[41] Namely economic indicators such as the Internal Rate of Return, Net Present Values, Simple Pay Back (Rates), Cost Benefit Analysis and other standard financial and economic indicators

[42] Electricity Wheeling Methodologies Consultation Document. Document No: ELE2012004_CON001. Office of Utilities Regulation (OUR). December 31, 2012

Below are some of the methodologies considered for Jamaica (see table below). A MW-km load flow-based method for the wheeling framework and implementation has been proposed as it offers reasonable economic efficiency, transparency in the rate charges, the ability to recover costs adequately and the benefits of stability and relative ease of implementation. As a historic-cost based method, it can also allow for the utility to recover the existing value of their assets in the T&D network[43].

Table 18: Indicative Comparison of Wheeling Methodologies with Key Principles.

Method	Efficiency	Cost recovery	Transparency	Stability	Non-discrimination	Ease of application	Score
Postage Stamp	×	✓	✓	✓	×	✓	2
Contract Path	×	✓	×	✓	×	✓	0
MW-km (distance)	-	✓	×	✓	×	✓	1
MW-km (flow-based)	✓	✓	✓	-	✓	-	4
Nodal Pricing	✓	-	×	×	✓	×	-1
SRIC	✓	-	-	×	✓	-	1
LRIC	✓	-	✓	✓	✓	-	4

[43] Electricity Wheeling Methodologies Consultation Document No: ELE2012004_CON001. Office of Utilities Regulation. December 31, 2012.

1.5 LEGAL AND REGULATORY FRAMEWORK FOR THE ELECTRICITY SECTOR

The legal and regulatory framework governing various key aspects of the Jamaican power are contained in and regulated by the following[44]:

- The OUR Act 1995 (as amended).
- The Electric Lighting Act.
- JPS's Amended and Restated All-Island Electric License, 2011 (amended).
- OUR's Regulatory Policy on Guidelines for the addition of Generating Capacity to the Public Electricity Supply System: June 2006 (Document # Ele 2005/08.1).
- Generation Expansion Plan 2010.

1.5.1 Legislative Framework - Addition of Generation Capacity

There is currently a national imperative to reduce the proportion of fossil fuel imported and used; increase fuel diversification to cleaner generation; increase the application of indigenous resources; reduce the cost of electricity; diversify generation sources (including distributed generation) and increase service reliability. OUR has as one of its mandates to secure new and additional generation capacity for the national grid[45].

A significant portion of the Jamaica National Energy Policy (JNEP) provides directions for the addition of new generation capacity to the grid as seen in the following 5 Goals:

Goal 2: Jamaica has a **modernized and expanded energy infrastructure that enhances energy generation capacity** and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis.

Goal 3: Jamaica realizes its energy resource potential through the **development of renewable energy sources** and enhances its international competitiveness and energy security whilst reducing its carbon footprint.

Goal 4: **Jamaica's energy supply is secure and sufficient** to support long-term economic and social development and environmental sustainability.

Goal 5: Jamaica has well defined and established **governance, institutional, legal and regulatory framework** for the energy sector that facilitates stakeholder involvement and engagement.

Under Goal #2 some of the applicable proposed strategies and key actions to 2030 include;

- Implementation of least economic cost solutions for the supply of energy, including source, conversion and distribution.
- On a competitive basis, retire the old generation plants and replace them with modern plants (including cogeneration technologies) to improve the energy conversion efficiency and cost efficiency.

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[44] OUR website (http://www.our.org.jm/).

[45] Office of Utilities Regulation (OUR) – Annual report and Financial Statements 2011 - 2012.

- Implement appropriate energy distribution and transmission systems including unbundling generation and transmission & distribution and creating an energy efficient electricity structure.
- Implement grid access principles, where demonstrated to be technically and economically feasible.
- Review and complete rural electrification programme including use of alternative energy sources.

Under Goal #3 some of the applicable proposed strategies and key actions to 2030 are:

- Develop diversification priorities based on cost, efficiency, environmental considerations and appropriate technologies and competitiveness.
- Prioritize renewable energy sources by economic feasibility criteria and environmental considerations including carbon abatement.
- Promote the development of efficient and low cost renewable plants with a size of 15 MW or more on a competitive basis through a level playing field.
- Introduce a strategy that ensures renewable energy plants of capacity less than 15 MW will be built on no-objection basis using base opportunity cost and negotiable premium cap and 15 MW capacity or more to be obtained on a competitive basis through the OUR process .
- Develop an inventory of all potential sources of wind, solar and renewable technologies and rank them according to their economics with full economic impact analysis.
- Introduce incentives, where feasible, and a plan of action for implementation to foster the development of wind, solar and renewable technologies. This will require the review by the relevant regulatory authority of existing renewable power generators to afford them such incentives that may be available, to encourage the sustainable development of the sector. The creation of an enabling legislative and regulatory framework will be a priority.
- Encourage research, development and implementation of qualified renewable energy projects.

Under Goal #4 some of the applicable proposed strategies and key actions to 2030 are:

- Determine the fuel diversification programme for the short, medium and longer term.
- Develop diversification priorities based on cost, efficiency, environmental considerations and appropriate technologies.
- Diversify energy sources by type and geographic location.
- Develop a framework for the introduction of natural gas.
- Construct new energy-efficient generating facilities on a phased basis to meet increasing demand.
- Establish an enabling environment for the development of renewable resources through private sector participation.
- Develop and implement a fast track generation plant retirement and replacement program.

- Develop the institutional capacity and regulatory framework to explore the establishment of small nuclear power generation plants in the event that nuclear power generation proves feasible for Caribbean Small Island Development States (SIDS).

Under Goal #5 some of the applicable proposed strategies and key actions to 2030 are:

- Develop necessary regulatory framework for the introduction of fuel diversification.
- Promote a market-based approach and increased competition in the sector including a transparent procurement process for new capacity and sourcing from private producers (both renewable and non-renewable energy sources).
- Develop regimes for pricing of electricity and petroleum products that will balance requirements for competitiveness with the long-term viability of the sector.
- Conduct studies to include net metering and wheeling in the tariff rates and introduce appropriate mechanisms for net metering and wheeling procedures and standards to encourage the development of renewable energy and cogeneration opportunities.
- Promote a market-based approach and increase competition in the sector by use of transparent procurement processes for new capacity.
- Implement policy regarding the development and export of electricity from co-generation and renewables to the national grid by private sector and citizens at large.

The legislative framework supports the addition of generation by private sector entities and the utility on a competitive basis. Under Condition 2(4) of the "Jamaica Public Service Company Ltd Amended and Restated All-Island Electric License 2011", (*All-Island Electric License*) - "*In the first three years from the effective date of this License [March 30, 2001], the Licensee shall have the exclusive right to develop new generation capacity. Upon the expiry of this period the Licensee shall have the right together with other outside person(s) to compete for the right to develop new generation capacity………..Provided that no firm or corporation or the Government of Jamaica or other entity or person shall be prevented from providing a service for its or his own exclusive use*"[46]. In the 3-year period, the License would therefore allow the utility to consolidate its assets and plan for the emerging competition.

The Office of Utilities Regulation is the chief state facilitator for the addition of new generation capacity to the grid under its governing Act – the OUR Act of 2000. The OUR Act in Section 4 (3), stipulates that *"the Office*[47] *shall undertake such measures as it considers necessary or desirable to –*

(a) encourage competition in the provision of prescribed utility services;

[46] Electricity Wheeling Methodologies Consultation Document No: ELE2012004_CON001. Office of Utilities Regulation. December 31, 2012.
[47] The Office of Utilities Regulation (OUR).

(b) protect the interests of consumers in relation to the supply of a prescribed utility service;
(c) encourage the development and use of indigenous resources; and
(d) promote and encourage the development of modern and efficient utility services.

The All Island Electricity License 2011, Condition 18 provides the regulatory framework within which JPS (the utility) has opportunities for the addition of generating capacity under a transparent tendering process. The License Condition provides as follows[48]:

1. *"Save to the extent the Office agrees, or as provided for in this License, the Licensee shall not contract for new capacity[49] other than pursuant to a competitive tendering procedure managed and administered by the Office in accordance with the Guidelines for the Addition of Generation Capacity to the Public Electricity Supply System June 2006 and amended by the Office from Time to Time.*
2. *The Licensee shall enter into an agreement for the purchase of electricity as shall be approved by the Office, with the successful bidder chosen as a result of such competitive tender procedure referred to in paragraph 1. In the event that the Licensee is chosen as the said successful bidder, the Licensee shall execute such agreements setting out the terms and conditions of Supply of electricity to the System as shall be required and approved by the Office.*
3. *For the purpose of their Condition "new capacity" shall include contracts for the purchase of electricity from existing or new Generation Sets: contracts for the construction of new generation sets or the extension or re-powering of existing Generation Sets to satisfy demand of electricity above 15 MW.*
4. *For capacity additions of under 15 MW the Office may, after consultation with the licensee, approve a simpler procurement methodology, or on a case-by-case basis. Notwithstanding the foregoing, for capacity additions of up to 25 MW which are generated from Renewable Sources, The Office, may approve a simpler procurement methodology provided that the capacity from Renewable Sources shall not exceed 20 percent (20%) of net energy to the System and provided that in the exercise of its functions herein the Office shall take account of the system stability and the overall price to be paid by customers of the Licensee for a Supply of electricity.*
5. *Notwithstanding the foregoing, the requirement for competitive tendering for the procurement of the new capacity will not become effective until the completion of three (3) years after the effective date of the License.*
6. *The Office may, in instances of Force Majeure, waive the requirements for competitive tendering. In such instances the Office shall make its reasons for so doing public.*

[48] Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System. June 2006.
[49] Clause 5 of the License defines **"new capacity"** to "include contracts for the purchase of electricity from existing or new generation sets; contracts for the construction of new generating sets or the extension or repowering of existing sets to meet demand for electricity above 15 MW".

Under Condition 21.3

"As of July 9, 2007 and for the remaining duration of this License the Office shall be responsible for the preparation of, and revisions to a Generation Expansion Plan after giving due consideration to any and all consultation with all stakeholders in the electricity sector, taking into account developments in internationally accepted best industry practice".

And in Condition 21.1 it remains that the generation expansion plan will be recommended to the Minister for his approval after which the Minister shall:

(a) approve the plan; or

(b) refer the recommendation back to the Office for further consideration.

In summary these are the critical steps, players and framework around the generation expansion process which has been followed and has resulted in various RfPs, and unsolicited bids of >15 MW. This regulatory framework therefore establishes the context within which a managed and scheduled process for the addition of generation capacity, at the minimum cost, and consistent with the country's long term national development. The framework also explicitly places a duty on the Office to ensure the adequacy of generation capacity from time to time[50].

Occasionally legislation is used to facilitate specific actions in the energy sector such as the exclusive rights provided to PCJ to explore and develop renewable energy resources in Jamaica through a Ministerial Order issued in 2006. By doing so Wigton Wind Farm was implemented to take advantage of global concerns about the emission of carbon from fossil fuels and petroleum products and to utilize renewable sources of energy to provide Jamaica with a benefit. Later it was agreed that PCJ was not vested with the right to establish a subsidiary involved in producing energy from sources other than petroleum, for which it had exclusive rights. It was also agreed that further investments in commercial grade renewable energy generation was hampered by the requirement to have PCJ as a joint venture partner or to give its permission for independent entities to pursue such projects. The exclusive right has since been withdrawn by another legislation (as previously mentioned).

As the OUR Act and the All Island Electricity License are applied, the determination of when to add generation, what technologies how much generation at a time and equity for investors and proponents, requires a balance of all major considerations and includes the utility which has the majority shares in generation and 100% ownership of the T&D assets, into the process.

[50] Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System. June 2006.

1.5.2 Legislative Framework – Least Cost Generation Expansion Plan

In June 2006, the OUR developed the "Regulatory Policy for the Electricity Sector - Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System" to set out the regulatory policy to guide the process for the addition of new generating capacity to the Jamaican electricity grid in a more transparent and predictable manner.

In order to execute long term plans for adding new generation and retiring old generation systems a generation simulation model referred to as the Least Cost Expansion Plan (LCEP) has been used to evaluate the projected technical and economic performance of potentially feasible generation, transmission and distribution alternatives and has provided information to facilitate selection of the optimal path for generation investment. A Wien Automatic System Planning Package (WASP) was the primary simulation tool used for evaluating the alternatives.

Formerly the utility had the responsibility under its License to develop the LCEP (Condition 21 of the License) however the amended and restated license requires the OUR to prepare the LCEP with the Minister approving the Plan. Typically the investments projected within the first 5 to 7 years of each LCEP would be regarded as fixed while investments later in the Plan may be afforded some justifiable variations in design and outputs. In developing the LCEP consideration is given to, inter alia:

- Realistic assumptions of increases in demand and energy consumption, influenced in turn by projections of growth in the national economy;
- Historic demand and consumption patterns;
- Fixed and variable costs (including relevant externalities) of the various alternative projects being evaluated;
- The performance of existing units and the appropriate date for the economic retirement of each;
- The economic value of supply reliability and its appropriate level

The utility has the responsibility to provide annual demand forecasts which then feeds into the LCEP updates. The LCEP has been reevaluated and updated to consider changing electricity demand and supply estimates, economic developments, technological advances and the relative price of competing fuel sources[51]. The LCEP in 2004 and 2010 are the most recent updates and have been effective in guiding the generation needs of the country considering the rapidly changing generation landscape in less than a decade including the following:

- Request for Proposal for 480 MW of new generation from LNG.
- Unsolicited bids for 360 MW new fossil fuel generations.
- Development of a wheeling legislative framework.
- Government and utility efforts to reduce electricity prices.

[51] Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System. June 2006.

- Development of a Net Billing policy and regulations.
- Discussions on the upgrade and unbundling of the grid network and grid network failures (2013/2015).
- Request for proposals for new 115 MW renewable energy generations.
- Three separate bids for hydropower feasibility studies.
- Addition of 6.3 MW of hydropower by the utility.
- Applied capacity additions of up to 25 MW as unsolicited bids generated from renewable sources.
- Two LNG supply and infrastructure bid rounds.
- Addition of 65 MW of new fossil fuel generation by West Kingston Power Partners.
- Addition of 3 MW wind generation by the utility (JPS).
- Addition of 18 MW of wind generation by Wigton Wind Farm.

New generation may be added in one of three (3) modes;

- New conventional technologies.
- New renewable energy technologies.
- New cogeneration technologies.

On the basis of the LCEP, and the License, the utility is not at liberty to change, retire or add new generation without the consent and approval of the Regulator (Condition 18. 1 and condition 21. 3 – *"The Licensee shall not, without the consent of the Office, permanently close, retire or cease utilising any Generation Set")*. The utility has protested that this constraint has limited its options to bid on the introduction of new natural gas or coal generation, or conventional petroleum generation since 2010 while old petroleum generation units are maintained beyond their designed commercial lifetime and due for retirement. In all cases the utility may also tender on bids for expansion or addition of generation or enter PPAs with IPPS under the terms of the License (Condition 18. 2).

Contracts with negotiated PPAs for all plants offering firm capacity of 100 KW or above will be structured in two-parts; a fixed rate per unit of guaranteed capacity (e.g. $/kW); and a variable rate to be applied to energy sales ($/kWh). Both fixed and variable charges may be subject to escalation that would be determined by indices stipulated upon in the PPA.

1.5.3 Addition of Conventional Technologies.

Conventional generation is one of three (3) modes for the addition of new generation to the national grid mostly using traditional fossil fuel generators. These include natural gas, oil or coal, or other such as nuclear and hydroelectric (renewable) designed to exclusively generate electricity. Currently only oil based fossil fuel plants and hydropower fall into this category and oil based fossil fuel plants account for approximately 95% of the capacity on the grid.

Under this category of conventional generation, new generation may be added to the grid as follows:

1. Up to 15 MW without the competitive tendering process (unsolicited bids).
2. Addition of new plants above the 15 MW rating is initiated through a request for proposal (RfP) process following the approval of the LCEP, meeting lowest evaluated economic generation and under the terms of the License Condition 18 (Competition for New Generation).
3. Capacity additions will be considered either on the basis of providing technically and financially sound firm capacity and energy to the system or supplying energy-only to the grid.
4. The utility can provide additional generation under the License Condition 18 and LCEP or may purchase power from an Independent Power Producer (IPP). Power purchased is based on the incremental avoided cost which would not be incurred by the utility.
5. The utility (JPS) and the IPP generator/investor will negotiate the contractual arrangements as a separate action to the LCEP and License, the contract which then will form the basis of the Power Purchase Agreement (PPA) between the parties. However the PPA must be approved by the Regulator before being executed.

The LCEP itself does not guarantee that new generation will be added to the grid. Since the 2010 LCEP, following the restated and amended All Island Electricity License, only 65 MW has been added through this mode from West Kingston Power Producers. An additional RfP was placed in 2010 for 480 MW of natural gas powered generation in two phases of 292 MW as an immediate replacement of old retired units and the balance in the second phase but was not successful due to financial constraints and failure of the government's bid round to secure supply and infrastructure of LNG. As a consolation bid to this 480 MW bid, a more recent bid for 360 MW of natural gas generation has also failed as the utility was not able to secure gas at viable rates within the bid period and due to challenges in securing financing. Finally OUR accepted unsolicited bids for 360 MW of fossil generation under its powers to do so which has yielded 5 proposals for LNG, LPG and diesel:

- Natural gas as primary fuel, with Automotive Diesel Oil (ADO) as backup fuel (combined cycle gas turbine).
- Natural gas as primary fuel with inlet air-cooling power enhancement, and ADO as backup fuel (combined cycle gas turbine).
- Liquefied Petroleum Gas (LPG) as primary fuel with an LNG alternative (combined cycle gas turbine).
- 2 heavy fuel oil/diesel proposal (reciprocating engines - combined cycle).

The successful bidder on this current effort for new conventional generation will be determined by April 15, 2013.

1.5.4 Addition of Renewable Energy Technologies:

A second mode for adding new generation is by renewable energy sources[52]. Generation in this mode for Jamaica will be through solar, wind, hydropower, waste to energy and biomass fuels. Because of the intermittent supply of power for some of these resources, it is necessary to have spinning reserves to back up the renewable capacity and so they do not form base load (excepting hydropower, waste to energy and solid fuel biomass). Renewable energy options are also typically not least cost with regards to infrastructure, though requiring no recurring fuel costs and rated capacity is not achieved. For these reasons there has been some hesitance from the utility and Regulator to encourage renewable energy generation for supply to the grid network. However in the Jamaica National Energy Policy, the government has insisted on adding electricity generation for the public grid from renewable sources and has set a target for 15% of the total generating capacity for the grid from renewable energy resources by 2015. To support investments, a premium of up to 15% above the utility's avoided costs will be allowed for purchases of electricity generated from renewable sources. Proposals for renewable energy addition may be done at any time with or without an RfP.

Projects for power supply to the grid from renewable energy sources will be classified in three categories:

1. **Large additions**: plants of sizes greater than 15 MW. These will be added on the basis of a competitive process consistent with Condition 18 of the License. Category is the preferred option for satisfying the total capacity reserved under the LCEP for renewables.
2. **Medium additions:** plants greater than 100 KW but less than 15 MW. Failing the complete uptake of the reserved portion for renewables under the large additions, medium to small additions are a second priority. Small and medium additions are not subject to a competitive tender process however technically sound and lowest evaluated economic costs apply. Distributed generation sets would apply under this category.
3. **Small additions:** plants of 100 KW and less will be subject to a Standard Offer Contract issued by JPS under the Net Billing Policy. Distributed generation sets would also apply under this category.

The OUR may also invoke its right to invite capacity additions of up to 25 MW from Renewable Sources under a simpler procurement methodology from time to time (All Island Electricity License - Condition 18. 4).

Under the License the restrictions placed on renewable energy generation on the grid is that *"the capacity from Renewable Sources shall not exceed twenty percent (20%) of net energy to the System and provided further that in the exercise of its functions herein the Office shall take account of system stability and the overall price to be paid by customers of the Licensee for a Supply of electricity"* (Condition 18. 4).

[52] OUR Regulatory Policy for the Addition of Generating Capacity. Document Ele 2005/08.19.

Since the last LCEP, renewable generation additions to the grid have been successful via small additions of commercial systems from JPS of 3 MW wind power at Munroe, Manchester, 18 MW wind from Wigton Wind Farm Ltd, Wigton in Manchester, 6.3 MW hydropower (construction in progress) from JPS and over 6 kW from small additions under 10 standard offer contracts[53].

1.5.5 Addition of Cogeneration Technologies:

Cogeneration (or sometimes referred to as "combined heat and power –CHP")[54] is the third main category for adding generation to the national grid. The objective is to increase overall plant efficiencies by simultaneously harnessing heat recapture for process heat. Steam generating stations using fossil fuels with cogeneration are expected to achieve maximum efficiencies of about 45% and combined cycle plants[55] burning natural gas may realize thermal efficiencies in excess of 60%. It is recognized that the integration of power generation and process heat requirements may place limits on the siting and power generating capacity of cogeneration plants. For these reasons except for the sugar industry, Jamaica Broilers (poultry producer) and other agro-processers, other cogeneration plants may not easily comply with the conditions for competitive bids. This option is still considered for generation addition for its potentially higher fuel efficiencies. Proposals for cogeneration plants may be done at any time with or without an RfP.

Conditions for the avoided costs will apply with the possibility of still lower cost from heat supply contracts. Proposals will also be assessed against the latest LCEP and for proposals outside of the competitive process the conversion efficiency for electricity production must average at least 65% of the heat value of the fuel.

Cogeneration plants burning biomass will qualify to be classified as renewable energy, provided that the biomass medium is produced in Jamaica. In such instances the Office may approve the purchase of electricity to be transacted at prices higher than the utility's avoided cost by application of the premium provided for electricity generated from renewable energy resources.

The cogeneration plants on the grid to date are;

1. JAMALCO (bauxite) – 50 MW capacity with supply of 5 – 6 MW on the grid.
2. Jamaica broilers Group - 5 MW installed with only "as available" supply to the grid.

JPS has also installed a 120 MW of combined cycle generating plant at Bogue, St James since 1972, which is fully on the grid. The configuration is 2 x 80 MW natural gas combustion turbines (currently using automotive diesel) and 1 x 40 MW steam generating plant.

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[53] March 2013 Report - Renewable Energy Sub-Committee of the National Energy Council.

[54] See operating definition below.

[55] Combined cycle plants reuse waste exhaust heat from a primary generator (usually gas turbines) for a secondary generation cycle (usually steam generators) while cogeneration reuses waste lower thermal steam (or exhaust gases) from a primary generator for either a secondary generation (usually steam) and the availability of useful process heat.

Installed cogeneration systems off-grid includes:

1. Windalco Ewarton and Kirkvine (bauxite) – 50 MW.
2. Alpart (bauxite) - 150 MW.
3. Sugar companies – 18 MW.
4. Petrojam Refinery Ltd – 1.4 MW.

Currently there are 2 proposals for coal burning cogeneration plants, both from cement manufacturing companies.

- Caribbean Cement Company Limited, has a proposal to build a US$70 million coal fired 40 MW cogeneration (heat and electricity) plant in east Kingston where its current cement manufacturing facility is the only importer of coal used for cement production.

- Cemcorp (Canada-based firm trading locally as Cement Jamaica Limited) has proposed a coal fired 30 MW plant and a 9 MW cogeneration plant which would use exhausted gas from the cement plant operations. This will be a new production plant in St Catherine (south central Jamaica).

1.5.6 Excess (Dumped) Energy Policy

Independent generators (from conventional or renewable sources) that provide energy to satisfy a part or their full energy needs may from time to time be allowed to sell to the national grid. The Regulator will allow for this type of transaction through a standardized PPA from JPS. The rate formula and pricing structure applicable must be approved by the Office before it becomes effective.

The Jamaica Broilers Group Ltd (agro processors) have benefited from this arrangement by dumping excess power when available to the JPS grid from their 5 MW cogeneration system. In the past generation has ranged from 2,000 MWh – 5,600 MWh per month.

Table 19: Summary of Options for the Addition of Generation to the Grid.

Procedure for Generation Capacity Additions

PLANT/ENERGY TYPE	GENERATION SIZE/ CAPACITY	CAPACITY AUTHORIZATION	PROCEDURE	LICENCE TYPE	CONTRACT TYPE	INTERCONNECTION AGREEMENT	PREMIUM APPLICATION	POWER PURCHASE TARIFF
Conventional Technology	Greater than 15 MW	LCEP	Competitive	Schedule 10	PPA	Yes	No	Avoided cost
	Less than 15 MW	LCEP	Competitive/ Non-competitive	Schedule 10	PPA	Yes	No	Avoided cost
Co-Generation	All sizes	N/A	Unsolicited/ Non-competitive	Schedule 10	PPA	Yes	Only if renewable energy source	Avoided cost discounted for shared benefits
Renewable Energy	Greater than 15 MW	Annual cap in LCEP	Competitive packages	Schedule 10	PPA	Yes	Yes	Avoided cost plus premium
	Less than 15 MW/Greater than 100 KW	Annual cap in LCEP	Competitive Packages/Non-competitive	Schedule 10	PPA	Yes	Yes	Avoided cost plus premium
	Less than 100 KW	N/A	Unsolicited/ Non-competitive	Schedule 11	Standard Offer	Standard Terms & Conditions	Yes	Avoided cost plus premium (Based on net billing)
Excess (Dump) Energy	All sizes	N/A	Unsolicited/ Non-competitive	Schedule 10	PPA	Yes	Only if renewable energy source	Avoided cost

Notes
1. All new generation supply are subject to grant of Licence from the Minister having responsibility for electricity matters
2. LCEP – Least Cost Expansion Plan
3. PPA – Power Purchase Agreement (If JPS is the owner of the facilities, a "virtual" PPA will be executed with the OUR)
4. Competitive – Public tendering for generation capacity addition
5. Non-competitive – Sole source or direct negotiations for power purchase
6. Unsolicited – May be submitted for consideration at any time
7. Renewable Energy – Energy source which is continually regenerated
8. Co-generation – Generator process heat used for dual purpose
9. Excess (Dump) Energy – Energy exported in excess of power producers' need

Source: OUR Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generation Capacity to the Public Electricity Supply System. June 2006.

1.6 Generation Sector Stakeholders:

The Ministry of Science, Technology, Energy and Mining (MSTEM) has the overall portfolio responsibility for the energy sector and as such has the role of formulating and promulgating the implementation of Jamaica's Energy Policy and sub-policies.

The OUR is a multi-sector regulatory agency which was established in 1995 by the Office of Utilities Regulation Act (the OUR Act) from which it derives its mandate to regulate the provision of certain utility services in Jamaica. Section 4 (1) of the OUR Act sets out the functions of the Office. Section 4(3) provides for the Office, in the performance of its functions under the OUR Act to "undertake such measures as it considers necessary or desirable to –

(a) encourage competition in the provision of prescribed utility services;
(a) protect the interests of consumers in relation to the supply of a prescribed utility service;
(b) encourage the development and use of indigenous resources;
(c) promote and encourage the development of modern and efficient utility services; and
(d) Enquire into the nature and extent of the prescribed utility services provided by a licensee or specified organization."

With respect to the electricity sector, the OUR has responsibility for, *inter alia*:

(a) Direct regulation of the electricity sector including the establishment of tariffs and service standards;
(b) Overseeing the preparation of generation expansion plans;
(c) Overseeing the procurement of additional generating capacity.

The electricity utility is comprised of a vertically integrated company, **the Jamaica Public Service Company Limited (JPS),** which owns the transmission and distribution grid and accounts for 68% or 634 MW of the total generating capacity on the national grid. The remaining 32% of the generating capacity is provided by three main **independent power producers (IPPs).** JPS is also the sole License holder for transmission and generation where it has exclusivity and may grant access to other generators under the legislative framework.

The various **independent power producers (IPP)** of commercial scale fossil fuel generation on the grid include:

- Jamaica Private Power Company Limited – 61 MW (slow speed diesel)
- Jamaica Energy Partners – 124 MW (medium speed diesel)
- Jamalco – 11 MW (Oil fired steam)
- West Kingston Power Plant – 65.5 MW (medium speed diesel)
- Jamaica Broilers supplying approximately 2 MW on an as available basis

There are a number of self-generators, mainly in the bauxite-alumina and the sugar sectors that operate independently of the national grid and are net consumers of electricity.

Commercial grade renewable energy Generation on the grid includes:

- Wigton Wind Farm expansion, 18 MW.
- Maggotty Hydro - JPS, 6.37 MW (due December 2013).
- Munro, Wind Farm – JPS, 3 MW.

2 DISTRIBUTED GENERATION & IMPLEMENTATION TRENDS.

2.1 History and Definition:

Electricity generation, distribution, and transmission options are seeing a return to the application of short distance transmittal of electricity after almost 100 years of centralized systems. The electrical grid has evolved from an insular system that serviced a particular geographic area to a wider, expansive network that incorporated multiple areas. At one point, all energy was produced near the generator or load or service center requiring that energy. The earliest generation and distribution of electricity developed over distribution grid lines which were DC based with limited supply voltage and the balancing of demand and supply was partially done using local power storage (batteries), which could be directly coupled to the DC grid. Interestingly modern distributed generation also included local commercial scale power storage[56].

As early as the 1880's and 1890's many small-scale companies emerged supplying electricity to the nearest load centers. These small generators engaged in competition as the concepts of centralized versus self-contained production systems became dominant. Emergent in the USA, the Thomas Edison's electric utility model, with a central generating unit connected to a larger grid, and George Westinghouse's addition of alternating current into the grid system, soon became the dominant model adopted in States such as Chicago and others. By the 19th century there was a clear pattern of acquisitions, centralization to distribute power with overlapping networks in cities to take advantage of economies of scale for centralized power generation, distribution, and system management. Technological evolutions such as the emergence of AC grids were critical in this shift, allowing electricity to be transported over longer distances.

Jamaica followed a similar trend towards centralization. Jamaica received electricity in 1892 generated by multiple small generators and emerging utilities such as West India Electric Company by 1897 and Jamaica Light and Power Company, to supply nearby loads. In 1923 Jamaica's first utility Jamaica Electric Light Company Ltd (which later became registered as the Jamaica Public Service Company - JPS) having acquired many of these small generators entered centralization using a coal-burning steam plant, was supplying 3,928 customers. By 1945 other electricity companies were acquired by the JPS, namely the County Electric Lighting Company, Northern Electric Lighting Company and St James Utility thus cementing the central grid model for the island. In the USA at this time there were over 4,000 individual electric utilities, each operating in isolation with low-voltage distribution lines to supply nearby customers.

Post World-War II, as the demand for electricity grew the trend for electric utilities interconnecting via transmission systems was established where the benefits of building

[56] Katholieke Universiteit Leuven, 2003

larger generators, sharing peak load coverage, reliability of supply (in the event of failures) and backup power at the lowest possible cost due to economies of scale became dominant. Interconnection also reduced the amount of extra capacity that each utility had to hold to assure reliable service. A trend developed for higher voltage interconnections to transport the additional power longer distances. As such the institutional arrangement of electric utilities changed to the systems we know now.

Electricity generated and delivered worldwide is now firmly based on conventional centralized, grid-dependent network structure dependent primarily on fossil fuels in most nations. This convention for transmitting and distributing power has several disadvantages such as high emissions, transmission losses, long lead times for plant construction, and large and long term financing requirements. Currently a trend towards decentralization has developed driven on the consumer end by demands for quality better service, lower electricity costs, reliability and grid independence stimulated by incidences of electricity shortages, power quality problems, rolling blackouts and electricity price spikes. On the utility side, utilities are also facing economic challenges of retiring old generation units and adding new generation to match the rate of electricity demand growth. In this regard, distributed generation sources located close to consumption provides an alternative to or an enhancement of the traditional electric power grid and the trend towards smaller scale affordable technologies to facilitate this option.

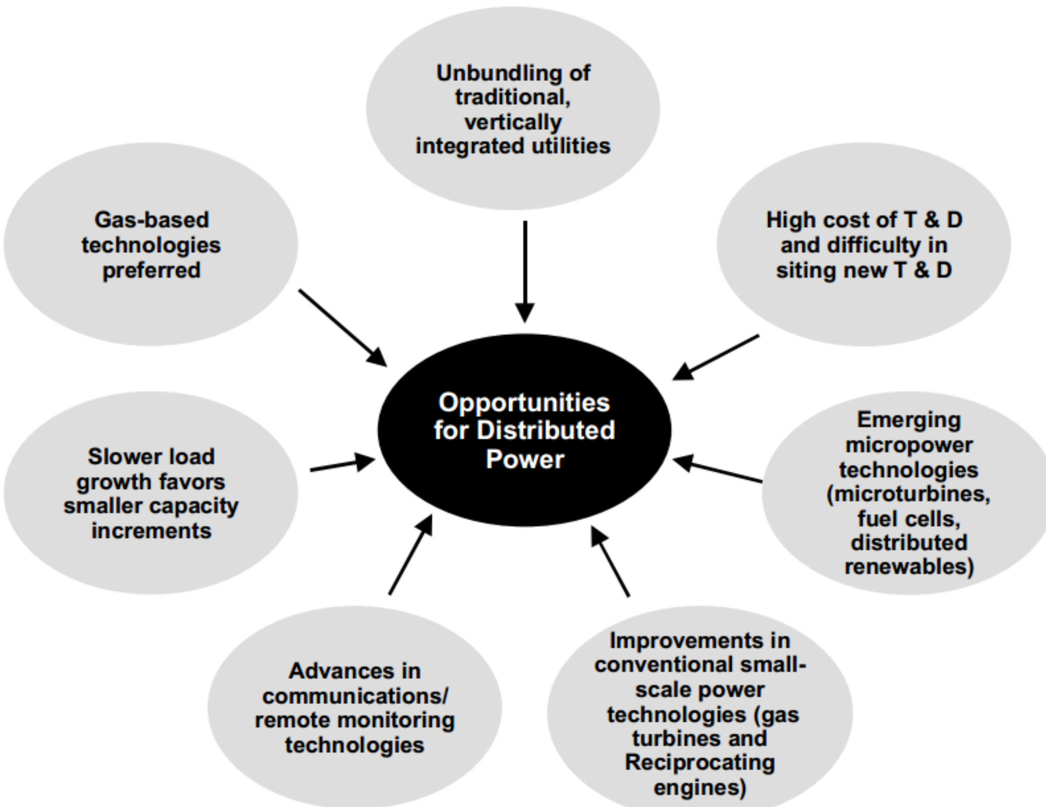
In the last decade, technological innovations and a changing economic and regulatory environment has therefore resulted in a renewed interest for distributed generation. This is confirmed by the IEA (2002), who lists 5 major factors that contribute to this evolution[57]:

- Electricity market liberalization allowing independent generation.
- Increased customer demand for high reliability for electricity supplies, lower costs and price volatility.
- Developments in distributed generation technologies and associated power electronics for smarter grids.
- Constraints on the construction of new generation, transmission, and distribution lines.
- Environmental concerns about climate change.

Therefore these key drivers and other reasons have resulted in the trend towards the rapid growth in applications for distributed generation (see figure below).

[57] Katholieke Universiteit Leuven, 2003

Figure 13: Key Drivers Affecting Distributed Generation Opportunities.



Source: Arthur D Little Report, 2000.

It is important at this point to clarify the general term "distributed generation" in the Jamaican context for the analysis. Generally distributed generation, also called *on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, distributed energy resources (DER)or small-scale power*, has been defined by different sources based on varying criteria.

For the purpose of this analysis, distributed generation in Jamaica will be defined as privately owned (residential, commercial or industrial) generation units and located at the point of consumption, which are **neither centrally planned nor dispatched by the control of the utility**. For this also analysis distributed generation plants with a **maximum capacity of 10 MW** is assigned as a generation cap and such systems should be capable of connecting to the primary distribution network at 24 kV, 13.8 kV and 12 kV or on the consumer side of the meter only for the purpose of supplying power to other nearby facilities of the generator or to use the grid as a backup or storage option. The rationale for a cap is based on the generation environment where the Office of Utilities Regulation (OUR) regulates small grid-tied generation systems < 100 kW under a Net Billing Policy. For small capacity renewable energy and cogeneration technologies above 100 kW and up to 15 MW the protocol which applies for dispatchable grid connection is the Least Cost Expansion Plan framework, allowing for a non-competitive and unsolicited application for a negotiated Power Purchasers Agreement (PPA) with a negotiated tariff[58]. This cap has been raised to 25 MW for renewable energy gen sets which would likely be centrally dispatched. A cap of 10 MW is reasonable also based on the following:

1. The load demand based on the scale of commercial or small industrial operations in Jamaica could be adequately met on a stand-alone basis by 10 MW.
2. Generation systems larger than 10 MW may have as primary objective of obtaining revenue from electricity sales vs. only meeting own demand. Large industries such as the bauxite companies which have fixed heat and power generation are also net consumers of power from the grid (e.g. Jamalco has installed an 11 MW oil-fired steam plant which supplies power to the grid as available).
3. The smallest privately owned IPP gen sets ranges 12 – 17 MW (e.g. Jamaica Energy Partners' 2 barges utilize medium speed diesel [MSD] generators using heavy fuel oil [HFO] in the configurations 8 x 12.06 MW and 3 x 17.08 MW).
4. Jamaica Broilers Group Ltd a large agro-processing and livestock company has installed 4 MSD units totaling 5 MW MSD to meet the heat and power demands from its broiler processing facility with "as-available" exports to the grid.
5. The largest hydro plant owned by JPS has a capacity of 6 MW. The estimated potential of the largest hydropower potential at Back Rio Grande is currently 28 MW (which would require a formal public bid process and grid connection). The potential capacity which follows is 8.0 MW for Great River. All other resources are estimated at >5 MW. One of the smallest hydropower plants has an installed capacity of 0.4 MW (Rams Horn).
6. The largest privately owned wind turbine for self-generation was a single Munroe Wind turbine with installed capacity of 225 kW which supplied Munroe College with power but also supplied power to the grid based on availability.
7. The modular self-contained components for most distributed generation technologies are <1 MW or below 5 MW (e.g. micro turbines up to 1 MW, fuel cells up to 5 MW, single horizontal wind turbines of 3 MW, and small reciprocating engines in the lower diesel power range of 1 – 1.5 MW).

Within this definition of distributed generation are included systems which are independent off-grid systems.

Distributed generation will be treated as not specific to any particular energy source or technology and may be firm, dispatchable or intermittent power.

Distributed generation should also be considered distinct from the primary revenue earning objectives of independent power producers (IPP) in that distributed generation

[58] OUR Generation Expansion Plan 2010

would be connected to circuits from which consumer loads are supplied directly, with or without the opportunity to spill back to the grid and are subject to different tariffs. Generators within this limit are able to supply their own power for economic, strategic or other reasons and have the opportunity to also sell the excess to the grid (example the Jamaica Broilers Group Limited [agro processing] which occasionally sells power from its 5 MW system to the Grid over the distribution lines) or Jamalco (bauxite company) which sells power to the grid from its 11 MW generation systems when surplus is available.

Distributed generation systems supply active power however the supply of reactive power and/or other ancillary services may be possible.

Though diverse, this definition of distributed generation has support from the International Council on Large Electricity Systems (CIGRE) and Institute of Electrical and Electronics Engineers (IEEE).

2.2 Grid Liberalization:

Up until 2001, the utility had the exclusive right under the All Island Electricity License 2001 to add generation. Under Condition 2(4) of the "Jamaica Public Service Company Ltd Amended and Restated All-Island Electric License 2011", (*All-Island Electric License*) - "*In the first three years from the effective date of this Licence [March 30, 2001], the Licensee shall have the exclusive right to develop new generation capacity. Upon the expiry of this period the Licensee shall have the right together with other outside person(s) to compete for the right to develop new generation capacity………..Provided that no firm or corporation or the Government of Jamaica or other entity or person shall be prevented from providing a service for its or his own exclusive use*"[59].

In this context there was little interest in providing on-site power except for back-up purposes. Some customers are now completely self-sufficient having installed onsite backup power. The removal of the constraint on generation generated interest not only for small scale self-generation but also to use the grid for banking of power and revenue under the Net Billing Policy or sale of excess power through negotiated unsolicited proposals to the Office of utilities Regulation which emerged under the Utilities Regulation Act of 1995 as part of the liberalization process. The utilities regulatory process then was new to Jamaica and was needed to protect the interests of consumer's vis-à-vis the utility service providers and to foster an environment which promoted competition, efficiency, and profitability, which are conducive to increased private sector investment in niche spaces suitable for as distributed generation sets.

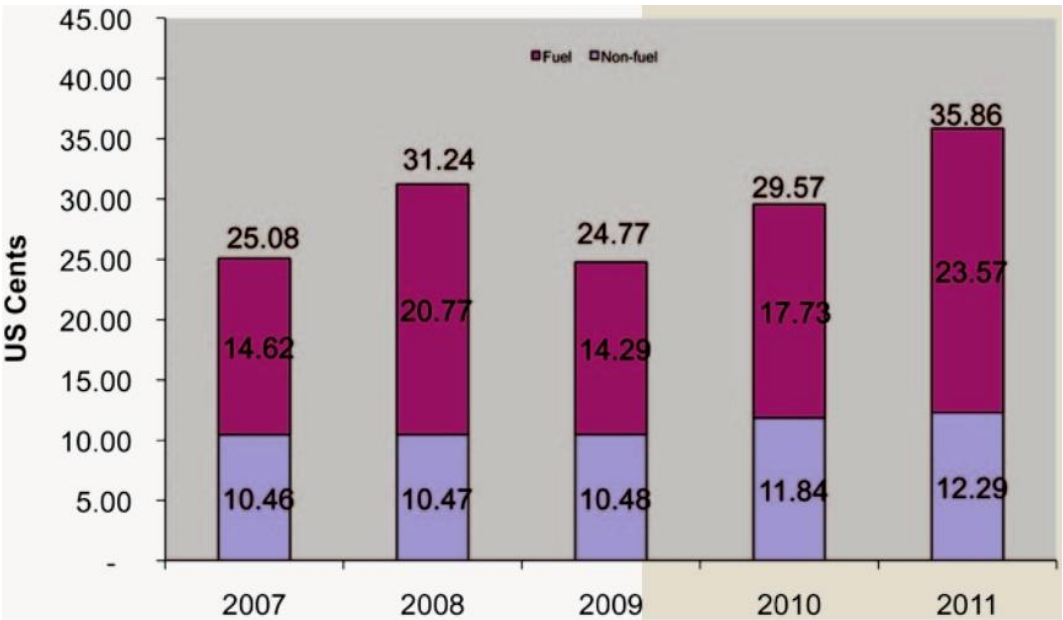
2.3 Increased Reliability and Reduced Price Volatility:

Perhaps the most significant driver for a growing distributed generation trend in Jamaica is the rising price of electricity. Electricity prices in Jamaica have traditionally been

[59] Electricity Wheeling Methodologies Consultation Document No: ELE2012004_CON001. Office of Utilities Regulation. December 31, 2012.

among the highest in the Latin American and Caribbean Nations which depend on fossil fuel generation (oil). Since 95% of electricity is generated from oil the price volatility of oil has a direct impact on electricity prices. In addition the JPS generation units are old and inefficient and some will be retired by 2015. The impact on consumers is reflected in the figure below and today electricity rates are in excess of US$ 0.38 ¢/kWh for residential and US$ 0.42 ¢/kWh for some commercial customers. At generation rates of US$ 0.26 ¢/kWh or less using solar photovoltaic, it is attractive to consider self-generation using distributed generation technologies.

Figure 14: Jamaica Public Service Company Revenue (US cents/kWh)



Source: JPS Annual Report 2011.

The grid is fairly stable with availability factor of 82% and forced outage rate of 8% per annum (JPS 2011). Only in the past was this a consideration for distributed generation, however if 292 MW of JPS generation units are not replaced by 2015, the availability factor and outages could increase significantly. Similarly power quality for 60 Hz 120 V, 220V, 440V and other voltages has been reliable and suitable for residential, commercial, and industrial users. Some users such as computer server providers may desire the application of distributed generation to meet their quality preferences.

The utilization of distributed generation also assists inadvertently in some peak shaving as generators consume their more of their own power during the warmer daylight hours for cooling needs and indoor illumination.

2.4 Developments in Distributed Generation Technologies:

In the environment of liberalization, privatization and high prices, the availability of emerging micro scale (<1 MW) generators which are approaching price parity with conventional generation systems is a major incentive. Such technologies will be discussed further in the document. In addition the inclusion of integrated or balance of system for power electronics management has facilitated easier integration into existing electrical supply.

In Jamaica the most prolific distributed generation option is solar photovoltaic (PV). Supporting PV development are the convenience of its scalable modular features; low maintenance requirements; ease of integration into the existing electrical wiring; new low interest financing; recent Net Billing Policy and broader Energy Policy; rapid growth in practitioner/installer market and current price of electricity. Small wind turbines have not been successful due to inappropriate wind regimes onsite.

2.5 Addition of New Generation, Transmission, and Distribution:

The addition of new generation is somewhat limited by the utilities ability to obtain new financing, and has been challenges due to pressures from existing loans, compensating for system losses, and legal demands. The entry into the market of IPPs who must provide their own financing has mitigated the pressures for new generation financing and has sustained the continued supply of adequate power. New generation addition is due for 2015 and will be determined primarily from the recent bids for 360 MW of conventional generation and request for proposals (RfP) for 115 MW renewable, both of which are to be determined by 2013. Distributed generation will therefore be critical to fill this need for Jamaica.

Whereas in 2011 JPS invested over US$ 23 M to improving the reliability of the transmission and distribution network, the focus was primarily on structural integrity and system security through replacement and electronics upgrades. Jamaica currently enjoys 98% electrification and the extension of grids to the remaining areas is the mandate of the Rural Electricification Programme (REP). The Rural Electrification Programme (REP) incorporated in 1975 continues to expand electricity supply to rural areas, where the provision of such services would not be economically viable for commercial providers of electricity. It does so by constructing electrical distribution pole lines and providing house wiring assistance to householders through a Revolving Fund loan programme. Under the Urban Electrification Regularization Programme, REP also minimized unauthorized connection in urban communities. Over 80,000 households have received the services of REP.

Although in other jurisdictions, according to the IEA (2002), on-site production could result in cost savings in transmission and distribution of about 30% of electricity costs and is seen as one of the biggest potential drivers for the distributed generation demand, the transmission and distribution (T&D) asset owner (JPS) in Jamaica does not benefit from distributed generation in this regard. Residents however will have an option for avoiding the infrastructural cost which would be levied for new distribution lines. This was already done in two rural communities of Ballemony and Middle Bonnet where PV systems were installed for basic electrical demand (TV, lights and a small refrigerator) and has been proposed by the Government to use a similar offer in reaching the remaining 5% of Jamaicans who are more than three kilometers from the grid and without electricity.

Well chosen distributed generation locations (i.e. close to the load) could however contribute to reduced grid losses and provide critical g*rid support as an* ancillary services of voltage support and power factor corrections with smaller systems. Whereas quality of supply is generally good, there are areas of the grid which could benefit from such grid support such as in the eastern end of the island or around the 3 main power islands; South-Eastern (Corporate Area Power Island - CAPI); South-Central (Old Harbour Power Island – OHPI); and North-Western (Bogue Power Island – BPI). There is no specific strategy to do maximize distributed generation in this way at this time.

2.6 Environmental Concerns:

The Government of Jamaica (GoJ's) National Energy Policy and its Policy for Trading Carbon Credits aim to stimulate Clean Technology and Renewable Energy development in Jamaica. Jamaica is also committed to the Kyoto protocol and its accompanying Clean Development Mechanism (CDM).

Table 20: Jamaica Genset Emissions Baseline 2008 - 2010.

	2008	2009	2010	
	HFO	HFO	HFO	
JPS	518,804,700	517,494,050	500,475,333	FC -Ltrs
EF CO2 Coef	2.969031303	2.967263685	2.965895884	Kg CO2/ltr
ton Co2	1,540,347	1,535,541	1,484,358	
	HFO	HFO	HFO	
IPPs	252,854,045	271,427,520	271,251,854	FC -Ltrs
EF CO2 Coef	3.013432202	3.011075377	3.012990298	Kg CO2/ltr
ton Co2	761,959	817,289	817,279	
	ADO	ADO	ADO	
JPS	279,879,790	280,922,026	267,606,023	FC -Ltrs
EF CO2 Coef	2.651629272	2.653470639	2.655291772	Kg CO2/ltr
ton Co2	742,137	745,418	710,572	
	2008	2009	2010	
total Ton Co2	3,044,443	3,098,248	3,012,209	
Total MWh FF Power	3,911,244	4,014,117	3,933,065	EG
tCO2e/MWh	0.7784	0.7718	0.7659	
		EF Grid OM	0.7720	Simple OM
		EF Grid BM	0.6134	Build Marin
	Other	50-50	0.6927	Combined Margin
	Wind/solar	75-25	0.7324	Combined Margin

Source: Ministry of Energy and Mining -
GOJ Grid Emission Baseline Publication for CDM Projects.

Except for combined heat and power applications, some distributed generation technologies do not present a significant energy efficiency improvement.

2.7 Markets for Distributed Generation Systems:

There are currently many micro generator systems both renewable energy and fossil fuel fired systems which are suitable for various markets as shown below. At this time however on the basis of power only, most are suitable enough to be applied in a distributed generation configuration based on their scalable modular characteristic and entry capacity/size in kilowatts. Although some are experimental in their stages of development, others at proof of concept, others are technically ready for central grid dispatch, commercial and industrial applications however are not commercial due to relatively high investment cost at this time.

Table 21: Micro Power Technologies and Markets

● Primary Target Market
○ Secondary Target Market

	Residential	Commercial	Industrial	Grid-distributed	Portable Power	Transportation	Typical Unit Size Range (installation size can be larger)
Microturbines		●	●	●	○	○	25 - 300 kW
Reciprocating Engines		●	●	●	●	●	5 kW - 50 MW
Low-Temperature Fuel Cells	●	●	○	●	○	●	2 - 250 kW
High-Temperature Fuel Cells		●	●	●	○		100 kW - 3 MW
Fuel Cell/Gas Turbine Hybrids		○	○	●			250 kW - 20 MW
Small Gas Turbines			●	●			500 kW - 5 MW
Photovoltaics	●	○	○	●			1 - 500 kW
Wind Power	○			●			50 kW - 2 MW
Biomass Power			●	●			250 kW - 50 MW

Source: Arthur D. Little Report 2000.

An analysis of the specific technologies will provide additional relevance in the Jamaican market.

It should be considered that not all micro generators for distributed generation are ready for full deployment as commercially competitive options. Some technologies will require more operational time to prove the technology, capital cost reductions are needed, fuel supply issues (natural gas), acceptance by potential customers and the necessary legislation and policies.

Table 22: Status of Various Micro-generation Technologies.

DISTRIBUTED GENERATION TECHNOLOGIES	COMMERCIALLY AVAILABLE	EMERGING

MICROTRUBINES	✓	✓
COMBUSTION TURBINES	✓	
RECIPROCATING ENGINES	✓	
STIRLING ENGINES		✓
FUEL CELLS	✓	✓
ENERGY STORAGE/ UPS SYSTEMS	✓	✓
PHOTOVOLTAIC SYSTEMS	✓	
WIND SYSTEMS	✓	
HYBRID SYSTEMS		✓
COMBINED HEAT AND POWER (CHP)	✓	✓

Source: California Energy Commission 2013.

2.8 Commercial Distributed Generation Systems:

As in the definition, the technologies related to DG are diverse, however there are technologies which have gone beyond proof of concept and are being applied domestically, commercially and industrially. Some of these technologies will be applicable as appropriate distributed generation options for Jamaica however others have more limited applications at this time. Below are some of the proven or emerging options for small to commercial grid scale generation applications.

Table 23: Mature and Emerging Distributed Generation Technology Options

Distributed generation technology (adapted from Rastler et al, 1996)

	Types	Size	Efficiency	Markets
Fuel cells	PEM (80°C)	1–500 kW	40%	L&MT, residential, PP, RP
	PAFC (200°C)	50 kW–1.2 MW	40%	MT, commercial cogeneration, PP
	MCFC (650°C)	1–20 MW	55%	HT, PP
	SOFC (1000°C)	1 kW–25 MW	45–65%	Residential, commercial cogeneration, PP, RP
Engines	Diesel	50 kW–6 MW	33–36%	SP for commercial and small industrial, T&D support,
	Internal combustion—natural gas	5 kW–2 MW	33–35%	PP and commercial cogeneration
	Stirling cycle	1–25 kW	20%	Residential, RP
Combustion turbines	Microturbines	25–500 kW	26–30%	SP, RP, commercial cogeneration
	"Small" turbines	1–100 MW	33–45%	Industrial cogeneration, T&D support
Renewables	Solar (PV)	1–1000 kW	10–20%	RP, peak shaving, power quality, green power
	Wind			RP, peak shaving, green power
	Biomass			

"Small" turbines include cascaded humidified air turbines, advanced turbine systems, and intercooled aero-derivative cycle.

Efficiencies = electric only (no heat recovery, heat value basis unknown); PV efficiency is estimated as sunlight irradiance to AC power.

L&MT—Light and medium duty transportation applications (e.g., automobiles, trucks, buses)

MT—Medium duty transportation applications (e.g., trucks, buses)

HT—Heavy duty transportation applications (e.g., rail, marine—ships, naval vessels)

PP—Premium Power

RP—Remote Power

SP—Standby Power

Source: Energy Center of Wisconsin, 2000.

While these DG options vary in their capacity, they are mostly scalable modular systems, some have heat recovery options to raise their overall efficiency levels (except for renewable sources) and can be suitable grid interactive or complete stand alone systems as an alternative to other traditional power applications. These are strengths and weaknesses of the various distributed generation systems which will now be examined in details.

2.8.1 Solar Power:

Solar power technologies are now very mature, with some having already entered commercial phases with the support of special incentives. Some of these applications by means of active exploitation, concentrating the sun's energy to produce steam in an enclosed system to produce electrical energy or mechanical force to electricity. These include:

1. Parabolic Trough Concentrators (medium grade commercial for process heat and power generation; Temp generated at 100 - 350ºC).
2. Parabolic Reflectors with or without or Stirling Engines (small to medium grade commercial for power).
3. Parabolic Reflectors with Receiving Power Tower (large scale commercial power generation using curved mirrors reflecting light to heat a central receiver with water or molten salt).

Table 24: Comparison of Parabolic Reflectors for Power Generation

	Parabolic Trough	Dish/Engine	Power Tower
Size	30-320 MW	5-25 kW	10-200 MW
Op.Temp (ºC/ºF)	390/734	750/1382	565/1049
Capacity Factor/yr	23-50 %	25 %	20-77 %
Peak Efficiency	20%(d)	29.4%(d)	23%(p)
Net Efficiency/yr	11(d)-16%	12-25%(p)	7(d)-20%
Commercial Status	Com. Scale Proto.	Demo.	Available Demo
Tech Devt. Risk	Low	High	Medium
Storage Available	Limited	Battery	Yes
Hybrid Designs	Yes	Yes	Yes
Cost USD/W	2,7-4,0	1,3-12,6	2,5-4,4

(p) = predicted; (d) = demonstrated;

Except of the Stirling engine the other applications are not suited for distributed generation.

Table 25: Applications for Parabolic Reflectors for Power Generation

	Parabolic Trough	Parabolic Dish	Power Tower
Applic ations	Grid-connected electric plants; process heat for industrial use.	Stand-alone small power systems; grid support	Grid-connected electric plants; process heat for industrial use.
Advan tages	Dispatchable peaking electricity; commercially available with 4,500 GWh operating experience; hybrid (solar/fossil) operation.	Dispatchable electricity, high conversion efficiencies; modularity; hybrid (solar/fossil) operation.	Dispatchable base load electricity; high conversion efficiencies; energy storage; hybrid (solar/fossil) operation.

The technology most suited for distributed generation and small to large-scale power generation is the modular photovoltaic (PV) arrangement based on crystalline silicon cells arranged in flat plates, achieving 12% efficiency, and increasing with technology improvements. Current technology includes thin film and rigid panels with the latter being dominant.

Figure 15: Operation of a Solar PV Cell

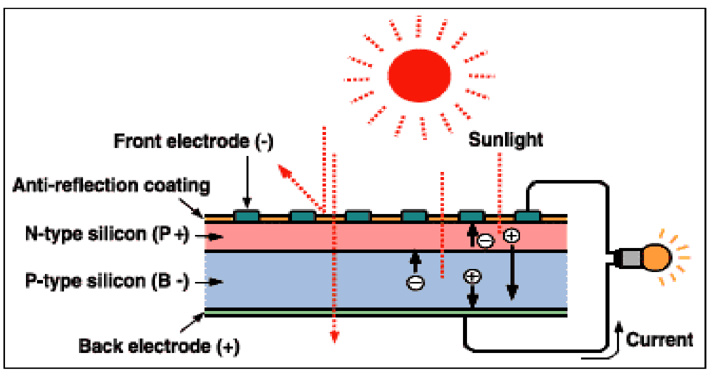


Figure 16: PV Solar Panels.

The crystalline silicon technology is differentiated into monocrystalline cells and multi-crystalline cells. In the former a single ultra pure crystal is grown into a larger ingot and cut into thin wafers. The multi-crystalline silicon PV technology casts a large ingot which is then sliced. Another approach to producing lower cost wafers is to grow Silicon Ribbons/Sheets from molten silicon, which is then cut into wafers. Their technical performance differences are below:

Table 26: Performances of Various PV Systems.

Efficiency/ Losses	mono c-Si	poly c-Si	Single junction a -Si	CdTe
Efficiency	16.10%	12.20%	6.70%	11.30%
PV loss due to irradiance level	-2.70%	-3.10%	-4.90%	-2.20%
PV loss due to temperature	-12.80%	-14.50%	-6.80%	-11.80%
Module quality loss	-0.30%	-1.60%	-1.70%	-2.60%
Module array mismatch loss	-2.10%	-2.10%	-1.10%	-1.10%
Spectral correction for amorphous	0%	0%	0.70%	0.60%
Ohmic wiring loss	-1.10%	-1.10%	-1.10%	-1.10%
Inverter loss during operation	-2.90%	-3.00%	-3.00%	-3.00%
Inverter Loss due to voltage threshold	0.00%	-0.10%	-0.10%	-0.50%
Total Generation Loss	-21.90%	-25.50%	-18.00%	-21.70%

Source: IT Power 2012.

In the Caribbean Region each kW of installed power capacity can produce 1,150 kWh of electricity per year for standalone or grid connected systems. Jamaica is well placed to exploit solar energy resources having superior and steady solar irradiation as much as 5.7 kWh/m^2/d.

Table 27: Variations of Solar Irradiation (Tilt Angle South 30Deg.) for Europe and Caribbean Region (kWh/m2.day)

	Southern Europe	Central Europe	North Europe	Caribbean
January	2,6	1,7	0,8	5,1
Feb	3,9	3,2	1,5	5,6
March	4,6	3,6	2,6	6,0
April	5,9	4,7	3,4	6,2
May	6,3	5,3	4,2	6,1
June	6,9	5,9	5,0	5,9
July	7,5	6,0	4,4	6,0
August	6,6	5,3	4,0	6,1
Sept	5,5	4,4	3,3	5,7
October	4,5	3,3	2,1	5,3
Nov	3,0	2,1	1,2	5,1
Dec	2,7	1,7	0,8	4,8
YEAR	5,0	3,9	2,8	5,7

Table 28: Global Horizontal Irradiance for Norman Manley Weather Station, Jamaica.

Measured Ground Data at Manley, Jamaica

Months	Measured Data (kWh/m^2/day)
January	4.42
February	5.00
March	5.64
April	5.75
May	5.56
June	5.42
July	5.53
August	5.94
September	5.28
October	4.81
November	4.39
December	4.28
Annual Average	5.17

Source: IT Power 2012.

Actual data recorded in Jamaica at ground level has an average annual value of 5.17 kWh/m/day.

The use of photovoltaic solar to electricity technologies in Jamaica is prolific however the preferred application is via the use of flat PV panels for grid tied systems. The inherent modularity of PV systems allows flexibility in the amount of power which can be installed from a few watts (a home with an average demand of 377 kWh per month can have its energy requirements completely supplied by 3 kWp) or scaled up to megawatts. For commercial buildings – a case study was carried out for the Portmore Mall. With two rooftop PV systems of capacity 60 kWp and 100 kWp each designed to meet around 63% and 100% of its electricity demand[60]. Other commercial operations in Jamaica have been estimated to require similar PV power designs e.g.:

- Jamaica Broilers Group Ltd (agro-industry) = 100 kW.
- DIGICEL Ltd (telecommunications) = 80 kW.
- American International School of Kingston (academic) = 100 kW.
- Foote Prints on the Sand (tourism) = 15 kW.
- Coronation Market = 30 kW

A PV system can also be used in a hybrid configuration with other generators for e.g. diesel or wind generators for better economic and reliable solutions. In Jamaica most PV applications have a permanent connection to the electricity grid (on-grid applications) and are installed primarily roofs but may be integrated into the roofs and facades of houses, offices, and public buildings. The current trend for connections in Jamaica include battery-based, grid-tied, hybrid (solar battery-and grid-tied and hybrid (solar and wind).

Figure 17: Simple Grid Tied Schematics.

It is estimated there may be over 400 kW of residential PV and in excess of 500 kW of Commercial PV making up more than 1% of the country's annual energy demand using

[60] IT Power Ltd, 2012

solar energy. Recently the Government of Jamaica implemented a solar street lighting project to illuminate the new central highways. Unfortunately this project has experienced some larceny and so has been suspended, waiting options for securing the systems batteries.

This demand for application of PV systems is rapidly growing due to the implementation of a Net Billing Policy, lower interest financing from commercial banks, building societies, and development banks, high electricity bills (grid based) and the liberalization of the generation market. The regulatory regime allows renewable energy self-generators below 100 KW capacity to interconnect to the utility grid and sell excess power (as available) to JPS at a rate equal to the avoided cost of fuel plus a 15% bonus.[61] Case studies and modeling by the PCJ has shown that net billing increases the return on investment for a solar installation by 3-10%[62] and reduces payback time to less than 7 years. PV generating costs in Jamaica is estimated at US $0.26 – 0.31 per kWh[63] (through it is expected that prices will decline as competition and a worldwide glut of PV panels continue to drive prices down). The price has not deterred interest, as grid electricity price remains between US$ 0.38 – 0.42/kWh and at this time there are over 100 applications or an aggregate capacity of more than 1.1 MW if implemented. The Office of Utilities Regulation has however set an aggregate capacity cap of 2% of peak demand or approximately 12 MW for net billing customers until May 2014, when the results of the net billing programme will be reviewed.[64]

On the centralized commercial side a recent Request for Proposal for 115 MW of renewable energy for central grid connection has received positive interest and a determination is to be made by 5 August 2013 regarding the successful bidder and system sizes. Based on the media release from the Office of Utility Regulation dated 3 June 2013 indicated strong interests in grid connected and dispatched renewable:

- Application from 20 companies.
- 28 different proposals (8 local/20 international).
- Technologies include 1 x biomass (21 MW); 2 x wind (total = 58 MW); 25 x solar (total = 765.5 MW ranging 10 MW – 115 MW). So this renewable energy RfP has been significantly oversubscribed.

This growth in PV is the dominant tend and will continue to grow rapidly over the next decade.

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61 OUR. "Jamaica Public Service Company Limited Standard Offer Contract for the Purchase of As-Available Intermittent Energy from Renewable Energy Facilities up to 100 kW Revised Determination Notice". 2012

62 PCJ. "Feasibility study of solar PV facility for Portmore, Jamaica" 2012

63 OUR. "Request for Proposals for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis." 2012

64 OUR. "Jamaica Public Service Company Limited Standard Offer Contract for the Purchase of As-Available Intermittent Energy from Renewable Energy Facilities up to 100 kW Revised Determination Notice". 2012

2.8.2 Wind Power:

It is estimated that approximately 13% of all measurement stations worldwide have resources belonging to class 3 or greater (i.e., annual mean wind speed ≥ 6.9 m/s at 80 m) and are therefore suitable for wind power generation. Studies done by Stanford University[65] demonstrate that the greater Antilles have class 1 – 2 wind potentials (5.9 ≤ 6.9 m/s at 80 m) while the eastern Caribbean (lesser Antilles) have wind classes as high as class 6 potentials at 80 m (8.6 ≤ V ≤ 9.4 m/s). This type of data has generated an increase in efforts to harness the full potential of the resource for clean renewable power.

Table 29: Classes of Wind Power Density at 10 m and 50 m.

WIND POWER CLASS	WIND POWER DENSITY AT 10 M (W/m^2)	WIND SPEED AT 10 M (m/s)	WIND POWER DENSITY AT 50 M (W/m^2)	WIND SPEED AT 50 M (m/s)
1	0 – 100	0 – 4.4	0 – 200	0 – 5.6
2	100 – 150	4.4 – 5.1	200 – 300	5.6 – 6.4
3	150 – 200	5.1 – 5.6	300 – 400	6.4 – 7.0
4	200 – 250	5.6 – 6.0	400 – 500	7.0 – 7.5
5	250 – 300	6.0 – 6.4	500 – 600	7.5 – 8.0
6	300 – 400	6.4 – 7.0	600 – 800	8.0 – 8.8
7	400 – 1,000	7.0 – 9.4	800 – 2,000	8.8 – 11.9

Table 30: Near-term Wind Potentials for Selected Caribbean Islands.

COUNTRY	NEAR POTENTIAL (MW) (<5 Yrs)
St. Lucia.	12.6
St. Vincent.	7.2
Barbados.	10
Grenada.	10
St. Kitts & Nevis.	3
Aruba.	5 – 8
Jamaica.	**80 MW (existing 38.7 MW)**

[65] Cristina L. Archer and Mark Z. Jacobson - Department of Civil and Environmental Engineering, Stanford University, Stanford, CA, 2012.

Cuba.	≥ 100
Curacao.	6 (existing 12 MW)

(Source: T. Scheutzlich CREDEP/CTZ, 2009)

Jamaica itself has been assessed as having significant cumulative wind potentials of 80 MW in available in different parishes.

Figure 18: Jamaica Wind Map Showing Wind Potentials at 30 m.

Wind Speed	Wind Energy	Rating	Parish
(m/s)	(W/m²)		
1.49 - 9.40	8 - 1010	1	Portland
1.48 - 8.69	6 - 949	2	St. Thomas
2.64 - 8.29	22 - 720	3	Manchester
1.61 - 8.24	8 - 681	4	St. Elizabeth
2.18 - 7.18	23 - 479	5	St. Catherine
2.61 - 6.95	23 - 396	6	Westmoreland
2.09 - 6.67	11 - 355	7	St. James
2.19 - 6.40	12 - 319	8	St. Ann
2.67 - 6.01	19 - 296	9	Clarendon
2.67 - 6.26	31 - 283	10	St. Mary
2.53 - 5.95	23 - 253	11	Hanover
2.30 - 5.52	10 - 216	12	St. Andrew
2.72 - 5.62	23 - 201	13	Trelawny
3.44 - 4.67	52 - 125	14	Kingston

Source: Amarakoon e.t.al, Wigton Wind Farm Ltd, Factor 4 Energy Ltd

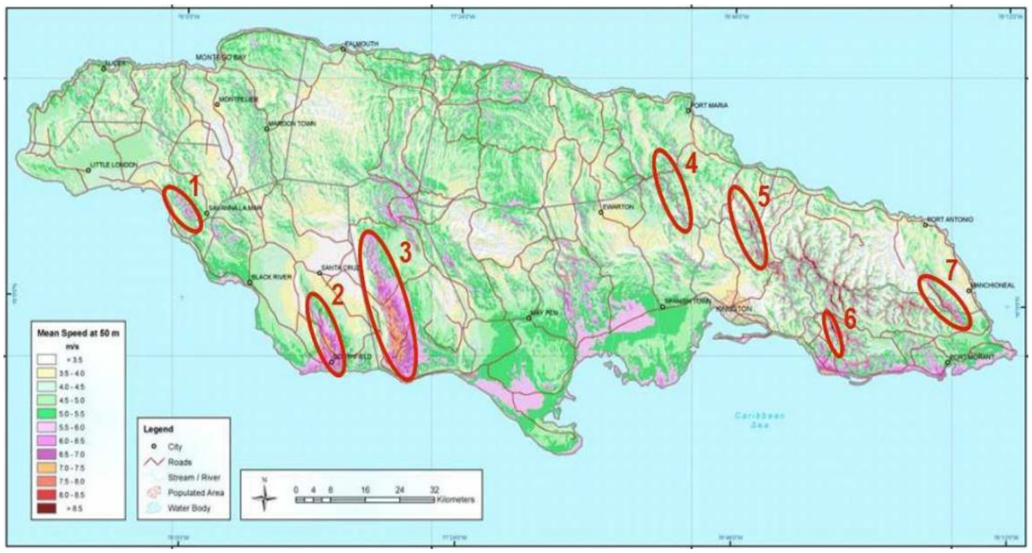
On the basis of recent analysis of wind sites in Jamaica in relation to all the varying factors and analysis of 20 sites with 1 yr continuous data and pre-feasibility of 1 site for wind farm development[66], the following conclusions were made:

- From interim 6 month results the potential for commercial wind farm sites existed at any of the 4 class III sites [commercial]. The commercial feasibility would be dependent on the other varying factors and the size of land available.
- Any residential area close to a class II or class III wind site may begin to look into investing in a wind turbine. The size of turbines will depend on household usage and location[67].

[66] Studies done by Wigton Wind Farm Ltd, Department of Physics UWI Mona, Factor -4 Energy, Meteotest Ltd funded by IDB. 2012.

The figure and accompanying key below identifies areas with significant opportunities for commercial wind farms.

Figure 19: Sites with Significant Potential for Wind



KEY

Area on Map	Location of Parish Area
1	Westmoreland
2	St Elizabeth (JPS Wind farm)
3	Manchester (Wigton Wind Farm)
4	St Ann and St Catherine
5	St Mary and St Andrew
6	St Thomas
7	St Thomas and Portland

Source: AWS Truewind, Wind Resource Maps of Jamaica, December 8, 2006, p. 3, modified

Wind turbines have been used commercially in Jamaica for over 15 years beginning with a single 225 kW Vesta wind turbine at Munroe College, Manchester.

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[67] Studies done by Wigton Wind Farms Ltd, Department of Physics UWI Mona, Factor -4 Energy, Meteotest Ltd funded by. 2012.

Wigton Wind Farm Ltd was Jamaica's first commercial scale wind park with an initial capacity of 20.7 MW (23 NegMicon x 900 kW) and later expanded to 38.7 MW (9 Vesta x 2 MW). In 2010 JPS added 3 MW (4 UNISON U50 x 750 kW) wind power to its generation complement. Power from these wind resources are dispatched from the central T&D control center.

Smaller distributed generation from small wind turbines < 10 kW has also increased at both the residential and commercial levels due to the interest in reducing electricity cost and as part of an environmentally positive image. For example Digicel (telecommunications sector) has installed 3 Sky Stream 3.7 model (3 x 1.8 kW; 208 V Split Phase output or 240 V 60 Hz output) wind turbines on the roof of its new headquarters as part of its energy efficiency and green objectives. Small wind generators like these are designed specifically for grid-connected residential or business use by having the wind generator, controls and inverter built into the nacelle. The Sky Stream is priced to produce energy at a cost (US$0.09 /kWh) with a potential payback of approximately 4 years. The units are also designed for very low winds, and begin producing power in an 8 mph with full output achieved at 20 mph and can be mounted on a 35 ft to 110 towers. Alternative Power Sources has reported installation of 52 kW of small wind systems.

Figure 19: Sky Stream Wind Turbine on Digicel Headquarters.

Skystream 3.7 Wind Turbines installed at
Digicel Caribbean Headquarters, Downtown Kingston

Source: Alternative Power Sources 2013.

The results of using small wind turbines in urban environments has been from unsuccessful to mixed positive results as insufficient site specific wind resource analysis has been done, there are issues of roughness due to ground infrastructure and unpredictable heating and wind patterns throughout the day do not guarantee consistent electricity generation. However with the current interest in reducing electricity cost and a bourgeoning renewable energy installers market, small turbines will continue to be added to the residential and commercial markets for the near future.

2.8.3 Biomass:

Though biomass power generation is a mature technology, factors such as land availability, financing, adequate and consistent fuel supply and environmental impact all impact on the appropriateness of a given generation technology.

Solid biomass power generation for distributed generation has been applied primarily in the Jamaican sugar cane industry (currently six factories remaining) for cogeneration primarily by using bagasse to supplement onsite power demand during the harvesting season. The factories remain permanently connected to the main grid. The use of boilers has produced steam, motive force, and electricity but has to be supplemented with fossil fuel (heavy fuel oil- HFO) using either a topping or bottoming cycle68. In the topping cycle system, fuel is combusted at the sugar factory and produce steam in boilers to generate electricity first. Energy normally lost from the hot exhaust and cooling systems is instead recovered to provide heat for sugar or alcohol production. Some of the high-pressure steam is also used for motive energy to grind cane. Some factories use a bottoming cycle system, also referred to as "waste heat recovery," where fuel is combusted to provide thermal input to a boiler (furnace) and heat rejected from the process is then used for electricity production. These boilers and generation units which are over 40 years will require significant efficiency upgrades, and some supplemental biomass (provided by cane tops, green cane harvesting or local wood) or an alternative fossil fuel to reach their maximum potential for energy production.

Table 31: Projected Annual energy Generation from Sugar Factories.

	Bagasse only			Biomass only			Combined operation		
Location	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**
Golden Grove	0	4,336	13,483	9,867	14,526	24,202	9,867	18,862	37,684
Everglades	0	4,045	8,577	5,481	8,068	13,443	5,481	12,113	22,021
Appleton	5,995	15,682	33,408	31,267	46,030	76,693	37,261	61,712	110,102
Worthy Park	2,782	7,851	17,636	11,425	16,819	28,023	14,207	24,670	45,659
Monymusk	0	10,288	27,556	16,815	24,754	41,244	16,815	35,042	68,800
Frome	0	22,066	50,880	30,974	45,599	75,974	30,974	67,665	126,854
Total, MWh	**8,777**	**64,267**	**151,540**	**105,827**	**155,796**	**259,579**	**114,604**	**220,063**	**411,119**
National, %	**0.2%**	**1.6%**	**3.7%**	**2.6%**	**3.8%**	**6.3%**	**2.8%**	**5.3%**	**9.9%**

Source: Biomass Feedstock and Cogeneration in the Sugar Industry of Jamaica 2012.

This option of bagasse cogeneration is not available to other sectors however there have been proposals to utilize municipal solid waste to power. Jamaica's waste disposal sites received about 850,000 tonnes of solid waste during the year 2010. Based on the historical growth rate of six percent (6%) per annum, the waste stream was projected to

68 USEPA Combined Heat and Power Partnership 2009.

increase to about 1,140,000 million tonnes by 2015. Estimates for Jamaica indicate the potential for a Waste to Energy (WTE) plant ≤5 MW if all solid waste is sorted and delivered to a single site. Otherwise the use of supplemental fuels may increase the potential up to 10 MW. A typical WTE plant can generate about 550 kilowatt-hours (kWh) per ton of waste. At an average price of four cents per kWh, the revenues per ton of solid waste could be $20 to $30 (USEPA 2013). However in the absence of a tipping fee, a feed in tariff for a power plant at Riverton (Kingston, city) would have to be approximately $0.169/kWh to breakeven, and approximately $0.167/kWh for Retirement (Montego Bay City).[69] No energy from waste proposals is under discussion currently.[70] This option would not e for distributed generation. Similarly landfill gas would be restricted to the central dispatch of power and Jamaica's 8 municipal solid waste disposal facilities are currently not suitable for the exploitation of landfill gas as there is no seal and trapping or piping infrastructure in place.

Biogas production from biodigesters on farms may have some future applications by utilizing small internal combustion engines with capacities from 100 kW to 3 MW[71,72,73]. A 100 m^3 biodigester fed by domestic waste and animal manure at the St. John Bosco Boys Home in Hatfield, Manchester, was implemented at a cost of US$ 14,200 and produces over 50 m^3 of gas per day (equivalent of about 300 kWh). The gas generator supplies cookers, stoves, water heaters brooders and some electricity[74]. There is however little interest in multiplying this use of biogas for electricity at this time.

2.8.4 Microgrids:

Micro grids are composed of one or more generation units that can be operated in conjunction with or independently from centralized large-scale transmission system75. The micro grid therefore forms a small independent power system. During disturbances in the central grid, the generation and corresponding loads can automatically separate from the distribution system to isolate the micro-grid's load without harming the transmission grid's integrity. This is intentional "islanding" of generation and loads often built into modern inverter systems and providing higher localized reliability than the central grid. These solutions rely on complex communication, control, responsive electronic components and require extensive site engineering. These systems ensure that no component of the system (e.g. a master controller or central storage unit) is

69 PCJ, "Technical Assistance for a Waste to Energy Financial Assessment", 2012
70 OUR. "Request for Proposals for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis". 2012.
71 USEPA, "Anaerobic Digestion of Food Waste" 2008.
72 USEPA "AgSTAR Handbook: A Manual for Developing Biogas Systems at Commercial Farms in the United States", 2007.
73 USEPA, LMOP Program "An Overview of Landfill Gas Energy in the United States", June 2012.
74 A technical cooperation project between Germany and Jamaica in 1993 -1995, which built on a previous technical cooperation funded by OLADE in the 1980s.
75 Center for Climate and Energy Studies (C2ES) 2012.

critical for the operation of the micro grid (peer-to-peer concept) thus ensuring independence in the event that a generator is lost. In the converse, the addition of any new generation source at any point on the electrical system where it is needed should not require complex re-engineering of the controls for functionality (plug-and-play concept). Micro-grids should island smoothly and automatically reconnect to the centralized power system however while islanding, problems from slight errors in frequency generation at each inverter and the need to change power-operating points to match load changes may occur.

Net efficiencies can be increased within the micro-grid by allowing waste heat to be utilized in a productive manner, such as heating water or space in nearby homes and businesses. Modern gated communities in Jamaica could theoretically benefit from micro-grids as developers are promoting renewable energy technologies, for power, water heating and backup generators within the community. At this time however there is no legislation supporting shared micro-grids and the utility has the exclusive license for distributing and transmitting electricity in the island whether on their infrastructure or other new infrastructure.

A benefit of DG systems applied in micro grids is for powering remote locations which may not be able to readily access the centralized grid and where grid extension into such areas is not commercially feasible. This could be a consideration for the Rural Electrification Programme for the remaining 2% of Jamaican households which do not have electricity from the grid.

Caution has to be applied as challenges can emerge during operation of the micro-grid. Integration of large numbers of DG sources into a micro-grid requires voltage regulation for local reliability and stability. In the absence of controls micro-grids could experience voltage and/or reactive power oscillations. Voltage control must also ensure that there are no large circulating reactive currents between sources as some small generators have narrow voltage set points which could be exceeded by such currents. One solution is a voltage vs. reactive power droop controller which can reduce the voltage set point when the reactive power generated by the micro source becomes more capacitive, the local voltage set point is reduced. Conversely, as Q (reactive power) becomes more inductive, the voltage set point is increased. In the instance when central grid power is lost there can be an apparent reduction in local frequency as the micro grid receives power from the DG sources. This frequency reduction coupled with a power increase allows for each micro source to increase its proportional share of power within the micro grid. Power vs. frequency droop functions at each micro source can effectively solve these problems without a communication network[76].

The current All Island Electricity License provides the utility with the exclusive right to distribute and transmit electricity until 2027 and as such the sharing of power with third parties in a micro grid will not be feasible (perhaps with the exception of the Rural Electrification Programme). Since the outcome of islanding is a safety hazard to utility

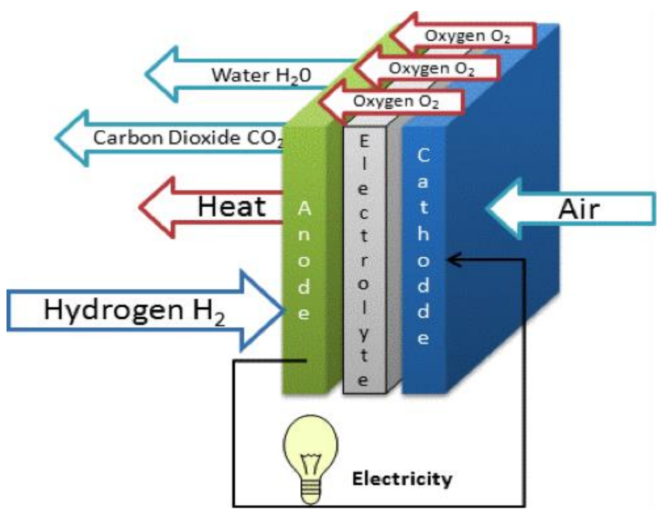
[76] Micro grid: A Conceptual Solution 2012. Robert H. Lasseter and Paolo Piagi University of Wisconsin-Madison Madison, Wisconsin.

workers distributed generators must detect islanding (as obligatory for approval for electrical wiring of a standby or self-generation plant) and immediately stop producing power (anti-islanding). For this reason micro grid systems would not be allowed in Jamaica at the time as all generation sets are required in law and by license to prevent islanding should there be a loss of power from the grid. The central grid would also require some reconfiguration towards a "smart grid" to accommodate the required interconnections, real-time responses, and voltage and frequency issues hence micro grids will not likely be a part of the Jamaican energy landscape in the near future.

2.8.5 Fuel Cells

Fuel cells are another distributed generation technology. The modern fuel cell is a device which utilizes a catalyst in an electrochemical matrix to combine elemental hydrogen from hydrogen rich fuels with oxygen (air or oxygen) in a reaction which produces electricity, water, and heat. The processes are inherently clean as neither the hydrogen nor the oxygen is "burnt". First, the hydrogen rich fuel (primarily natural gas, but also landfill gas, biogas, methanol) is converted into hydrogen gas using fuel processing equipment which removes sulfur from the fuel, preheats the fuel near the operating temperature of the cell, and reforms it to a hydrogen-rich gas stream. After processing (reformatting) the hydrogen gas is delivered to the fuel cell where it passes across the anode of the fuel cell stack and is electrochemically oxidized to produce electricity, water, and heat. As long as there is fuel, air, and heat, the process is continuous. Electrical efficiencies range from 36–60 %, depending on the type of fuel cell and the configuration of the system. By using conventional heat recovery equipment for combined heat and power, overall efficiency can be as high as 85 percent[77].

Figure 21: General Design for a Single Fuel Cell Unit.

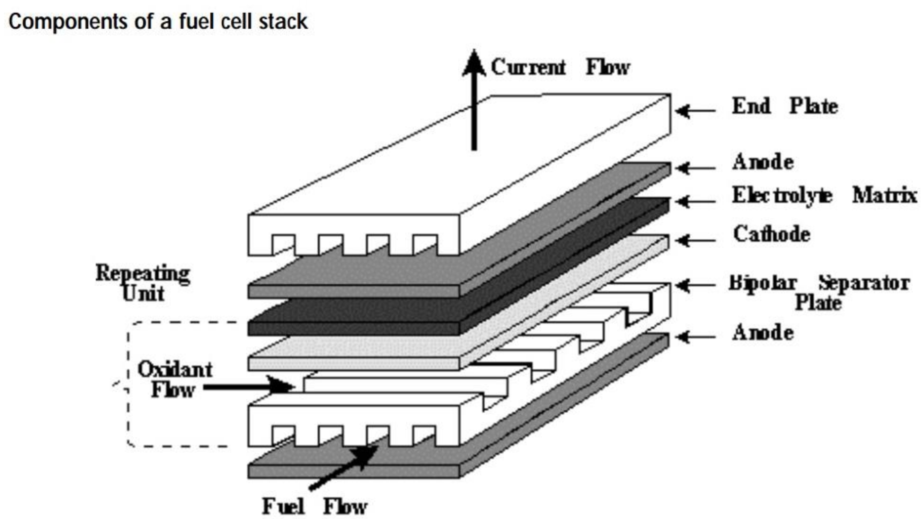


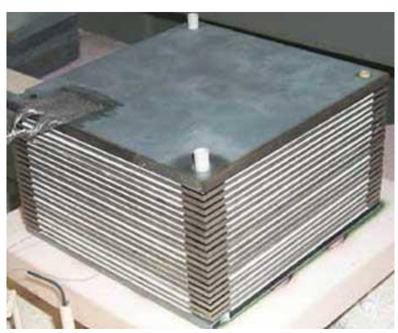
[77] Energy Center of Wisconsin – Report 193-1. Fuel Cells for Distributed Generation A Technology and Marketing Summary March 2000.

Source: U.S. Department of Energy 2011

A single fuel cell will produce approximately 25 W (enough to power a single light bulb) or <1 volt of electrical potential and therefore to generate useful power, fuel cells are stacked and connected in series of repeating fuel cell units, each cell comprised of an anode, cathode, electrolyte, and a bipolar separator plate - a fuel cell "stack. Multiple stacks are aggregated together into a "power module", and then multiple power modules, along with a common fuel input and electrical output are assembled as a complete system. The final power output is therefore a function of the number of cells in a stack to form a module which is ideal for DG systems as demand can be matched with power supply.

Figure 22: General Design for a Fuel Cell Stack.

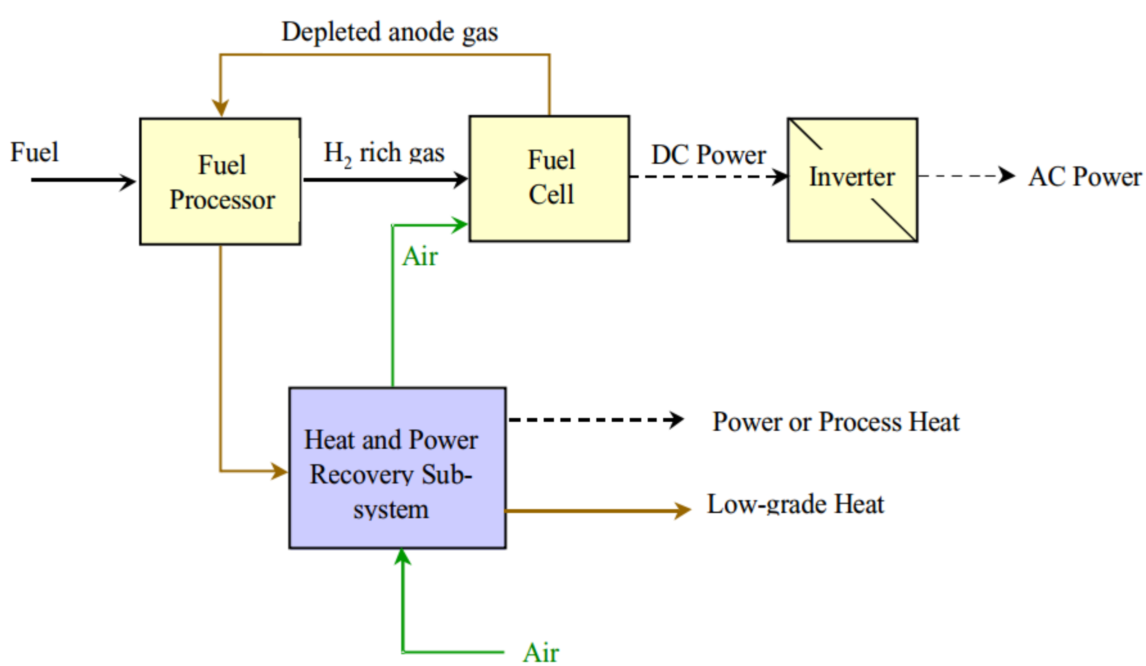




Source: Energy Center of Wisconsin, 2000.

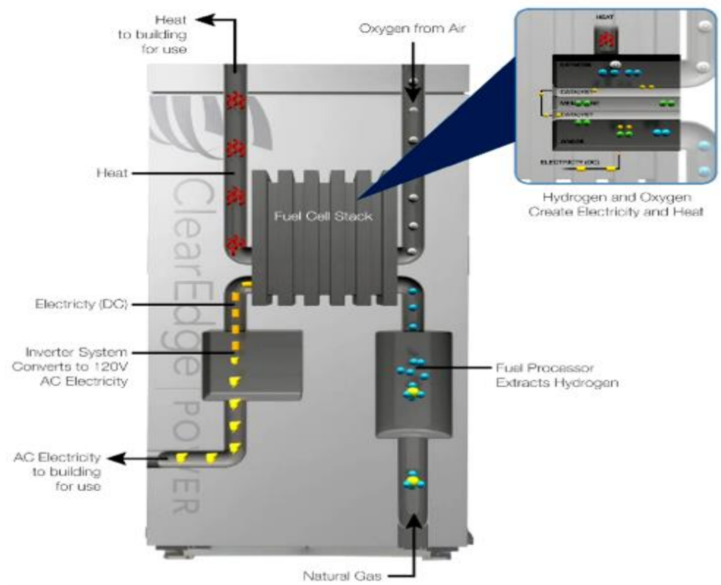
Figure 23: Entire Fuel Cell System - Simplified

Diagram of a generic fuel cell system (adapted from Blomen and Mugerwa, 1993)



Source: Energy Center of Wisconsin, 2000

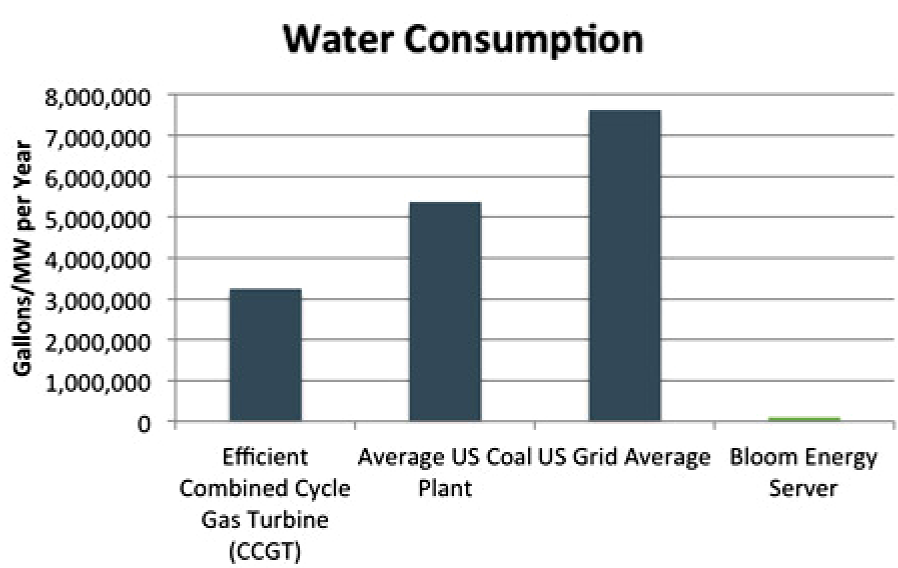
Figure 24: Fuel Cell Module and Complete System Components



Source Clear Edge Power 2011.

Unlike conventional centralized generation systems, fuel cells are net producers of hot water or process steam which is environmentally desirable as other technologies are significant consumers of water. This allows for combined heat and power opportunities.

Figure 25: Water Consumption Comparison for Generation Systems.



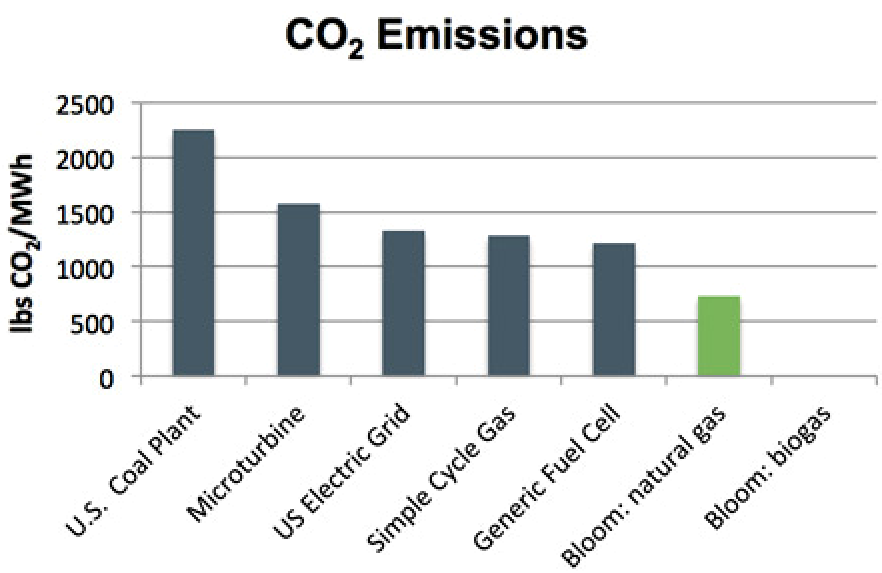
Source: BloomEnergy.com 2013

Generally fuel cells have a number of advantages over conventional power generating equipment:

- High efficiency.
- Low chemical, acoustic, and thermal emissions.
- Siting flexibility.
- Reliability.
- Low maintenance.
- Excellent part-load performance.
- Modularity.
- Fuel flexibility.

Due to higher efficiencies and lower fuel oxidation temperatures, fuel cells are low carbon and nitrogen dioxide emitters per kilowatt of power generated which is suitable for conforming with Jamaica's commitment to the Kyoto protocol. Emissions from some systems average 773 pounds of CO_2/MWh, which is just below the average U.S. natural gas power plant at 800 to 850 pounds of CO_2/MWh[78].

Figure 26: Comparison of Emission Levels of Generation Systems.



Source: BloomEnergy.com 2013

[78] Center for Climate and energy Solutions 2002.

Except for pumps, blowers, and transformers, fuel cells have no moving parts and so operate silently (as low as 55 dB at 90 feet (Appleby, 1993)) and without excessive vibration. In addition these fuel cell modules are not land intensive. These features makes then ideal for localized use in residential strata communities and commercial applications. Except for chemical byproducts of feedstock which may poison the catalyst, the absence of moving parts should increase reliability and reduce maintenance requirements[79].

Figure 27: Bloom Energy Server Outdoor Installation

Source: Bloom Energy 2012

There are at least 6 leading fuel cell technologies namely:

- Phosphoric acid fuel cells (PAFC).
- Proton exchange membrane fuel cells (PEMFC).
- Molten carbonate fuel cells (MCFC).
- Solid oxide fuel cells (SOFC).
- Alkaline fuel cells (AFC).
- Direct methanol fuel cells (DMFC).

For each technology further development is required and of the technologies above, 4 are advanced in their commercial development stages with significant cogeneration potentials. These 4 leading fuel cell technologies are:

- Proton exchange membrane fuel cell (PEMFC) = 175°F (80°C).
- Phosphoric acid fuel cell (PAFC) = 400°C (200°C).
- Molten carbonate fuel cell (MCFC) =1,250°F (650°C).
- Solid oxide fuel cell (SOFC) =1,800°F (1,000°C).

The fuel cell technologies vary significantly in operating temperatures, construction materials, power densities and cooling medium (see table below).

[79] Energy Center of Wisconsin – Report 193-1. Fuel Cells for Distributed Generation A Technology and Marketing Summary March 2000.

Table 32: Comparison of Different Fuel Cell Technologies.

Fuel cell characteristics (adapted from Penner, 1995)

	PEMFC	PAFC	MCFC	SOFC (tubular)
Operating temperature	<210°F	~400°F	~1250°F	~1800°F
Operating pressure	1–5 atm	1–8 atm	1–3 atm	1–15 atm
Construction materials	Graphitic carbon	Graphitic carbon	Ni and stainless steel	Ceramics and metals
Power density (pounds/kW)	8–10 (DOE goals)	~25	~60	~40
Efficiency (LHV)	35-40%	35-40%	50–55%	45-50%
Cooling medium	Water	Boiling water	Excess air	Excess air

LHV = lower heating value basis

Efficiency = (net AC power)/(LHV fuel in)

Source: Energy Center of Wisconsin, 2000.

MCFC and SOFC are considered the more efficient and advanced technologies with significant combined heat and power options. These two technologies are also less sensitive to fuel sourcing and the gaseous by products which could potentially poisonous the catalysts therefore more resilient as a commercial option (see table below).

Table 33: Comparison of Different Fuel Sources and Technological Challenges.

Fuel cell requirements (adapted from Penner, 1995)

	PEMFC	PAFC	MCFC	SOFC (tubular)
H_2	Fuel	Fuel	Fuel	Fuel
CO	Poison*	Poison at ≥ 2% (vol.)	Fuel	Fuel
CH_4	–	–	Fuel	Fuel
NH_3	Poison	Poison	–	Fuel
Cl_2	Poison	Poison	Poison	Poison?
S_2	Poison	Poison	Poison	Poison
Special problems	Moisture control in the membrane	High-voltage operation Cell life	High fuel utilization Cell life	High oxidant utilization

* A poison is a substance that harms fuel cell performance or longevity.

Source: Energy Center of Wisconsin, 2000.

Table 34: Stages of Commercialization of Fuel Cell Technologies.

FUEL CELL TYPE	APPLICATIONS	SCALE/SIZE	BENEFITS	STATUS
Proton Exchange Membrane Fuel Cell (PEMFCs)	• Residential & commercial stationary power. • Portable generators & battery replacements. • Light and medium duty transportation.	2 – 1-kW & 250 – 500 kW.	• Low temperature heat recovery applications. • Rapid on-demand operations.	• Commercialization challenges due to susceptibility to electro catalyst poisoning, fuel sensitivities and balance-of-plant costs for cleaning fuel.
Phosphoric Acid Fuel Cells (PAFCs)	• Commercial stationary power.	50 – 200 kW	• Process heat 200°C (400°F) (low-pressure steam or hot water) & power. • CHP opportunities. • Tolerance to fuel contaminants.	• Commercially available (estimated at 40,000 hrs commercial operation).
Molten Carbonate	• Utility-scale power	250 kW – 3MW	• Process heat (650°C /1,200°F)	• Demonstration plants ready for

Fuel Cell (MCFCs)	generation. • Industrial CHP applications.		(high-pressure steam). • Sufficient heat for internal reforming of hydrocarbon fuels. • Can use variety of H_E bearing fuels.	commercialization.
Solid Oxide Fuel Cells (SOFCs)	• Primarily niche markets (small portable generators and remote locations). • Stationary residential, commercial, industrial and utility.	• 0.5 – 300 kW (planar SOFCs). • 1 – 5 MW (tubular SOFCs).	• Commercial cogeneration. • High tolerance of fuel impurities and poisons; and to wide range of H_2 bearing fuels. • Costly external reformers or catalyst for H_2 production not needed. • High electrical efficiencies.	• Near commercial application ready with 1 – 5 MW plants. • Projected 10 – 20 yr lifetimes (2 – 4 times other fuel cells). • Tubular SOFCs are closer to commercialization than planar geometry SOFCs.

Source: Energy Center of Wisconsin, 2000.

Whereas these technologies are advanced and particularly SOFC, they are not yet ready for wide commercialization in a Jamaican energy market. The durability and reliability of fuel cells, brief life spans of < 10-year life (including cell replacements) and no operational fuel cell systems which have exceeded 10 years, makes other proven technologies such as solar PV and wind more favourable as distributed generation systems. Jamaica has also not yet secured natural gas fuel for power generation, and the solid waste disposal sites are not designed to capture landfill gas, however liquefied petroleum gas could be a substitute.

The high cost for fuel cell energy also militates against this technologies being considered for Jamaica at this time. Small prototype PEMFCs systems (3- 10) may cost US$5,000 per unit for residential use and stationary PEMFC onsite fuel cell systems will have to eventually cost US$1,500/kW to be commercially competitive against the other centralized and DG system options available. Current PAFCs systems range US$3,000/kW or US$4,000/kW installed and significant improvements are still needed. Costs for PAFCs systems would have to be reduced to an installed cost of US$1,500–$2,000/kW for smaller generation sizes and approximately US$1,000/kW for larger systems. Commercialization of MCFCs still requires significant decreases in power density, improvement in operational life, reliability, and durability of the stacks. MCFCs have an estimated installed cost of

US$ 3,000 – 5,000/kW. Finally SOFC systems could become comparable with current commercialized technologies if it can attain costs of US$ 800–1,000/kW[80].

These current costs are significantly higher than the cost for solar PV installed at US$ 2,500/kW with backup diesel generators, however their main advantage in that solar generation is intermittent while fuel cells provides firm continuous power. Interested generators could attempt to offset some of their costs using the Net Billing policy (purchase price at the short-run avoided cost of energy, approximately US$ 0.21 – 0.23/kWh) or via unsolicited bids with a negotiated sale price for the electricity through the Office of Utilities Regulation (OUR).

The most significant competition, both among fuel cell types and with other technologies such as solar, stirling engines and micro-turbines, occurs in the light commercial sector (see table below). Fuel cells are not likely to be considered in the near-term landscape for Jamaica distributed power systems.

Table 35: Competing Distributed Generation Power Technologies.

Markets for fuel cells and competing technologies

Residential (1–15 kW)	Light commercial (25–250 kW)	Commercial w/cogeneration (50 kW–3 MW)	Industrial & distributed (3–50 MW)
PEM	PEM	PAFC	MCFC
SOFC	PAFC	MCFC	SOFC
Solar PVs	SOFC	SOFC	Gas Turbines
Stirling Engines	Solar PVs	IC Engines	Wind Turbines
	IC Engines	Microturbines	
	Microturbines		
	Stirling Engines		

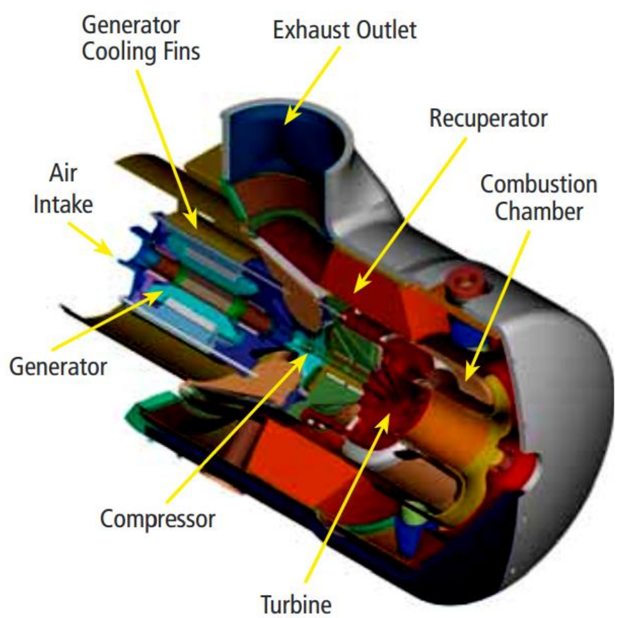
Source: Energy Center of Wisconsin, 2000.

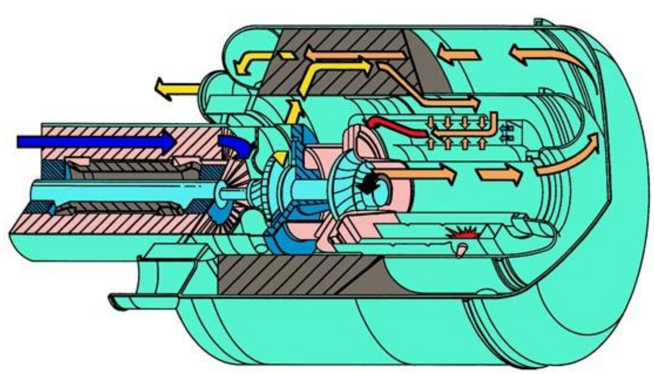
80 Source: Energy Center of Wisconsin, 2000.

2.8.6 Micro Turbines

Micro-turbines are among the more advanced new small generation system for DG applications. Most are single-stage, gearless radial flow devices coupled to a high speed generator with high rotating speeds from 90,000 to 120,000 revolutions per minute while others have multiple stages with lower rotation speeds.

Figure 28: Capstone Micro Turbine Design





Source: Capstone 2013.

Micro turbines are becoming a viable alternative to conventional commercial centralized generation systems, and an excellent DG stationary generation source, however others are still undergoing field tests or are part of large-scale demonstrations.[81] Micro turbines can also be used for improving power quality and reliability, peak shaving, boost power, energy cost saving and cogeneration applications.

Table 36: Overview of Micro turbine Systems.

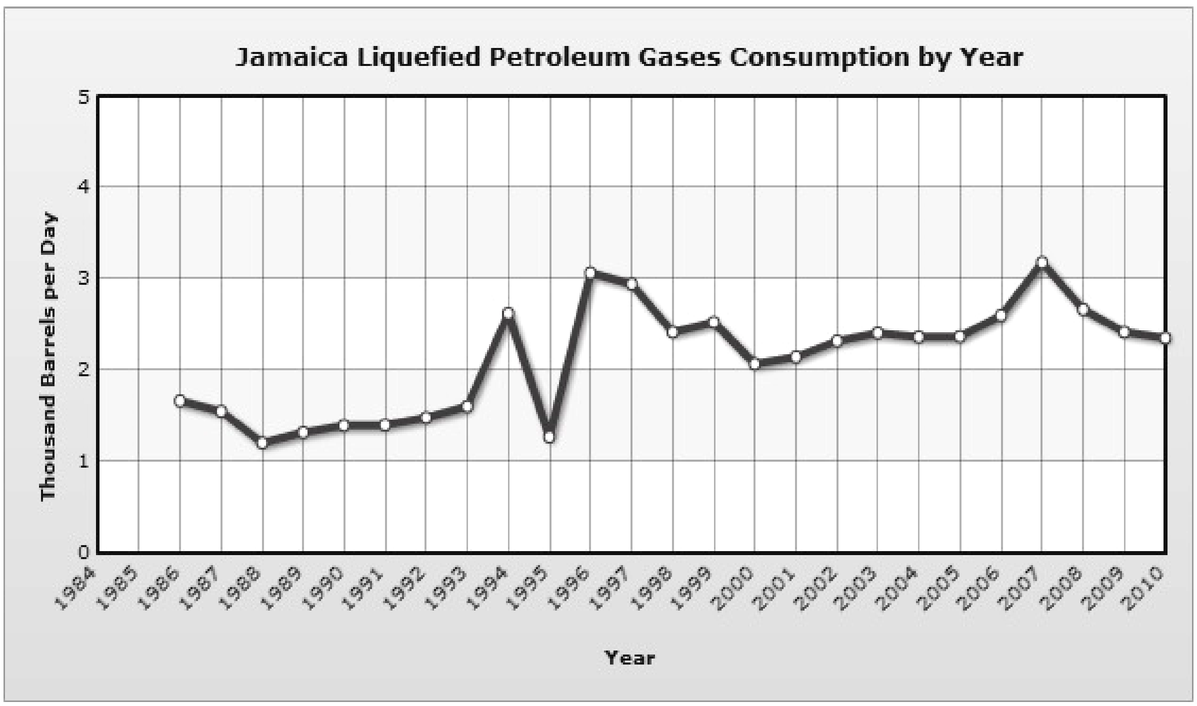
CHARACTERISTICS	STATUS
Commercially Available	Yes (Limited)
Size Range	25 – 500 kW
Fuel	Natural gas, hydrogen, propane, diesel
Efficiency	20 – 30% (Recuperated)
Environmental	Low (< 9 – 50 ppm) NOx
Other Features	Cogen (50 – 80°C water)
Commercial Status	Small volume production, commercial prototypes now.

Source: California Energy Commission 2013.

Systems may be 30 – 500 kW[82] and are fuelled by cleaner low carbon fuels such as natural gas, landfill gas, hydrogen, propane or diesel. Such systems may be technically suitable for small Jamaican firms which have heat and power demands however Jamaica has not yet developed a natural gas pipeline infrastructure which could occur by 2020. Clean replacement fuels could include propane from the established LPG trade, as there are two main sources of bulk gases, Industrial Gas Ltd (IGL) and Petrojam Refinery Ltd which supply bulk Liquefied Petroleum Gas (LPG) to markets. IGL supplies 70% of Jamaica's fast food business and hotels, industrial and commercial users with bulk LPG in steel cylinders (bullets) which would be suitable for constant power generation at a price of approximately US$ 0.51 to US$ 0.58 per litre. Petrojam supplies the retail markets. GasPro (previously Shell) is also a LPG supplier.

[81] California Energy commission, 2013
[82] Center for Climate and Energy Solutions, October 2012

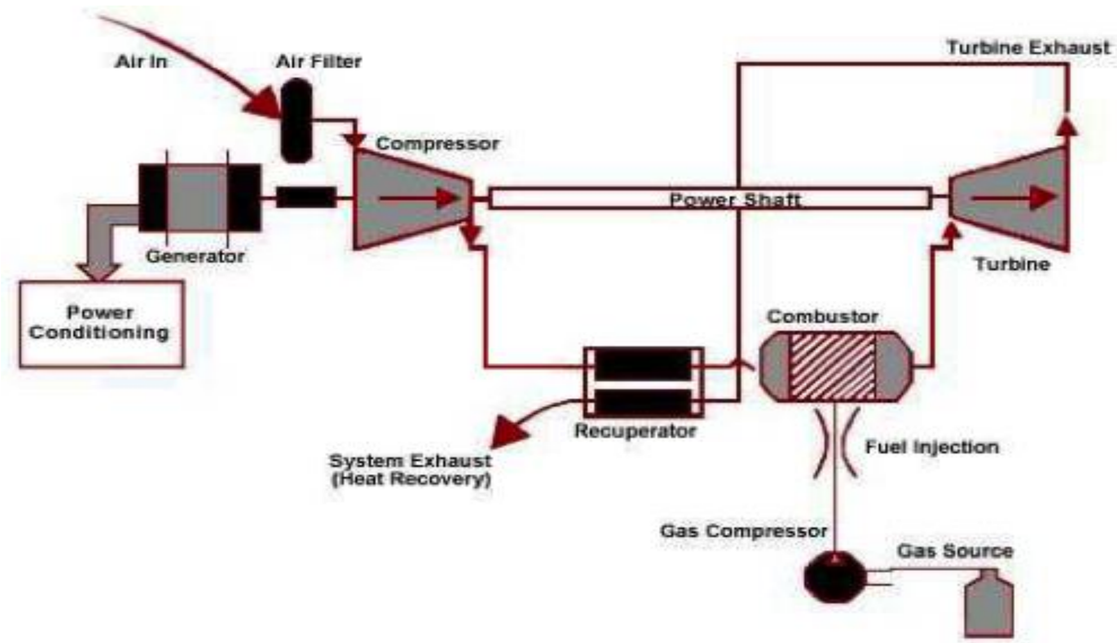
Figure 29: LPG Supplies for Jamaica.



Source: United States Energy Information Administration

Smaller 3 – 5 kW micro for combined heat and power (CHP) systems are being developed for single homes and small businesses for application in 2013. Systems deliver both power and heat in a cogeneration configuration including an exhaust gas recuperator therefore achieving efficiencies reportedly as high as 90%. Residential applications are less significant as small self-generation is more focused on solar power.

Figure 30: Micro turbine Schematic



Source: Electric Power Research Institute 2003

The modular characteristics of micro turbines means they are scalable and by adding multiples of micro-turbines onsite demand loads can be satisfied. Trends for residential developments in Jamaica are that of the gated community with shared facilities such as pools, green spaces, and standby generators. Currently it is not allowed for multiple owners to form cooperatives and supply constant power to such gated residences via wheeling or other mechanism[83] [84] however shared standby (only) generators are allowed.

Exhaust heat can be used for water or space heating, space cooling (in conjunction with absorption chillers) and/or low temperature process heating or drying. The utilization of exhaust heat would not be beneficial for shared residential use under the prevailing policies and legislations due to intermittent use of the micro turbines as a standby; however it would be well utilized in commercial and industrial spaces as constant generation. Existing micro turbines worldwide have been installed in commercial and industrial sectors, agro industry, academia, oilfields, and waste to energy facilities (landfills) and as backup power to small isolated grids. Other benefits include their small compact size, fewer moving parts, and maintenance intervals (maintenance intervals are estimated at 5,000-8,000 hours) than traditional generators and low noise for small commercial and residential use. Suitable competences are present in Jamaica for combustion type systems, which could be transferred to operation of micro turbines.

Figure 31: Micro turbine for Residential and Commercial Installation

Source: Micro Turbine Technology (MTT)

The use of hydrocarbons and relatively low electrical efficiency in micro turbines results in emissions of approximately 1,290 pounds of CO_2/MWh[85]. Other energy challenges include parasitic load loss from running a natural gas compressor and loss of power output and efficiency with higher ambient temperatures and elevation. At 80°F outdoor air temperature, the micro turbines are about 3 % less efficient than at 50°F outdoor air temperature (U.S. Environmental Protection Agency (EPA) data). Jamaica's tropical climate could however potentially further reduce the levels of efficiencies.

83 All Island Electricity License (Restated) 2011

84 Consultation on National Wheeling Policy.

85 Center for Climate and Energy Solutions 2013.

Table 37: Micro Turbine Summary

Company	Electricity Conversion	Usable Heat	Thermal Electric Efficiency	Market
Capstone	25-35 %	Yes	70-90 %	Commercial, Industrial
Flex Energy	30 %	Yes	N/A	Commercial, Industrial
MTT	N/A	Yes	N/A	Residential

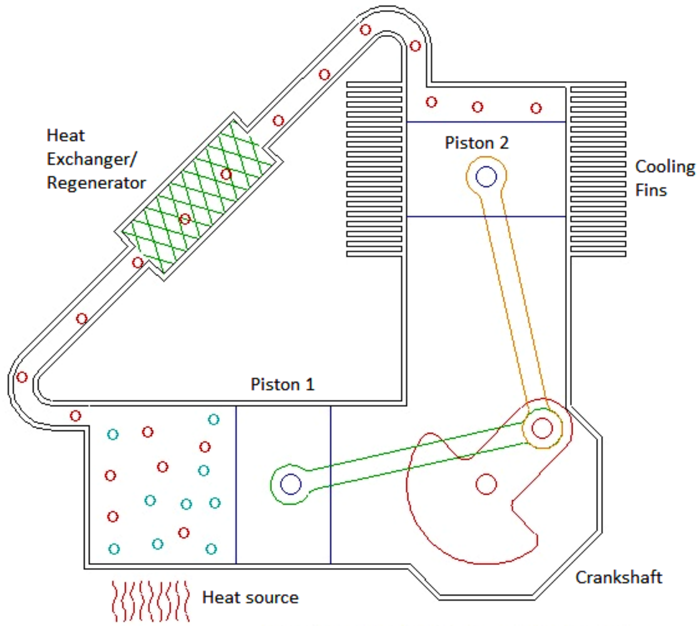
Source: Center for Climate and Energy Solutions 2013.

Micro turbine capital costs may range from US$700/kW for larger units to approximately US$1,100/kW for smaller ones (inclusive of hardware). Heat recovery balance of system will add US$75 - US $350/kW. Though varied, site preparation and installation costs are generally 30-70% additional to the total capital cost. Estimated forecasts range from US$ 0.005 - 0.016 per kWh (comparable to costs for small reciprocating engine systems). At US$ 0.38 – 0.40/kWh in Jamaica, elevated costs for micro turbine generation may be justified. Though there are no know systems in Jamaica there has been small interest in the systems.

2.8.7 Stirling Engines

The Stirling engines are types of external combustion engines which utilize a sealed system with air, helium, or hydrogen as working fluids to drive two (2) pistons (alphas configuration). The engine works by the process of heating one of the cylinders and as the sealed gas expands (expansion) it drives the pistons inward. The flywheel momentum carries the crankshaft to the next 90 degrees and forces the sealed gas into the second cylinder which is cooler (transfer). Some of the heat is removed in the regenerator cooling the gas on the way to the second cylinder. The second cylinder further cools the hot gas which contracts (contraction) and forces both of the pistons outward. The flywheel momentum turns the crankshaft 90 degrees again forcing the sealed gas back over and crankshaft and the gas is transferred back to the hotter piston over the regenerator which preheats the gas in transit (transfer). The cycle is then repeated. This rotational motion is transferred to the external generator via a pulley mechanism or direct coupling to a shaft.

Figure 32: Operations of 2-Piston Stirling engine (Alpha Configuration)



Source: Animated Engines..com 2000 - 2011

They have been patented since 1816 however the Otto cycle engine provided a more favourable engine and as such their use was suspended until recent space and marine industry interests stimulated research and development efforts[86] and are currently being produced in small quantities and sizes (1 – 25 kW) for specialized applications but no significant commercial applications as a stand-alone combustion engine. There are better commercial opportunities if both heat and power outputs are utilized. Stirling engines can cost US$ 1.2/W for up to 40 kW; US$ 6 – 12/W for systems approximating 1 kW; but can be as high as US$ 31/W for smaller systems < 500 W (solar PV in Jamaica is approximately US$ 2.6/W).

Table 38: Stirling Engine Overview

Stirling Engine Overview	
Commercially Available	No
Size Range	<1 kW - 25 kW
Fuel	Natural gas primarily but broad fuel flexibility is possible
Efficiency	12 – 20% (Target: >30%)

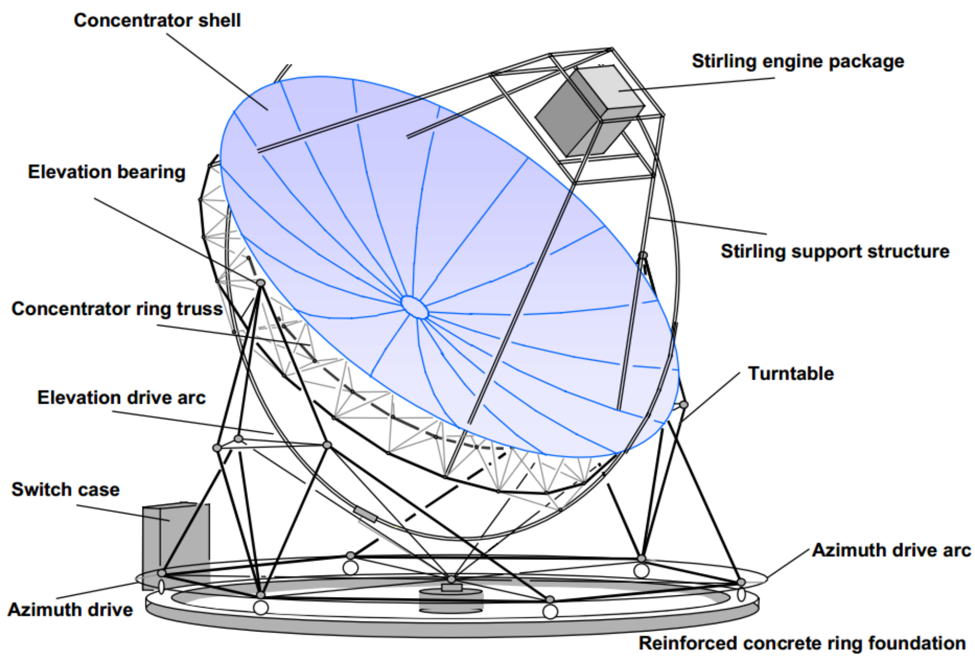
[86] California Energy Commission 2013. http://www.energy.ca.gov.html

Environmental	Potential for very low emissions
Other Features	Cogen (some models)
Commercial Status	Commercial availability 2003-2005

Source: California Energy Commission 2013.

Stirling engines can utilize many different fuels for heat and their best power generation application is with solar parabolic mirrors. In these systems solar energy to electricity conversion is more efficient than non-concentrated photovoltaic cells, and comparable to Concentrated Photo Voltaic. These systems range from 5 – 25 kW and can be assigned in clusters up to megawatt size farms to meet moderate scale grid-connected demands if necessary.

Figure 33: Solar Parabolic Reflectors with Stirling Engines.



Source: Schlaich Bergermann und Partner GbRShop.

The parabolic concentrator focuses solar radiation unto the stiring engine receiver located at the concentrator's focal point. The heat exchanger (receiver) on the engine thus heats the working gas (helium) of the Stirling engine to temperatures of about 650° C and the resultant heat is converted into mechanical energy by the Stirling engine. An electrical generator is directly connected to the crankshaft of the engine and converts the mechanical energy directly into electricity (AC). Tracking of the sun is programmed to maintain the heated focal point for the engine. The electrical output of the system is proportional to the size of the reflector, its optical losses, and the efficiencies of the Stirling engine and the generator[87]. Since the efficiency of the Stirling engine increases with increasing upper process temperature, this engine is effective for producing energy with a solar collector.

The Stirling engine will not have meaningful application in Jamaica at this time as solar PV systems are smaller and occupy less space, are more convenient to mount (e.g. as part of roofing or on roofs) and cost less to install and operated than required by solar dishes. In the future Stirling solar dish systems may be applicable for solar farms due to their modular characteristics and lower land demand than (solar) power towers, however even then flat panel solar PV farms may still be more economical and there may be a higher level of expertise which could mitigate against another mega-scale solar dish farm option.

[87] EuroDish Stirling System - Schlaich Bergermann und Partner GbR, Structural Consulting Engineers.

2.8.8 Reciprocating Engines:

Reciprocating engines, or internal combustion engines, require fuel, air, compression, and a combustion source. This is a proven technology and make up the largest share of the current small power generation market and can be used in a variety of applications due to their small size (5 kW – 5 MW), low unit costs, and useful thermal output for combined heat and power applications. For convenience modern small reciprocating engines are sold as pre-engineered and pre-commissioned standard packages with power electronics. Commercially available engines range in size from 10 kW to more than 7 MW and are suitable for many distributed-power applications where the most promising markets for reciprocating engines are on-site at commercial, industrial, and institutional facilities[88].

Table 39: Reciprocating Engine Sizes

Reciprocating Engine Types by Speed (Available MW Ratings)

Speed Classification	Engine Speed, rpm	Stoic/ Rich Burn, Spark Ignition[6]	Lean Burn, Spark Ignition	Dual Fuel	Diesel
High Speed	1000-3600	0.01 – 1.5 MW	0.15 - 3.0 MW	1.0 - 3.5 MW[7]	0.01 – 3.5 MW
Medium Speed	275-1000	None	1.0 - 6.0 MW	1.0 – 25 MW	0.5 – 35 MW
Low Speed	58-275	None	None	2.0 – 65 MW	2 – 65 MW

Source: SFA Pacific, Inc.

Reciprocating engines are either spark ignition (SI) typically fueled by gasoline or natural gas; or compression ignition (CI), typically fueled by diesel oil or heavy fuel oil. The engines may be two-stroke or four-stroke engines. Fuel Flexibility is being added to generator systems where natural gas-fired engines are to be adapted to handle biogas, renewables, propane and hydrogen, as well as dual fuel capabilities to meet more stringent environmental standards.

Installed cost for reciprocating engines may range between US$ 695 and US$ 1,350/kW which may vary with size and whether combined heat and power applications are incorporated since exhaust temperatures may range 700 - 1,200°F in non-CHP mode and 350 - 500°F in a CHP system after heat recovery for hot water or low pressure steam for CHP applications. Electric efficiencies of natural gas engines range from 30 % LHV[89] for small stoichiometric engines (<100 kW) to over 40 % LHV for large lean burn engines (> 3 MW). Overall CHP system efficiencies of 65 to 80 % are achievable.

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[88] Source: National Renewable Energy Laboratory. Gas-Fired Distributed Energy Resource Technology Characterizations. NREL/TP-620-34783. November 2003.

[89] LHV – lower heating value of the fuel.

Waste heat may be obtained from the exhaust gas, engine jacket cooling water, lube oil cooling water, and turbocharger cooling in the form of hot water or low pressure steam (<30 psig). Direct engine exhaust gas can be used for non-food process drying, and hot water and low pressure steam for space heating (in temperate and cold climates), water heating, and to drive absorption chillers providing cold water, air conditioning or refrigeration. Jamaican commercial operations can benefit significantly from such systems[90].

Reciprocating engine maintenance costs may be generally higher than comparable gas turbines, but an important advantage for distributed generation is that maintenance can often be handled by in-house staff or provided by local service organizations. Operating and maintenance costs range US 0.8 -1.8 ¢/kWh.

A disadvantage of the reciprocating engines is the release of combustion emissions. New diesel engines using low sulfur diesel will achieve rates of approximately 0.65 lb NO /MWh and assorted heavy hydrocarbons and particulate emissions. Diesel engines produce significantly less CO than lean burn gas engines and the NO emissions from diesels burning heavy oil are typically 25 to 30 % higher than diesels using distillate oil however there are emissions control technologies for post-stack emissions reduction.

Table 40: Emissions Characteristics of Reciprocating Engines.

Gas Engine Emissions Characteristics with Available Exhaust Control Options*

Emissions Characteristics	System 1	System 2	System 3	System 4	System 5
Electricity Capacity (kW)	100	300	1000	3000	5000
Electrical Efficiency (HHV)	28.4%	31.1%	35.0%	36.0%	39.0%
Engine Combustion	Rich	Rich	Lean	Lean	Lean
NO_x, (lb/MWh)	0.10	0.50	1.49	1.52	1.24
CO, (lb/MWh)	0.32	1.87	0.87	0.78	0.75
VOC, (lb/MWh)	0.10	0.47	0.38	0.34	0.22
CO_2, (lb/MWh)	1,404	1,284	1,142	1,110	1,024

* *For typical systems commercially available in 2007.*
Source: EEA/ICF

The Ritz Carlton Jamaica, utilizes a 1 MW Caterpillar Engine for prime load service (100% demands – 80 – 85% of operation time) for both electricity demand and hot water. Other sectors such as the bauxite and sugar industries have utilized similar small systems <

[90] Environmental Protection Agency Combined Heat and Power Partnership Program Washington, DC. 2008.

1 MW. Currently other small reciprocating systems are being marketed in Jamaica for systems around 1 – 1.5 MW for application in commercial operations and academic institutions as back-up power. This may become a route for Jamaican businesses to reduce electricity costs for operations which currently is budgeted at as much as 1/3 of operational costs @ US$ 0.38 -0.42/kWh.

Figure 34: Wärtsilä Reciprocating Engine

Source: Wartsila Website 2013.

2.9 Opportunities and Challenges for Distributed Generation Technologies.

The main opportunities for distributed generation technologies in Jamaica are arguably;

1. Favourable changes in policy and legislations.
2. High cost of electricity from the grid and reducing cost of the technologies.
3. Retirement of old generation plant and an urgent need for the addition of new generation.
4. Environmental and energy efficiency expectations/demands.

Conversely, perhaps the challenges are;

1. The need for more rapid further policy and legislative changes.
1. Current higher cost of the technologies than power from the central grid as a deterrent.
2. Inadequate expertise or familiarity with the newer technologies and an inertial for change.

3. Resistance by the utility to accept distributed generation as a generation competitor on the grid.
4. Supporting fuel supply and infrastructure (natural gas or landfill gas).

These opportunities and challenges are experienced worldwide.

Table 41: Key Drivers for Onsite Distributed Generation.

	Favors onsite Generation	Barriers to Onsite Generation
Residential	• High electric rates for grid power imply a large potential for savings with onsite generation • *Green* and *clean* power may become important niches in a deregulated market, and would favor certain micropower technologies, especially fuel cells and photovoltaics	• Low load factors for electricity and heat hurt economics. Thermal and electric load profiles do not match well • Very small unit sizes required for single family homes (<10 kW) limits choice of technology • Non-traditional market for onsite generation requires new approaches to ownership and operation • Permitting, interconnect standards and similar issues need to be addressed to facilitate access to this market
Commercial	• Electric rates for grid power are favorable for onsite generation • Loads and load factors well suited to several micropower technologies, especially high-load factor buildings such as hotels and hospitals • Moderate cogeneration potential	• Non-traditional market for onsite generation requires new approaches to ownership and operation • Permitting, interconnect standards and similar issues need to be addressed to facilitate access to this market • Many buildings types have low load factors (e.g., retail, office)
Industrial	• Best cogeneration potential • Attractive electric loads and load factors • Industrial end-users are most familiar with the concept of onsite generation and cogeneration	• Lowest electric rates makes onsite generation more difficult • Permitting, interconnect standards and similar issues need to be addressed to facilitate access to this market • Micropower technologies are too small for many facilities, even in bundles of several units

Source: Arthur D. Little Report 2000.

2.10 Opportunities:

2.10.1 Policy and Legislation:

The Jamaica's National Energy Policy (JNEP) 2009 – 2030 is built around a vision which states that Jamaica will have a "modern, efficient, diversified, and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework". Also the Policy states **"Energy diversification will involve moving from an almost total dependence on**

petroleum to other sources, including natural gas, coal, petcoke, nuclear, and renewable energy such as solar, wind, and bio-fuels. In the short to medium term, natural gas would be the fuel of choice for generation of electricity and the production of alumina".

This applicable strategic vision is supported by the following goals in particular for the energy sector and provides directions for the addition of new generation capacity to the grid as seen in the following Goals:

Goal 2: Jamaica has a modernized and expanded energy infrastructure that enhances energy generation capacity and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis.

Goal 3: Jamaica realizes its energy resource potential through the **development of renewable energy sources** and enhances its international competitiveness and energy security whilst reducing its carbon footprint.

Goal 4: **Jamaica's energy supply is secure and sufficient** to support long-term economic and social development and environmental sustainability.

Goal 5: Jamaica has well**-defined and established governance, institutional, legal, and regulatory framework for the energy sector that facilitates stakeholder involvement and engagement**.

Under Goal #2 some of the applicable proposed strategies and key actions to 2030 include;

- Implement least economic cost solutions for the supply of energy, including source, conversion, and distribution.
- On a competitive basis, retire the old generation plants and replace them with modern plants to improve the conversion efficiency.
- Establish a system to identify and replace old and inefficient units/plants with more fuel-efficient and cost efficient technologies and plants.
- Establish a combined cycle capacity to replace old and inefficient units/plants with more fuel-efficient and cost efficient technologies and plants.
- Implement appropriate energy distribution and transmission systems.
- Unbundle generation and transmission & distribution creating an energy efficient electricity structure.
- Unbundle existing vertically integrated industry structures and establish and implement common carrier and common access principles, where demonstrated to be technically and economically feasible
- Review and complete rural electrification programme including use of alternative energy sources.

Under Goal #3 some of the applicable proposed strategies and key actions to 2030 are:

- Develop diversification priorities based on cost, efficiency, environmental considerations and appropriate technologies and competitiveness.
- Prioritize renewable energy sources by economic feasibility criteria, environmental considerations including carbon abatement. Promote the development of efficient and low cost renewable plants with a size of 15 MW or more on a competitive basis through a level playing field.
- Promote the development of efficient and low cost renewable plants with a size of 15 MW or more on a competitive basis through a level playing field.
- Introduce a strategy that ensures that less than 15 MW of renewable energy plants will be built on no-objection basis using base opportunity cost and negotiable premium cap and 15MW or more to be obtained on a competitive basis through the OUR process .
- Develop an inventory of all potential sources of wind, solar and renewable technologies and rank according to their economics with full economic impact analysis.
- Introduce incentives, where feasible, and a plan of action for implementation to foster the development of wind, solar and renewable technologies. This will require the review by the relevant regulatory authority of existing renewable power generators to afford them such incentives that may be available, to encourage the sustainable development of the sector. The creation of an enabling legislative and regulatory framework will be a priority.
- Encourage research, development, and implementation of qualified renewable energy projects.

Under Goal #4 some of the applicable proposed strategies and key actions to 2030 are:

- Determine the fuel diversification programme for the short, medium, and longer term.
- Develop diversification priorities based on cost, efficiency, environmental considerations, and appropriate technologies.
- Diversify energy sources by type and geographic location.
- Develop a framework for the introduction of natural gas.
- Construct new energy-efficient generating facilities on a phased basis to meet increasing demand.
- Establish an enabling environment for the development of the renewable resources through private sector participation.
- Develop and implement a fast track generation plant retirement and replacement program.
- Develop the institutional capacity and regulatory framework to explore the establishment of small nuclear power generation plants in the event that nuclear power generation proves feasible for Caribbean Small Island Development States (SIDS).

Under Goal #5 some of the applicable proposed strategies and key actions to 2030 are:

- Develop necessary regulatory framework for the introduction of diversification fuels.
- Promote a market-based approach and increased competition in the sector including a transparent procurement process for new capacity and sourcing from private producers (both renewable and non-renewable energy sources).
- Develop regimes for pricing of electricity and petroleum products that will balance requirements for competitiveness with the long-term viability of the sector.
- Conduct studies to include net metering and wheeling in the tariff rates and introduce appropriate mechanisms for net metering and wheeling procedures and standards to encourage the development of renewable energy and cogeneration opportunities.
- Promote a market-based approach and increase competition in the sector by use of transparent procurement processes for new capacity.
- Implement policy regarding the development and export of co-generation and renewables electricity to the national grid by private sector and citizens at large.

These strategies driving the unbundling of supply, fuel diversification, incentivizing generation especially renewable, special focus on net billing and wheeling and legislative and policy frameworks have contributed positively to the desired trends in distributed generation

Jamaica's national developmental plan to 2030 "Vision 2030" supports the objectives of the JNEP and states that "Jamaica will create a **modern, efficient, diversified,** and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security that contributes to international competitiveness throughout all the productive sectors of the Jamaican economy. **By 2030, no less than 20 per cent of our energy supply will come from renewable sources**"[91].

With these two central expressions of the national policy on energy, Jamaica's electricity sector is being transformed through two main areas of focus; fuel diversification and generation plant modernization through a transition from oil to natural gas; and the accelerated addition of indigenous commercial scale renewable energy resources for power.

The legal and regulatory framework governing the Jamaican power sector as guided by this National Energy Policy is contained in and regulated pursuant to the following[92]:

- The Office of Utilities Regulation (OUR) Act 1995 (as amended).
- The OUR Generation Expansion Plan 2010.

[91] Vision 2030 Jamaica, National Development Plan. Panning Institute of Jamaica 2009.

[92] OUR website (http://www.our.org.jm/).

- The Electric Lighting Act
- JPS's Amended and Restated All-Island Electric Licence, 2011 and as may be amended from time to time.
- OUR's Regulatory Policy on Guidelines for the addition of Generating Capacity to the Public Electricity Supply System: June 2006 (Document # Ele 2005/08.1)

The single **most important** opportunity **for distributed generation proliferation is the unbundling and liberalization of the generation market.** Pursuant to Condition 2 of the All Island Electric Licence, 2001 JPS was granted the exclusive right (the Licence) "….to generate, transmit, distribute and supply electricity for public and private purposes in all parts of the Island of Jamaica" and "shall have the exclusive right to transmit, distribute and supply electricity throughout Jamaica for a period of 20 years"[93]. After the third year of the license, generation was no longer exclusive to JPS and as such, the company now has "the right together with other outside person(s) to compete for the right to develop new generation capacity". This has encouraged other generators to produce their own electricity but was however not allowed to distribute that power. The significant benefit to be derived under the current Amended and Restated All-Island Electric Licence 2011 is that under its Clause 12 "Electricity Power Wheeling"[94] is permitted. The Licence of 2011 allows for wheeling, development of charges by the Licensee (JPS), tariffs, a cost of services study to be done by the Licensee by 2012 for approval by the Regulator (OUR) for implementation. This clause allows self-generators to supply their own other facilities and gain the economic benefits of reducing their electricity cost from the grid through self-supply.

At this time the Electricity Wheeling Methodology study and consultations area advanced and a determination is to be made in 2013. The agreed methodology is the **MW-km Load Flow methodology** with some historic pricing factored. The regulator will ensure that non-wheeling clients should be completely isolated from the additional costs of wheelers as they are not involved in this commercial transaction, Wheelers should have a capacity floor/threshold to qualify to avoid unnecessary complexity to the system initially as a natural constraint to the number of wheelers and also to reduce any inequities or discrimination in pricing for smaller wheelers; and allow the utility to benefit from existing generation infrastructure. Estimated cost to the Wheeler is US$ 175/MW-km/month with variables such as gains from relieving congestion, time of use, buy back, and top up rates among others.

Another significant policy, legal and economic instrument for small renewable energy generation (<100 kW), is the Net Billing Policy and accompanying Standard Offer Contract. The Government has set a target of 15% of total generation from renewable

[93] Jamaica Public Service Company Limited All-Island Electricity Licence, 2001.

[94] Restated All Island Electricity License 2011 defines Power Wheeling as - *"the transportation of electric power on the Transmission System and/or Distribution System of the Licensee [JPS] which is generated by self-generator, other than the Licensee, at one location for use by the self-generator at another location"*.

energy sources by 2015. The Regulator (OUR), which is responsible for the addition of generating capacity to the grid, has reserved a block of capacity for renewable sources, one portion of which should be in the category of 100 kW or less. As such the Net Billing Standard Offer Contract Program is intended to support greater use of renewable sources of energy in Jamaica. The program seeks to encourage electricity production by small intermittent sources of renewable energy of 100 kW or less, via a simple contract arrangement with the Utility (Standard offer Contract – SOC). These installations will require supplemental power from the JPS on a day to day basis and will on occasion have excess electricity, which can be sold to the utility as long as the Gross System Output does not exceed 10 kW (AC) output for residential facilities, or 100 kW (AC) for commercial facilities under the following definitions:

- Non residential entity - refers to a Qualified Entity (QE) which is a company Or Other Business Entity whose Qualified Facility (QF) has a nameplate capacity of less than or equal to 100 kW.
- Residential entity - refers to a QE who is an individual whose QF has a nameplate capacity of less than or equal to 10 kW.

The feed in tariff in the form of a Standard Offer Contract (SOC)[95] with the utility on a non-competitive basis will usher in Net Billing under the jurisdiction of the Office of Utilities Regulation (OUR). Self-generation using a distributive generation option is permitted, according to Condition 2: Clause 4 of the License, which states, *"that no firm or corporation or the Government of Jamaica or other entity or person shall be prevented from providing a service for its or his own exclusive use"* however under the Net Billing Policy, the generator can also sell excess power to the utility at wholesale or retail cost, an agreed tariff equivalent to the short-run avoided cost (fuel) as stipulated by the Regulator. This rate is between US$ 0.21 – 0.23 /kWh. The net billing licensee must purchase power from the utility at the normal tariff rate (approximately US$ 0.38 – 0.42/kWh), that is they must remain a client of the utility to benefit from net billing. In both the case of Wheeling and Net Billing, the generator has an inducement to recover capital cost in an accelerated timeline while enjoying lower electricity costs and independence of the central dispatch. Licenses are of 5 years however this first trial is a 1-year programme. Net billing investors must also meet technical equipment specifications stipulated by the utility including.

(a) IEEE Standard 1547 (2003):"Standard for Interconnecting Distributed Resources with Electric Power Systems"

(b) JPS Interconnection Guidelines (mostly for >10 MW but indicative for smaller independent generators).

(c) Electric Utility Sector Generation Code (private sale, service standards and interconnection).

(d) Distribution Code (to be prepared by JPS and approved by the OUR).

[95] http://www.our.org.jm/images/stories/content/PublicNotice/JPS%20SOC-%20FINAL%20DRAFT.pdf

The current pilot programme supports all renewable sources and technologies of an intermittent nature however to date most projects have proposed to generate electricity from solar photovoltaic (PV) though there is consideration for wind also. The contact terms and conditions are for 5 years and may be reviewed every 5 years in keeping with the programme's experience and policy guidelines of the OUR. At the end of the pilot phase which there will be an assessment of the programme which will lead to modifications to similar future programmes arising from this assessment. At this time there are over 100 applicants for Net Billing Licenses but only two (2) QE's which have signed contracts with the utility.

Net metering was not supported by the utility and Regulator which opined that net metering does not consider the capital or maintenance cost for maintaining transmission and distribution systems. As such the net billing policy restricted QFs that sell electricity to JPS under the Net Billing Program to the prevailing short run avoided cost of generation (fuel costs not incurred/or avoided by the Utility), plus a premium of up to 15% at this time. The Regulator therefore approved the mechanisms for a net billing pilot project in 2012. Under Net Billing the domestic and commercial entities which are serviced by JPS are permitted to generate their own electricity and sell excess generation to the utility's power grid (the All Island Electricity Licenses does not allow generators to sell excess generation to other parties) and as such net billing does not encourage competition market forces into the generation and retail aspects of the system.

The impact on the national grid is not significant as the programme allocation is currently 2% of peak (around 12 MW). This amounts to less than 1.5% of total generation capacity. The utility has indicated its willingness to tolerate 5% of the peak demand from intermittent/not-guaranteed power on the grid (solar and wind) to avoid additional expenditure on standby base load capacity for conditions of low or no generation. Nevertheless small initiatives such as net billing can improve energy security, reduce foreign exchange flight, diversify the energy base and when distributed at nodes across the grid can improve grid quality/reliability.

OUR has as one of its mandates to secure new and additional generation capacity for the national grid[96] and has facilitated the addition of private generating capacity to the privatized and liberalized national electricity supply system as part of the Regulatory Policy for the Electricity Sector (2006) which outlines the procedures for the addition of new generating capacity to the electric power grid. Under the Office of Utilities Act of 1995 (amended in 2000), the OUR "*undertakes such measures as it considers necessary or desirable to:*

(a) encourage competition in the provision of prescribed utility services;

(b) protect the interests of consumers in relation to the supply of a prescribed utility service;

[96] Office of Utilities Regulation (OUR) – Annual report and Financial Statements 2011 - 2012.

(c) encourage the development and use of indigenous resources;

(d) promote and encourage the development of modern and efficient utility services; and

(e) enquire into the nature and extent of the prescribed utility services provided by a licensee or specified organization".

Some of these objectives have therefore been achieved under the Net Billing Policy and the current process for implementation of Wheeling. Other initiatives have contributed to the changing landscape of new generation which has shown some favorability for distributed generation in the past decade including the following:

1. Development of a wheeling legislative framework.
2. Government and utility efforts to reduce electricity prices.
3. Development of a net billing policy and regulations.
4. Request for proposals for new 115 MW renewable energy generations.
5. Three separate bids for hydropower feasibility studies.
6. Addition of 6.3 MW of hydropower by the utility.
7. Two LNG supply and infrastructure bid rounds.
8. Addition of 3 MW wind generation by the utility (JPS).
9. Addition of 18 MW of wind generation by Wigton Wind Farm.

New generation may be added in one of three (3) modes;

- New conventional technologies.
- New renewable energy technologies.
- New cogeneration technologies.

In this context distributed generation has been facilitated by policy or legislative changes for implementation either as standalone generation or placing power on the grid for self-consumption or revenue to reduce capital payback timelines. The changes have also supported the opportunities for lower energy costs to the generator-consumer.

2.10.2 Expansion, Retirement and Replacement of Central Generation Plans.

The utility has the responsibility to provide annual demand forecasts which then feeds into A Least Cost Expansion Plan (LCEP) or Generation Expansion Plan. The LCEP is regularly n reevaluated and updated to consider changing electricity demand and supply estimates, economic developments, technological advances, and the relative price of competing fuel sources[97]. The LCEP in 2004 and 2010 are the most recent updates. This is the mandate of the Regulator (OUR) [98] for short-term (5 years) and long-

[97] Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System. June 2006.
[98] Also referred to as the Least Cost Expansion Plan.

term (10 years) planning horizons[99]. This is an urgent matter for Jamaica where existing oil-fired steam plants have aged considerably. Over the years a number of turbines and boilers have been refurbished as an interim measure however with the average age of the steam plants being 37 years replacement is now overdue. At Old Harbour the four steam units are over 35 years old, despite their rehabilitation over the years, their operating parameters at present indicate that all these units have surpassed their useful economic life. The need to replace such plants creates an opportunity for new distributed generation to contribute to part of that new generation supply.

Table 42: Current Mix of Generation Technologies

Technology	Plant Type	No. of Plants	Fuel Type	Total Capacity (MW)	% of Total
Fossil Fuel Plants	Steam (Power only)	5	HFO	292.0	95%
	Steam (CHP)	6	HFO	1.0	
	Diesel	1	HFO	224.4	
	Combined Cycle	1	ADO	114.0	
	Combustion Turbine	8	ADO	165.5	
Total Fossil				**796.9**	
RET	Hydro	7		22.3	5%
	Wind	1		20.7	
Total RET				**43.0**	
TOTAL				**839.9**	**100%**

Source: Office of Utilities Regulation 2010.

The Generation Expansion Plans objective states:

"The generation expansion plan is largely influenced by the need for new and more efficient generating capacity to reliably meet system demand at least economic cost. The plan is also an integral part of an overall strategy to reduce energy cost and Jamaica's dependence on imported liquid based fossil fuels. As such the plan aims to support the implementation of the National Energy Policy 2009 - 2030, focusing on: (1) increasing the contribution of renewable energy (wind, solar, hydro and biomass) in electricity generation; (2) effecting fuel diversification through the development of the natural gas industry".

In this regard the Expansion Plan encourages the use of the renewable energy technologies used in distributed generation, the technologies which are cost in the current high electricity price environment, and technologies which encourage fuel diversity. Distributed generation technologies can achieve all three benefits.

Prior to the OUR Act 1995, and before privatization of the Utility – Jamaica Public Service Co. Ltd (JPS) in 2001, JPS had responsibility for identifying new generation for addition to

[99] Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System. June 2006.

the grid under the All-Island Electric Licence 2001. Ti has been assumed that the utility's power under law was not conducive to allowing new and clean generation to impact the generation market nor encourages small generators. However subsequently the management and administration of the procurement process for new generating plant capacity as well as the preparation of the Least Cost Expansion Plan (LCEP) was transferred to the OUR by means of an agreement in 2007 between the Government of Jamaica (GOJ) and Marubeni Corporation acting through its affiliate Marubeni Caribbean Power Holding Inc. (Marubeni), consequent on the sale of Mirant Corporations' shares (which held 80% of the shares of JPS) to Marubeni, which has influenced the changes seen to date for small self-generation options.

The Generation Expansion Plan 2010 however does not focus on distributed generation but on centralized power and dispatch. As such the technologies and fuel options considered for new generation and expansion of the electricity generation system large plants for;

- **Gas turbines**: open-cycle and combined-cycle variants running on Natural Gas or Automotive Diesel Oil (ADO).
- **Diesel engines**: medium-speed and low-speed units running on Heavy Fuel Oil or Natural Gas.
- **Conventional steam units**: powered by coal with electrostatic precipitators, Flue Gas Desulphurization and Selective Catalytic Recovery Controls.

Table 43: Generation Technology and Fuel Options for System Expansion.

TECHNOLOGY	FUEL			
	Natural Gas	Automotive Diesel Oil	Heavy Fuel Oil	Coal
Combined Cycle	✓	✓		
Combustion Turbine	✓	✓		
Medium Speed Diesel	✓		✓	
Slow Speed Diesel	✓		✓	
Steam				✓

Source: OUR, Generation Expansion Plan 2010.

The main strategies for expansion into to 2029 would include the following strategies;

1. Natural gas fired combined cycle or simple cycle gas turbines from 2014 – 2029 to satisfy growing demands and displace aged plants (1,360 MW) at a cost of approximately US$ 5.77 Billion.
2. Natural gas fired combined cycle and simple cycle gas turbines between 2014 – 2017; followed by pulverized coal plants from 2018 - 2028 to satisfy growing demands and displace aged plants (1,360 MW) at a cost of approximately US$ 5.85 Billion.
3. Business-as-usual (BAU) case marinating the familiar oil burning plants; slow speed diesel plants and oil-fired combustion plants from 2014 - 2029 to satisfy growing demands and displace aged plants (1,280 MW) at a total cost of US$ 8.18 Billion. The BAU case was considered unsustainable, uneconomic, and unresponsive to growing power demand.

Table 44: Optimum Generation Plan under a Natural Gas/Coal Strategy

Year	Plant Type to be added to the System	No. of units x Capacity (MW)
2014	Natural Gas-fired Combined Cycle unit	3 x 120
2016	Coal unit	1 x 120
2017	Natural Gas-fired Simple Cycle Gas Turbine unit	1 x 40
2018	Coal unit	1 x 120
2020	Coal unit	1 x 120
2021	Coal unit	1 x 120
2023	Coal unit	1 x 120
2025	Coal unit	1 x 120
2026	Coal unit	1 x 120
2028	Coal unit	1 x 120

Source: OUR, Generation Expansion Plan 2010.

Table 45: Procedures for Addition of Generation Capacity.

Procedure for Generation Capacity Additions

PLANT/ENERGY TYPE	GENERATION SIZE/ CAPACITY	CAPACITY AUTHORIZATION	PROCEDURE	LICENCE TYPE	CONTRACT TYPE	INTERCONNECTION AGREEMENT	PREMIUM APPLICATION	POWER PURCHASE TARIFF
Conventional Technology	Greater than 15 MW	LCEP	Competitive	Schedule 10	PPA	Yes	No	Avoided cost
	Less than 15 MW	LCEP	Competitive/ Non-competitive	Schedule 10	PPA	Yes	No	Avoided cost
Co-Generation	All sizes	N/A	Unsolicited/ Non-competitive	Schedule 10	PPA	Yes	Only if renewable energy source	Avoided cost discounted for shared benefits
Renewable Energy	Greater than 15 MW	Annual cap in LCEP	Competitive packages	Schedule 10	PPA	Yes	Yes	Avoided cost plus premium
	Less than 15 MW/Greater than 100 KW	Annual cap in LCEP	Competitive Packages/Non-competitive	Schedule 10	PPA	Yes	Yes	Avoided cost plus premium
	Less than 100 KW	N/A	Unsolicited/ Non-competitive	Schedule 11	Standard Offer	Standard Terms & Conditions	Yes	Avoided cost plus premium (Based on net billing)
Excess (Dump) Energy	All sizes	N/A	Unsolicited/ Non-competitive	Schedule 10	PPA	Yes	Only if renewable energy source	Avoided cost

Notes
1. All new generation supply are subject to grant of Licence from the Minister having responsibility for electricity matters
2. LCEP – Least Cost Expansion Plan
3. PPA – Power Purchase Agreement (If JPS is the owner of the facilities, a "virtual" PPA will be executed with the OUR)
4. Competitive – Public tendering for generation capacity addition
5. Non-competitive – Sole source or direct negotiations for power purchase
6. Unsolicited – May be submitted for consideration at any time
7. Renewable Energy – Energy source which is continually regenerated
8. Co-generation – Generator process heat used for dual purpose
9. Excess (Dump) Energy – Energy exported in excess of power producers' need

Source: OUR Regulatory Policy for the Electricity Sector. Guidelines for the Addition of Generation Capacity to the Public Electricity Supply System. June 2006.

The current urgent requirement for new base load power resulted in the Generation Expansion Plan recommending 360 MW of natural gas fired combined cycle capacity in 2014, from which 292 MW will be for displacement of aged and inefficient capacity. The balance of 68 MW would be for demand growth requirements.

This Plan is therefore focused on central grid connected generation expansion. As a result parties interested in distributed generation are providing self-generation or excess power to the grid via policies and legislation designed significantly for central grid connections at a disadvantage.

This presents a challenge and the National Energy Policy (2009 – 2030) seeks to overcome the constraint by attempting to achieve a balance of energy diversification "*Energy diversification will involve moving from an almost total dependence on petroleum to other sources, including natural gas, coal, petcoke, nuclear, and renewable energy such as solar, wind, and bio-fuels. In the short to medium term, natural gas would be the fuel of choice for generation of electricity and the production of alumina*".

As the OUR Act and the All Island Electricity License are applied, the determination of when to add generation, what technologies how much generation at a time and equity for investors and proponents, requires a balance of all major considerations and includes the utility which has the majority shares in generation and 100% ownership of the T&D assets, into the process. Without the requisite balance distributed generation may be denied a space/proportion in new generation for the future, as they are not specific to central grid connection.

In seeking to achieve greater energy efficiency, cleaner alternative, energy security and generation modernization the Energy Policy recommends a number of strategies and key actions as Jamaica's generation approaches Year-2030. Selected strategies include;

- Implement least economic cost solutions for the supply of energy, including source, conversion, and distribution options.
- Through a competitive basis, retire the old generation plants and replace them with modern plants to improve the conversion efficiency.
- Establish a system to identify and replace old and inefficient units/plants with more fuel-efficient and cost efficient technologies and plants.
- Establish a combined cycle capacity to replace old and inefficient units/plants with more fuel-efficient and cost efficient technologies and plants.
- Implement appropriate energy distribution and transmission systems.
- Unbundle generation and transmission & distribution creating an energy efficient electricity structure.
- Unbundle existing vertically integrated industry structures and establish and implement common carrier and common access principles, where demonstrated to be technically and economically feasible.
- Facilitate greater energy efficiency and lower energy costs in the bauxite and alumina industry and in the manufacturing sector.
- Review and complete rural electrification programme including use of alternative energy sources.

The Energy Policy is clear that energy efficiency will be a point focus for any new generation. Whereas small reciprocating systems, fuel cells and micro turbines can achieve up to 40% efficiency their best efficiency levels is with CHP at >70%. This is an advantage for distributed generation if a heat demand can be satisfied such as air-conditioning using evaporative cooling or process heat demands.

Most of the distributed generation however is disadvantage as their capital costs are elevated due to insufficient economies of scale at this time; expensive technology and material components. However some technologies can generate power below the US$0.38/kWh in the Jamaican market at this time.

Conventional generation is one of three (3) modes for the addition of new generation to the national grid mostly using traditional fossil fuel generators. These include natural gas, oil or coal, or other such as nuclear and hydroelectric (renewable) designed to exclusively generate electricity. Currently only oil based fossil fuel plants and hydropower are in this category and oil based fossil fuel plants account for approximately 95% of the capacity on the grid.

Under this category of conventional generation, new generation may be added to the grid as follows:

1. Up to 15 MW without the competitive tendering process (unsolicited bids).
2. Addition of new plants above the 15 MW rating is initiated through a request for proposal (RfP) process following the approval of the LCEP, meeting lowest evaluated economic generation and under the terms of the License Condition 18 (Competition for New Generation).
3. Capacity additions will be considered either on the basis of providing technically and financially sounds firm capacity and energy to the system or supplying energy-only to the grid.
4. The utility can provide additional generation under the License Condition 18 and LCEP or may purchase power from an Independent Power Producer (IPP). Power purchased is based on the incremental avoided cost which would not be incurred by the utility.
5. The utility (JPS) and the IPP generator/investor will negotiate the contractual arrangements as a separate action to the LCEP and License, the contract which then will form the basis of the Power Purchase Agreement (PPA) between the parties.

These modalities are specific to central grid connection, however it does not prevent self-generation for onsite loads only. Larger conventional distributed generation sets are able to benefit from wheeling when it is implemented.

A second mode for adding new generation is by renewable energy sources[100]. Generation in this mode for Jamaica will be through solar, wind, hydropower, waste to energy and biomass fuels. Because of the intermittent supply of power for some of these resources, it is necessary to have spinning reserves to back up the renewable capacity and so they do not form base load (excepting hydropower, waste to energy and solid fuel biomass). Renewable energy options are also typically not least cost with regards to infrastructure, though requiring no recurring fuel costs and rated capacity is not achieved. For these reasons there has been some hesitance from the utility and Regulator to encourage renewable energy generation for supply to the grid network. However in the Jamaica National Energy Policy, the government has insisted on adding electricity generation for the public grid from renewable sources and has set a target for 15% of the total generating capacity for the grid from renewable energy resources by 2015. To support investments, a premium of up to 15% above the utility's avoided costs will be allowed for purchases of electricity generated from renewable sources. Proposals for renewable energy addition may be done at any time with or without an RfP.

Projects for power supply to the grid from renewable energy sources will be classified in three categories:

1. Large additions: plants of sizes greater than 15 MW. These will be added on the basis of a competitive process consistent with Condition 18 of the Licence. Category is the preferred option for satisfying the total capacity reserved under the LCEP for renewables.

[100] OUR Regulatory Policy for the Addition of Generating Capacity. Document Ele 2005/08.19.

2. Medium additions: plants greater than 100 KW but less than 15 MW. Failing the complete uptake of the reserved portion for renwables under the large additions, medium to small additions are a second priority. Small and medium additions are not subject to a competitive tender process however technically sound and lowest evaluated economic cost applies.
3. Small additions: plants of 100 KW and less will be subject to a Standard Offer Contract issued by JPS under the Net Billing Policy.

Distributed generations sets do not benefit specifically from this modality as it is geared to central grid connection, however Net Billing creates an opportunity for renewable energy generation[101].

Cogeneration (or sometimes referred to as "combined heat and power –CHP")[102] is the third main category for adding generation to the national grid. The objective is to increase overall plant efficiencies by simultaneously harnessing heat recapture for process heat. Steam generating stations using fossil fuels with cogeneration are expected to achieve maximum efficiencies of about 45% and combined cycle plants[103] burning natural gas may realize thermal efficiencies in excess of 60%. It is recognized that the integration of power generation and process heat requirements may place limits on the siting and power generating capacity of cogeneration plants. For these reasons except for the sugar industry, Jamaica Broilers (poultry producer), and other agroprocessers, other cogeneration plants may not easily comply with the conditions for competitive bids. This option is still considered for generation addition for its potentially higher fuel efficiencies. Proposals for cogeneration plants may be done at any time with or without an RfP.

Conditions for the avoided costs will apply with the possibility of still lower cost from heat supply contracts. Proposals will also be assessed against the latest LCEP and for proposals outside of the competitive process the conversion efficiency for electricity production must average at least 65% of the heat value of the fuel.

Cogeneration plants burning biomass will qualify to be classified as renewable energy, provided that the biomass medium is produced in Jamaica. In such instances the Office may approve the purchase of electricity to be transacted at prices higher than the utility's avoided cost by application of the premium provided for electricity generated from renewable energy resources.

Under this modality, distributed generation technologies may only benefit from Net Billing or Wheeling, as the target technologies are large and for grid connection.

A fourth opportunity exists for distributed generators in the megawatt scale that is through Excess (Dumped) Energy Policy. Independent generators (from conventional or

[101] March 2013 Report - Renewable Energy Sub-Committee of the National Energy Council.
[102] See operating definition below.
[103] Combined cycle plants reuse waste exhaust heat from a primary generator (usually gas turbines) for a secondary generation cycle (usually steam generators) while cogeneration reuses waste lower thermal steam (or exhaust gases) from a primary generator for either a secondary generation (usually steam) and the availability of useful process heat.

renewable sources) that provide energy to satisfy a part or their full energy needs may from time to time be allowed to sell to the national grid. The Regulator will allow for this type of transaction through a standardized PPA from JPS. The rate formula and pricing structure applicable must be approved by the Office before it becomes effective. The Jamaica Broilers Group Ltd and Jamalco are beneficiaries – having supplied some or all their power needs, they can sell the excess to the grid.

There is insufficient experience in most of the distributed generation options presented except for small gasoline or diesel engines used for back up and solar PV and wind. There is no know fuel cell, micro turbine, micro grid or other distributed generation systems in Jamaica at this time. This also leads to insufficient familiarity with the technologies by decision makers and energy engineers to drive the markets and as such these applications will be considered novel on implementation. It means there is currently no market for these and so small solar, wind and some reciprocating engines will continue to dominate the distributed generation market.

The traditional electric utility perspective has been that large central power plants are preferred, because of their economies of scale and significant competence has been developed. The utility is perceived as being unsupportive of micro generation systems as expressed by practitioners and based on the delays experienced by the net billing programme related to JPS approvals. It should also be considered that the utility is mainly interested in central grid options. Additionally the lack of sufficient expertise mentioned above does not advance the purposes of adding small generation to the generation market. As a result at the generation and transmission and distribution market levels, utilities are not yet assertive to add renewable generation for cost reasons and a preference for base load dispatchable resources. Nevertheless this is the overarching environment in which distributed renewable generation finds significant value.

As a matter of course as the market for distributed power technology matures, the cost of electricity from distributed power generation will decrease and offer many benefits that centralized utilities cannot match. It is expected that at this time the utility will access the benefits of peak-shaving, transmission and distribution line conditioning reducing line losses, reduced transmission, and distribution (T&D) expansion costs, lower cost energy demand for small incremental additions of generation, lower risk investment—essentially enabling a "just-in-time" philosophy. The utility will also obtain small but incremental other revenue streams from aged and capitalized grid infrastructure from Net Billing programs, wheeling and dumped power from on-site distributed generation.

Utilities can also improve their cumulative heat rate from cleaner technologies such as solar, hydropower and wind technologies and reduce their greenhouse gases through more efficient electric generation technologies and by increasing the quantity of distributed generation, which is the generation of electricity at or near to where it will be consumed. Some combustion technologies which can facilitate lower emissions include micro turbines, and small reciprocating engines, or natural gas-fueled solid-oxide fuel cells which utilize natural gas however the current absence of natural gas infrastructure and no access to landfill gases will be a barrier to achieve this opportunity. High upfront capital costs are likely to discourage investment in new generation technologies, especially at a time when low natural gas prices are putting downward pressure on energy bills. Without the necessary financial incentives for residential and commercial consumers however who could install distributed generation systems, could further hinder implementation.

Table 46: Benefits of Distributed Generation Power Technologies

BENEFITS	PV	WIND	HYDROPOWER	GAS - MICRO GENERATORS/ TURBINES	FUEL CELLS
Avoided Energy Loss In T&D Network/Grid.	✓	✓	✓	✓	✓
Modular - Incremental Changes (+/-) to Match Demand.	✓	✓	✕	✓	✓
Modular – Less Capital Investment in Unproductive Generation.	✓	✓	✕	✓	✕
Clean, Quiet Operation, Low Environmental Impacts.	✓	✓	✓	✕	✓
Potential to Release Transmission Assets for Increased Wheeling Capacity.	✓	✓	✓	✓	✓
Greater Market Independence & Consumer Choice.	✓	✓	✓	✓	✓
Avoided Fuel Transportation & Storage.	✓	✓	✓	✕	✓
Reduced O&M Cost to Utility.	✓	✓	✓	✓	✓
Capacity to Match Daytime Peak Demand.	✓	✓	✓	✓	✓
Capacity to Match Nighttime Peak Demand.			✓	✓	✓

Avoided/Differed T&D Line & Substation Upgrades.	✓	✓	✓	✓	✗
Faster Permitting than T&D Line Upgrades.	✓	✓	✓	✓	✗
Enhanced Power Quality and Reliability on T&D Grid.	✓	✓	✓	✓	✓
Potential Secondary Cash Flow to Consumers.	✓	✓	✓	✓	✓
Off-grid Supply Options.	✓	✓	✓	✓	✓
Dispatchable.	✗	✗	✓	✓	✓

(Source: US Department of Energy September /National renewable Energy Laboratory-National Center for Photovoltaics [enhanced], 1999)

Table 47: Summary of Drivers for Distributed Generation

TECHNOLOGY	STANDBY	PEAK SHAVING	RELIABILITY	POWER QUALITY	AVOIDING /AVERTING GRID EXPANSION	GRID SUPPORT	GREEN POWER
Reciprocating Engines	Yes	Yes	Yes if dispatchable		Yes if dispatchable	Yes if dispatchable	No/yes
Gas Turbines	Yes	Yes	Yes if dispatchable		Yes if dispatchable	Yes if dispatchable	No/yes
Microturbines	Yes	Yes	Yes if dispatchable		Yes if dispatchable	Yes if dispatchable	No/yes
Fuel Cells	Yes	No	Yes if dispatchable		Yes if dispatchable	Yes if dispatchable	No/yes
Photovoltaics	No	No	No	No	Difficult	Difficult	yes
Wind	No	No	No	No	Difficult	difficult	Yes
Other Renewables	no	No	No (except hydro and biomass).		Difficult	difficult	yes

Key:

Yes – technology contributes to….

No – technology does not contributed to….

Difficult – requires additional technologies (e.g. energy storage).

Green power is available if biogas and biodiesel are used.

Source: Katholieke Universiteit Leuven, 2003

3 NEW CONVENTIONAL (CENTRALIZED) AND DISTRIBUTED GENERATION TECHNOLOGIES.

3.1 Conventional Generation Technologies:

3.1.1 Retirement of Old Conventional Generation Systems and New Conventional Options

In Jamaica's case, conventional generation technologies are mature generation systems and are primarily fossil fuel based. Hydropower is also a mature generation option and will be addressed in the following section.

The current national focus on new generation is primarily on large scale grid connected systems aimed at reducing electricity cost and fuel diversification. Smaller distributed generation while evolving at the private sector commercial levels for cost reduction and rapidly residential level also for cost reduction and grid independence, will have a smaller share in the transformation of Jamaica's energy landscape. Commercial distributed generation is focused primarily on fossil based generation but also photovoltaics (PV) for renewable energy solutions. Residential distributed generation is predominantly solar PV based with some efforts in small wind turbines.

Jamaica has had decades of experience with liquid fuelled generation systems (oil-fired steam generators, combustion turbines, reciprocating engines and combined cycle systems) and this continues to be the dominant option. These systems have low capital costs relative to most renewable energy systems (US$ 1.5 /W and below) but relatively high operating costs because of the consumption of relatively expensive fuel. This leads to levelised energy costs in the range US$ 0.14 - 0.51/ kWh for each utility conventional generator, and a system average cost of generation of approximately US$ 0.25 / kWh.[104]

Table 48: Current Mix of Generation Technologies

Technology	Plant Type	No. of Plants	Fuel Type	Total Capacity (MW)	% of Total
Fossil Fuel Plants	Steam (Power only)	5	HFO	292.0	95%
	Steam (CHP)	6	HFO	1.0	
	Diesel	1	HFO	224.4	
	Combined Cycle	1	ADO	114.0	
	Combustion Turbine	8	ADO	165.5	
Total Fossil				**796.9**	
RET	Hydro	7		22.3	5%
	Wind	1		20.7	
Total RET				**43.0**	
TOTAL				**839.9**	**100%**

Source: OUR Generation Expansion Plan 2010.

With costs for transmission, distribution, losses and other factors taken into consideration, the final retail price of electricity in Jamaica is approximately US $0.40/ kWh. Note that these are the costs at the utility scale; small, liquid fuelled distributed generation in Jamaica can be more expensive, except for those large industrial consumers who can deploy technology at the megawatt scale.

The reason that electricity costs are high in Jamaica and most countries of the Caribbean is that these countries are heavily reliant on oil-based fuels, such as heavy fuel oil (HFO) and diesel oil. There are opportunities for reducing costs by changing the main fuel used for electricity generation to cheaper fuels, such as coal or natural gas. For example, although Mauritius has a smaller power system than Jamaica (with a peak demand of about 380 MW in 2008), it has been able to achieve much lower power costs by opting for bagasse and coal generation.

Reducing these high prices will require a switch in generation fuels. Coal and natural gas have been contemplated by the Government of Jamaica for decades. It is estimated that a switch in primary generation fuel to coal or natural gas would reduce electricity costs by around US$ 0.10 per kWh for all utility customers[105]

104 Castalia Strategic Advisors, "Options to Bring Down the Cost of Electricity in Jamaica." 2011.

105 Ibid.

Jamaican energy policy recognises these requirements. Goal 2 of the National Energy Policy 2009 -2030 speaks to the modernization and expansion of conventional generation technologies.

> ***Goal 2: Jamaica has a modernized and expanded energy infrastructure that enhances energy generation capacity and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis***[106]

Goal 2 contemplates the orderly retirement and replacement of conventional plants (the majority of which are currently over 30 years old) and the commensurate reinforcement of transmission infrastructure.

Goal 4 of the energy policy additionally contemplates diversification of fuel sources away from the current preponderance of heavy fuel oil (HFO) and automotive diesel (ADO) and towards coal and natural gas. Government policy contemplates an increase in the amount of natural gas and coal in Jamaica's generation mix to 42% and 5% respectively.

Besides the need to obtain lower electricity costs and diversify the fuel base, there is an urgent need to replace some of the old generation sets. Current power generation technologies, plants include:

- Oil-Fired Steam (Conventional - Power only).
- Combustion Turbines (Aero-derivative and Industrial).
- Slow Speed Diesel.
- Medium Speed Diesel (Power only).
- Oil-Fired Steam (Co-generation).
- Combined Cycle Gas Turbine (Oil-fired).
- Medium Speed Diesel (Co-generation).
- Run of River Hydro.
- Wind Turbine (HAWT).
- Solar (Photovoltaic).

According to standard industrial project assessment practices, the technical lifetime for steam plant is 35 - 40 years. Plant that uses gas turbines including combined cycle is 25 years and diesel plant 25 years. In addition power purchase contracts for two of the IPP terminate 20 years after initial commercial operations date; these plants were retired accordingly in the study.

In its Generation Expansion Plan 2010, the OUR stated that over the next 20 years (2010 – 2030), "approximately 1,400 MW of new fossil fuel power plant capacity will have to be constructed in Jamaica, to meet the projected demand for electricity and to displace aged power plants, depending on the penetration of Renewables and possibly nuclear power."[107]

106 MSTEM. "Jamaica National Energy Policy 2009-2030." 2010.

107 OUR."Generation Expansion Plan 2010."

Table 49: Base Forecast – Net Generation and Net System Peak (2010 – 2029)

Year	Net Gen (MWh)	Net Gen Growth Rate (%)	Load Factor (%)	Net System Peak (MW)	Peak Growth Rate (%)
2009	4,213,981	-	77.6	619.9	-
2010	4,253,796	0.94%	77.6	625.8	0.95%
2011	4,373,845	2.82%	77.96	640.5	2.35%
2012	4,531,735	3.61%	78.28	660.8	3.17%
2013	4,725,330	4.27%	78.57	686.5	3.89%
2014	4,951,437	4.78%	78.84	717.0	4.44%
2015	5,190,379	4.83%	79.07	749.3	4.50%
2016	5,434,953	4.71%	79.28	782.6	4.44%
2017	5,681,720	4.54%	79.47	816.1	4.28%
2018	5,949,989	4.72%	79.64	852.8	4.50%
2019	6,223,245	4.59%	79.8	890.3	4.40%
2020	6,502,098	4.48%	79.93	928.6	4.30%
2021	6,786,213	4.37%	80.06	967.7	4.21%
2022	7,075,842	4.27%	80.17	1007.6	4.12%
2023	7,370,946	4.17%	80.27	1,048.3	4.04%
2024	7,671,693	4.08%	80.35	1,089.9	3.97%
2025	7,978,175	3.99%	80.43	1,132.3	3.89%
2026	8,290,569	3.92%	80.51	1,175.6	3.82%
2027	8,609,043	3.84%	80.57	1,219.8	3.76%
2028	8,933,808	3.77%	80.63	1,264.9	3.70%
2029	9,265,086	3.71%	80.68	1,310.9	3.64%

Source: OUR Generation Expansion Plan 2010.

Approximately 800 MW of this new capacity needs to be constructed in the coming decade (2010 – 2020), highlighting the urgency of the issue. The capital requirements for the new power plant fleet are in the range of US$ 6.0 to 8 billion depending on the mix of technologies that will be deployed.

Castalia estimates that a switch in primary generation fuel to coal or natural gas over the next 2 decades would reduce electricity costs by around US$ 0.10 per kWh for all utility customers.[108] Fuel switching to either coal or natural gas is the best option of electricity price reduction in Jamaica, along with the deployment of certain renewables, the reduction of losses, and increasing end-user efficiency.

Table 50: Summary of Electricity Pricing Reform Options for Jamaica.

108 Castalia Strategic Advisors. "Options to Bring Down the Cost of Electricity in Jamaica. 2011."

Option	Description	Impact on electricity costs: With current capacity	Impact on electricity costs: With NGCC plant*	Recommendations
1. Change main fuel for electricity generation	Using LNG or coal to generate a large portion of the electricity in Jamaica	n/a	**Reduction of US$0.10/kWh across all customer categories** from the commissioning of 360MW Natural Gas Combined Cycle (NGCC) plant, conversion of the combined cycle plant at Bogue to LNG, and assuming that JPS's oil-fired steam units are no longer used for regular dispatch	Top priority to pursue
2. Increasing the use of renewable energy	Implementing economically viable utility-scale renewable energy projects, and increasing or enabling the use of commercially viable distributed generation technologies	**Reduction of US$0.02/kWh** across all customer categories	**Reduction of US$0.001/kWh** across all customer categories	Second priority
3. Reducing system losses	Reducing technical and non-technical losses in the electricity system	A reduction in losses by 5 percentage points would enable a **reduction of US$0.01/kWh** in electricity tariffs across all customer categories	A reduction in losses by 5 percentage points would enable a **reduction of US$0.006 per kWh** in electricity tariffs across all customer categories	Third priority
4. Increasing the use of energy efficient technologies	Promoting the use of technologies that would enable customers to save electricity at a cost lower than the electricity tariff	Net savings equivalent to: ▪ **16% of electricity bills** for residential customers ▪ **14% of electricity bills** for commercial customers ▪ **8% of electricity bills** for large commercial and industrial customers	Net savings equivalent to: ▪ **6% of electricity bills** for residential customers ▪ **6% of electricity bills** for commercial customers ▪ **2% of electricity bills** for large commercial and industrial customers	Fourth priority
Option	**Description**	**Impact on electricity costs**		**Recommendations**
5. Forcing vertical and horizontal separation of electricity services with open access	Separating the generation, transmission and distribution of electricity, and introducing competition in electricity generation and retailing	**Increase of US$0.11/kWh** across all customer categories if competition was introduced amongst current generation assets Electricity costs would also increase further due to transaction and restructuring costs, and increased overhead and administration costs	**Increase of US$0.12/kWh** across all customer categories Implementing this reform may prevent financing of the NGCC plant, thereby forfeiting the potential saving of US$0.10 per kWh	Do not implement
6. Enabling competition in generation and supply for large electricity users	Enabling large electricity users to buy electricity from suppliers other than JPS, and pay JPS a wheeling charge for transmitting and distributing the power	▪ Unlikely reduction in cost for large industrial users ▪ Increase in costs for residential and small commercial customers	▪ No reduction in cost for large industrial users ▪ Increase in costs for residential and small commercial customers	Do not implement
7. Creating an independent system operator	Creating a new, separate entity that would be responsible for the dispatch of the various generators on the system	No impact or increase: ▪ There is no evidence to confirm that JPS is manipulating the dispatching to its advantage ▪ The OUR is already monitoring the dispatching ▪ Setting up a new system operator would involve transaction costs and increase in overheads and administration costs, in order to achieve the same result as what can be done with effective monitoring.		Do not implement

Source: Castalia Strategic Advisors 2011.

This perspective is supported by the OUR's Generation Expansion Plan 2010 which recommends the commissioning of 360 MW (3 x 120 MW) of Natural Gas-fired combined cycle capacity in 2014. Of this amount, 292 MW will be for displacement of aged, inefficient capacity and the remainder for demand growth requirements. The OUR is currently evaluating 5 bids for the supply of this new generation using combined cycle gas turbines or mixed fuel reciprocating engines. A determination will be made by July

2013. While the proposed locations of these plants are not yet know, it is expected that at least 140 MW of medium-speed diesel may be installed in the Caymanas Estate area by a private power producer by 2015.

While fuel switching is a policy imperative and the 2009-2030 policy prescribes a fuel mix, the Minister of Science, Technology, Energy, and Mining clarified in late 2012 and reinforced in 2013 that the Government would not dictate fuel sources for large central power generation on the grid though succeeding political regimes have emphasised a preference for natural gas options (no restriction has been placed on private small distributed generation systems).[109] Rather than direct involvement in fuel procurement, the Government will allow the private sector to procure fuel as it sees fit. Given the size of the Jamaican market and the need for importation infrastructure this policy shift is an important one. While this puts additional costs on the project developer, it allows Government to more closely follow its National Energy Policy, which calls for private sector led development, while removing the spectre of political interference. This choice was taken in the wake of failed bid processes for the procurement of natural gas as the preferred transition fuel. The effect of this choice may be to allow coal to be utilised as a more favourable option, given the comparative complexity of natural gas importation infrastructure relative to solid fuel (coal) importation infrastructure.

In the near-future, and as part of national fuel diversification and cost reduction, coal will likely be considered primarily by private industrial companies with high thermal demands and not by dedicated independent power producers. Jamalco, a bauxite/alumina industrial entity partly owned by the Jamaican Government, will be installing 40 - 50 MW of coal-fired generation by 2016. Windalco another bauxite/alumina company will also consider installing 40 MW of coal-fired generation around the same timeframe. Both mid-island locations will involve circulating fluidized bed technologies with the intention of self-supply and some sale to the national grid. A proposed new limestone quarry and cement manufacturing plant - Cement Jamaica Limited – to be located at Port Esquivel Industrial Complex, St Catherine and Rose Hall District in Clarendon, will be powered by a 39 MW coal-fired plant, with 23% of the total power generated from the waste heat recovery from the cement plant[110]. This 39 MW will provide onsite power/self-supply with 1 coal-fired power generation system configured with two (2) high-temperature, high-pressure pulverized coal boilers with the steam capacity of 70 t/h and 1 high-pressure pure condensing turbine generator. In addition a Waste Heat Recovery (WHR) System with a horizontal Suspension Pre-heater boiler, an Air Quenching Cooler boiler, and a low pressure pure condensing turbine generator will have a capacity of 9 MW in cogeneration. The existing Caribbean Cement Company Ltd in Harbour view (south-east) has also signalled its intent to build a 40 MW coal plant for self-supply in the near-future in order to save approximately US$ 8 M per annum in energy costs (electricity is the single largest cost to operations). With the advantage of its existing coal port, supply

109 Phillip Paulwell, M.P. "Budget Debate: 2013 - 2014 - Minister Phillip Paulwell." 2013.

110 Addendum - Environmental Impact Assessment for the Quarry and Cement Plant, EnviroPlanners Limited. September 2011

contracts and experience in coal handling, construction and implementation would be less challenging than for a new plant.

PETROJAM the only national oil refinery signed a Letter of Intent in 2008 with the Jamaica Public Service Company (JPS) to advance the development of a 120 MW petcoke-fired project in Hunts Bay, (southern Jamaica) as part of its refinery upgrade programme. PETROJAM will produce 280,000 metric tonnes of petcoke per annum from a new delayed coker unit as a by-product of crude refining from its expanded and upgraded refinery[111], to fuel the 120 MW cogeneration power plant managed by JPS. JPS will in turn supply the refinery with 20 MW of power from the grid, as well as, process steam generated during the production of electricity. The remaining 100 MW will be sold on the grid. Petcoke is currently the cheapest among solid fuels and is expected to reduce the overall cost of electricity on the national grid by 5%. This project has had delays due to the global economic downturn and the economic challenges in Venezuela the 49% shareholder in PETROJAM. Plans for the petcoke plant have resumed in 2013.

Nevertheless, natural gas remains a compelling option. Many of the plants currently in the generation market can switch fuels to natural gas and thereby reduce generation costs without stranding assets. Natural gas is substantially less environmentally impacting than coal in terms of emissions of carbon, particulates, acid gases and heavy metals. Meeting air quality standards for coal requires substantial investment in scrubbing technology to curtail emissions, which contributes to the high capital cost of coal: the levelised capital cost of coal is approximately 4 times the capital cost of a conventional natural gas combined cycle plant (US $65.8 /MWh, versus $17.5 /MWh). It may be for these reasons that natural gas, rather than coal, was the generation fuel of choice for all of the unsolicited bids that came before the OUR in 2013 for the construction of 360 MW of generation capacity. Coal still has the advantage of lower variable costs and a cheaper, more readily available fuel with less volatile pricing.[112] OUR also stated that the business-as-usual strategy with the continued proliferation of petroleum based fuels is not sustainable and unresponsive to the National Energy Policy objectives.

As well as fuel choice, conventional generation must also take into account the state of the transmission infrastructure and dispatch management. JPS is required by regulation to keep its heat rate below a certain monthly level (currently 10,400 KJ / KWh). This influences their dispatch merit order, as lower heat rate units should be dispatched preferentially. However this has led to plants with high variable operating costs (related to the cost of fuel) but with low heat rates to be dispatched ahead of relatively cheaper plants with high heat rates. Quoting JPS:

> *"When fuel prices are high generally, generating units with good heat rates will have a higher merit order ranking than units with a worse heat rate, subject to their respective variable operating and maintenance (O&M) costs. Good heat rate units will therefore deliver a substantial share of the energy required, all other*

[111] The refinery upgrade is expected to increase processing capacity from 36,000 bbls/day to 56,000 bbls/day, with higher value added products and petcoke as a residue.

112 Energy Information Administration. "Annual Energy Outlook 2012."

factors being normal. The system heat rate will therefore be good while the system fuel cost will be high.

Conversely, when fuel prices are low, the system fuel cost will be lower and the difference in the fuel component of merit order cost for good and bad heat rate units will be smaller. The merit order ranking of generators will be influenced a lot more by the value of the variable O&M than was the case in a high fuel price environment. The share of energy from units with relatively poor heat rates will also be greater and hence system heat rate will deteriorate".[113]

This underscores the need to replace current plants which have poor heat rates, with cheaper operated plants that have better heat rates. By doing so, the merit order of dispatch changes in a way that will allow JPS to meet its heat rate targets without uneconomic dispatch choices.

Table 51: Current Conventional Generation Plants (2010)

Owner	Technology	Old Harbour	Hunts Bay	Bogue	Rockfort	Other	Total (MW)
JPS	Hydro					22.29	**22.29**
	Steam	223.5	68.5				**292.0**
	Diesel				40.0		**40.0**
	Comb Turbine		54.0	103.5			**157.5**
	Combined Cycle			114.0			**114.0**
IPPs	Steam					5.0	**5.0**
	MSD	124.36					**124.36**
	SSD				61.0		**61.0**
Total							**816.15**

Source: OUR Generation Expansion Plan 2010.

113 JPS 2009-2014 Tariff Rate Review Application

In 2012 a 66 MW medium speed diesel power plant was added to the total generation by a private IPP - Jamaica Energy Partners (JEP) in Kingston[114]. This was the most recent conventional generation addition.

Since Jamaica already has ample transmission infrastructure and several plants at the end of project life, a reasoned option for power generation replacement and capacity expansion would be to install newer plants on the same sites as retired plants. This would work around issues of land availability and would be a least cost option with respect to transmission system and substation investment. Whereas the regulator does not permit the utility to directly replace its own generation sets outside of a bid process, this wisdom was tacitly reflected in the unsolicited proposals for 360 MW plants evaluated by the OUR in 2013: all were proposed to be sited at Old Harbour (south-east Jamaica), where 292 MW of oil-fired capacity was to be retired.[115]

Other sites for major conventional generation which are supported by substantial grid infrastructure include Rockfort in St. Andrew, the Jamalco refinery in Clarendon (central Jamaica), and the Bogue site in St. James (north-west). Any of these sites would be good locations for conventional generation expansion.

Figure 35: Diagram of the JPS Generation and Transmission System

[114]West Kingston Power Partners added a 66 MW medium-speed diesel power plant to the grid in 2012.

115OUR. "Media Release: OUR Review Unsolicited Proposals", March 26, 2013. This topic was also the main topic of discussion at the May meeting of the Jamaica Energy Council.

Source: JPS

There are several generation technology options available that were considered for the expansion of the electricity generation system. These options include:

- Gas turbines: open-cycle and combined-cycle variants running on Natural Gas or Automotive Diesel Oil (ADO).
- Diesel engines: medium-speed and low-speed units running on Heavy Fuel Oil or Natural Gas.
- Conventional steam units: powered by coal and with electrostatic precipitators, flue gas desulphurization for emission controls and selective catalytic recovery controls[116].

The OUR estimates that an optimal generation system would contain a mixture of natural gas and coal-fired base load plants. This comports somewhat with the government policy of fuel diversification away from liquid fuels, though the OUR plan contains more coal generation than is contemplated by the Government of Jamaica, which projects that coal generation will form 5% of the energy in the energy mix. The OUR projects a total cost of US$ 5.85 billion for a mixed fuel strategy, which compares favourably with the cost of an all-gas strategy (US$ 5.77 billion) or a business as usual liquid fuels strategy (US$ 8.18 billion).[117]

Table 52: Optimum Generation Plan under a Natural Gas/Coal Strategy

[116] OUR. "Generation Expansion Plan 2010."

117Ibid.

Year	Plant Type to be added to the System	No. of units x Capacity (MW)
2014	Natural Gas-fired Combined Cycle unit	3 x 120
2016	Coal unit	1 x 120
2017	Natural Gas-fired Simple Cycle Gas Turbine unit	1 x 40
2018	Coal unit	1 x 120
2020	Coal unit	1 x 120
2021	Coal unit	1 x 120
2023	Coal unit	1 x 120
2025	Coal unit	1 x 120
2026	Coal unit	1 x 120
2028	Coal unit	1 x 120

Source: OUR, Generation Expansion Plan 2010.

It is however anticipated that there will be some addition of petroleum-fired plants along with the natural gas/coal-fired optimal case. As such, performance and cost characteristics of the candidate generation plants that may be considered for expansion of the country's power generation system are below. OUR will have timely requests for proposals for the addition of the required new generation.

Table 53: Performance and Cost Characteristics of Candidate Technologies

Plant Type	Fuel Type	Plant Capacity (MW)	Planned Outage Days	Forced Outage Rate (%)	Net Heat Rate at Maximum Capacity (kJ/kWh)	Fixed O&M Cost (US$/kW-Month)	Variable O&M Cost (US$/MWh)
Combined Cycle	NG	120	26	3.0	7,654	1.07	2.53
Combined Cycle	ADO	120	26	3.0	7,654	1.07	2.53
Combustion Turbine	NG	40	18	3.0	10,600	1.04	3.70
Combustion Turbine	ADO	40	18	3.0	10,600	1.04	3.70
Medium Speed Diesel	HFO	60	18	4.0	8,569	6.05	13.60
Slow Speed Diesel	HFO	60	18	4.0	7,596	7.00	8.50
Coal Fired Steam	COAL	120	26	5.0	9,729	2.40	5.00

Source: OUR, Generation Expansion Plan 2010.

All new conventional generation power plants over 25 MW will be subject to open international tender and connected to the central grid for dispatch and as such will not have the opportunity to be considered under distributed generation sets.

Smaller distributed generation systems (1 – 2 MW each) using more conventional fossil fuels in medium-speed reciprocating diesel or heavy fuel oil (HFO) engines are expected to be implemented by the private sector as they seek to reduce their electricity cost which can be as high as 30% of total operational costs. These engines can also accommodate the use of biodiesel as an environmentally benign option. For example, Wisynco a food and beverage manufacturer and distributor has considered installation of 4 MW of prime power from medium-speed reciprocating engines. Quasi Government organisations have also considered the use of onsite distributed generation from medium-speed reciprocating engines to reduce operating cost for electricity including the Port Authority of Jamaica (approximately 4 MW) and Airports Authority of Jamaica (approximately 4 MW) both south-east of the Island. There are no bids or firm plans for self-generation at this time. Major academic institutions have also considered the use of these small reciprocating engines including the University of the West Indies (Kingston) as part of Phase II of its evaporative cooling and cogeneration project for self-sustenance in energy and the University of Technology (Kingston) as part of a strategy for electricity cost reduction. Both institutions have considered 4 MW of self-generation. Other considerations for power generation using small reciprocating engines include stand-by supply as in the June 2013 call for procurement of rated 500 KVA power plants for each of the National Housing Trust (Clarendon) and the Tax Authority of Jamaica (Kingston).

3.2 New Renewable Energy Generation:

3.2.1 New Renewable Energy Generation Plans:

Jamaica has utilized renewable energy technologies both on and off grid and current proposals are for the further addition of renewable generation in both contexts.

Table 54: Renewable Energy Contribution to Total Net Generation

Year	Renewable (GWh)	Total Net Gen (GWh)	RE % of Net System Generation
2005	201.22	3,877.99	5.2%
2006	225.04	4,046.43	5.6%
2007	211.75	4,075.48	5.2%
2008	207.41	4,123.29	5.0%
2009	198.64	4,213.98	4.7%
Average			**5.1%**

Source: OUR Generation Expansion Plan, 2010

Since 2010, Wigton Wind Farm has added 18 MW of wind and JPS 3 MW to increase shares of renewable energy contribution to the grid.

It is anticipated that more renewable electricity will be added to the grid, though there are concerns regarding the intermittent nature of renewable energy technologies which are not predictable. These technologies may include wind, solar photovoltaic, solar thermal and run-of-river hydro.[118]

Not all the renewables are commercially variable at this time. Biomass and hydro are considered dispatchable renewable energy technologies, as such, they can be contracted to supply firm capacity to grid. Variability is not a new phenomenon in power systems. Demand fluctuates continually, as does supply. However, a greater share of variable renewable energy will increase the aggregate variability and uncertainty that the power system will have to manage. In the case of wind power where large fluctuations in output are possible over very short time periods, accurate predictions of wind power output will be crucial to reduce the allocation of reserves in advance, particularly on a timescale of several hours to days ahead of dispatch. Improved output forecasting and intra hour revised dispatch may facilitate more efficient scheduling of flexible reserves.

Even with more reliable forecasts, power systems will still require some enhancement of management and ancillary services to absorb large shares of fluctuating variable renewable energy output in a reliable manner.

3.2.2 Size and Technology considerations

Several considerations must be examined in the determination of appropriateness of new conventional and distributed generation technology for the Jamaican context in the near term. Factors of land availability, policy and regulatory constraints, financing, fuel supply diversification, and environmental impact all may have positive or negative implications for the appropriateness of a given generation technology.

In the consideration of many technologies, issues of size and technology maturity are the dominant considerations. Of 923 MW of installed grid connected capacity, over 55% is over 30 years old. There are over 292 MW of old generation capacity to be retired by 2015, and the reserve capacity is about 300 MW (difference between available generation of 923 MW and peak demand of approximately 640 MW). The Generation Expansion Plan of 2010 which is focused on centralized megawatt sized generation projected a peak demand 1,310 MW by 2029 under base-case growth scenarios[119] to be satisfied with new proven conventional generation. However currently a smaller portion of generation has come from small-decentralized domestic and commercial sources

[118]Not all the renewables are variable. Biomass and dammed hydro are considered dispatchable renewable energy technologies that may be contracted to supply firm capacity.

119 OUR. "2010 Generation Expansion Plan." The low-growth scenario projects a system peak demand of 963 MW by 2029. The high load growth scenario projects peak demand of 1,856 MW by 2029.

such as biogas, solar and wind (less than 1% of demand) which may not be captured in this Generation Plan.

The policy and regulatory position of the Government of Jamaica is such that unproven technologies are unlikely to survive the regulatory steps that would result in the granting of a license. The 115 MW Request for Proposals (RfP) for renewable generation issued by the Office of Utilities Regulation required applicants to *"demonstrate experience in the development of power generation facilities with emphasis on the renewable energy technology being proposed"*[120;] the National Energy Policy 2009-2030 emphasizes *"economic feasibility"*[121] in the ranking of renewable energy technologies compared on the basis of generation cost of currently available conventional fossil technologies. The 115 MW RfP also demonstrates a preference towards firm base load power at the lowest cost which was restated by the Office of Utilities Regulation at its pre-bid meeting on January 17, 2013.

3.2.3 Biomass and Energy from Waste

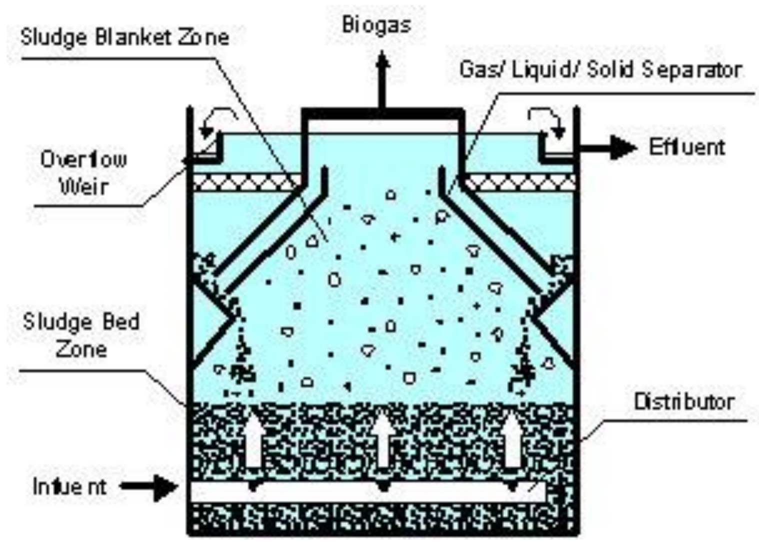
Biomass and energy from waste technologies may be generally divided into biochemical and thermo-chemical conversion platforms. Biochemical or biogas conversion technologies are those which convert carbonaceous material to usable fuel by microbial action, typically with the production of combustible methane. Thermo-chemical conversion is the conversion of carbonaceous matter to fuel or usable energy via purely non-biological means of temperature, reactive gases, and pressure. For capacities appropriate for distributed generation purposes, there are only a few technologies that are both mature and of an appropriate size for Jamaican deployment.

3.2.4 Biogas Technologies

Whereas there are large-scale biogas technologies utilized by sewerage treatment, agro-processing and other companies, there is no consideration for large-scale application at this time due to cost and volume flows for commercial viability. Small-scale biogas technologies are generally restricted to distributed generation due to storage and transportation issues compared to other bioenergy technologies, and are therefore well suited to localized DG deployment. These technologies will involve the generation and combustion of gaseous methane fuel derived either from anaerobic digestion (AD) or landfill gas (LFG). The Scientific Research Council has patented Up Flow Anaerobic Sludge Blanket (UASB) and Biodigester Septic Tanks (BST™) capable of generating 10 to 50 cubic metres of gas per day. These designs have been encouraged by high fuel costs, as Biogas is relatively cheaper if it can be harnessed compared with other sources of fuel, such as Liquid Petroleum Gas (LPG) and electricity[122.] UASB reactors are typically suited to dilute wastewater streams (3% TSS with particle size >0.75 mm).

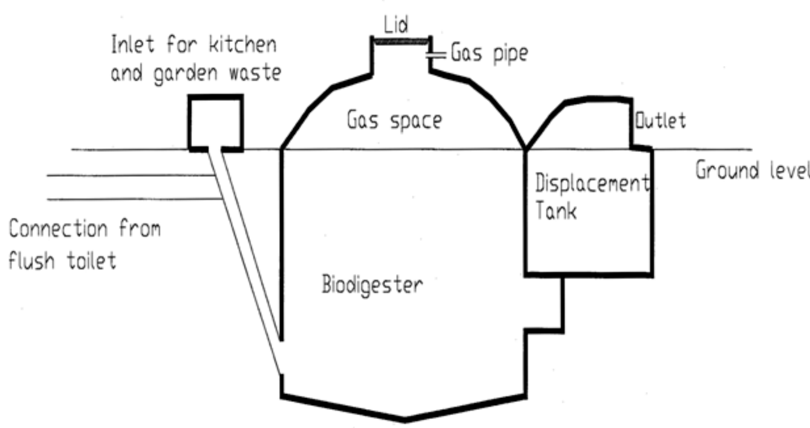
120 OUR 115 MW RFP, Paragraphs 145, 150, 155
121 National Energy Policy 2009-2030, page 31, 32
122 SRC website, 2013.

Figure 36: Up Flow Anaerobic Sludge Blanket (UASB)



Source: Industrial Technology Research Institute 2013

Figure 37: Biodigester Septic Tank (BST)



Source: Scientific Research Council 2013

Landfill gas is another source of combustible fuel for power generation. Landfill gas produced by anaerobic degradation of organic matter is composed primarily of methane (CH_4) (45 – 75%) and carbon dioxide (CO_2), but also has low concentrations of hydrogen sulfide (H_2S), volatile organic compounds (VOCs), ammonia, hydrogen gas and carbon monoxide[123]. In modern landfills, methane production ranges between 50 and 100 kg per tone of the waste. In general, some 50% of such gas can be recovered and used for power and heat generation. Jamaica's 8 municipal solid waste disposal facilities are currently not suitable for the exploitation of landfill gas, as there is no seal and trapping or piping infrastructure in place. Discussions are ongoing regarding conversion of these disposal sites into municipal solid waste disposal landfills but there has been no implementation to date.

AD and LFG both offer significant environmental benefits. LFG capture mitigates methane emissions from landfills, which are both a potent greenhouse gas and the cause of landfill fires that affect local air quality. AD has similar benefits, since methane can be captured and utilized rather than emitted into the atmosphere as is typical of sludge lagoon waste treatment. Methane-mitigating projects have heretofore been considered favourably under the Clean Development Mechanism, but the collapse of international carbon prices and Jamaica's status as a lower-middle income country makes opportunities for funding dubious.

AD is generally deployed in waste conversion processes, converting waste into usable fuel and a fertilizer by product. While there have been problems of social acceptance for AD by-product fertilizers derived from human waste in the past, several countries have moved past these issues as AD deployment increases. Since AD and LFG production are typically part of larger waste management processes and provide integrated solutions to the attendant problems of that industry, they are typically easily bankable where regulation allows. Currently the EfW draft policy speaks to "*creating partnerships between the energy sector and the waste management and agriculture sectors*" and to "*a well-defined governance, institutional, legal and regulatory framework for the generation of energy from waste*" including tipping fees, favourable tax policy and integrated sector planning, indicating clear Government support for EfW projects.[124]

The deployment of AD and LFG in Jamaica to provide electric power generation is technically feasible at large food and agri-business concerns, wastewater treatment facilities, and waste disposal sites. A large source of feedstock is needed because, as a rule of thumb, 1,000 kg per hour of wet waste biomass is needed to provide enough methane for a 1 MW plant of electricity under ideal conditions.[125] This fairly large flow rate rules out most Jamaican sites which have relatively low waste flows.

Practically speaking, inasmuch as wastewater treatment and municipal sludge waste disposal are in the province of fairly large public works within complex regulatory situations, large businesses such as factory farms, dairies, food processing facilities, etc. –

123 International Solid Waste Association – Guidelines for Design and Operation of Municipal Solid Waste Landfills in Tropical Climates, 2013.

124MSTEM. National Energy from Waste Policy 2010-2030 (Draft).Last edited in 2012.
125USEPA, "Anaerobic Digestion of Food Waste" 2008.

may be the entities nimble enough to provide electricity from biogas at commercial scale in the next 20 years in Jamaica.

Possible locations for distributed generation biogas technologies in Jamaica would be the Serge Island Dairy farm in St. Thomas (east) and the Soapberry wastewater treatment facility in St. Catherine (having a capacity of 75,000 m^3/day). The National Water commission has committed to expansions of wastewater treatment services island wide, particularly around the cities of Portmore, Montego Bay and Savanna-la-Mar; each of these is a potential site for commercial-scale biogas generation. The Jamaica Broilers Group Ltd in St. Catherine (south central) which has been involved in various renewable energy projects also has the potential for biogas development based on their slaughterhouses and other wastes flows.

Future power generation using AD and LFG may come from using internal combustion engines with capacities from 100 kW to 3 MW, while small gas turbines of up to 10.5 MW fuelled by LFG have been referenced by the United States Environmental Protection Agency.[126,127,128] Except of the wastewater treatment plants and solid waste WTE technologies Jamaica has limited large-scale generation opportunities. If feasible these would be added to the grid as there would be insufficient load at the fuel source points to justify a project for onsite power only.

AD and LFG fuel generation technologies are quite mature. AD has already been employed extensively in Jamaica, with over 200 functional digesters in operation, generally on farms. This gas has heretofore only been occasionally used to power production, typically on the scale of tens of kilowatts off-grid. More often, such gas is only used for cooking purposes. One good example of a biodigester catering domestic waste and animal manure was established at the St. John Bosco Boys Home in Hatfield, Manchester. The 100-m^3 biodigester, which was implemented at a total cost of US$ 14,200, produces over 50 m^3 of gas per day, equivalent to about 300 kWh. The school presently utilizes the gas generated to operate cookers, stoves, water heaters and brooders. This was one of 10 biodigesters installed as a part of a technical cooperation between Germany and Jamaica in 1993 -1995, which built on a previous technical cooperation funded by OLADE in the 1980s.

Inasmuch as small-scale biodigesters are proven in Jamaica, additional AD projects may be rolled out with the development of new housing schemes. Such a project is currently being contemplated for Richmond Estates in St. Ann on Jamaica's north coast.

In summary, potential future projects for biogas in Jamaica may include:

- Anaerobic digestion and power generation at an expanded Soapberry and for future water treatment facilities in St. Catherine, Savannah-la-Mar and Montego Bay. This would be suitable for distributed generation.

126USEPA, "Anaerobic Digestion of Food Waste" 2008.
127USEPA "AgSTAR Handbook: A Manual for Developing Biogas Systems at Commercial Farms in the United States", 2007.
128USEPA, LMOP Program "An Overview of Landfill Gas Energy in the United States", June 2012

- Anaerobic digestion with community gas piping / power generation at Richmond (St. Ann) and other housing schemes. This would be suitable for distributed generation.
- Anaerobic digestion for distributed generation at the Serge Island Dairy in St. Thomas.

3.2.5 Thermo-chemical Biomass Conversion

Thermo-chemical biomass conversion technology is at varying states of maturity worldwide. Given the particular regulatory constraints of Jamaica (i.e. the requirement that technology be proven), several technologies are inappropriate for Jamaica at this time – for example, pressurized gasification and bio-refineries. These technologies are still in the research and development stages.[129]

Table 55: Comparison of Data for Biomass Power Generation Technologies

Typical Data and Figures for Power Generation from Biomass

Data Confidence – Power generation from biomass includes a number of processes and feedstocks. Data refer to typical technologies but wide ranges exist, depending on process, feedstock, transport and local conditions.

Technologies	Efficiency % (LHV)	Typical size MWe	Typical Costs [1] Capital, $/kW	Electricity, $/kWh
Co-firing	35-40	10-50	1100-1300	0.05
Dedicated steam cycles	30-35	5-25	3000-5000	0.11
IGCC	30-40	10-30	2500-5500	0.11-0.13
Gasific.+engine CHP [2]	25-30	0.2-1	3000-4000	0.11
Stirling engine CHP	11-20	<0.1	5000-7000	0.13

Further Information - www.iea.org; www.ieabioenergy.com; International Bio-Energy Partnership (www.fao.org); *Energy Technology Perspectives* (IEA, 2006); *World Energy Outlook* (IEA, 2006); REN21 – Global Status Report 2005 and Update 2006 (www.ren21.net)

1) Biomass cost $3/GJ; Discount rate 10%; 2) Heat value $5/GJ.

Source: www.iea.org/Textbase/tecno/essentials.htm 2007

The most mature generation technologies are typically those that leverage the substantial body of existing technology in power generation from solid fuels. Those technologies of a size appropriate for distributed generation in Jamaica are typically those that use biomass combustion in a variety of boiler configurations, including low-rate co-firing of biomass with conventional solid fuels (coal) or oil. Biomass pyrolysis, atmospheric biomass gasification and medium-rate co-firing technologies are sufficiently close to deployment to also be included in the list of appropriate technologies. Combined heat and power applications (CHP, also called cogeneration) in biomass power generation such as in the sugar cane industry are also appropriate. The immediate best locations for biomass power generation plants using thermo-chemical

129 International Renewable Energy Agency, "Renewable Energy Technologies Cost Analysis Series Volume 1 issue 1/5", June 2012.

conversion are the six-sugar factories island wide. These are summarized in the Table below. Combined heat and power (CHP) is a valuable form of distributed generation for the sugar industry, located at the refineries Its higher efficiency comes from recovering the heat normally lost in power generation to provide heating or cooling on site, or to generate additional electricity. Combined heat and power (CHP) generates electric power and useful thermal energy from a single fuel source and does so either from a topping or bottoming cycle[130]. In the topping cycle system, fuel is combusted at the sugar factory and produce steam in boilers to generate electricity first. Energy normally lost from the hot exhaust and cooling systems is instead recovered to provide heat for sugar or alcohol production. Some of the high-pressure steam is also used for motive energy to grind cane.

In the bottoming cycle system, also referred to as "waste heat recovery," fuel is combusted to provide thermal input to a boiler (furnace) and heat rejected from the process is then used for electricity production.

Note that while these sugar factories all run on bagasse now, they will require both efficiency upgrades, and some supplemental biomass (provided by cane tops, green cane harvesting or local wood) or an alternative fossil fuel to reach their maximum potential for energy production. These efficiency upgrades will be a function of the choice of boiler technology/pressure as these sugar factories retool following the 2012 divestment of Jamaica's sugar assets. Note that different boiler pressure choices (20, 40, or 80 bar) have dramatically different effects on energy production.

Additionally, the requirement of supplementary biomass can be challenging given the aforementioned low energy density of biomass. An instructive example is a Nicaraguan case: a 15 MW sugar mill cogeneration plant using eucalyptus during the off-harvest season was commissioned in 2000 which requires 60,000 tonnes of woodchips per season, for which 590 hectares of trees have to be cut annually.[131]Woody biomass requires large scale, and Jamaica currently has neither the commercial plantations nor the regulatory framework for forestry to enable this.

Nevertheless, the sugar factories and the companies behind them are private businesses with multiple revenue streams in the process of major investment and retooling, making them promising and likely candidates for distributed energy generators.

Table 56: Projected Annual Energy Generation from Sugar Factories.

130USEPA Combined Heat and Power Partnership 2009.

131United Nations Economic Commission for Latin America and the Caribbean, "Renewable energies potential in Jamaica" 2005.

	Bagasse only			Biomass only			Combined operation		
Location	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**
Golden Grove	0	4,336	13,483	9,867	14,526	24,202	9,867	18,862	37,684
Everglades	0	4,045	8,577	5,481	8,068	13,443	5,481	12,113	22,021
Appleton	5,995	15,682	33,408	31,267	46,030	76,693	37,261	61,712	110,102
Worthy Park	2,782	7,851	17,636	11,425	16,819	28,023	14,207	24,670	45,659
Monymusk	0	10,288	27,556	16,815	24,754	41,244	16,815	35,042	68,800
Frome	0	22,066	50,880	30,974	45,599	75,974	30,974	67,665	126,854
Total, MWh	**8,777**	**64,267**	**151,540**	**105,827**	**155,796**	**259,579**	**114,604**	**220,063**	**411,119**
National, %	**0.2%**	**1.6%**	**3.7%**	**2.6%**	**3.8%**	**6.3%**	**2.8%**	**5.3%**	**9.9%**

Source: Biomass Feedstock and Cogeneration in the Sugar Industry of Jamaica 2012.

These technologies all leverage the maturity of boiler and gasification technology in coal-fired power generation. In particular, stoker boilers and fluidized bed boilers are technologically appropriate steam generation technologies leveraging combustion. Gasification via downdraft fixed bed, updraft fixed bed or bubbling or circulating fluidized bed reactors are all appropriate, though pressurized fluidized bed reactors are at the upper limit of appropriate sizes for distributed generation and can be engineered to be much larger than the contemplated scope of this assignment (tens to hundreds of megawatts). Larger gasification systems, such as pressurized entrained flow gasifiers, are not appropriate for DG due to their size.

Any of these systems may be paired with condensing steam turbines for standalone electricity generation. CHP applications may use extracting steam turbines or backpressure steam turbines. All of these technologies are fully mature. Gasification systems may also deploy gas treatment technologies (filters, scrubbers and cracking technology) to upgrade their gas from low energy producer gas to higher energy syngas, particularly where steam or oxygen mixtures are used as the reactive gas rather than pure air. Syngas may be combusted in internal combustion engines or gas turbines. These technologies are near commercialization, so are appropriate to consider, but generally lie in capacity ranges of tens of megawatts and above. In June 2013 the short listed/preferred bidders for 115 MW of renewable energy technologies was announced and only the Petroleum Corporation of Jamaica placed a bid for 20.98 MW for a biomass generation technology (potentially considering grasses or woody biomass). There were no bids by the sugar industry however this does not exclude the possibility of private sector owned factories such as Golden Grove Estate upgrading equipment for the production of onsite power. Current Bidders who are finally selected are expected to have installed and operational plants by 2015 and such plants will be centrally dispatched instead of DG options. The maximum tariffs available to such generators will be US $ 0.1488 /kWh for waste to energy plants, and US$ 0.1516 / kWh for bagasse fueled generation.[132]

Environmentally, thermo chemical technologies share some of the carbon emissions benefits of biochemical technologies. However, inasmuch as these systems are similar to conventional combustion technologies, particulate and NOx emissions can be problematic (though heavy metal and SOx pollution is negligible compared to coal-fired generation). Because thermo chemical biomass projects use waste that would ordinarily be land filled or dumped (e.g. municipal solid waste) there is a clear environmental benefit to such energy projects, as they would minimize the amount of waste which would eventually be disposed.

Thermo-chemical conversion technology requires large amounts of feedstock – much more than similar coal technologies, because of the much lower energy density of solid biofuels (up to 19 GJ / dry ton, with bulk densities of 100 - 300 kg/ m^3) compared to coal (20-30 GJ / dry ton, with bulk density of 700 - 850 kg/ m^3).[133] The low energy density of biomass makes the deployment of these technologies a logistics challenge, since large amounts of fuel are needed at a central conversion facility Large-size plants using MSW, agricultural wastes and industrial organic wastes (large-scale co-digestion) need some 8,000 - 9,000 tonnes of solid wastes per year per MW of installed capacity.[134] In the case of the conversion of municipal solid waste and sugar waste (bagasse), these logistics issues are handled within the larger context of the enterprise and are therefore not insurmountable; however, energy-only enterprises will face logistics challenges.

The use of densification technologies such as pelletization can be used to overcome logistics challenges, and may be necessary to enable a wider range of bioenergy projects, both for biomass fuels and refuse derived fuel. Relatively small-scale pelletization is already technologically mature, but a requirement is created for the development of a secondary market for fuel to meet the needs of boiler operators. This will undoubtedly require regulation of activity in forestry and waste management. Where farmers and small producers can be integrated into the biomass / waste supply chain, there may be considerable positive social impact. Business models for solid fuel collection, pelletization and supply to power plants already exist[135]. Nevertheless, it is important that care be taken to ensure sustainable harvesting of farm and forest biomass.

With respect to thermo chemical projects, the future possibilities are bagasse cogeneration with an aggregated export capacity of approximately 58 MW (with an

132 OUR."Request for Proposals for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis." 2012.

133 US Department of Energy Oak Ridge National Laboratory. Biomass Energy Data book Appendix B – Biomass Characteristics." 2008.

134 IEA Energy Technology Essentials 2007.

135 Abellon Clean Energy of Gujarat, India, which harvest waste biomass from a network of small farmers in a sustainable and integrated way, is one such example.

aggregate installed capacity of approximately 90 MW) at 6 sugar factories island wide. Of these, the smaller projects could be considered as distributed generation projects (e.g.

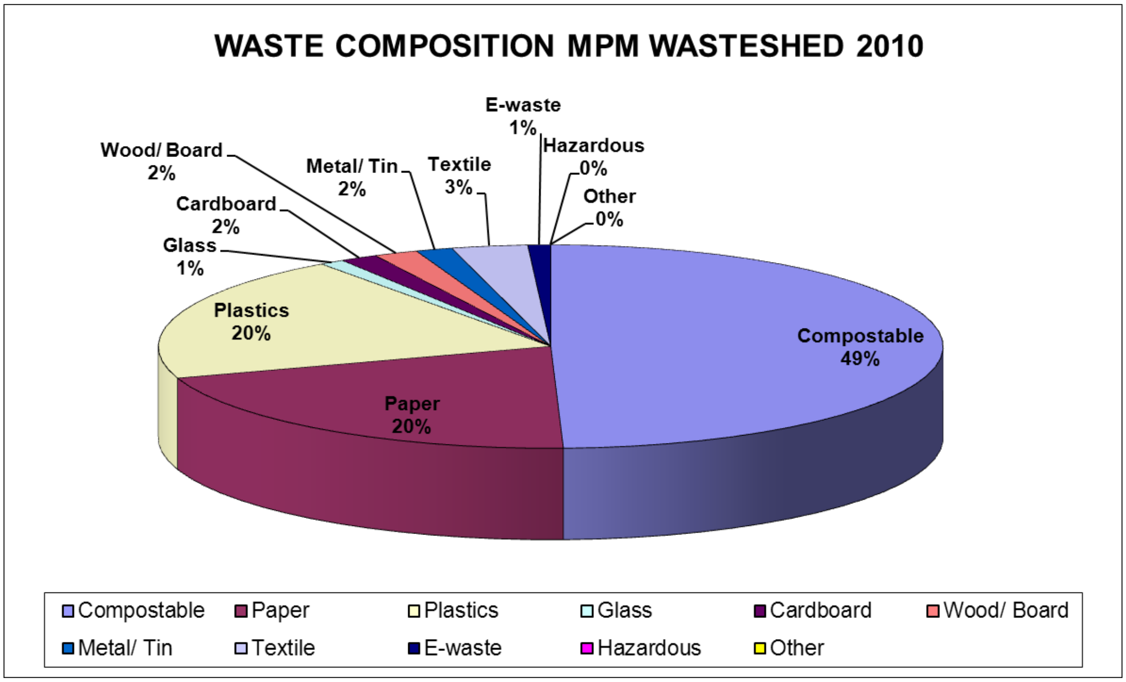
Golden Grove) while larger plants would have to be implemented as more centrally controlled projects connected through 69 kV interconnections or higher:

- Golden Grove in St. Thomas (exporting 5.3 MW) (eastern).
- Everglades in Trelawney (3.1 MW) (north-west).
- Appleton in St. Elizabeth (15.7 MW) (south-west).
- Worthy Park in St. Catherine (6.5 MW) (south-central),
- Monymusk in Clarendon (9.8 MW) (central).
- Frome in Westmoreland (18 MW) (western).
- The Petroleum Corporation of Jamaica's biomass cogeneration project in St. Elizabeth (south-west Font Hill).

3.2.6 Municipal Solid Waste

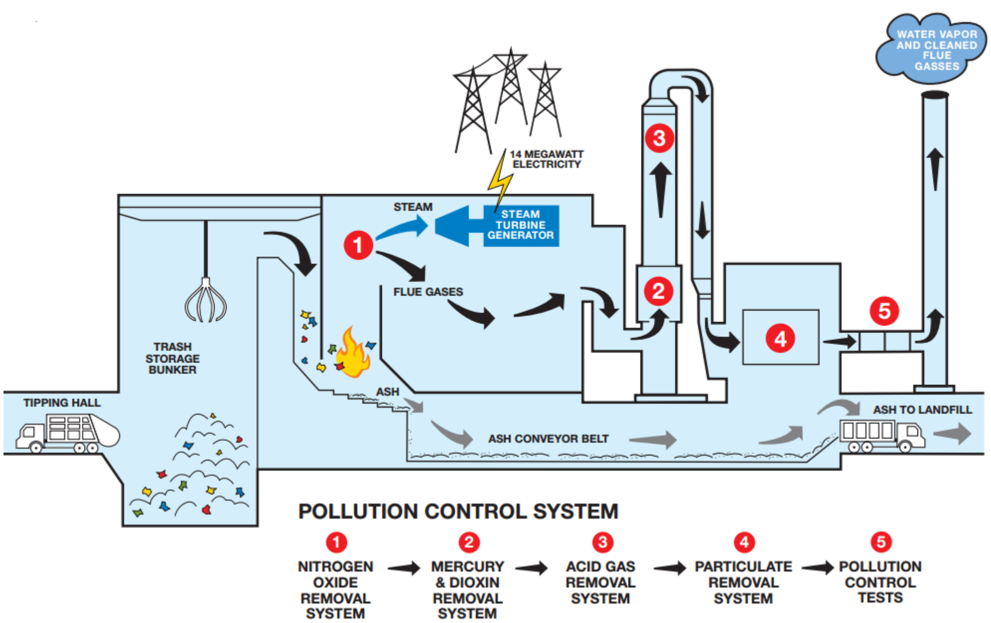
Jamaica's waste disposal sites received about 850,000 tonnes of solid waste during the year 2010. Based on the historical growth rate of six percent (6%) per annum, the waste stream was projected to increase to about 1,140,000 million tonnes by 2015.

Figure 38: Jamaica's Solid Waste Composition 2010.



Source: NSWMA

Figure 39: Waste to Energy Mass Burn Systems for Municipal Solid Waste.



Source: USEPA 2013 (EcoMarine)

A typical WTE plant generates about 550 kilowatt-hours (kWh) per ton of waste. At an average price of four cents per kWh, revenues per ton of solid waste would be US$ 20 to US$ 30 (USEPA 2013)

Modern and efficient Combined Heat and Power (CHP) generation plants using solid wastes can achieve 28% - 30% electrical efficiency, and above 85% - 90% overall efficiency in Combined Heat and Power mode if good matching is achieved between heat production and local demand[136]. Municipal solid waste modern generators can generate approximately 600 kWh of electricity per tonne of waste and mixed fossil fuel, emitting net 220 - 440 kg CO_2. There is also the significant benefit of net reduction of CO_2 emissions as methane emissions from MSW in modern landfills would be between 50 - 100 kg/t (equivalent to 1,150-2,300 kg CO2), approximately half of which is released in the atmosphere. Methane has been the primary source of fuel for spontaneous fire events at the disposal site in Kingston in particular thus, electricity production from

MSW could offer a net emission saving between 725 and 1,520 kg CO2/t of wastes. Saving is even higher for CHP[137].

Finding integrated solutions makes thermo-chemical biomass projects bankable. Projects that integrate energy generation as a part of a larger enterprise, with multiple income streams and a strong balance sheet, are easier to finance than stand-alone power projects. As such projects that involve generation of energy from farm or municipal waste are comparatively easier to finance. Combines heat and power systems are good examples.

CHP projects produce energy at a levelised cost of US$ 40 to US$ 90/MWh[138]– the presence of a large, steady thermal energy customer lowers project risk.

Table 57: Comparison of CHP Technologies with Other Power Generation Options.

136International Energy Agency Technology Essentials 2007.
137International Energy Agency Technology Essentials 2007.
138International Energy Agency Technology Essentials 2007.

Category	10 MW CHP	10 MW Wind	10 MW Natural Gas Combined Cycle
Annual Capacity Factor	85%	34%	70%
Annual Electricity	74,446 MWh	29,784 MWh	61,320 MWh
Annual Useful Heat	103,417 MWh_t	None	None
Footprint Required	6,000 sq ft	76,000 sq ft	N/A
Capital Cost	$20 million	$24.4 million	$9.8 million
Cost of Power*	7.6 ¢/kWh	7.5 ¢/kWh	6.1 ¢/kWh
Annual Energy Savings	316,218 MMBtu	306,871 MMBtu	163,724 MMBtu
Annual CO_2 Savings	42,506 Tons	27,546 Tons	28,233 Tons
Annual NOx Savings	87.8 Tons	36.4 Tons	61.9 Tons

Table Assumptions: 10 MW Gas Turbine CHP-28% electric efficiency, 68% total efficiency, 15 PPM NOx; Electricity displaces National All Fossil Average Generation (eGRID 2010)-9,720 Btu/kWh, 1,745 lbs CO_2/MWh, 2.3078 lbs NOx/MWh, 6% T&D loss; Thermal displaces 80% efficient on-site natural gas boiler with 0.1 lb/MMBtu NOx emissions; NGCC NOx emissions = 9 ppm; DOE EIA Annual Energy Outlook 2011 assumptions for Capacity Factor, Capital cost, and O&M cost of 7 MW utility scale PV, 100 MW utility scale Wind (1.5 to 3 MW modules) and 540 MW NGCC; Capital charges based on: 7% interest, 30 year life for PV, Wind and NGCC, 9% interest, 20 year life for CHP; CHP and NGCC fuel price = $6.00/MMBtu.

*The cost of power for CHP is at the point of use; the cost of power for PV, wind and central station combined cycle is at the point of generation and would need to have transmission and distribution costs added to the totals in the table (2 to 4 ¢/kWh) to be comparable.

Source: USEPA Combined Heal & Power Partnership 2009

Waste to energy from the Riverton waste disposal site in St. Catherine and the Retirement site in St. James is a long-contemplated possibility, made especially attractive due to public outcry over atmospheric pollution due to frequent fires. Riverton could accommodate possibly two generation projects of 20 - 25 MW, while Retirement could accommodate one 20 - 25 MW project, based on the availability of waste and supplemental fossil fuel (FF).

While this is technically feasible, it is a regulatory challenge given the current state of waste management regulation in Jamaica, which is still in a process of development. The current fiscal situation of the Government of Jamaica also puts limits on the availability to finance and execute large generation projects of this nature, particularly through tipping fees. It has been estimated that, for Riverton, in the absence of a feed in tariff for EfW, a tipping fee of approximately $42/ton would be required in 2016 in order to break even. For Retirement, the tipping fee required to break even $45/ton. In both cases, the tipping fees would have to grow at a rate roughly equal to the short-term debt interest rate. In the absence of a tipping fee, a feed in tariff for a power plant at Riverton would have to be approximately $0.169/kWh to breakeven, and approximately $0.167/kWh for Retirement.[139] These projected costs are well above the US$ 0.1488/ kWh maximum contemplated by the OUR in their recent 115 MW tender, which received no energy from waste proposals.[140] The National Solid Waste Management authority has not been clear projections regarding a proposed tipping fees or waste feedstock prices.

The possible projects in MSW WTE:

- 40 - 50 MW of MSW coal-cofired generation at Riverton, St. Catherine.

139PCJ, "Technical Assistance for a Waste to Energy Financial Assessment", 2012.

140 OUR."Request for Proposals for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis". 2012.

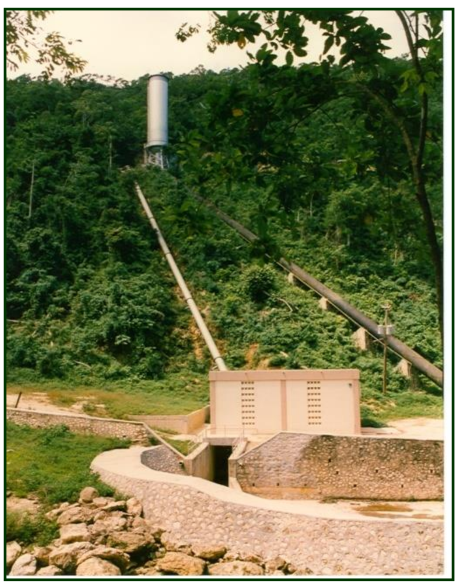
- 20 - 25 MW of MSW coal-cofired generation at Retirement, St. James.
- A WTE project at either sites without supplemental fossil fuel would be restricted to 5 MW.

3.2.7 Hydroelectricity

Hydroelectric technology is the most mature of the commercially exploited renewable energy technologies, and hydropower has been generated in Jamaica for over a century. The Jamaica Public Service company currently owns and operates 7 hydroelectric plants with a combined capacity of 22.6 MW. These produced 776 MWh of electricity between 2005 and 2009, or 3.7% of all electricity generation in Jamaica.

During the 2005 - 2009 period, generation averages 155 MWh / year. This is somewhat higher than the 1990 - 2009 Average of 117 MWh / year. This variability, which is related to seasonal flow variations and changes in rainfall patters, underlines the variability of run of the river hydroelectricity in Jamaica. As such, the OUR does not consider these plants to be dependable in capacity, although the Jamaica Public service company always accepts hydroelectricity whenever it is available.[141] As such, the OUR requires ample firm capacity to be installed to back up any run of the river hydroelectric plants.

Figure 40: Rio Bueno Run-of-the-River Hydro Power Plant.



For reasons of environmental preservation, the planning focus in Jamaica has been on low-impact small run-of-the-river facilities, as opposed to dams which would be more disruptive to the natural environment and human settlement. In this regard hydropower has been limited by the need to make allocations for "social water" and "environmental

141 OUR Generation Expansion Plan 2010.

water" demands as required by the Water Resources Authority (WRA). Under the Water Resources Act of 1995 and the Water Resources Master Plan, the WRA oversees the orderly development and equitable allocation of water resources and includes avoidance of damage to the environment and economic setback. It is estimated that the levelised cost of hydroelectricity in Jamaica is US$ 111.3 /MWh.[142] A license is required to abstract the water resources.

Regulation for land availability, surface water access rights, and environmental protection is such that there are considerable barriers to entry to the hydroelectric generation market. The Government of Jamaica is especially concerned with minimal environmental impact for hydropower projects. A 2005 draft of a proposed Electricity Act stipulates, that the OUR "*may require through license conditions any licensed generator who owns, operates or plans to operate a hydro-electric generation to operate such station in such manner as will reasonably protect the interests of users of water downstream of the generation station in respect of such water*"(Paragraph 65). Existing water access legislation requires a license for all types of water uses, issued by the Water Resources Authority. The license is granted for a period of 5 years, but can be extended thereafter. In competing situations preference is given to irrigation and domestic fresh-water use over any energetic purposes. All environmental aspects have to be resolved with the National Environment Protection Agency (NEPA).

Over the years Jamaica has implemented 22.6 MW of installed small hydroelectricity and 56.1 MW of potential run-of-the river plants over 11 sites have been studied for new potentials (feasibility studies completed). Feasibility studies on 5 more sites were initiated by the PCJ in the second quarter of 2013, with the aim of packaging "investment ready" projects to put to eventual tender.[143] To date there has been no interest in the smaller micro hydro (≤100 KW) systems in Jamaica.

Table 58: Installed Hydropower Plants in Jamaica

Hydroelectric Plant	Installed Capacity (MW)
Roaring River	4.05
Upper White River	3.19
Lower White river	4.75
Rio Bueno– A	2.50
Rio Bueno – B	1.10
Magotty	6.30
Constant Spring	0.70

142OUR."Request for Proposals for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis". 2012.

143MSTEM/ World Bank. "Technical Assistance and Capacity Building for the Promotion and Development of Cost Effective Small Hydro Projects (Request for Proposals." 2013

Total	**22.59**

Source: OUR Generation Expansion Plan 2010

Table 59: Hydropower Potential in Jamaica.

Hydroelectric Scheme	Potential Capacity (MW)
Back Rio Grande (BRG)	28
Great River	8.0
Green River	1.4
Laughlands Great River	2.0
Martha Brae River	4.8
Morgan's River	2.3
Negro River	1.0
Rio Cobre	1.0
Spanish River	2.5
Wild Cane River	2.5
Yallahs River	2.6

Source: PCJ

Additionally, the Ministry of Science, Technology, Energy and Mining (MSTEM) seeking to encourage additional hydropower generation for the centralized grid through a call for Expressions of Interests for *"Technical Assistance and Capacity Building for the Promotion and Development of Cost Effective Small Hydro Projects*". Funding is to be provided by the International Bank for Reconstruction and Development (IBRD) for the promotion and development of cost-effective small hydropower projects. The rivers being contemplated are the Rio Cobre River in St. Catherine (south central), Morgan's River and Negro River in St. Thomas (eastern), Martha Brae River in Trelawny (northwest) and Spanish River in Portland (northeastern). Following these prospects, the Petroleum Corporation of Jamaica (PCJ) intends to initiate the procurement of another set of hydropower feasibility studies for five (5) additional rivers by mid-2013. Expressions of Interest will be received in June 2013 with the aim of packaging "investment ready" projects for eventual tender for new power generation.[144]

Prefeasibility studies on one relatively large potential dam site at Mahogany Vale in the foothills of the Blue Mountains suggest that more than 50 MW of potential exists. This dispatchable, storage-backed generation capacity was originally proposed to be a part

144 Summarized from PCJ data available at http://www.pcj.com/dnn/HydropowerStudies/tabid/184/Default.aspx

of a multipurpose water management project, making it additionally attractive. The Government has not pursued it, though there is interest from Sinohydro, a Chinese developer.[145]

This feasibility and pre-feasibility work is in line with Jamaica's energy policy. Hydroelectricity expansion is supported by Jamaican energy policy and is repeatedly mentioned in the National Energy Policy 2009-2030 as a potential renewable energy focus are for Jamaica. Like other renewable technologies, hydroelectricity is afforded a 15% bonus over the avoided cost when added to the grid on a non-competitive basis. The importation of hydroelectric turbines is not subject to taxation under the Common External Tariff or General Consumption Tax.

While the technical feasibility has been proven for several hydroelectric projects. There have been little recent investments due to high specific costs. JPS is currently expanding its Maggoty hydroelectric plant by adding 6.3 MW at US$ 5 / W. The primary system-wide benefit of hydroelectric plants is a lowering of the overall system heat rate which is factored in the tariff for the utility. JPS's hydroelectric projects thus serve a regulatory compliance function.

Regulation for land availability, surface water access rights, and environmental protection is such that there are considerable barriers to entry to the hydroelectric generation market by small players for distributed generation. The Government of Jamaica is especially concerned with minimal environmental impact for hydropower projects. A 2005 draft of a proposed Electricity Act stipulates, that the OUR "*may require through license conditions any licensed generator who owns, operates or plans to operate a hydro-electric generation to operate such station in such manner as will reasonably protect the interests of users of water downstream of the generation station in respect of such water.*" Existing water access legislation requires a license for all types of water uses, issued by the Water Resources Authority. The license is granted for a period of 5 years, but can be extended thereafter. In competing situations preference is given to fresh-water use for irrigation and domestic use over any energetic purposes. All environmental aspects have to be resolved with the National Environment Protection Agency (NEPA).

The call of proposals for new 115 MW renewable energy generation was expected to receive 1 – 2 small hydropower proposals (<10 MW). However this did not manifest and it is expected that the 6.3 MW expansion by JPS may reflect the near-future expansion of hydropower and that the outcome of the feasibility studies for the named potential resources will guide future efforts to include hydropower as unsolicited proposals submitted to the Office of Utilities Regulation. Maximum available tariffs for unsolicited bids would be pegged to the avoided cost of generation, with a bonus of up to 15%. With regard to projects requiring public tender, the recent 115 MW tender for renewable energy contemplated a USD 0.1113/kWh price for hydroelectricity, which could be the hurdle rate for new tariff revisions. Projects can occur in partnership with the utility or as other private sector investments.

145 PCJ "Blue Mountain Multi-Purpose Project Pre-investment Study", 1980.

The most likely hydroelectricity projects in Jamaica are summarized in table 12 above. All except the Back Rio Grande project are appropriate for distributed generation. The rivers most likely to be developed in the future are:

- Rio Cobre River in St. Catherine (1 MW)
- Morgan's River in St. Thomas (2.3 MW)
- Negro River in St. Thomas, (1 MW)
- Martha Brae River in Trelawny(4.8 MW)
- Spanish River in Portland (2.5 MW)

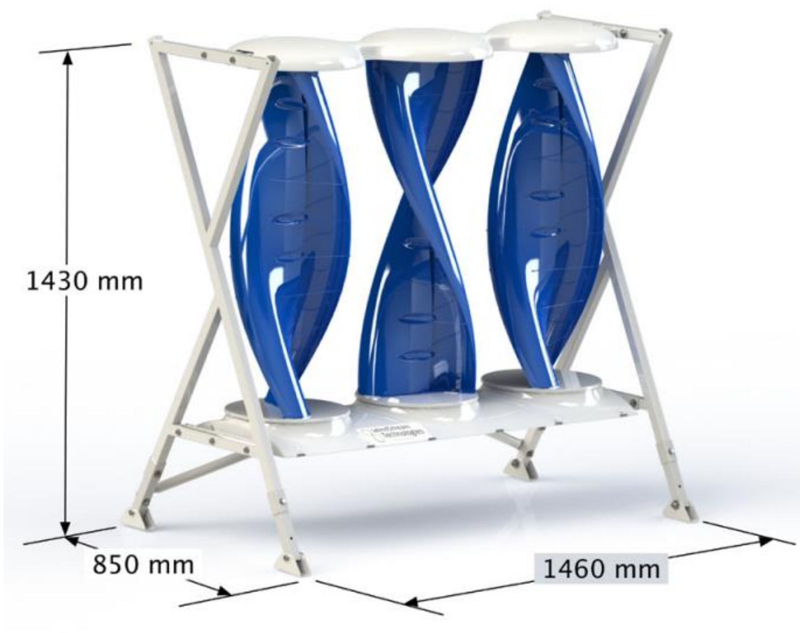
These rivers are the subject of the most recent projects aimed at investment promotion by MSTEM. More distant possibilities include the development of Back Rio Grande in Portland (28 MW) and the possibility of the Mahogany Vale dam project in the foothills of the Blue Mountains in St. Andrew and St. Thomas.

3.2.8 Wind Energy

Wind energy is a mature technology at the utility scale, having reached parity with conventional generation costs in several countries with levelised costs in the range of US $60-110 / MWh[146]. Horizontal axis turbines are preferred over vertical access turbines as a proven technology for reasons of efficiency and scalability,[147] but locally made vertical axis turbines are being piloted by the Caribbean Maritime Institute. These turbines have a peak output of less than 10 kW, are manufactured from scrap materials, and are designed to be maintained by the small households or communities which will use them. They are an attractive option for very small small-scale systems. One of the pilot turbines is in operation at the Pedro Cay, an isolated fishing outpost off Jamaica's south coast. Vertical micro wind turbines such as the Wind Stream Technologies "Turbo Mill" with rated power output of 143 W at a wind speed of 11 m/s has been tested at the JPSCo head office building for possible dissemination to remote locations. These turbines have relatively low cut in speeds of 2 m/s and operate more efficiently at the resource margins than larger wind systems. Their small size, easy installation and low cut in speeds, makes them suitable for urban environments with less favourable wind regimes.

Figure 41: Wind Stream Technologies Vertical Wind Turbine.

146 IRENA "Renewable Energy Technologies Cost Analysis Series" Volume 1, Issue 5/5, 2012.
147 IRENA "Renewable Energy Technologies Cost Analysis Series" Volume 1, Issue 5/5, 2012.



Source: Wind stream Technologies, 2012.

The Jamaica National Energy Policy 2009 - 2030 and the National Renewable Energy Policy 2009 - 2030 support wind energy, with frequent reference to wind as a potential resource.[148] The Policy calls for the deployment of large-scale wind turbines and of small wind turbines (with the potential to provide water-pumping services for irrigation with small wind-powered installations). Government has also shown fiscal support for wind generation: customs duties and consumption taxes on wind generation equipment have been removed.

Policy calls for sustainable tariffs and an enabling regulatory framework for all renewable energy projects, including wind power.[149] Feed-in tariffs have been contemplated and are recognized in government energy policy[150] but the final determination on feed in tariffs will depend on the outcomes of the 115 MW renewable energy tender exercises which were initiated in 2012 and was closed in June 2013.[151] The exercise was competitive, with a maximum tariff of US$ 0.1336 / kWh, as opposed to a system of unsolicited bids and fixed feed-in tariffs; thus, the outcome of the process will be

148 National Energy Policy 2009-2030. In particular, Goal 3 of the policy is "Jamaica realizes its energy resource potential through the development of renewable energy sources and enhances its international competitiveness, energy security whilst reducing its carbon footprint." Wind power is mentioned frequently throughout the document.

149 National Energy Policy 2009-2030

150 National Renewable Energy Policy 2009-2030. Mentioned under "key policies" in Goal 2.

151 National Energy Policy 2009-2030.

important in deciding whether fed-in tariffs or competitive tender processes are best for wind energy. Two proposals for new wind generation were received from Wigton Wind Farm (24 MW) and Blue Mountain Renewables (34 MW) and are to be evaluated. The technologies, model/make of turbines and locations have not been stated.

The Wigton Wind Farm Ltd. is a 38.7 MW installation in Manchester, southern Jamaica. The Wigton site has average wind speeds of over 8 m/s Wigton began with a 20.7 MW installation of 23 NEG MICON turbines (model NM900/52) rated at 900 kW, with a 52.2 m rotor diameter at a hub height of 49 m. It was the first modern utility-scale wind project in the Caribbean. Wigton expanded in 2008 with the installation of 9 Vestas turbines rated at 2,000 kW each at a hub height of 80 m. While it has highly variable output with a capacity factor of 0.31, Wigton supplies energy to the national grid at US $ 0.106 per kWh, making it one of one of the cheapest electrical generators in Jamaica.

The expansion of Wigton Wind farm is a priority for the Government of Jamaica, and is specifically mentioned as a flagship project in the National Renewable Energy Policy 2009 – 2030.[152]

The Jamaica Public Service Company Ltd (JPSCo) has also included wind turbines to its total generation capacity with 3 MW of UNISON U50 turbines[153]. The UNISON generator has nominal power of 750 kW, rotor diameter of 54 m and is a wind class generator - IEC IIa. JPSCo turbines represent the new trend towards direct drive permanent magnet generators (PMGs) which are expected to have better efficiency reliability because of the simplified electronics and drive train, and lower maintenance costs due to nacelle weight reduction. The UNISON U50 turbines used by JPSCo is the first gearless, continuous drive commercial scale wind turbine used in Jamaica and is expected to perform well compared with geared systems. JPS will also engage in marketing hybrid solar/wind technology developed by WindStream Technologies called the Solar Mill, in Jamaica and the Caribbean as part of the developing distributed generation tend[154].

Figure 42: Wigton Wind Farm – Turbines

152 National Renewable Energy Policy, 2009-2030.

153 JPSCo wind park is located in Munroe, Manchester

154 http://www.jamaicaobserver.com/news/JPS-to-become-distributor-of-SolarMill-renewable-energy-system#ixzz2f85Xg3iN

Source: World Watch Institute

Figure 43: UNISON U50 Turbine

Source: UNISON

Wigton Wind Farm is conducting an assessment of wind sites across the island to be concluded in the 3rd quarter of 2013. The preliminary results of the Wigton assessment provide average wind speed projections over six months from October 2011 to April 2012 at 18 sites. Preliminary results show a significant degree of wind resource availability for new projects (See Table below).

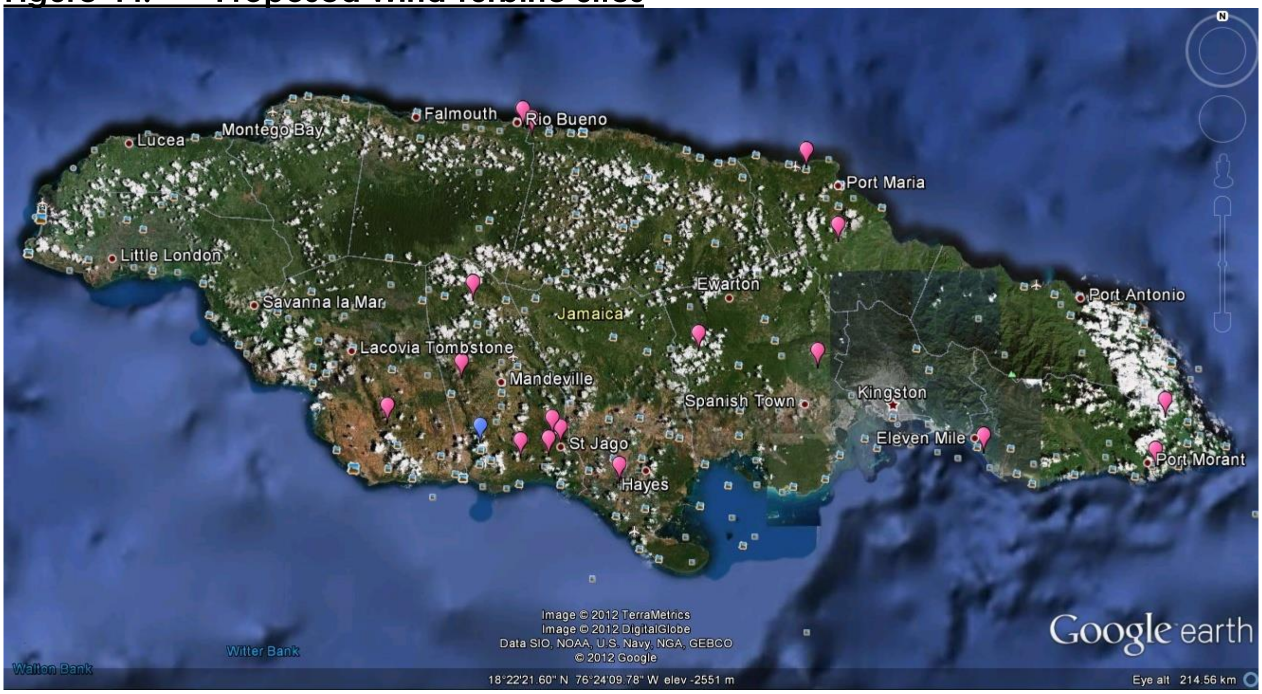
Table 60: Average Wind Speeds by Site (Preliminary)

Station	Projected Average Wind Speed (Meters Per Second) At 80 Meters
1. Albion	**4.6**
2. Bowden	**6.7**
3. Winchester	9.7*
4. Fair Mountain	7.6*
5. Mount Dawson	**5.0**
6. Rio Bueno	**7.5**
7. Oracbessa	**5.2**
8. Highgate	**4.8**
9. Kemps Hill	8.2*
10. Juan de Bolas	**7.0**
11. Ibernia	**6.8**
12. Pratville	**6.7**
13. Mt. Oliphant	**5.8**
14. Groove Town	**5.3**
15. Bengal	**6.2**
16. Victoria Town	**4.2**
17. Top Lincoln	8.3*
18. Rose Hill	8.5*

Source: Wigton Wind Farm / IDB Wind Resource Assessment

Sites indicated in bold and with * have particularly high average wind speeds suitable for commercial scale wind farms. Sites in red were unfavourable because of low average speeds. Several of these sites compare favorably to the existing Wigton Wind Farm, which has average wind speeds of 8.3 meters per second (m/s) at the 49 m hub height of Phase I.[155]

Figure 44: Proposed Wind Turbine Sites



The construction of wind farms at these locations will be a challenge, according to Wigton. Due to the low quality of the road network, the difficulty in moving large equipment, the unavailability of suitable cranes on the island, and it has been estimated that installation of utility-scale wind turbines may cost up to 40% more in capital costs in Jamaica than in mainland Europe.[156] Wigton phase I and II faced these challenges, including the need to get 14 permits for various phases of construction, importation, and transportation. There has have been so far, few environmental issues associated with wind farm construction in Jamaica, particularly with regard to view sheds (i.e. the potential for negative community reactions to the aesthetic effects of wind farms; such reaction has been minimal in Jamaica). Wigton was built on former mining lands, so there was little in the way of environmental permitting inasmuch as the wind farm was much less environmentally impacting than the previous mining operations. Detailed environmental studies of other potential wind sites have not yet commenced, but it is known that some high wind resource areas are located in or near the Blue and John Crow Mountains, a protected area to the east of Jamaica for which construction permits are not likely to be granted. Current local work at the University of Technology will

155 Wigton Wind Farm / IDB "Wind Resource Assessment" 2010-2013. Public presentation of preliminary results at Wigton in June 2012.

156 Source: MSTEM. Typical installed costs for wind turbines in Europe are US$ 2.1 / W.

integrate known environmental and spatial planning data to determine the ideal sites for Wind farm development, with work to be completed in 2013.[157]

Besides these 2 onshore commercial power projects (Wigton and JPSCo) there have been other efforts at using wind for localized onshore and off-grid distributed generation. DIGICEL (a telecommunications company) has installed 4 turbines on its head office in downtown Kingston. DIGICEL installed 3 Sky Stream 3.7 model (3 x 1.8 kW; 208 V Split Phase output or 240 V 60 Hz output) wind turbines on the roof of its new headquarters as part of its energy efficiency and green objectives. Mystic Mountain (an ecotourism enterprise) also has plans to supply part of its commercial loads with wind power. The College of Agriculture Science and Education in Portland has a 3 KW turbine installed and hybridized with a 500 W PV hybrid renewable energy system. Residential and other commercial interests have installed as many as 50 small turbines ranging from 400 W to 3 KW, however these have been less successful as installations have been done in poor wind regimes due to lack of the requisite site assessment. It is estimated that there is approximately 40 - 50 kW of small wind residential wind power systems installed and possibly 20 kW at commercial sites.

Jamaica also has a strong offshore wind resource. Satellite assessments of various locations off Jamaica's coast indicate an average modeled wind speed of 8.41 m/s at a hub height of 80 m, with an expected capacity factor of 53%. However, Jamaica has comparable onshore resources which would be less of an engineering challenge to exploit. It is unlikely that offshore wind will be developed before the maximization of onshore wind generation.[158]

The variability of wind power creates grid integration challenges wherever wind power is developed. The Office of Utilities Regulation and the JPSCo have stated the focus on grid supply of firm base load and dispatchable new generation[159]. Currently WWFL delivers approximately 30% of its rated power per annum and wind conditions change seasonally and daily. As such there will be some limitation to wind penetration as part of an overall limit for intermittent generation. It has been suggested that this limit may be 184 MW by 2030, given generation expansion targets. The maximization of this potential will be important to meeting government targets for renewable energy.[160] MSTEM commenced a grid impact assessment in 2013 to determine the system-wide effects of the penetration of intermittent renewable energy to the JPS infrastructure in line with 30 of electricity being renewable by 2030. The study will include recommendations for grid upgrades and ancillary services.

The most likely wind generation projects include two that were submitted to the OUR in June 2013 under its RfP for 115 MW of renewable electricity. These include a 24 MW project by Wigton in the area bordering Manchester and St. Elizabeth, and a 34 MW

157 Lawrence Neufville, "Multi-criteria Analysis GIS for Wind Farm Site Suitability Determination", working paper presented on April 9, 2013.

158 World Watch Institute, "Designing, and Communicating Low Carbon Roadmaps for Small Island States in the Caribbean" 2013.

159 OUR. 2010 Generation Expansion Plan.

160 Xavier Vallve. "Jamaican Tariffs for Renewable Energy." 2012.

project of an undetermined location. Preliminary results from wind mapping studies indicate the possibility of wind power expansion in St. Thomas, which has the advantage of a relatively short distance from port infrastructure. None of these possible projects would be appropriate for distributed generation.

The additional possibility of distributed generation projects for wind is not determined, but the Government of Jamaica has expressed interest in an undetermined quantity of distributed wind generation for irrigation pumping.[161]

3.2.9 Solar Energy

Solar PV technology is mature, particularly monocrystalline and polycrystalline modules. Solar electricity however remains the most expensive renewable electricity options with levelised costs in Jamaica of US $0.26 - 0.31 per kWh[162] (through it is expected that prices will decline as competition and a worldwide glut of PV panels continue to drive prices down). Thin film and multi-junction technologies using non-silicon materials may improve efficiencies and can be deployed at the distributed generation scale. Nevertheless, current solar PV technology is substantially cheaper than the current utility supply in Jamaica (approximately US$ 0.40 / kWh), particularly for grid-tie systems as opposed to battery-backed systems. Megawatt scale systems pre-feasibility studies have shown favourable results for PV projects.[163]

The favourable economics is positively compounded by the generally high annual global horizontal irradiance in Jamaica, (GHI ranges from 5-8 kilowatt-hours per meter squared per day)[164] which is above the 90^{th} percentile worldwide.

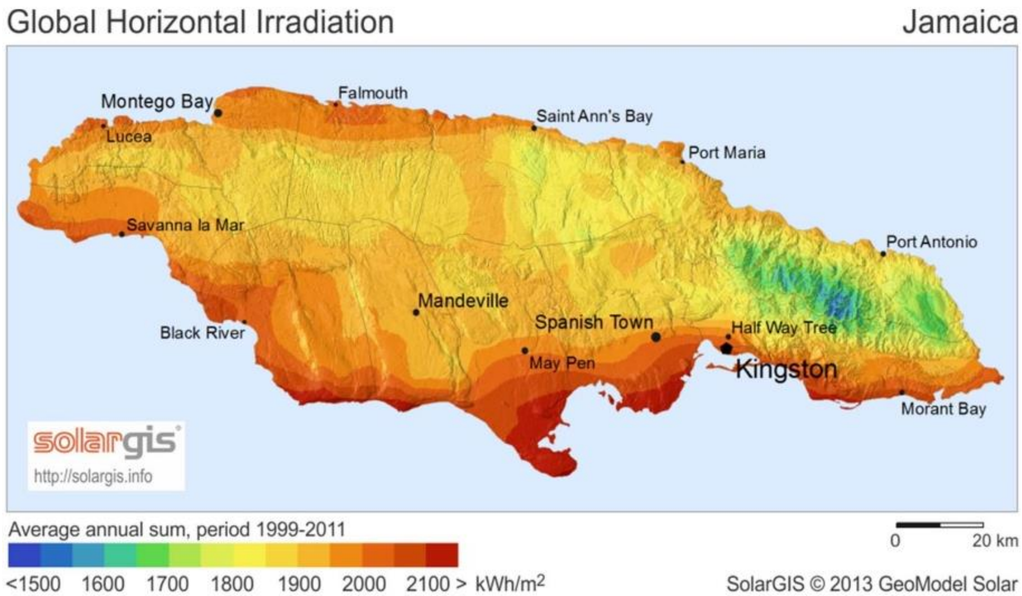
161 MSTEM. http://neich.gov.jm/node/48#overlay-context=node/47

162 OUR.“Request for Proposals for Supply of up to 115 MW of Electricity Generation Capacity from Renewable Energy Based Power Generation Facilities on a Build, Own and Operate (BOO) Basis.” 2012.

163 PCJ. “Feasibility study of solar PV facility for Portmore, Jamaica” 2012

164 World Watch Institute “Roadmap to a Sustainable Electricity System: Harnessing Jamaica’s Sustainable Energy Resources”, 2012.

Figure 45: Jamaica's Solar Potential



Source: Joint Research Center, 2013.

While the entire country has a very good solar resource, it is particularly strong in the southern half of the country. Nearly the entire region from Long Bay to Portland Blight has a GHI of at least 6.5 kWh/m^2/day. Also in the southern half of the country, Jamaica's most populous cities of Kingston, Portmore, and Spanish Town are all located in regions with a GHI that ranges from 6 - 8 kWh/m^2/day. The northwest of Jamaica also has a strong solar resource, as the GHI ranges from 6 - 8 kWh/m^2/day in and around Montego Bay. The only region that has a relatively low GHI (4 - 5 kWh/m^2/day) is in the east, just south of Port Antonio. This region has a very low population density, however, and its solar resource could still be used for off-grid generation.

While GHI is generally high island-wide, direct normal irradiance (DNI) is much lower due to atmospheric moisture, averaging 4 - 5 kWh/m^2/day. DNI is radiation that comes in a straight line from the sun to the measurement point, while GHI is the sum of this direct irradiance and diffuse irradiance that comes indirectly from the sun (for example radiation scattered by the atmosphere and clouds). Jamaica experiences humidity and cloud cover that lowers DNI, which negatively affects concentrated solar power installations.

Concentrated Solar Power (CSP) has yet to be demonstrated at a scale appropriate for Jamaica, but small-scale CSP projects using organic Rankine cycle generators are nearing the demonstration stage, with 3M and Gossamer Technologies nearing completion of a 10.5 MW plant in Louisiana, USA. The organic working fluid and the large trough aperture of this demonstration system may be able to overcome the low DNI values in Jamaica.[165]

Figure 46: Concentrated Solar Power

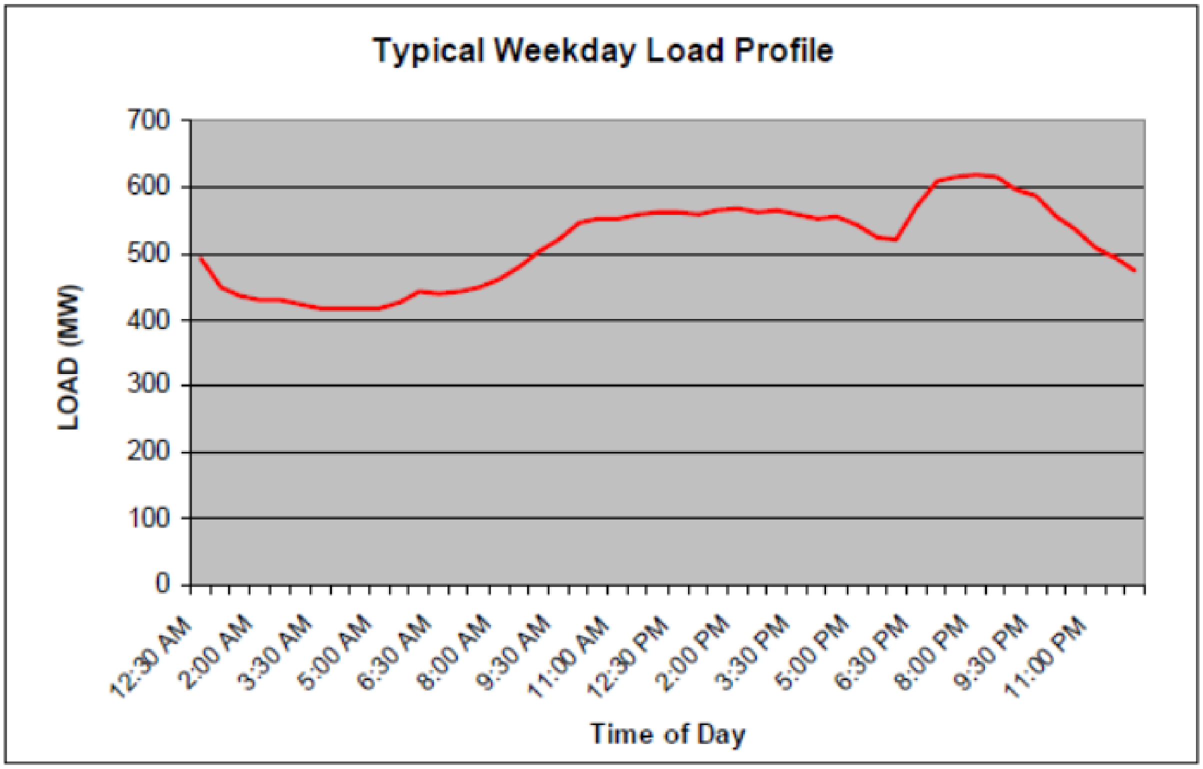
(Source: http://www.greenissexy.tv/wp-content/uploads/2012/10/Concentrated-solar-power.jpg)

The availability of solar energy corresponds well with the incidence of daytime electricity load.[166]

Figure 47: Jamaica's Daytime Electricity Load Profile

165 Proceedings of IEC TC82/WG2 Biannual Meeting, Montego Bay, Jamaica, May 2013. "Concentrated Solar Power (CSP) for Jamaica" Dr. Harold Creel, 3M.

166 OUR "Generation Expansion Plan 2010".



(Source: OUR 2010 Generation Expansion Plan)

Additionally, the even distribution of the solar energy resource across Jamaica and the modularity of PV installations make solar energy an appropriate technological choice for distributed generation especially in commercial offices with primary daytime lighting and cooling demands.

Electricity generation from solar technologies is, while not the largest contributor to renewable electricity generation is certainly one of the more visible sets of technology options in the Jamaican energy sector. To date there has been significant interest in renewable energy technology application and solar in particular, The Petroleum Corporation of Jamaica (PCJ) estimates that there are close to 300 kW of residential and small commercial solar photovoltaic (PV) capacity in Jamaica today, however with the advent of the Net Billing Policy, the number of onsite distributed commercial enterprises and residential systems would increase this capacity to > 800 KW by Q4-2013. The PCJ itself is a developer, having installed PV modules on hospitals, schools and some light posts driven by small commercial and residential interests. For example, poultry farmers contracted by the Jamaica Broilers Group Ltd (JBGL) have been implementing onsite distributed generation PV to reduce the cost of production by reducing the cost of energy. The project, valued at US$ 10 million seeks to introduce energy-saving devices such as LED lamps, or light-emitting diodes, as a source of light, as well as solar photovoltaic systems, on chicken farms throughout the Jamaica Broiler's supply chain.

Over a 2-year period an estimated 50 farmers will implement PV systems from 10-kW to 30 KW or more (potentially 600 kW to > 1,200 kW). More recently it has been estimated there may be over 400 kW of residential PV and in excess of 1,000 kW of Commercial PV making up < 1% of the country's annual energy demand using solar energy. An additional 1.5 – 2 MW may be added by 2014 from onsite distributed commercial generation on commercial farms utilizing the Net Billing Policy.

The US$ 10 million funding for the project will be financed by the Development Bank of Jamaica (DBJ) through the PanCaribbean Bank at 8.5 percent interest with a payback period of five to six years. The current phase of the Jamaica Broilers Group Ltd solar project is aimed at supplying energy for daytime use at the chicken farms. Grid access is still necessary however farmers will expand their systems to supply the grid under a Net Billing Policy to further reducing the company's electricity expenses. This commercial entry into distributed PV generation is part of the current trend related to cost saving and revenue raising efforts.

Several local entrepreneurs have entered the renewable energy space, primarily as providers and installers of solar PV and water heating technologies. The Jamaica Solar Energy Association (JSEA), an industry lobby group, has approximately 75 corporate and individual members up from approximately 30 members in 2011/2012. There is substantial popular support for "going solar"[167],[168]. This has been facilitated by regulator changes. Since 2011 a new distributed generation opportunity was implemented via a Government of Jamaica Net Billing regulation. This regulatory regime allows renewable energy self-generators below 100 KW capacity to interconnect to the utility grid and sell excess power (as available) to JPS at a rate equal to the avoided cost of fuel plus a 15% bonus. Case studies and modeling by the PCJ has shown that Net Billing increases the return on investment for a solar installation by 3-10%.

Of 48 licensed for grid-connected distributed generation facilities under the Government of Jamaica's Net Billing programme, 46 designs include solar photovoltaic (PV) technologies. The over 100 applications to date would have an aggregate capacity of more than 1.1 MW if implemented. The Office of Utilities Regulation has set an aggregate capacity cap of 2% of peak demand or approximately 12 MW for Net Billing customers. This cap is in place until May 2014, when the results of the Net Billing programme will be reviewed.[169]

Government policy has been supportive of solar PV development both small-scale onsite generation and utility scale. In addition to the Net Billing arrangements, the current tax policy has been to remove customs duties and value added taxes on solar panels, inverters, and related equipment (e.g. DC cables, connectors, junction boxes etc.). Solar developers are also members of the Jamaica Energy Council, a ministerial advisory

167 Jamaica Observer, "Solar Power Comes of Age", April 11, 2012.
168 Jamaica Gleaner, "Do More to Capitalise on Solar Availability", July 12 2012.
169 OUR. "Jamaica Public Service Company Limited Standard Offer Contract for the Purchase of As-Available Intermittent Energy from Renewable Energy Facilities up to 100 kW Revised Determination Notice" 2012.

group, and the Ministry of Science, Technology, Energy and Mining and Bureau of Standards consult with the Jamaica Solar Energy Association regularly through standing meetings.

Despite this Government support and the clear interest in the Net Billing, the programme has not had the expected uptake. Only one grid-tie solar installation has been connected under the Net Billing programme, despite the many licenses issued and applications received. Among the main issues for the low uptake of the Net Billing programme were coordination between State agencies; protracted delays in safety inspections at installations; approvals by the utility; inspection requirements by the Bureau of Standards Jamaica and Government Electrical Inspectorate; securing affordable insurance for Net Billing applicants (which is new to the insurance industry); and a lack of technical capacity among local developers. Reforms to date include a simplification of the application process, a waiver of the insurance requirement for installations below 10 kW, and a lowering of the programme fees.

Tables 61: Status of the Net Billing Programme

Net Billing Report - RSC			
Last updated 5-Apr-13			
CATEGORY	**TOTALS**	**COMMERCIAL**	**RESIDENTIAL**
Applications Received by JPS	103	55	48
Applications Accepted	103	55	48
Applications Rejected	0	0	0
Inspections	56	19	37
License Granted by MSTEM	42	10	32
License Not Granted by MSTEM	61	45	16
Commissioning and Connection	2	1	1
Contracts Executed	10	2	8
O.U.R. License Fees Collected	N/A (JPS does not collect license fees)	N/A (JPS does not collect license fees)	N/A (JPS does not collect license fees)
Total kW connected	6.0	2.4	3.6
Total kW of applications	1161.75	870.09	291.66

Source: Jamaica Energy Council

Table 62: Challenges in the Net Billing Process and Actions Taken.

Challenges	Mitigating Action
Inspection and resource challenges JPS for this new and additional requirement.	Improvement by JPS to accelerate the inspection process.
Documentation and technical drawings from applicants not up to required standard for some applicants.	JPS has prepared standard drawing templates for dissemination.
Various registration challenges to potential clients of the SOC.	Various stakeholders meeting including MSTEM, OUR, JPS, GEI, JSEA and others.

Source: Jamaica Energy Council

Nevertheless, only one grid-tie solar installation was connected under the Net Billing programme up to Q1-2013.

Besides private sector and residential applications of solar the Government of Jamaica is seeking to use renewable to supply onsite power where possible at its key agencies. The National Water Commission (NWC) is to pursue the use of renewable energy in its island-wide supply locations (unspecified) as a means of reducing its high-energy cost. Onsite photovoltaic power generation is being considered at various sites for pumping water into storage tanks then gravity feeding to communities at lower altitudes. Power wheeling is also being considered for supplying power from new hydropower sources and wind energy from the Wigton Wind Farm in Manchester to multiple NWC sites. If these prospects are viable, NWC may be able to replace over 300 inefficient pumps. The NWC's objective is to achieve a 30% reduction in energy costs over the next five years as it is currently consumes on average 16 million kWh/month almost 200 million kWh per annum and approximately 5% of the electricity generated by JPS[170].

Academia has also considered the use of solar PV for power and training. The JPS and the University of Technology have signed a Memorandum of Understanding On October

[170] Energy Efficiency Potential in Jamaica: Challenges, Opportunities, and Strategies for Implementation. UN ECLAC, Federal Ministry for Economic Cooperation and Development, Ministry of Energy and Mining of Jamaica and GiZ. 2011.

2012 to install 100 kW of PV. Students are expected to design and install the system. The system should be installed by end-2013.[171]

Government plans to diversify utility scale electricity generation sources and lower electricity prices over the medium to long term will have an effect on the competitiveness of solar generation versus available conventional generation, but it is unlikely that this will render PV uncompetitive within the next 5 - 8 years, which is the typical payback period on investment in Jamaica. Residential payback is estimated for systems at 5 – 10 years for US$ 3/W of investment and US$ 4/W for investments

Financing remains problematic for solar developers and entrepreneurs despite these favourable natural and economic conditions towards a positive growth trend. Current collateralization rules, loan periods (generally 7 years or less) and interest rates at various banks (From 8.5% up to 14%) make financing solar projects challenging at the distributed generation scale, especially for smaller systems. It remains to be seen whether utility scale solar will be bankable in Jamaica as it is anticipated that solar PV will be the highest cost utility-scale technology option and thus uncompetitive.

As at June 2013, the Office of Utilities Regulation (OUR) received twenty (20) interested entities who submitted proposals to supply renewable energy electricity generation of greater than 100 kW and up to 115 MW to the national grid. The bids, which were tendered by both local and international entities, included twenty eight proposals from these 20 companies, with two proposals received for wind (24 and 43 MW), one for biomass (30.98 MW) and 25 for solar energy (ranging 10 -115 MW; typical were the 20 MW and 25 MW systems). The actual technologies proposed have not yet been revealed. Eight of the proposals were received from local companies. Evaluation of the proposals will be completed by August 5, 2013[172]. The OUR set the maximum price of PV power from the RFP at US $ 0.2673 / kWh.

Jamaica's National Energy Policy (NEP) 2009-2030, identifies fuel diversification and the development of the country's renewable energy sources as two of its main objectives. The request for renewable electrical energy and/or capacity from renewable sources is in keeping with the Government of Jamaica's (GOJ's) vision of having 12.5% electrical energy from renewable energy sources by 2015 as set out in the NEP 2009-2030 and the draft National Renewable Energy Policy (NREP) 2010-2030. Based on the projected centralized system configuration for 2015 in conjunction with the NEP, 115 MW capacity from renewable energy sources is required to be commissioned by 2015 to mid-2016, which was the subject of the Request for Proposals (RFP).

The Jamaican Government has set a target of 30% of electricity generation from renewable resources by 2030 on and off grid. Preliminary studies by MSTEM indicate that this target will likely be met with substantial wind and solar energy investments, given the comparatively limited availability of biomass, waste and hydroelectric resources. The upper technical limit of the grid to absorb these intermittent resources is not yet clear;

[171] http://www.jpsco.com/
172OUR Media Advisory 4 June 2013.

MSTEM is undertaking a grid study to clarify the ability of the grid to accept large amounts of renewable electricity and that will be concluded in late 2013. The current capacity cap for interconnect of DG below 100 kW is approximately 12.8 MW, as set by the OUR.[173]

Solar PV installations can last for decades in some conditions. However, there are a number of mitigating factors that make the assumption untrue for Jamaica. Environmental conditions such as high humidity, high ambient temperatures, salt spray, high UV irradiance, and high seasonal wind loading result in accelerated aging and higher than expected rates of performance degradation and catastrophic failure compared to similar installations in drier or more temperate climates.

Recognizing this, the International Electro-technical Commission (IEC, an international standards body) and associated standards and testing bodies are developing standards for PV module manufacture, durability, and performance under a wider variety of environmental conditions than have been heretofore contemplated under IEC and other standards. Work is nearing completion on these standards, which will be generally numbered IEC62XXX.[174] Addressing the issues of standards and durability may help to mitigate the financing difficulties by providing for greater confidence on the part of financiers.

The most likely solar energy projects above the scale of distributed generation include those projects currently under evaluation by the OUR. Of 28 proposed projects as of June 2013, 25 were for solar photovoltaic projects with capacities of over 20 MW. It is not determined where these projects may be, but given the evenness of the solar resource in Jamaica, these projects may only be limited by grid interconnectivity.

On the distributed generation scale, small-scale onsite generation projects for households and businesses (< 1 kW to 100 kW) will continue to proliferate rapidly under the Net Billing programme. Inasmuch as an interconnection framework already exists for these projects, these are limited only by the appetite of the investors.

With respect to larger projects for distributed generation on the megawatt scale, the PCJ has established the feasibility of a 1 MW photovoltaic project near Portmore, St. Catherine.

3.2.10 Nuclear Energy

The primary barriers to the deployment of nuclear energy are regulatory. Jamaica is a signatory to the Treaty on the Non-Proliferation of Nuclear Weapons, which commits it to stringent regulatory steps under the oversight of the International Atomic Energy Agency (IAEA) before the deployment of nuclear energy. The development of a nuclear power programme entails attention to many complex and interrelated issues over a long duration, particularly with respect to grid infrastructure, fuel inventory management,

173OUR "Standard Offer Contract (SOC) for the Purchase of As-Available Intermittent Energy from Renewable Energy Facilities up to 100 kW Determination Notice" (2012). The cap is set at 2% of peak demand.

174Proceedings of IEC TC82/WG2 Biannual Meeting, Montego Bay, Jamaica, May 2013.

safety, waste disposal and other issues that require legislative and regulatory action. The introduction of a nuclear power programme involves a commitment of at least 100 years to maintain a sustainable national infrastructure throughout operation, decommissioning, and waste disposal.175 Jamaica does not have the technical expertise or experience in any of these areas. There are no currently applied waste disposal methodologies. For a country like Jamaica with no prior technical expertise in nuclear power generation or in waste disposal beyond the research scale, the implementation of a commercial nuclear power plant may take about 15 years.

This long development period makes financing and executing nuclear projects difficult, particularly when no financial backing from the state is available. The long time frame for plant development makes financing costs and escalation hard to estimate, but MIT estimated and overnight cost of $ 4 / W ; cost estimates vary widely, and the slowdown of nuclear development and frequent cost overruns make many projections moot.[176] Price projections are generally made in the context of countries with a fully functional nuclear regulatory environment, which Jamaica does not have.

Nuclear technology is generally implemented on a very large scale. "Small" nuclear plants are under 300 MW, which is about half of Jamaica's current demand. Ship-bound small units are typically larger than 100 MW. Small modular reactors (SMRs) under 25 MW are currently available for research purposes, but not for commercial applications; commercial nuclear reactors remain much larger.[177]

Given the size of these units, the requirements of the regulator for tender of generation capacity above 15 MW[178], the need of the utility company to cap the size of individual generators for system stability purposes in the case of generator tripping[179], and the existing capacity of the transmission infrastructure, nuclear power is not suitable for distributed generation. Any additions of nuclear power, regulatory hurdles notwithstanding, would have to be executed on a centralized basis. The long development time frames and regulatory commitments would necessitate substantial Government involvement and investment, which may not be contemplated under Jamaica's current agreements the International Monetary Fund and other international financiers.

Table 63: Small (25 MWe up) Reactors Operating (Source: World Nuclear Association)

Name	Capacity	Developer
CNP-300	300 MWe	CNNC, operational in Pakistan

[175]IAEA "Milestones in the Development of a National Infrastructure for Nuclear Power", 2007

[176]John M. Deutch et al. (2009). Update of the MIT 2003 Future of Nuclear Power Study (PDF).Massachusetts Institute of Technology.

[177]World Nuclear Association. "Small Nuclear Reactors". http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Small-Nuclear-Power-Reactors/

[178]OUR. "Guidelines for the Addition of Generating Capacity to the Public Electricity Supply System: June 2006."

[179]JPS. "JPS Transmission Network - Interconnection Criteria." 2010.

PHWR-220	220 MWe	NPCIL, India

Source: World Nuclear Association

Table 64: Small (25 MWe up) Reactor Designs Under Construction

Name	Capacity	Developer
KLT-40S	35 MWe	OKBM, Russia
CAREM	27 MWe	CNEA & INVAP, Argentina
HTR-PM	2x105 MWe	INET and Huaneng, China

Source: World Nuclear Association

Table 65: Small (25 MWe up) Reactors for Near-Term Deployment – Well Advanced Developments.

Name	Capacity	Developer
VBER-300	300 MWe	OKBM, Russia
IRIS	100-335 MWe	Westinghouse-led, international
Westinghouse SMR	200 MWe	Westinghouse, USA
MPower	150-180 MWe	Babcock & Wilcox + Bechtel, USA
SMR-160	160 MWe	Holtec, USA
SMART	100 MWe	KAERI, South Korea
NuScale	45 MWe	NuScale Power + Fluor, USA
Prism	311 MWe	GE-Hitachi, USA
BREST	300 MWe	RDIPE, Russia
SVBR-100	100 MWe	AKME-engineering, Russia

Source: World Nuclear Association

Figure 48: Small Modular Nuclear Reactor (SMR)

Source: Babcock and Wilcox 2011.

Regarding health and safety issues and human risk, the required expanse of sterile areas in the event of an incident may challenge the use of nuclear. In the Fukushima Daiichi nuclear disaster in 2011, the Japanese authorities implementing 20 km exclusion zone around the power plant, and the continued displacement of approximately 156,000 people as of early 2013. 20 years after the Chernobyl accident - the Chernobyl exclusion zone maintains a 30-kilometer zone. The exclusion zone covers an area of approximately 2,600 km. The 25th anniversary of Chernobyl and the continuing crisis at Fukushima - both Level 7 nuclear disasters - are clear reminders that standard evacuation zones in any case cannot protect the public from a nuclear accident. Current USA regulations stipulate a 10-mile evacuation zone around nuclear plants. This was deemed insufficient and 50 miles has since been recommended[180].

Similar accident in Jamaica would mean approximately half the width of Jamaica (> 84 km wide) would be considered part of this evacuation zone. There have been discussions about placing nuclear generator on one of the marine cays however this is also unlikely as the cays are protected or considered sensitive and valued ecosystems. Usually nuclear plants have very compact sites of 500 to 1,000 acres including the exclusion area around the plant.

In addition the long durations for restoration of normalcy due to air, land and ground water contamination from nuclear materials is also a major deterrent on a small island state.

It is unlikely that nuclear power will be deployed in Jamaica within the next decade, and if so, not for distributed generation.

180 Physicians For Social Responsibility - Http://www.psr.org/

4 ECONOMIC ANALYSIS OF CONVENTIONAL AND DISTRIBUTED GENERATION TECHNOLOGIES.

4.1 Current State of Generation in Jamaica

Jamaica employs a variety of generation capacities that are owned by both Independent Power Producers (IPPs) and the public utility, JPS (See Table below). There are also a number of self-producers of electricity in the country, with the largest being the bauxite alumina companies and the sugar refineries.

Approximately 27 MW is from renewable sources – predominantly wind and hydro. The balance is produced from approximately 855.4 MW of net output is from liquid fossil fuel sources – HFO and ADO. Existing capacity of fossil fuel generation is in excess of 30 years old and must be retired. The future economics of generation in Jamaica will therefore strongly influenced by the technology and fuel employed.

Jamaica's peak demand (OUR RFP for 115 MW of base load capacity) is 644 MW and average base load demand of 477 MW.

Table 66: Power Plants in Jamaica 2013.

List of Plants By Location							
Item	Plants	Location	Name Plate Capacity (MW)	Net Output (MW)	Technology	In Service Date	Scheduled Retirement

A	**Kingston**				**Fossil Fuel**		
1	B6	Hunts Bay	68.5	65.1	Oil Fired Steam	1976	2012/2014
2	GT-4	Hunt's Bay	22.8	0	Combustion Turbine	1974	2012/2014
3	GT-5	Hunt's Bay	22.5	21.4	Combustion Turbine	1974	2012/2014
4	GT-10	Hunt's Bay	33	32.1	Combustion Turbine	1993	
5	RF-1	Rockfort	20	17.3	Slow Speed Diesel	1985	
6	RF-2	Rockfort	20	17.3	Slow Speed Diesel	1985	
7	JPPC (IPP)	Rockfort	60	60	Slow Speed Diesel	0	2018
8	JEP-3 (IPP)	Hunt's Bay	66	60	Medium Speed	2012	
	Subtotal		**312.8**	**273.2**			
B	**Old Harbour**						
9	OH-1	Old Harbour	33	28.5	Oil Fired Steam	1968	2012/2014
10	OH-2	Old Harbour	60	57	Oil Fired Steam	1970	2012/2014
11	OH-3	Old Harbour	68.5	61.8	Oil Fired Steam	1972	2015
12	OH-4	Old Harbour	68.5	65.1	Oil Fired Steam	1973	2015
13	JEP-1 (IPP)	Old harbour	73	124.2	Medium Speed		
14	JEP-2 (IPP)	Old harbour	51.2	0	Medium Speed		
15	Jamalco (IPP)	Halse Hall	11	11	0		
	Subtotal		**365.2**	**347.6**			
C	**Montego Bay**				**Fossil Fuel**		
16	GT-3	Bogue	22.8	21.4	Combustion Turbine	1973	2012/2014
17	GT-6	Bogue	18.5	13.9	Combustion	1990	

					Turbine		
18	GT-7	Bogue	18.5	13.9	Combustion Turbine	1990	
19	GT-8	Bogue	16.5	13.9	Combustion Turbine	1992	
20	GT-9	Bogue	20.5	19.9	Combustion Turbine	1992	
21	GT-11	Bogue	20	20	Combustion Turbine	2001	
22	GT-12	Bogue	40	38	Combined Cycle	2002	
23	GT-13	Bogue	40	38	Combined Cycle	2002	
24	ST-14	Bogue	40	38	Steam (CC)	2003	
	Subtotal		**236.8**	**217**			
D	**Various Locations**				**Renewables**		
25	JPS Hydro	Various	23	20.4	Hydro	0	
26	Wigton	St. Elizabeth	20	7	Wind Turbines	0	
27	JPS	St. Elizabeth	0	0	Wind Turbines	0	
	Subtotal		**43**	**27.4**			
	Grand Total		**957.8**	**865.2**			

4.2 Main Pathways in Improving the Cost of Electricity in Jamaica

To improve its competitiveness and to stimulate GDP growth, Jamaica must reduce the cost of energy. Critical to the path of reduction in the cost for electricity generation is the replacement of the existing old and inefficient generating capacity. Most new diesel or gas turbine technology will be almost twice as efficient as the oldest block of power (292 MW) on the JPS grid. By virtue of this technology change, using the existing fuel, Jamaica can realize a 20% reduction in the cost of energy. The switch to natural gas in the form of LNG is also proposed as a critical component in the long-term reduction in electricity cost. Migrating to LNG, will realize another 5% reduction. In this context LNG as a transitional fuel is an important fuel diversification strategy and will also reduce Jamaica's Carbon Footprint.

Both the replacement of old fossil fuel generation (HFO and ADO) and the introduction of natural gas are embedded in the National Energy Policy and Vision 2030.

This analysis of Jamaica's economic cost for generation will serve to compare the available technologies, their economics and ultimate impact on energy price.

4.3 Technology Review:

The technologies as outlined below are available today at competitive prices in their respective categories. Any solution to Jamaica's energy crisis must include generating capacity from renewable source to attain fuel diversification and reduction in Jamaica's oil import bill.

The technologies being evaluated include:

1. Combined Cycle Gas Turbine.
2. Dual Fuel Reciprocating Technology.
3. Coal.
4. Petcoke.
5. Renewable Energy.

a. Wind.
b. Biomass.
c. Solar.
d. Hydro.
e. Waste-to-Energy.

Table 67: Comparison of Characteristics of New Generation Plants.

Technology / Fuel	Minimum Economic Capacity for Grid Scale	Efficiency in Size Range	[181]Required Real Estate for Construction	[182]Time to Construct (Size Range)	Dual Fuel (LNG / HFO)
Gas Turbines[183]	> 70 MW	40% to 60%	5 to 20 acres	2 to 3 years	Yes
Reciprocating	>20 MW	38% to 45%	> 5 acres	12 to 18 mths	Yes
Coal	> 50 MW	25% to 35%	20+ acres	4 to 6 years	NA
Petcoke	> 50 MW	25% to 35%	5 to 10 acres	3 to 4 years	NA
Wind	> 1 MW	NA	<1 acre/MW	1 to 2 years	NA
Biomass[184]	> 5 MW	25% to 35%	5 to 10 acres	2 years	Yes

[181] For nominal sized plant with fuel storage
[182] For average economic sized plants
[183]Combined Cycle Mode
[184]Dual fuel contemplates bagasse, wood chip, or other cellulostic fuel.

Solar	> 1 MW	NA	3 acres per MW	< 10 months	NA
Hydro	> 1 MW	NA	Average flow or high head	4 to 6 years	NA
Waste to Energy	> 1 MW	NA	1.5 acres per MW	18 to 24 months	NA

4.3.1 Combined Cycle Gas Turbine

4.3.1.1 Overview:

Combined cycle gas turbines are proven technology employed in power generation the world over. They are typically used for base load operations and for peaking support in the simple cycle mode. Efficiencies of Gas turbine technology vary from 25% in the simple cycle mode to up to 55% in the Combined Cycle mode under ISO conditions. However, at high ambient temperatures and high humidity, the performance of gas turbines deteriorate rapidly and the efficiencies could decrease significantly.

4.3.1.2 Economics:

Project cost averages US$ 2.2 M per MW and the price of energy averages US$ 0.16162 per kWh (Appendix 8).

4.3.1.3 Implementation Timelines:

This technology requires 24 to 36 months to implement.

4.3.1.4 Factors Which Will Impact Use of the Technology:

- Looses efficiency due to relatively high ambient temperature and humidity as is typical in Jamaica.
- Longer time to implement, and cannot be implemented unless LNG is in place.
- Limitations with fuel flexibility and will be costly if operated on its alternate fuel, Automotive Diesel Oil.
- Higher cost per MW to install.
- Minimum size of installed capacity limits their use in smaller markets, like the Caribbean islands.
- Not suited for distributed generation due to minimum economic size.
- Positively impact carbon footprint due to its efficiency.

4.3.2 Dual Fuel Reciprocating Combined Cycle Gas Turbine

4.3.2.1 Overview:

Reciprocating technology is proven technology and dominates the region for power generation. They are used extensively for base load operations in tropical climates. Efficiencies of varies from 35% in the simple cycle mode to up to 46% in the Combined Cycle mode under a wide range of temperature and humidity conditions.

4.3.2.2 Economics:

Project cost averages US$ 1.9 M per MW and the price of energy averages US$ 0.15567 per kWh. See Appendix 8.

4.3.2.3 Implementation Timeline:

This technology requires 18 to 24 months to implement.

4.3.2.4 Factors That Will Impact Use of the Technology:

- Remain efficient over wide range of temperature and humidity conditions.
- Can be quickly implemented.
- Fuel Flexibility, lending itself to fuel hedging.
- Moderate capital cost.
- Highly adaptable and flexible in small generation markets, like those in the Caribbean islands.
- Because of multi-engine configuration, and efficiency at varied output, it is great for grid stability with the erratic output of wind and solar technologies.
- Positively impact carbon footprint due to its efficiency and fuel flexibility.

4.3.3 Coal:

4.3.3.1 Overview:

Coal technology is among the oldest technology and most widely used for power generation globally. All developed nations either currently have or had extensive base load coal generating capacity. This is primarily due to the low cost of coal. However, it has the most deleterious effect on the environment. As such, this technology is being both displaced and replaced with gas fired and renewable technology.

4.3.3.2 Economics:

Project cost averages US$ 3.5 M per MW. The price of energy there averages less than 11.5 US cents per kWh.

4.3.3.3 Implementation Timeline:

Implementation time ranges from 4 to 6 years

4.3.3.4 Factors That Will Impact Use of the Technology.

- Remain efficient over wide range of temperature and humidity conditions.
- Among all technologies, this takes the longest time to implement.
- Single Fuel.
- High capital and operating costs, but low fuel cost.
- Requires large blocks to be economic. As such, not suitable for use in small generation markets, like those in the Caribbean islands.
- Based on minimum economic size, not suited for distributed generation.
- Has the most deleterious impact on the environment.

4.3.4 Petcoke:

4.3.4.1 Overview:

Widely used in countries with petroleum refinery as it is a by-product of the process. This has similar attributes of coal technology, in that they both use steam turbines driven by a steam boiler.

4.3.4.2 Economics:

Capital costs average US$ 3 M per MW. The price of energy will average 10.165 US cents per kWh.

4.3.4.3 Implementation Timeline:

3 to 4 year implementation schedule is typical.

4.3.4.4 Factors That Will Impact Use of the Technology:

- Remain efficient over wide range of temperature and humidity conditions.
- Moderate implementation timeline.
- Could use coal as alternate fuel but with added infrastructure.

- High capital and operating costs.
- Can be implemented in smaller blocks.
- Based on minimum economic size, not well suited for distributed generation.
- Though higher than some competing technologies, has a somewhat balanced impact on the environment.

4.3.5 Renewable Energy – Wind:

4.3.5.1 Overview:

Wind turbine technology, is the most widely employed in the region as it was the most developed RE technology on the market. This is changing with the advent of inexpensive PV solar.

4.3.5.2 Economics:

Capital cost for this technology averages US$ 3.5 M per MW while Operating Cost averages US$ 0.039 per kWh. Effective levelized cost of energy from this technology averages US$ 0.1433 per kWh.

4.3.5.3 Implementation Time-line:

Timeline for Project Implementation ranges from 18 to 24 months.

4.3.5.4 Factors that will Impact use of Technology:

- Not impacted by temperature and humidity conditions of the region.
- Moderate implementation timeline.
- Renewable Source so no fossil fuel input.
- Relatively low capital cost today, and low operating costs.
- Great for distributed generation and grid balance provided that adequate site is available.
- No emissions hence great for the environment.

Table 68: Existing, Planned and Potential Wind Capacity

Wind Energy	Owner	Capacity 2011 (MW)	Capacity Factor (%)	Generation (MWh)
Existing				
Wigton I	WWF	20.7	0.3	54,400

Wigton II	WWF	18	0.3	47,304
Munro	JPS Co	3	0.3	7,884
	Total	**41.7**	0.3	**109,588**
Planned				
Wigton III	WWF	28	0.3	73,584
Delta Nu Plant		24	0.3	63,072
Munro Expansion	JPS Co	20	0.3	52,560
	Total	**72**	0.3	**189,216**
Additional Potential	***Total***	**70.3**	0.3	**184,748**
	TOTAL	**184**	0.3	**483,552**

Table 69: Wind Projected Generation and Attainable Installed Capacity By 2030

	Real	**Forecast**			
Wind Energy	**2011**	**2015**	**2020**	**2025**	**2030**
Generation (MWh)	109,588	298,804	386,842	483,552	822,038
Capacity (MW)	41.7	114	147	184	313
Realised Potential	23%	62%	80%	100%	170%

4.3.6 Renewable Energy – Biomass:

4.3.6.1 Overview:

This technology is well suited for the sugar industry, this industry generating its own fuel (bagasse) as a by-product of its process. Size is limited to 3 to 10 MW due to limited amount of "year-round" fuel. Two technologies are widely used – mass burn and gasification with the latter being the more expensive, but with less emission.

4.3.6.2 Economics:

Capital cost for this technology averages US$ 2.5 M per MW while Operating Cost averages US$ 0.06 per kWh. Effective levelized cost of energy from this technology averages US$ 0.174 per kWh.

4.3.6.3 Implementation Time-line:

This technology can be implemented within 18 to 24 months.

4.3.6.4 Factors that will Impact use of Technology:

- High rainfall during the crop season impacts the fibre content of the sugar cane, hence the amount of fuel available
- Moisture content of bagasse will have a significant impact on fuel rate. Increased capex for fuel drier is required to attain low moisture content.
- Moderate implementation timeline.
- Renewable Source so no fossil fuel input.
- Relatively low capital cost today, and low operating costs.
- By virtue of the locations of the various sugar mills around the island, distributed generation can be attained if this technology is implemented at the more significant sugar mills around the island.
- Nuisance dust from bagasse handling contributes negatively to the environment. Emissions can be contained via emissions abatement equipment. Overall, the offset from savings to be derived from not using fossil fuel to generate energy balances the environmental impact.

Table 70: Bagasse Installed Capacity and Estimated Extra Electricity Generation Potential – Feasible Approach

Bagasse		Capacity MW (2011)	Capacity Factor	Generation (MWh)
Additional Potential				
Golden Grove		4	28%	9,867
Everglades		2	31%	5,481
Appleton		8	53%	37,261
Worthy Park		4	41%	14,207
Frome		6	32%	16,815
Monymusk		11	32%	30,974
	Total	**35**	37%	**114,605**
	TOTAL	**41**		**134,052**

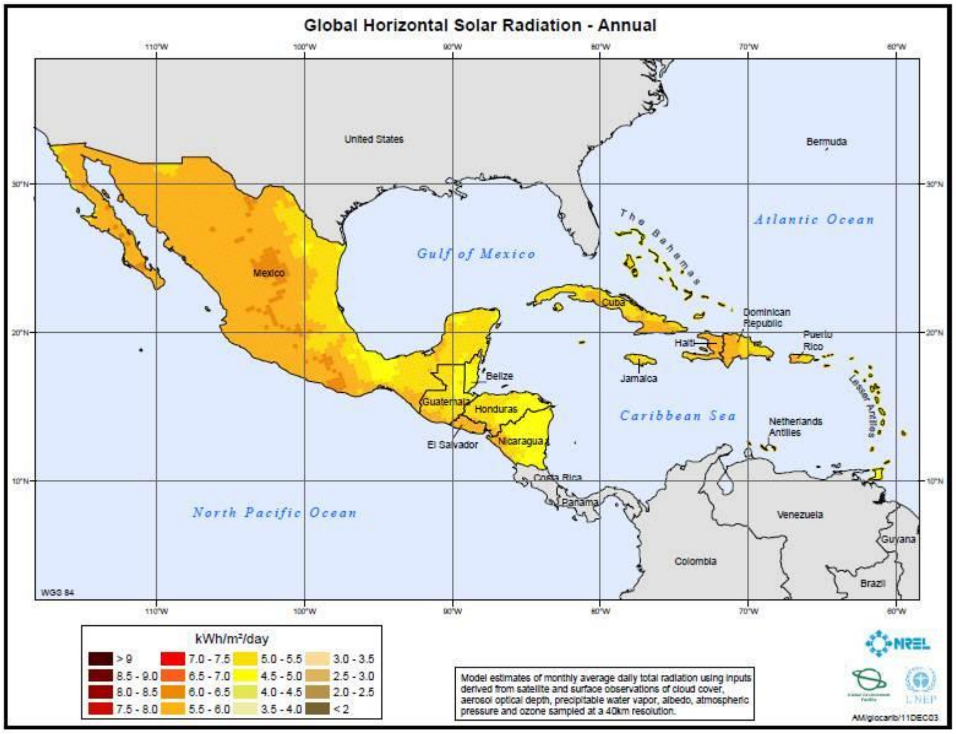
Source: Landell Mills, 2011

4.3.7 Renewable Energy – Solar

4.3.7.1 Overview:

By virtue of the rapidly declining price per MW, PV Solar technology is becoming the renewable energy of choice in regions where average annual irradiation is acceptable. Jamaica receives above average irradiation.

Figure 49: Solar Irradiance



4.3.7.2 Economics:

Capital cost for solar energy now averages US$ 2.9 M per MW and operating costs remain a low US$ 0.189 cents per kWh.

4.3.7.3 Implementation Time-Line

PV Solar technology up to 50 MW can be fully deployed in less than 12 months.

4.3.7.4 Factors that will Impact use of Technology:

- Marginally impacted by temperature and humidity. However, with cloud cover, it produces only limited power.
- Can be quickly implemented.
- Renewable Source so no fossil fuel input.
- Relatively low capital cost today, and low operating costs.
- Great for distributed generation and grid balance provided that adequate site is available.
- Requires significant real estate – 3.5 acres per MW)
- No emissions hence great for the environment.

4.3.8 Renewable Energy – Hydro:

4.3.8.1 Overview:

Hydro power is a very mature renewable energy technology and it is widely employed globally. Jamaica has been using this technology albeit on a small scale for over 30 years. Potential for up to an additional 100 MW of hydro power exist in Jamaica.

Table 71: Hydropower Estimated Available Potential (CERE/PCJ)

Additional Potential	Capacity 2011 (MW)	Capacity Factor (%)	Generation (MWh)
Back Rio Grande	28	0.6	147,168
Great river	8	0.6	42,048
Green River	1.4	0.6	7,358
Laughlands Great River	2	0.6	10,512
Martha Brae River	4.8	0.6	25,229
Morgan's River	2.3	0.6	12,089
Negro River	1	0.6	5,256
Rio Cobre	1	0.6	5,256
Spanish River	2.5	0.6	13,140
Wild Cane River	2.5	0.6	13,140
TOTAL	**53.5**		**281,196**

Source: CERE/PCJ, 2012

4.3.8.2 Economics:

It is relatively expensive to be implemented and the CAPEX averages US$ 3.5 M to US$ 6 M per MW. OPEX is however relatively low at under US$ 0.09 cents per kWh. Levelized Cost of energy averages US$ 0.11 cents per kWh.

4.3.8.3 Implementation Time-line:

Due to the major infrastructural cost, implementation will take an average of 4 to 6 years.

4.3.8.4 Factors that will Impact use of Technology:

- Not impacted by temperature and humidity conditions of the region. Moderate rainfall improves consistency of output.
- Long time to implement.

- Renewable Source so no fossil fuel input.
- High capital cost, and low operating costs.
- By virtue of the location of the rivers around the island that can support Hydro power, they are great for distributed generation.
- No emissions hence great for the environment. However, due to occasional damming of some of the water resources, environmentalists usually object to the larger scale hydro project.

4.3.9 Renewable Energy – Waste to Energy:

4.3.9.1 Overview

Waste to Energy plants solves an environmental problem and produces a clean product, electricity. Unfortunately, by virtue of the complexity of the input costs and material handling, this technology, unless heavily subsidized is extremely difficult to implement. With the financial burdens of the Government of Jamaica, any subsidy in terms of tipping fees is an unreasonable expectation. It is therefore highly unlikely that such a project will be realized in the near term.

4.3.9.2 Economics:

Capital cost for a waste to energy plant averages US$ 3.5 M per MW and operating costs averages US$ 0.05 per kWh. Levelized Cost of energy will average US$ 0.18 cents per kWh.

4.3.9.3 Implementation Time-line:

A waste to Energy plant requires 24 to 36 months to be implemented.

4.3.9.4 Factors that will Impact use of Technology:

- Not impacted by temperature and humidity conditions of the region.
- Take a relatively long time to implement.
- Renewable Source so no fossil fuel input. However, for this technology to make economic sense, a tipping fee must be charged for the waste that goes into the plant. Waste disposal is a government service, it is not likely that a project could rely on such tipping fees for its viability.
- High capital cost, and high operating costs.
- By virtue of the location of the waste sites around the island that can support waste to energy plants, they could be suitable for distributed generation.

- No emissions hence great for the environment. However, due to occasional damming of some of the water resources, environmentalists usually object to the larger scale hydro project.

Table 72: Waste to Energy Planned and Potential Capacity If All Sites Were Developed

	Owner	Capacity 2011 (MW)	Capacity Factor (%)	Generation (MWh)
Waste to Energy				
Existing	***Total***	**0**		**0**
Planned				
Riverton		45	77%	301,563
Retirement		20	77%	134,028
	Total	**65**		**435,591**
Additional Potential	***Total***	**40**	85%	**297,840**
	TOTAL	**105**		**733,431**

Source: Own elaboration with data from CERE/PCJ

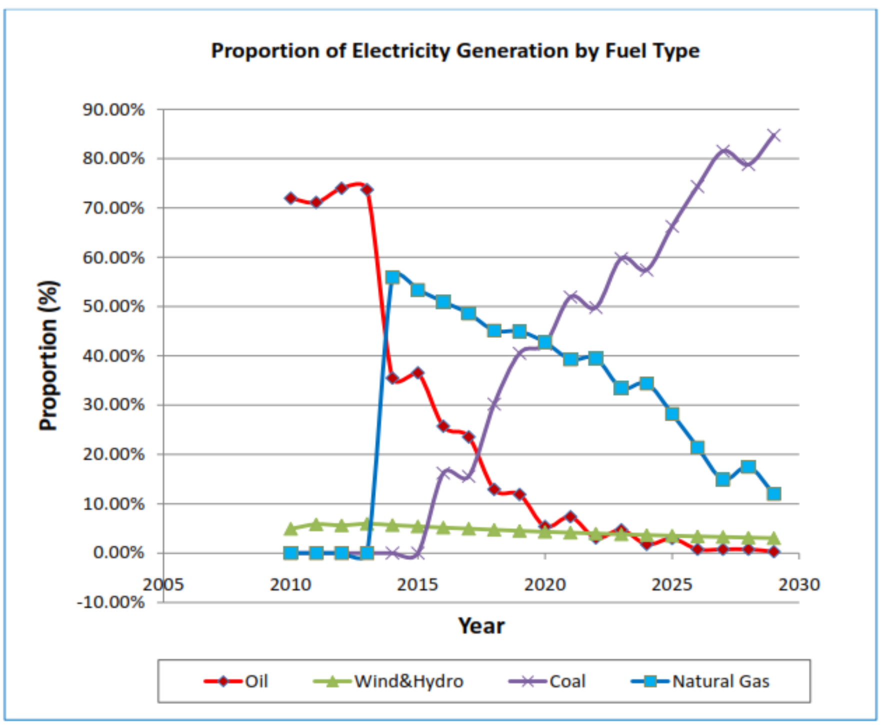
5 SUMMARY AND CONCLUSIONS:

Base load and distributed generation is urgently needed by 2014 and over the next 20 years to satisfy approximately 1,400 MW of demand. Fossil fuel options have been recommended by the Government of Jamaica and framed in various bid rounds by OUR. Based on recommended addition of new generation to the grid (using international bidding mechanisms) of at least 360 MW of Natural Gas-fired combined cycle, this capacity should be in place by 2015, however the fuels used will continue to be predominantly petroleum based until natural gas infrastructure is in place, however continuing generation based on petroleum is unsustainable and fuel diversification is critical. Once gas is introduced it will quickly become a significant fuel source by 2015, potentially displacing a significant amount of liquid petroleum.

Of the 360 MW in the 2013 bid process, 292 MW is urgently needed for the displacement of aged and inefficient generation capacity, to lower the heat rates (regarding greater efficiency) and reduce electricity costs for power delivered. New large central generation will also rapidly increase generation supply to meet the remainder for demand growth requirements. Approximately 800 MW of this new capacity needs to be constructed from a mix of technologies by 2020 highlighting the urgency of the issue. Ironically the success of more large-scale central generation will possibly also lead to a lower appetite for distributed generation options.

The summary of the projected transition is in the figure below:

Figure 50: Projection of Generation Mix in Jamaica until 2030.



Source: OUR Generation Expansion Plan 2010.

Though there is a rapidly growing trend towards renewables, mostly intermittent contributions, renewable energy will support the generation market and some of this will come from distributed generation depending on Policy Measures, financing and growth of the centralized grid supply from fossil fuels. If the full quota from the recent RfP for 115 MW renewable energy generation is applied, it has the potential for bringing the renewable market for grid supply close to saturation by 2016 and likely only smaller distributed generation will continue to have meaningful expansion in capacity for the future depending significantly on the price of electricity. Existing and proposed renewable energy and distributed generation plants have been incorporated in the expansion plan as reflected in the overall future annual generation of the system. It is likely renewables will contribute the most to new distributed generation plants and ultimately steering the electricity sector and country along a sustainable path, compatible with the goals of the national energy and environmental policies.

The optimal technology mix for the power generation sector of the future is the one that simultaneously reduces emission, fossil fuel consumption and the production cost of electricity. It is therefore apparent from this analysis that specific market and technology development conditions need to be met for these objectives to be accomplished at the same time. As a consequence, the policy maker or regulator must develop and implement the relevant strategies to influence the factors that define the evolution of power generation capacity. Importantly, the actions taken are essential towards new generation capacity investment decisions and thus, provide useful information to the market place. However, given the uncertainties and risks that may be involved, investment decisions related to new power plant projects must be carefully evaluated and analyzed with the background of all generation options including distributed generation.

Distributed generation in the Jamaican generation market (self-generation < 10 MW and not dispatched from the central grid) is at an early stage of development as the generation market was previously an established electrical monopoly under law. The National Energy Policy and other significant policy measures and legislative changes have successfully opened up the generation market to include firstly independent power providers, followed by the allowance for private generators to benefit economically and also to reduce onsite electricity costs via Net Billing. Though Net Billing is potentially the most significant policy initiative driving a rapid growth in distributed generation from solar PV (as much as 100 kW at some sites), the price of electricity for businesses and residential customers is also a current driving mechanism for addition of distributed generation sets. Solar PV is likely to be the fastest growing distributed generation option for the next decade.

If power wheeling is eventually implemented, it may catalyze the progressive liberalization of generation and the grid will be modernized sufficiently to allowing companies to send their power over the utility's central grid to their other facilities.

The trend toward distributed generation is primarily demonstrated by private solar installations, followed in numbers and impact by private wind installations. Both are facilitated by strong positive natural resource bases. Fossil fuel distributed generation is expressed primarily as standby diesel fired generation however there are large industrial, agro industry and large commercial customer who either generate all or some of their electrical demand using HFO or ADO fired generators. Generators may range from tens of kW to a few MW. Some of them sell power to the grid as available via a "dumped power" agreement at a discounted rate to the utility.

Newer mico-generation technologies are largely not applied in Jamaica as the next evolution of the distributed generation trend. Some have not yet emerged as commercially proven, while other technologies are fully deployed for use in other countries but may have higher costs when compared with traditional generation options and therefore are implemented under special conditions or used to meet specific customized objectives. Micro-recriprocating engines are already in use but it is likely that newer technologies such as micro turbines will eventually be utilized in Jamaica however perhaps not in the near-term. More innovative and complex technologies such as fuel cells would likely follow. Some technologies such as fuel-cells and some microturbines will also experience a delay in proliferation until Jamaica has natural gas delivered and infrastructure installed.

Micro generators will be critical for achieving reduced environmental impacts and overall improved heat rates; however some are not as efficient as conventional generation but can benefit from combined heat and power applications.

Distributed generation will however continue to experience some challenges in early proliferation as the Generation Expansion Plan 2010 is focused on adding large conventional generation to the centrals grid. Also a deterrent is that these technologies are often more expensive (contrary to the Energy Policy objective of reducing electricity costs), and are not well understood.

Considering the convenience and numerous benefits of distributed generation for private onsite generation, the grid and for incremental addition to the national generation sources, the favourable trend of proliferation will continue and should be encouraged. The current legislation and policies will continue to facilitate this positive change however other mechanisms including implementation of Wheeling, financial incentives, and the supply of natural gas will be critical for the next significant change in the trend towards increasing application of small decentralsied distributed generation.

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APPENDIX 1:

JAMAICA PUBLIC SERVICE COMPANY LTD – AMENDED AND RESTATED ALL-ISLAND ELECTRIC LICENSE 2011.

APPENDIX 2:

JAMAICA'S NATIONAL ENERGY POLICY 2009 – 2030.

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APPENDIX 3:

JAMAICA PUBLIC SERVICE COMPANY STATISTICS.

Jamaica Public Service Company Ltd - Statistical Review (2011)

Summary

OPERATING REVENUE (US$ '000)	
Residential	412,259
Commercial & Industrial (Sml)	521,845
Commercial & Industrial (Lge).	189,589
Other	29,703
TOTAL	**1,153,396**

AVERAGE NO. OF CUSTOMERS	
Residential	513,970
Commercial & Industrial (Sml)	61,401
Commercial & Industrial (Lge).	145
Other	246
TOTAL	**575,762**

NET DISPATCHABLE GENERATION & PURCHASES (MWH)	
Steam & Slow Speed Diesel	1,583,387
Hydro	152,087

Gas Turbines	179,914
Combined Cycle Plant	810,212
Purchases	1,411,279
TOTAL	**4,136,879**

Losses & Unaccounted for (MWH)	920,889
System Losses as a % of Net Generation	22.3
Average Heat Rate (kJ/kWh)	10,112
*JPS System Heat Rate (kJ/kWh)**	13,290
*Purchased Power Heat Rate (kJ/kWh)**	8,246

NET ENERGY ONLY GENERATION & PURCHASES (MWH)	
Wind	

GENERATION SYSTEM CAPACITY	
Generation Capacity (MW)	920
System Peak Load (MW)	618
System Reserve (%) *	21.8
Capacity Factor (%)	54.4
Spinning Reserves on Max Capacity	5

ENERGY SALES (MWH)	
Residential	1,064,535
Commercial & Industrial (Sml)	1,437,283
Commercial & Industrial (Lge).	615,041
Other	99,131
TOTAL	**3,215,990**

AVERAGE USE & REVENUE PER RESIDENTIAL CUSTOMER	
Annualized kWh Consumption/Customer	2,071
Annualized Revenues/Customer	802
Average Billing Exchange Rate for Period	86.03
US¢/kWh	38.7

*2002 Data

Source: JPS Annual Report 2011

Jamaica Public Service Company Ltd - Statistical Review (2012)
Generating Capacity by Units

			2002	2012
UNITS	**LOCATION**	**UNIT #**	**MW**	**MW**
Steam (HFO)				
(HFO)	*Old Harbour*	1	28	
		2	60	
		3	65	
		4	68.5	
Sub-total Steam			**221.5**	
(HFO)	*Hunts Bay*	1	-	
		4	-	
		5	-	
		6	68.5	
Sub-total Steam			**68.5**	
Total Steam			**290.00**	
Steam (Diesel)				
(Currently HFO)	*Rockfort*	1	18.00	
		2	18.00	
Total Diesel			**36.00**	
Gas Turbines				
(# 2 Diesel/ADO)	*Hunts Bay GT*	1	-	
	Hunts Bay GT	2	-	
	Hunts Bay GT	4	-	
	Hunts Bay GT	5	21.50	
	Hunts Bay GT	10	32.50	

Sub-total Gas Turbines			**54.00**
(# 2 Diesel/ADO)	*Bogue*	3	21.50
	Bogue	6	14.00
	Bogue	7	14.00
	Bogue	8	14.00
	Bogue	9	20.00
	Bogue	11	20.00
	Bogue	12	40.00
	Bogue	13	40.00
Sub-total Gas Turbines			**183.50**
Total Gas Turbines			**237.50**
<u>Hydro</u>			
	Magotty		6
	L. White River		4.7
	Roaring River		4.1
	U. White River		3.1
	Constant Spring		-
	Rio Bueno "A"		2.5
	Rio Bueno "B"		1.1
	Ram's Horn		-
Total Hydro			**21.5**
TOTAL JPS CAPACITY (MW)			

		585.00
PURCHASED POWER		
	Antilles (Diesel)	-
	Kenetich (G.T.)	-
	JEP (HFO)	74.16
	Jamalco (HFO)	11.00
	JBGL (HFO)	12.10
	Braco	-
	JPPC (HFO)	61.30
TOTAL PURCHASED POWER (MW)		**158.56**
TOTAL CAPACITY (MW)		**743.56**

Jamaica Public Service Company Ltd - Statistical Review (2012)
Annual Efficiency (Heat Rate)

		2002	2005
HEAT RATES (KJ/KWH)			
JPS			
Steam			
Hunts Bay		**12,558.00**	**13,246.00**
	Unit #6	12,558.00	
Old Harbour		**13,406.00**	**13,426.00**
	Unit #1	-	
	Unit #2	14,241.00	
	Unit #3	13,140.00	
	Unit #4	12,669.00	
Rockfort		**10,066.00**	**9,790.00**
	Rockfort Diesel	10,066.00	
Gas Turbines			
Hunts Bay		**16,399.00**	**15,312.00**
	Unit #4	-	
	Unit #5	16,399.00	
	Unit #10	-	
Bogue		**14,245.00**	**9,235.00**
	Unit # 3		

	-	
Unit # 6	17,109.00	
Unit # 7	17,189.00	
Unit #8	17,197.00	
Unit #9	16,564.00	
Unit #11	11,438.00	
Unit #12	13,083.00	
Unit #13	13,265.00	
Total JPS Efficiency (kJ/kWH)	**13,189.00**	**10,336.00**
PRIVATE POWER		
JEP	8,355.00	
JPPC	7,982.00	
Total Private Power Efficiency (kJ/kWH)	**8,176.00**	
TOTAL COMBINED SYSTEM (KJ/KWH)	**11,245.00**	

JPS ELECTRICITY STATISTICS

ELECTRICITY GENERATION (MWh)

	2007	2008	2009	2010	2011p
Steam & Slow Speed Plants	1,671,219	1,701,220	1,725,785	1,673,386	1,583,387
Gas Turbines Plants	968,888	1,016,117	1,001,221	968,752	990,125
Hydro	159,819	158,205	140,118	151665	152157
JPS Net Generation	**2,799,926**	**2,875,542**	**2,867,124**	**2,793,803**	**2,725,669**
JPS Purchases	1,278,844	1,257,658	1,346,899	1,346,496	1,411,178
Total Net Generation	**4,078,770**	**4,133,200**	**4,214,023**	**4,140,299**	**4,136,847**
Losses	*903,564*	*1,006,735*	*980,869*	*902,116*	*961,357*

ELECTRICITY SALES (MWh)

Category	2007	2008	2009	2010	2011p
Rate 10 (Residential)	1,075,120	1,032,181	1,091,901	1,106,955	1,051,219
Rate 20 (General Service)	659,523	650,425	670,030	673,471	643,615
Rate 40 (Power Service)	771,338	748,893	777,591	750,289	775,584
Rate 50 (Large Power)	567,435	584,791	594,626	602,248	607,272
Rate 60 (Street Light)	66,421	69,407	70,388	71,029	71,127
Other	24,185	27,609	26,875	31,240	26,773
TOTAL	**3,164,022**	**3,113,306**	**3,231,411**	**3,235,232**	**3,175,590**

AVERAGE RATE CHARGE (JA¢/kWh)

Category	2007	2008	2009	2010	2011p
Rate 10 (Residential)	1,652.36	1,783.41	2,257.98	2,730.43	3,229.93
Rate 20 (General Service)	1,832.13	1,832.13	2,337.95	2,790.58	3,326.06
Rate 40 (Power Service)	1,510.73	1,510.73	1,908.95	2,335.35	2,848.56
Rate 50 (Large Power)	1,373.03	1,373.03	1,750.73	2,153.32	2,656.72
Rate 60 (Street Light)	1,972.59	1,972.59	2,531.94	3,063.57	3,577.46
Other	1,219.50	1,219.50	1,484.80	1,778.58	2,491.70

Notes:
(1) p - preliminary

Source:
Jamaica Public Service Co. Ltd.

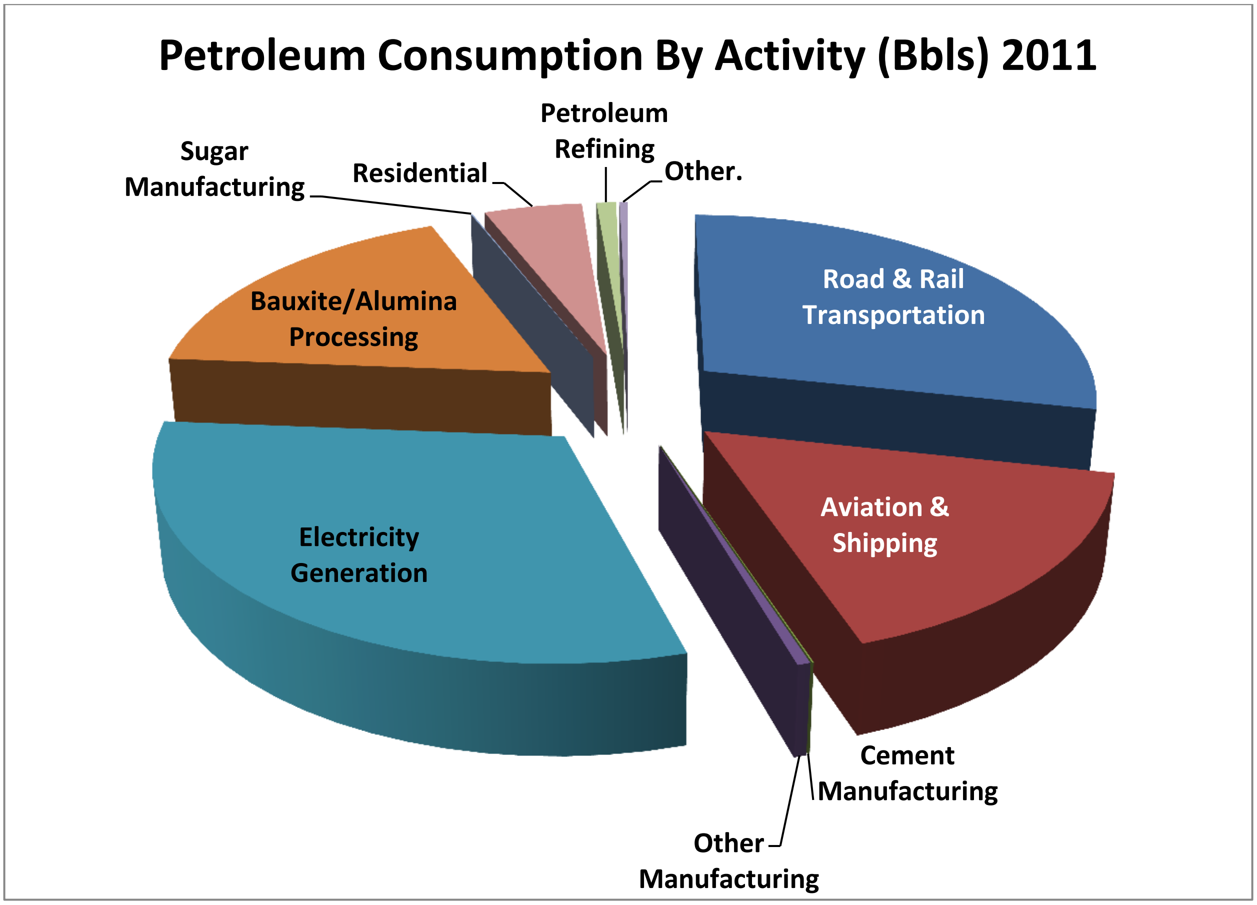
APPENDIX 4:

JAMAICA – PETROLEUM STATISTICS.

Petroleum Consumption by Activity (bbls) 2011

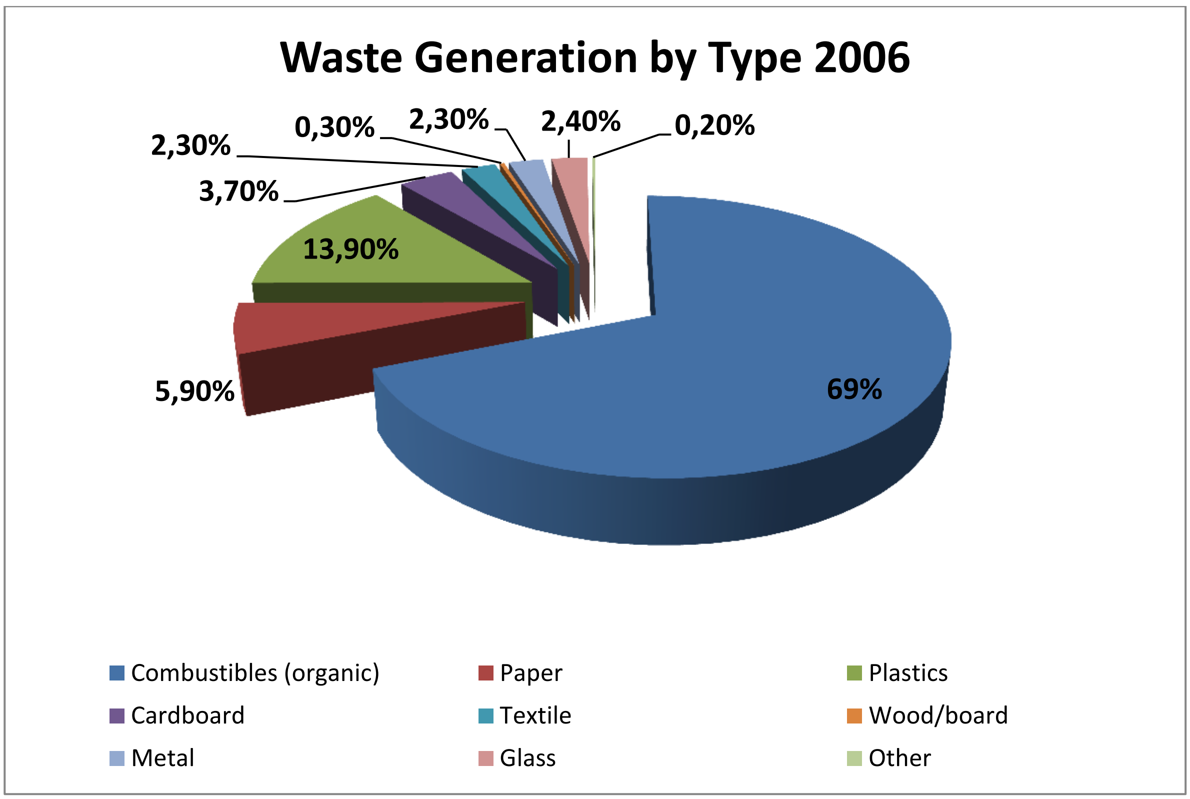
	Bbls	%
Road & Rail Transportation	6,012,476	28.4
Aviation & Shipping	3,513,596	16.6
Cement Manufacturing	11,698	0.1
Other Manufacturing	97,373	0.5
Electricity Generation	6,529,445	30.8
Bauxite/Alumina Processing	3,752,927	17.7
Sugar Manufacturing	15,464	0.1
Residential	987,844	4.7
Petroleum Refining	195,700	0.9
Other.	82,279	0.4
GRAND TOTAL	**21,198,802**	**100.0**

MSTEM Amendments	**Bbls**
Activities	2011r
Road & Rail Transportation	6,012,476
Shipping	1,634,809
Aviation	1,878,787
Cement Manufacture	11,698
Electricity Generation	6,529,445
Bauxite/Alumina Processing	3,752,927
Sugar Manufacturing	15,464
Residential	987,844
Other Manufacturing	97,373
Other	82,279
TOTAL*	21,003,103
Petroleum Refinery	287,237
GRAND TOTAL	**21,290,340**


Petroleum Consumption By Activity (Bbls) 2011
Petroleum Refining
Sugar Manufacturing
Residential
Other.
Road & Rail Transportation
Bauxite/Alumina Processing
Electricity Generation
Aviation & Shipping
Cement Manufacturing
Other Manufacturing

APPENDIX 5:

JAMAICA'S SOLID WASTE GENERATION



Waste Generation by Type 2006.

Type of Waste	Percentage	Volume (Tonnes)
Combustibles (organic)	69%	1,010,094.80
Paper	5.90%	86,370.50
Plastics	13.90%	203,482.90
Cardboard	3.70%	54,164.50
Textile	2.30%	33,669.80
Wood/board	0.30%	4,391.70
Metal	2.30%	33,669.80
Glass	2.40%	35,133.70
Other	0.20%	2,927.80
	100%	1,463,905.50

APPENDIX 6:

Major Constituents of Gaseous Fuels

	Natural Gas	LPG	Digester Gas	Landfill Gas
Methane, CH_4, (percent)	80 – 97	0	35 – 65	40 – 60
Ethane, C_2H_6, (percent)	3 – 15	0 – 2	0	0
Propane, C_3H_8, (percent)	0 – 3	75 - 97	0	0
Butane, C_4H_{10}, (percent)	0 – 0.9	0 - 2	0	0
Higher C_xH_x, (percent)	0 – 0.2	0 - 20[17]	0	0
CO_2, (percent)	0 – 1.8	0	30 – 40	40 - 60
N_2, (percent)	0 – 14	0	1 - 2	0 - 13
H_2, (percent)	0 – 0.1	0	0	0
LHV, (Btu/scf)	830 - 1075	2500	300 - 600	350 - 550

Source: SFA Pacific, Inc.; North American Combustion Handbook

APPENDIX 7

COMPARISONS OF DISTRIBUTED GENERATION OPTIONS

	General information	Application range	Electric conversion efficiency	Application	Fuel	Comments
Reciprocating Engines		• Diesel: $20kW_e$ - $10+MW_e$ (IEA) • Gas: $5kW_e$ - $5+MW_e$ (IEA) • By far most common technology below $1MW_e$	• Diesel: 36%-43% (IEA) • Gas: 28%-42% (IEA)	• Emergency or standby services • CHP	• Diesel, also heavy fuel oil and bio-diesel • Gas, mainly natural gas, biogas and landfill gas can also be used	
Gas turbines		• 1 - $20MW_e$ (IEA)	• 21%-40% (IEA)	• CHP • Peak power supply units	• Gas, kerosene	
Micro turbines		• $30kW_e$ - $200kW_e$ (IEA) • $35kW_e$ – $1MW_e$ (A) • Small-scale applications up to < 1 kW_e	• 25%-30% (IEA)	• Power generation, possible with CHP added	• Generally uses natural gas, but flare, landfill and biogas can also be used	
Fuel cells	• Molten carbonate: MCFC • Proton-exchange membrane: PEMFC • Solid oxide: SOFC • Phosphoric acid: PAFC • Direct Methanol : DMFC Only PAFC is currently commercially available	• $50kW_e$-$1+MW_e$ (IEA) • PAFC: $200kW_e$-$2MW_e$ • MCFC: $250kW_e$-$2MW_e$(A) • PEMFC: $1kW_e$-$250kW_e$ (A) • SOFC: $1kW_e$-$5MW_e$ (A)	• 35%-60% (IEA) • MCFC: ± 50-55% (IEA) • PAFC: ± 35% (IEA) • PEMFC: ± 35% (IEA) • SOFC: ± 50-55% (IEA) • Electric efficiency of small-scale applications : ~ 25%	• PEMFC: low temperature applications in transport and stationary use • MCFC: high temperature • Transport sector is major potential market • SOFC: high temperatures • Power generation is the most likely immediate application • CHP, UPS	• Methanol • Hydrogen or natural gas. Reforming of CH_4 to H_2 leads to decreased efficiency	
Photovoltaic	• Generates no heat	• 1+kW (IEA) • 20+kW (A); • Every range possible when using more cells	• not applicable	• Household and small commercial applications • Off-grid applications • Developing countries • Small scale applications	• Sun	• Non predictable output; capacity factor ~ 10 – 15% in Western Europe
Wind	• on shore and in-land	• 200W – 3MW (A)	• not applicable		• Wind	• Non predictable output • Capacity factor on shore ~ 20-25%
Other Renewables	• Includes thermal solar, small hydro, geothermal, ocean…		• not applicable			

Source: Katholieke Universiteit Leuven 2003

APPENDIX 8

ECONOMIC AND FINANCIAL COMPARISONS OF DISTRIBUTED AND CENTRAL GENERATION OPTIONS

Analysis and Comparsion of Various Generation Economic and Financial Costs

	Flexicycle Dual Fuel Reciprocating Technology	Combined Cycle Gas Turbines	Coal	Petcoke	Biomass	Solar	Wind	Waste to Energy	Hydro
Capacity (MW)	120	120	100	50	25	25	25	25	10
Assumed Availability	92%	92%	90%	90%	85%	25%	31%	90%	35%
Heat Rate at Ambient - 90F (btu/kWh)	7,010	7,250	14,500	15,000	19,200	0	0	0	0
Efficiency (%)	49%	47%	24%	23%	18%	NA	NA	NA	NA
Energy Delivered (MWH)	967,104	967,104	788,400	394,200	186,150	54,750	67,890	197,100	30,660
Total Capital Cost (US$)	$ 230,000,000	$ 260,000,000	$ 400,000,000	$ 150,000,000	$ 64,000,000	$ 70,000,000	$ 88,000,000	$ 87,000,000	$ 50,000,000
Term of Loan (Years)	14	14	14	12	12	12	12	12	12
Assumed PPA Term (Years)	20	20	20	20	20	20	20	20	20
Project Internal Rate of Return (over PPA Term)	19%	19%	21%	19%	21%	21%	19%	21%	20%
Typical Leverage									
Debt -- 70%	$ 161,000,000	$ 182,000,000	$ 280,000,000	$ 105,000,000	$ 44,800,000	$ 49,000,000	$ 61,600,000	$ 60,900,000	$ 35,000,000
Equity -- 30%	$ 69,000,000	$ 78,000,000	$ 120,000,000	$ 45,000,000	$ 19,200,000	$ 21,000,000	$ 26,400,000	$ 26,100,000	$ 15,000,000
Time To Construct (Mths)	18 - 24	24 - 36	48 - 72	36 - 48	18 - 24	5 - 9	20 - 30	24 - 36	48 - 72
Life Cycle Cost (US $ / kWh)									
Variable	0.00785	0.00779	0.01852	0.02400	0.00630	0.0360	0.0398	0.0500	0.003
Fixed	0.05535	0.05423	0.0449	0.0326	0.0594	0.1526	0.1035	0.0616	0.09
Fuel (Gas)	0.09247	0.09960	0.0516	0.0450	0.10824	NA	NA	0.0528	NA
Levelized Cost of Energy (US$/kWh)	0.15567	0.16162	0.11500	0.10165	0.17390	0.189	0.1433	0.1644	0.092

Notes

1 *Estimated Cost of Gas is US$13/mmbtu*
Estimated Cost of Coal is US$3.56/mmbtu
2 *Flexicycle DF has advantages over CCGT in that it can burn HFO, LFO and Gas and it can commence construction using HFO fuel*
3 *CCGT does not have HR advantage over Flexicyle DF at ambient temperatures*
4 *CCGT cannot commence construction until gas is secured.*
5 *CCGT and Flexicyle DF analysis is based on Gas*
6 *Assumed interest rate is 7%*