GOVERNING BOARD OF THE
VIRGIN ISLANDS WATER AND POWER AUHORITY

Energy Production Action Plan

Prepared by the Governing Board

September 2012

The Governing Board of the Virgin Islands Water and Power Authority has determined that a review of the non-fuel oil options, as well as the fuel oil efficiency improvement options, and the adoption of a plan prioritizing the Authority's deployment of the appropriate technologies is a necessary step in reducing the cost of electricity in the Territory. To this purpose, the Board has developed and adopted this Energy Production Action Plan as the policy of the Governing Board of the Virgin Islands Water and Power Authority.

Governing Board of the Virgin Islands Water and Power Authority
Energy Production Action Plan

1. CURRENT SYSTEM CONFIGURATION 1
2. CURRENT SYSTEM CHALLENGES 2
3. RECENT COMPREHENSIVE SYSTEM PLANNING EFFORTS 5
4. ACTION PLAN 6
5. DEFINITIONS 6
6. TECHNOLOGIES 7
7. TECHNOLOGY DEPLOYMENT SCENARIOS 20
8. IMPLEMENTATION TARGETS 20
9. REFERENCES 22

Governing Board of the Virgin Islands Water and Power Authority
Energy Production Action Plan

The Virgin Islands Water and Power Authority (VIWAPA) has invested considerable time and resources in the past several years to implement measures to mitigate against the severe price volatility in the fuel oil market. This investment has been particularly intense in recent years as fuel oil prices have steadily increased. Like all other small island power systems that are dependent primarily on fuel oil for power production, rising oil costs has driven electric rates upward and created an extreme burden on utility ratepayers.

Understanding the need to clearly communicate to the utility's customers what efforts are being made to mitigate high energy cost, the Governing Board of the Water and Power Authority has prepared this planning document. This plan represents a description of the options currently available to VIWAPA for the reduction of energy costs as understood by the Board. The plan also includes anticipated timelines that represent a conservative estimate as to when specific steps should be completed towards achieving the objective of reducing electric rates.

1. Current System Configuration

St. Croix Electric System

Load Requirements

Base Load ≈30 MW; Peak Load ≈50 MW

Electric and Steam Generating Units

Unit No.	Technology	Fuel Type	Rated Capacity (MW)	In Service Date
10	Steam Turbine/Oil-Fired Boiler	No. 6 Oil	10	1967
11	Steam Turbine/Oil –Fired Boiler	No. 6 Oil	19.1	1970
16	Combined Cycle Combustion Turbine	No. 2 Oil	20.9	1981
17	Combined Cycle Combustion Turbine	No. 2 Oil	21.9	1988
19	Simple Cycle Combustion Turbine	No. 2 Oil	22.5	1994
20	Combined Cycle Combustion Turbine	No. 2 Oil	22.5	1994
21	Heat Recovery Steam Generator	-	-	1990
24	Heat Recovery Steam Generator	-	-	2010
			116.9	

St. Thomas Electric System

Load Requirements

Base Load ≈50 MW; Peak Load ≈80 MW

Electric and Steam Generating Units

Unit No.	Technology	Fuel Type	Rated Capacity (MW)	In Service Date
7	Reciprocating Engine	No. 2 Oil	2.5	1985
11	Steam Turbine/Oil-Fired Boiler	No. 6 Oil	18.5	1968
13	Steam Turbine/Oil –Fired Boiler	No. 6 Oil	36.9	1973
14	Simple Cycle Combustion Turbine	No. 2 Oil	12.5	1972
15	Combined Cycle Combustion Turbine	No. 2 Oil	20.9	1981
18	Combined Cycle Combustion Turbine	No. 2 Oil	23.5	1993
21	Heat Recovery Steam Generator	-	-	1997
22	Simple Cycle Combustion Turbine	No. 2 Oil	24	2001
23	Simple Cycle Combustion Turbine	No. 2 Oil	39.5	2004
25	Simple Cycle Combustion Turbine[1]	No. 2 Oil	22	2012
			212.8	

2. Current System Challenges

Dependence on Expensive Fuel Oil

Like most small island communities throughout the world, the U.S. Virgin Islands is dependent on fuel oil for the generation of electricity. Approximately 71 percent[2] of the installed generation capacity in the Caribbean region utilizes fuel oil (The World Bank 2011). By contrast, less than 1% of the electricity in the United States was generated by fuel oil in 2011 (E.I.A. 2012). The Virgin Islands Water and Power Authority (WAPA) specifically uses distillate fuel oil (#2) and heavy fuel oil (#6) for power and water production.

Fuel oil is widely used by small islands due to the low capital costs of the generation technologies, the relative ease of transport, and the ability to be scaled down to accommodate smaller generation requirements. The absence of natural resources suitable for use as fuel (i.e. natural gas deposits, coal deposits, oil wells, geothermal resources, and hydroelectric resources) forces the U.S. Virgin Islands to depend on imported fuels such as oil.

During the past several years, oil prices have reached historic highs, peaking at $147/barrel in July 2008, and averaging over $100/barrel during 2011. This cost was as low as $11/barrel in December 1998. At current oil prices, fuel oil electricity generation is higher than almost all power generation technologies.

[1] Unit leased for temporary operation only
[2] This figure is inclusive of natural gas producers Trinidad and Tobago and Barbados

Although WAPA has been able to purchase fuel from the HOVENSA refinery at below market prices due to the contractual agreement between the U.S. Virgin Islands government and HOVENSA, those prices have still been subject to the price volatility of the market and have not been isolated from increasing oil prices over time. Therefore, higher oil prices have led to higher electricity prices.

Limitation on Integrating Renewables

Wind and solar energy are indigenous sources of energy that could be utilized as alternatives to fuel oil generation. However, wind turbines and solar photovoltaic arrays are intermittent energy sources whose power outputs are dependent on weather conditions. The electrical grid must have sufficient capacity to adjust to the constant fluctuations in power output from these systems, brought on by cloud cover and unpredictable winds, in order to maintain stability. The larger the amount of intermittent energy connected to the grid, the greater the challenge of maintaining adequate power output to consumers. As a result, the level of integration of wind and solar energy is limited to no more than 15-25% of the grid's expected consumer demand at any particular time: St. Croix's peak load of approximately 50 MW suggests a combined maximum integration of solar and wind of 7.5 MW to 12.5 MW and St. Thomas' peak load of approximately 80 MW suggests a combined maximum integration of solar and wind of 12 MW to 20 MW. To surpass this technical threshold would require investments in costly energy storage technology or the establishment of a grid interconnection with another utility.

Lack of Economies of Scale

The Virgin Islands Water and Power Authority operates two relatively small power systems that are both completely isolated. This prevents WAPA from achieving beneficial economies of scale and requires the duplication of resources that would not typically be required for such a small customer base. As isolated grids, maintaining high levels of reliability would require high reserve margins. The depth of the waters between St. Thomas and St. Croix make the combination of these two systems technologically prohibitive.

Spinning Reserves

Spinning Reserve is the on-line reserve capacity that is synchronized to the grid system and ready to meet electric demand in the event of any on-line generation failure. Spinning reserve is needed to maintain system frequency stability during emergency operating conditions and unforeseen load swings. The spinning reserve criteria established by the Authority is to have reserve generation on line to support the power demand in an event that results in the failure of the largest generator in service at any given time.

While this standard that has been established is typical and ideal, the high cost of fuel oil, which the Authority's generation is dependent on, has forced the Authority to operate with very little or no spinning reserve in most instances. The high cost of fuel oil today makes it prohibitive for the Authority to operate with its established reserve spinning criteria, thus resulting in a compromise of the reliability of the power generating systems.

Limited Financial Resources

The Virgin Islands Water and Power Authority is experiencing significant cash flow management challenges. Chronic nonpayment and slow payment for electricity services has hindered cost recovery

and affected equipment maintenance. The Government of the Virgin Islands as WAPA's largest customer is also the greatest contributor to the cash flow concerns. The cost of energy for public street lighting has not been adequately covered for the last several years. Over the years, several large government departments and semi-autonomous agencies have been slow in making monthly bill payments, resulting in large account receivable balances for WAPA. The cash flow concerns are further exacerbated when adequate revenues to cover expenses are not allowed to be recovered through the ratemaking process.

As a result, major equipment overhauls have been delayed, spare parts have not been kept at adequate inventory levels, and preventative maintenance has been deferred. These circumstances have increased the frequency of equipment outages and failures, often resulting in the power production facilities operating at less than optimal generating efficiency. The cost of energy to the utility's customers is negatively impacted.

Environmental Regulations

Unlike most Caribbean utilities, the Virgin Islands Water and Power Authority is subject to the standards and regulations of the federal Environmental Protection Agency (EPA) and the local Department of Planning and Natural Resources (DPNR). Burning oil to generate electricity produces nitrogen oxides, sulfur dioxide, carbon dioxide, methane, and mercury compounds which are all regulated by the EPA as pollutants. The amount of sulfur dioxide and mercury compounds can vary depending on the sulfur and mercury content of the oil that is burned. As a result, the sulfur and mercury content of the fuel utilized by WAPA is restricted. The type of generation equipment that is utilized is also restricted. These regulations prevent WAPA from burning lower cost fuel and utilizing more efficient generating units, (ex. slow-speed reciprocating engines) utilized by utilities with less stringent emission standards.

EPA standards are also contribute to the high initial capital costs of generating units that process solid fuels such as coal and municipal solid waste. This is significant because plants that burn those fuels are generally very efficient and generate power at high capacity factors.

Community Acceptance

Projects to reduce the cost of energy ultimately must gain public support through education and transparency. The bidding, evaluation, contract negotiation, permitting, and regulatory requirements for any generation project is a multi-year process, so the rejection of a generation project results in a significant loss of time and a delay in solving our energy problems. In August 2009, the Water and Power Authority executed power purchase agreements for a 33-MW project on St. Thomas and a 16-MW project on St. Croix, both fuelled by a mixture of petroleum coke and municipal solid waste. Although these projects would have provided more than one-third of WAPA's peak generating demand, they failed to gain strong public support. WAPA executed a revised and restated power purchase agreement in August 2011 for a 16-MW waste-to-energy facility on St. Croix. This project also failed to generate sufficient public support. There is a significant public sentiment in opposition to the re-start of the coal-fired boiler at the St. Croix Renaissance Park on St. Croix. Similar opposition is anticipated with natural gas storage facilities and even the development of utility-scale wind farms. Without a strategy to win the clear support of the general community, and with it, the necessary legislative and regulatory

approvals, special interest groups can derail proposed energy projects and severely limit the options available to WAPA to address the energy crisis.

3. Recent Comprehensive System Planning Efforts

3.1 Power Evaluation Study

In 2008, the design engineering company R.W. Beck completed a power evaluation study that was commissioned by the Public Services Commission and the Virgin Islands Water and Power Authority. The report evaluated WAPA's future electricity and water production options. The primary purpose of the power supply evaluation was to compare selected potential technologies and fuels that would assist WAPA:

(i) To reduce Electric System operating costs and lessen dependence on fossil fuels,

(ii) To develop conceptual projections of electric operating and capital costs for feasible alternative technologies and fuels,

(iii) To compare the cost of utilizing reverse osmosis technology with existing water production technology and costs, and

(iv) To serve as a basis for evaluating responses to the Request for Proposals to provide alternative electric energy.

3.2 Energy Development in Island Nations Global Partnership

In 2010, a partnership between the U.S. Virgin Islands, the U.S. Department of Energy (DOE), and the U.S. Department of Interior (DOI) was formed under the guidance of DOE's Energy Development in Island Nations (EDIN) initiative. This partnership has supported efforts in the Territory towards reducing dependency on utilizing fossil fuel for generating electricity by 60% by the year 2025.

As part of this relationship, the National Renewable Energy Laboratories (NREL) has developed a comprehensive roadmap for the development of clean energy resources in the Virgin Islands. NREL has developed technology specific reports on waste-to-energy and wind energy in the Virgin Islands. NREL has also prepared a study on integrating renewable energy on the local grid. NREL is currently leading policy development efforts on interconnection policies and procedures. NREL has provided technical guidance on the development of the subsea grid connection with Puerto Rico and continues to support that project. It helped develop the request for proposals, participated in the evaluation of the proposals, and helped negotiate the contracts that ultimate resulted in six power purchase agreements for 18 MW of solar energy.

The EDIN partnership has hosted five workshops in the Territory since 2010. Additionally, EDIN has supported demand side management and energy efficiency initiatives and public outreach activities. The

efforts of this partnership should allow WAPA to achieve the 30% renewable portfolio standard by 2025 as required by law, in addition to the fossil fuel reduction goal.

4. Action Plan

It is the position of the Governing Board of the Virgin Islands Water and Power Authority, through consultation with technical experts and management staff, that the best strategy for the reduction of the cost of energy in the Virgin Islands are as follows:

1. Implement measures to enhance production efficiency at existing power generation facilities.
2. Convert base load power production from fuel oil to liquefied natural gas or liquefied petroleum gas.
3. Develop grid interconnection between the Virgin Islands and Puerto Rico
4. Maximize development of solar and wind resources.
5. Pursue biomass energy and ocean thermal energy as potential diversification of base load energy.

5. Definitions

Avoided Cost - the cost WAPA incurs to generate or purchase power from another source

Base Load Demand - the minimum amount of electric power required over a given period of time at a steady rate

Capacity Factor - is the ratio of the actual output of a power plant over a period of time and its potential output if it had operated at full nameplate capacity the entire time

Dispatchable Energy - those energy sources that can be turned on and off in a relatively short amount of time

Fossil Fuel - hydrocarbons, primarily coal, fuel oil or natural gas, formed from the remains of dead plants and animals

Heat Rate – a measurement used in the energy industry to calculate how efficiently a generator uses heat energy computed by dividing the total Btu content of fuel burned for electricity generation by the resulting net kilowatt-hour generation.

Imported Fuel Source – fuels that must be imported into the Virgin Islands

Indigenous Fuel Source – fuels that are manufactured or produced locally

Intermediate Load Demand - the range from base load to a point between base load and peak

Intermittent Energy - those energy sources in which power output cannot be directly controlled and therefore cannot be relied upon to meet power demands

Kilowatt - a unit for measuring power that is equivalent to one thousand watts

Kilowatt-Hour - a unit of energy equivalent to one kilowatt of power expended for one hour of time

Megawatt - a unit for measuring power that is equivalent to one million watts

Peak Load Demand - the highest point of customer consumption of electricity

Renewable Energy - energy sources that are naturally replenishing

6. Technologies

Conventional Base Load Energy Sources

6.1 Improved Efficiency of the Oil-Fired Generation

- Dispatchable
- Fossil Fuel
- Imported

Resource

The Virgin Islands Water and Power Authority is still solely dependent on petroleum fuel oils for generation of electricity. Such a high level of dependency on fuel oils for power production is typical throughout the Caribbean region. The popularity of this fuel source amongst small islands has been driven by the relatively low capital costs of the generation units using this fuel and the benefit of scalability of this technology on very small power grids. (The World Bank 2011)

The largest contributor to the retail price of electricity provided by WAPA to its customers is the high cost of imported fuel oil. The cost of fuel oil in the Virgin Islands is ultimately indexed to international market pricing. Even with the favorable discount pricing contractually provided by the Hovensa refinery on St. Croix, the relative cost of fuel oil as a source of electric energy exceeds most other conventional fuel sources. The absence of those discounts, coupled with the high cost of transport and environmental compliance, renders fuel oil a costly commodity for the foreseeable future.

However, there exist technologies and operational considerations that could reduce significantly the consumption of fuel oil by WAPA to meet customer demand loads and improve overall plant efficiency. Production of potable water by reverse osmosis instead of the existing multi-effect distillation process could greatly reduce the use of heavy fuel oils by WAPA. Retrofitting WAPA's largest unit, Unit No. 23 on St. Thomas with a heat recovery steam generator, allowing it to maximize its efficiency by operating in combined cycle, would also reduce heavy fuel oil consumption. The transition of existing generating units to medium-speed diesel reciprocating engines could significantly reduce the consumption of

distillate fuel oil. Finally, Conservation Voltage Reduction could reduce overall power demand on the grid by reducing voltage on the distribution feeders.

Siting

The optimization of plant efficiency would be expected to take place at the existing plant facilities, and in the case of the Conversation Voltage Reduction, possibly at the electrical substations.

Permitting

The permitting of new, more efficient oil-fired generating units is expected to be a meticulous and time-consuming process. The ability of new technology to meet applicable air quality standards cannot be determined until site-specific emissions are modeled. Medium-speed diesel reciprocating engines would likely require the inclusion of selective catalytic reduction, diesel oxidation catalysts, flow-through filters, and other advanced control technologies. These environmental controls could significantly increase the upfront capital investment required to realize the efficiency gains.

Capital

The capital expenditures for new generating equipment can be significant. A new heat recovery steam generator with a capacity of 400,000 lbs/hr is projected to cost approximately $44 million (Beck 2008). Medium-speed diesel reciprocating engines are estimated to cost $1.4 million/MW of rated capacity or approximately $25 million for a typical 16.5 MW engine (Wartsila 2012). Recently enacted legislation establishing a revenue stream for the acquisition of power generation equipment could finance one or more of these initiatives.

Benefits

- Lower fuel consumption
- Reduction of potable water production to less than one-third of current cost
- Benefits achieved from enhanced efficiencies can be of realized by both fuel oil and natural gas generation

Drawback

- No additional fuel diversity
- Significant upfront capital investments required to acquire more efficient generation
- Reciprocating engines potentially more polluting
- Reciprocating engines not compatible with existing generating inventory
- The relative size of Unit 23 operating in combined cycle creates reliability concerns

6.2 Liquefied Natural Gas/Liquefied Petroleum Gas

- Dispatchable
- Fossil Fuel
- Imported

Resource

Liquefied natural gas (LNG) is created by cooling natural gas to a temperature of -258°F, at which point it becomes a liquid. This process reduces its volume significantly (approximately 600 to 1) allowing it to be transported and stored more efficiently in large quantities in large specialized ships with insulated containment system that can only be used to hold LNG. These large LNG carriers require deep-water port access to accommodate their draft requirements. Small-scale LNG refers to transporting and storing LNG in small vessels and storage and regasification facilities in much smaller quantities. Small-scale LNG carriers require significantly lower water depth requirements than traditional LNG carriers, thus allowing them to potentially utilize some marine facilities.

There is one primary sources of LNG in this region of the world, the Atlantic LNG Company of Trinidad and Tobago. Atlantic LNG presently operates a four train plant and sells all of its output to BG, BP, Repsol, Gas Natural Fenosa and GDFSuez. Atlantic LNG does not presently serve small-scale ships. Another potential future source of LNG is several LNG export project on the Gulf and Atlantic coasts of the US. Only one of these projects, Sabine Pass trains 1 and 2, has received all the necessary permits and financing and has only recently started construction. Its output is already contracted to BG and Gas Natural Fenosa. Sabine Pass and most of the other projects are not expected to plan to accommodate small-scale LNG ships. (Galway 2011). A third potential supply source is the small-scale LNG export project in Colombia being developed by Pacific Rubiales. Construction has started on the project and Pacific Rubiales is actively marketing the output from this project to potential small-scale buyers in Central America and the Caribbean region.

Another potential source of natural gas supply would have WAPA supplied from one of the two existing LNG terminals in close proximity. In Peñuelas, Puerto Rico the Ecoelectrica LNG terminal supplies a 540-MW power plant in Puerto Rico, and in Andres, Dominican Republic, the AES LNG terminal supports a 310-MW power plant. The Virgin Islands could seek to establish commercial agreements with the terminal (or terminal capacity) owners to acquire additional LNG supplies and re-export them to the Virgin Islands. Additional regulatory approvals may be required to facilitate such re-exports from these two facilities.

Liquefied Petroleum Gas ("LPG" or "propane") is also a viable alternative fuel technology that could be deployed by WAPA. Refining petroleum or processing and fractionating natural gas are used to extract LPG. LPG comes in multiple varieties including pure propane, pure butane, or a propane/butane mix. LPG is widely distributed and sold in the Caribbean region and is transported via either refrigerated or pressurized LPG ships which are generally significantly smaller than LNG carriers and therefore do not require access to marine facilities in deep-water ports. There is an existing LPG carrier fleet operating in the region. LPG in the region is delivered from Trinidad and Tobago, West Africa or the US Gulf Coast.

LPG storage and vaporization facilities tend to be less expensive to build than similar LNG facilities and can generally be permitted and built more quickly than similar LNG facilities.

Siting

Securing the use of a small-scale LNG vessel could allow for shipments of LNG directly into the Harley Power Plant on St. Thomas. Storage and regasification could potentially be accommodated offshore on floating barges. However, the shallowness of the Christiansted Harbor and proximity to recreational boating areas, are likely to make direct shipments to the Richmond Power Plant facility on St. Croix unfeasible. (Galway 2011). A likely approach would be to develop a small LNG import terminal on the south shore of St. Croix and transport the gas by truck, pipeline, or barge to the Richmond Power Plant.

Permitting

The transportation of liquefied natural gas into the Virgin Islands will require U.S. Coast Guard approvals. The construction of storage and regasification facilities will require local Coastal Zone Management regulatory approvals. Finally, the conversion of existing oil-fired generation to LNG will require U.S. Environmental Protection Agency approvals. As with oil-fired generating units, the ability to meet applicable air quality standards cannot be determined until site-specific emissions are modeled.

Capital

The capital costs associated with LNG fuel conversion by WAPA include the acquisition of a small-scale LNG vessel, storage and regasification facilities on each island, dock improvements, and the conversion of existed generation units or the acquisition of natural gas-burning generation units. Estimated costs are projected to be between $134-$158 million. (Beck 2008). There may be additional requirements for operations and maintenance.

Benefits

- Potentially lower cost of generation relative to fuel oil
- Comparable fuel cost to coal
- Improved fuel consumption efficiencies in gas turbines
- Reduced maintenance costs relative to oil generation
- Fuel supply diversity
- Creates infrastructure for additional uses of natural gas (e.g. industrial use, transportation fuel)
- Lower carbon dioxide and other pollutant emissions relative to fuel oil and coal plants

Drawback

- Potential proximity of LNG unloading and storage facilities to residential and industrial areas
- Proximity of LNG ships to existing navigation lanes and recreational boating areas
- Potential issues with Coast Guard regulations

- Dock improvements and dredging may be needed to accommodate operation
- Future events in LNG and LPG market outside local control could produce unfavorable price volatility

6.3 Coal

- Dispatchable
- Fossil Fuel
- Imported

Resource

Coal is a commonly used source of source of electricity generation in the United States. Approximately 42% of electric power produced in the U.S. is produced from coal. (EIA) In the Caribbean, the use of coal amounts to less than 6% of total electricity generation. The coal supplied to the Caribbean is generally imported from the Columbia, Venezuela, or the United States. (The World Bank 2011)

In most coal fired power plants, chunks of coal are crushed into a fine powder and are fed into a combustion unit where it is burned. Heat from the burning coal is used to heat water in boilers and produce high pressure steam. That steam is used to drive one or more steam turbines to generate electricity.

In recent months, coal has been surpassed by natural gas as the least expensive conventional technology for the generation of electricity from fossil fuel. In the Caribbean region, the transport of coal to small islands increases the expense. The economics of coal are also influenced negatively by environmental externalities. Furthermore, coal generating units are ideally operated in baseload mode at or near full capacity. Therefore, utilization of coal plants for cycling and load-following operations on small power grids reduces the economic performance of the units. (Beck 2008)

Siting

Coal-fueled power plants require significant physical space for the generating equipment, coal storage, and bulk storage of reagents such as limestone, ammonia, and activated carbon. These plants also require access to water sources for cooling, boiler makeup, and other uses. The current Water and Power Authority owned facilities are inadequate for siting new coal generating units. A previously industrialized site would be the most favorable location for development of a coal plant.

The only existing coal plant in the Virgin Islands is on the island of St. Croix. The St. Croix Renaissance Group currently owns a pulverized coal-fired steam boiler that can generate up to 60 MW of electricity. The power plant contains two 12.5 MW steam turbines and two 5 MW steam turbines, for a total current capacity of 35 MW of electricity. Coal for this power plant was transported by ship to the facility's deep water port terminal. The coal-fired boiler has been inactive since 2000.

Permitting

Recent EPA regulations place restrictions on carbon dioxide emissions from new coal-fired plants and essentially require additional investments in carbon capture and storage technology. Additionally, the EPA has adopted restrictions on mercury and other toxic air emissions (MATS) that affect both new and existing coal plants. These standards are to be fully enforced by 2015.

Capital

New coal-fueled power plants have much higher initial capital costs than other generators such as diesel or gas turbine units. Existing coal plants are also facing significant capital investments to facilitate compliance with current and proposed environmental mandates. This includes investments in emission control technologies such as activated carbon injection (ACI), baghouses, electrostatic precipitators (ESP), and selective catalytic reduction (SCR).

Benefits

- Lower cost of generation relative to fuel oil
- Fuel supply diversity
- High capacity factor and unit availability relative to other technologies
- Coal plants are often flexible enough to burn alternative fuels such as biomass

Drawbacks

- Coal releases considerably more CO_2, NO, SO_2 and other pollutants than oil or natural gas
- Environmental impacts provide a hindrance to permitting
- Coal technology requires the installation of more pollution controls to meet environmental regulations than natural gas generation
- Coal plants must operate at near full capacity and are unsuitable for load following adjustments to power output as demand for electricity fluctuates throughout the day
- While coal could supplant base load requirements at the existing power plants, WAPA would need to maintain non-coal plants and production capacities sufficient for its customer needs for those times when the coal plant is off as a result of scheduled or emergency outages
- A means of disposal of the resulting ash must be identified.

6.4 Subsea Grid Interconnection

- Dispatchable
- Fossil Fuel/Renewable Energy
- Imported

Resource

In 2011, Siemens Energy, Inc., on behalf of the Government of the Virgin Islands and the Virgin Islands Water and Power Authority, conducted a feasibility study on the interconnection of the Puerto Rican and U.S. Virgin Islands electrical grids. The study concluded that it was technically feasible to connect the St. Thomas electrical grid to Puerto Rico by subsea cable. The study also concluded that while technically feasible to connect the St. Croix electrical grid to Puerto Rico, such a connection would exceed the deepest current subsea electrical cable deployment by approximately 340 feet and would require additional laboratory testing. The St. Croix interconnection also anticipates connection at a substation that it is currently not designed or installed.

The existing power system in Puerto Rico has an installed capacity of approximately 5,830 MWs and a peak load of about 3,350 MW. The Puerto Rico Electric Power Authority charges approximately 27¢/kwh to residential customers. WAPA would need to negotiate a power purchase price that can beat avoided cost for electric generation when the capital costs for necessary system upgrades and the financing cost of the cable installations are included.

Siting

The subsea interconnection project currently contemplated would connect the Randolph Harley Power Plant in Krum Bay, St. Thomas to the Fajardo substation on the east coast of Puerto Rico, a distance of approximately 50 miles. The St. Croix interconnection contemplates a connection between a substation to be constructed in Frederiksted to the Yabucoa substation in southeastern Puerto Rico, a distance of approximately 80 miles.

Permitting

Successful permitting of the subsea gird interconnection project will require the conduct of a very extensive environmental impact study to identify the risks related to the construction and operation of the cables. The main environmental concerns about submarine cable installations relate to seabed impact and erosion of the ocean floor (The World Bank 2011). Federal permitting agencies will be involved in the environmental review of the project, as well as state permitting agencies in the Virgin Islands and Puerto Rico. The cable landing sites will require Coastal Zone Management approval.

Capital

The cost of the subsea grid interconnection project can be estimated between $125 Million - $300 Million depending on whether one or both islands are connected and on the decision of the sizing of the cable. The major portion of the costs is anticipated to be the submarine cable installations. There are however, other costs associated with the upgrades of the power systems on both islands that are required to accommodate the project and maximize its efficiency.

Benefits

- Increased capacity for renewable energy integration without impacting grid stability
- Reduction in air emissions resulting from power generation within the Virgin Islands
- Potential cost reduction on overall electric rates

- Reduced reserve requirements and resulting fuel savings
- Allows for more economical dispatch of existing generation
- Enhances resilience to hurricanes and other natural disasters or fuel shortages

Drawbacks

- Contractual obligations must anticipate issues related to joint ownership and management of the project

Intermittent Energy Sources

6.5 Solar

- Nondispatchable
- Renewable Energy
- Indigenous

Resource

Photovoltaic (PV) panels convert sunlight into electricity. Solar maps of the region show conform that the U.S. Virgin Islands has a good solar resource for solar PV development. In June 2012, The Water and Power Authority announced the execution of six power purchase agreements, with three different firms for the development of utility-scale solar PV energy in the Virgin Islands. The cost of energy prices contracted for in the agreements range from 14.22₵/kwh – 24.5₵/kwh with a weighted average of approximately 17₵/kwh. These projects have a total rated capacity of 18.3 MW (DC) with 8.3 MWs on St. Thomas and 10 MWs on St. Croix. This installed capacity exceeds the 5-12 MWs anticipated in the USVI Clean Energy Roadmap. The capacity factor is expected to be between 16 -20%.

Siting

Solar PV systems require approximately 3 to 5 acres of rooftop space or suitable land per megawatt of rate capacity. PV systems must also be protected to greatest extent possible from vandalism and accidental damage. Due to the impact of cloud cover on the output of PV systems, it is advantageous to seek geographic diversity when siting PV projects.

Of the announced projects on St. Thomas, 5 MWs are to be located at Estate Donoe and 3.22 MWs at the Tutu Park Mall. On St. Croix, approximately 4 MWs are to be located at the Island Crossings Shopping Center, 3.3 MWs at Estate Hogensborg, and at 2.77 MWs at Estate Gasperi.

Permitting

The permitting of photovoltaic systems is a relatively straightforward process. Typical earth change and building permit requirements are the primary permitting considerations. Stormwater management and state historic preservation requirements will also have to be satisfied.

Capital

Utility-scale photovoltaic systems can currently be developed for as little as $3.50/w (NREL 2011). At this low-range cost, 18 MWs of photovoltaic generation would cost approximately $63 Million. WAPA has utilized competitively bid, long-term power purchase agreements to procure utility-scale solar energy.

Benefits

- Reduction in air emissions resulting from power production from fuel oil
- Fuel supply diversity and protection from price volatility
- After initial capital costs, free, indigenous source of fuel for power production
- Relatively low maintenance requirements
- Maximum power output coincides with the time of day of peak load demand

Drawbacks

- Significant land requirements
- Very low capacity factor
- High initial capital cost
- Intermittent energy output that can potentially cause grid stability concerns
- Susceptible to damage from hurricanes and tropical storms

6.6 Wind

- Nondispatchable
- Renewable Energy
- Indigenous

Resource

Wind power is considered one of the lowest cost renewable energy technologies. Current utility-scale turbine technology typically features three-bladed machines with rated capacities of 1–3 MW and tower heights of 250–300 feet (NREL 2011). The potential for wind power in the Caribbean is relatively large due to the presence of the trade winds throughout the year. Wind energy has the potential to be the fastest-growing renewable energy technology in the Caribbean over the next two decades (The World Bank 2011).

The National Renewal Energy Laboratories estimates 12 MW to 33 MW of potential utility-scale wind energy deployment in the Virgin Islands. Those estimates assume the possibility of siting 10 to 20 wind turbines with rated capacities of greater than 1 MW each. Logistical considerations and space limitations may make achieving the higher end of the range very difficult. The National Renewable Energy

Laboratories has also determined that, when the wind resource potential in the U.S. Virgin Islands is compared to the costs of recent utility scale projects in the Caribbean region, the cost of energy in the Virgin Islands can be expected to range between 15¢–30¢/kWh (NREL 2011).

Siting

Ideal sites for wind power projects must have an adequate wind resource, an ability to interconnect economically to the power grid, and be able to satisfy the permitting requirements and other environmental considerations. Additionally, a project site must facilitate the transport of the turbine equipment to the site and provide suitable space to allow for the assembly and installation of the wind turbines. Finally, the project site must obtain public acceptance.

The southern shore of St. Croix and the Bovoni Point on St. Thomas have been identified as potentially viable sites for utility-scale wind energy production by the National Renewable Energy Laboratories (NREL 2011). Detailed wind measurements must be conducted at these potential sites to confirm the economic feasibility of wind power development.

Permitting

To date, the Virgin Islands has not promulgated rules, regulations, or ordinances to govern the installation of utility-scale wind energy systems. It is anticipated that such permitting requirements will establish setbacks from occupied buildings, roads, and non-participating property boundaries. The regulations are likely to also include minimum requirements for potential nuisance issues including sound and shadow flicker. Environmental regulations would seek to mitigate the disruption of protected habitats and the incidental taking of endangered species.

Capital

Based on wind projects recently constructed in the region, the National Renewable Energy Laboratories estimates that a 5 MW –13 MW project cost on the order of $12 million to $36 million (NREL 2012). WAPA could finance the projects through the issuance of bonds for development and construction of the wind turbines and assume sole ownership of the project. Alternatively, WAPA could incentivize the project development through a long-term power purchase agreement with an independent power producer. Under this structure a third-party would assume the responsibility of developing, operating, and maintaining the wind power plant, along with the associated risks. WAPA would agree to purchase power from the project at a negotiated price for the duration of the agreement.

Benefits

- Reduction in air emissions resulting from power production from fuel oil
- Potential cost reduction on overall power production costs
- Fuel supply diversity and protection from price volatility
- After initial capital costs, free, indigenous source of fuel for power production

Drawbacks

- Variable energy output that can potentially cause grid stability concerns

- Relatively poor capacity factor
- Susceptible to damage from hurricanes and tropical storms
- Significant aesthetic impacts
- Potential environmental impacts to birds and bats
- Challenging logistics for installing large turbines on small islands

Alternative Base Load Energy Sources

6.7 Biomass

- Dispatchable
- Renewable Energy
- Indigenous

Resource

Biomass energy is energy derived from grassy and woody plants, residues from agriculture or forestry, the organic component of municipal and industrial wastes, and the methane gases produced by landfills.

Although there are several technologies available to convert biomass into electricity, all 87 waste-to-energy plants operating in the United States utilize direct combustion (NREL – WTE 2011). A direct combustion system burns the biomass feedstock to generate hot flue gas, which is fed into a boiler to generate steam. The steam is used to power a steam turbine thereby generating electricity. The amount of electricity that can be generated depends on the energy content of the waste, the amount of waste available, and the efficiency of the waste-to-energy plant.

The U.S. Virgin Islands creates approximately 150,000 tons of municipal solid waste per year, of which approximately 135,000 tons is suitable for use in a waste-to-energy plant. The National Renewable Energy Laboratory estimates that this amount of fuel is sufficient to generate 13 MWs of electricity. NREL further estimates that 1-2 MWs of energy can be generated from biomass energy crops. These energy crops could consist of fast-growing species such as Tan Tan (Leucaena leucocephala) or Australian Pine (Casuarina equisetifolia). Additionally, industrial wastes such as rum bottoms from the local distillery operations can serve as supplemental biomass fuels (NREL 2011).

In April 2011, WAPA executed a power purchase agreement with the Alpine Energy Group for 16.5 MWs of power to be provided by a waste-to-energy facility at $0.14/kWh. This cost included the construction of two refuse-derived fuel processing facilities and the inter-island transportation of the municipal solid waste from St. Thomas to St. Croix. The power purchase cost was subsidized by solid waste service fees. The National Renewable Energy Laboratory suggests that a cost of energy from $0.12–$0.16/kWh is reasonable (NREL 2011).

Siting

A waste-to-energy system typically needs access to water, so a location along the coast or access to waste water is often required. The waste-to-energy plant will also require a site that can accommodate heavy traffic and provide storage for biomass fuel prior to use. WAPA has identified the industrial zone on the south shore of St. Croix and the Bovoni peninsula on St. Thomas as the two most suitable locations for waste to energy facilities in the Virgin Islands. A means of disposal of the resulting ash must also be identified.

Permitting

Air emissions from waste to energy facilities are stringently regulated by Environmental Protection Agency and Department of Planning and Natural Resources standards. New facilities must meet Maximum Achievable Control Technology requirements. These standards are likely to require the installation of emission control devices such as selective catalytic reduction, dry sorbent injection, fabric filters, and electrostatic precipitators. Coastal Zone Management permitting would likely also be a regulatory requirement.

Capital

Installed costs for waste-to-energy systems have been projected by the U.S. Energy Information Administration to be approximately $8,200/kW on the U.S. mainland (NREL 2011). At this estimated cost, a 13 MW facility would cost upwards of $106.6 Million to construct. A waste to energy project in the Virgin Islands would likely require two refuse-derived fuel processing facilities instead of a single site, so additional costs are likely.

Benefits

- Fuel supply diversity
- Indigenous source of fuel for power production
- Lower cost of generation relative to fuel oil
- Provides solid waste disposal alternative

Drawbacks

- High initial capital cost
- Negative public perceptions in the United States
- Environmental impacts provide a hindrance to permitting
- Public concern of energy crops displacing food crops on available farmland

6.8 Ocean Thermal Energy Conversion

- Dispatchable

- Renewable Energy
- Indigenous

Resource

Ocean thermal energy conversion (OTEC) generates electricity by utilizing the temperature difference between the surface of the ocean and the colder, deeper waters. A temperature differential of approximately 20°C (36°F) is required for viable power generation. The deep waters between St. Croix and St. Thomas provide a potentially viable resource for ocean thermal energy conversion.

The high cost of oil has encouraged recent exploration in OTEC technology for deployment in tropical regions. Since 2009, the U.S. Naval Facilities Engineering Command has awarded Lockheed Martin $12.5 million to advance the design for a 10-MW OTEC pilot project. That plant should be operational by 2015. In 2011, Ocean Thermal Energy Corporation executed a Memorandum of Understanding with the Bahamas Electricity Corporation to develop two commercial ocean thermal energy conversion plants.

The Department of Energy does not currently consider ocean thermal energy conversion to be a commercially viable energy technology.

Siting

Ocean thermal energy conversion is particularly effective in tropical temperature zones on small islands and in coastal communities. The northern coast of the island of St. Croix has drawn considerable attention from OTEC developers.

Permitting

OTEC systems have relatively little environmental impact. These systems would be subject to local coastal zone management regulations and by the federal standards of the Environmental Protection Agency and the National Oceanic and Atmospheric Administration.

Capital

Since OTEC utilizes a renewable source of energy, recurring costs to generate electricity are minimal. However, the initial capital costs of OTEC systems per kilowatt of generating capacity are very high because large pipelines and heat exchangers are needed to produce relatively small amounts of electricity. A 10 MW OTEC plant is estimated to cost between $10 million - $20 million per MW of installed generating capacity.

Benefits

- Fuel supply diversity
- Indigenous source of fuel for power production
- Reduction in air emissions resulting from power production from fuel oil
- Produces desalinated water for industrial, agricultural, and residential uses
- Can provide economically air conditioning of coastal buildings

Drawbacks

- Technology has not been commercially deployed for power production at utility-scale
- Extremely high initial capital cost

7. Technology Deployment Scenarios

The appropriate technologies to be adopted are not a "one size fits all". Various variables must be considered, particularly differences in the two island grids. Each island grid needs its own dispatchable generation capacity and each island has its own maximum cap on non-dispatchable or intermittent energy. As an example, because the total cost of connecting a grid between Puerto Rico and St. Croix is higher than the total cost of such a connection between Puerto Rico and St. Thomas, it is more likely that St. Thomas will receive the dispatchable benefits of interconnection before St. Croix and, flowing from that, it is more likely that St. Thomas would be able to escape its non-dispatchable intermittent energy cap sooner. Without the grid interconnection in the near future, it is logical that WAPA should prioritize non-grid and non-petroleum dispatchable production capacity on St. Croix. Likewise, there is an existing non-operating coal plant on St. Croix but none on St. Thomas. Any analysis of a coal option needs to take this into account.

8. Implementation Targets

1. Implement measures to enhance production efficiency at existing power generation facilities.

1.1. Commission study of Conversation Voltage Reduction ability – December 2012

1.2. Complete permanent reverse osmosis installation at Harley Plant Facility – March 2013

1.3. Secure project financing with gasoline tax revenue source (depending on market conditions) – September 2013

1.4. Issue RFP for more efficient generating units to replace selected existing units – September 2013

1.5. Issue RFP for installation of heat recovery steam generator on St. Thomas – September 2013

1.6. Complete permanent reverse osmosis installation at Richmond Plant Facility – September 2013

1.7. Complete heat recovery steam generator installation (proposal review, contract negotiation, permitting, construction and commissioning) – 2016

1.8. Complete generating unit installation (proposal review, contract negotiation, permitting, construction and commissioning) – 2017

2. **Convert base load power production from fuel oil to liquefied natural gas or liquefied petroleum gas.**

   2.1. Issue LNG and LPG supply contract Request for Qualifications – October 2012

   2.2. Award LNG and/or LPG Supply Contract – February 2013

   2.3. Conversion of generating units to gas-fired – June 2014

3. **Develop grid interconnection between the Virgin Islands and Puerto Rico.**

   3.1. Issue Request for Proposal for environmental impact study – October 2012

   3.2. Identify funds for environmental impact study – October 2012

   3.3. Complete study – December 2013

   3.4. Negotiate interconnection and power purchase with PREPA – December 2013

   3.5. Issue Request for Proposals for construction – December 2013

   3.6. Complete cable interconnection (proposal review, contract negotiation, design, cable fabrication, permitting, and construction) – 2015

4. **Maximize development of solar and wind resources.**

   4.1. Wind anemometry installed – November 2012

   4.2. First photovoltaic systems deployed – March 2013

   4.3. Request for Proposals for wind power purchase agreements issued – November 2013

   4.4. All photovoltaic systems in place – December 2013

   4.5. Proposals evaluated – January 2014

   4.6. Wind power purchase agreements executed – July 2014

   4.7. Wind projects commenced – December 2014

5. **Pursue biomass energy and ocean thermal energy as potential diversification of base load energy.**

   5.1. Bovoni Landfill Gas-to-Energy project commissioned – October 2012

5.2. Bovoni Landfill Gas-to-Energy project grid-tied – December 2012

5.3. Request for Proposals for Waste-to-Energy Issued – December 2012

5.4. Contracts awarded for WTE project(s) – September 2013

5.5. Project(s) commences – 2014

5.6. Project(s) completion - 2016

9. References

Davis, J.; Haase, S.; Warren, A. (2011). Waste-to-Energy Evaluation: U.S. Virgin Islands. NREL/TP-7A20-52308. Golden, CO: National Renewable Energy Laboratory. http://www.edinenergy.org/pdfs/waste-to-energy_eval_usvi_nrel_52308_final.pdf

Energy Information Administration (EIA). (2012). Annual Energy Outlook 2012 with Projections to 2035. http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf.

Lantz, E.; Olis, D.; Warren, A. (2011). U.S. Virgin Islands Energy Road Map: Analysis. NREL/TP-6A20-52360. Golden, CO: National Renewable Energy Laboratory. http://www.edinenergy.org/pdfs/52360.pdf

Gerner, Franz; Hansen, Megan (2011).Caribbean Regional Electricity Supply Options: Toward Greater Security, Renewables and Resilience. The World Bank.

RW Beck. (2008). Power Supply Evaluation Report on the Electric System of the Virgin Islands Water and Power Authority. Christiansted, USVI: WAPA.