EXTRACTED FROM TECHNICAL ASSESSMENT OF THE RENEWABLE ENERGY NEEDS OF THREE (3) DOWASCO WATER PUMPING STATIONS, DOMINICA by Nathan Hart

ABBREVIATIONS AND ACRONYMS

~ - Approximate/Approximately

AC – Alternating Current

AWG – American Wire Gauge

BMS – Battery Management System

BOS – Balance of the System Components

CARICOM – Caribbean Community

CCCCC – Caribbean Community Climate Change Centre

CO_2 – Carbon Dioxide

DC – Direct Current

DG – Distribution Generator/Generating

DOD – Depth of Discharge

DOMLEC - Dominica Electric Power Company

DOWASCO – The Dominica Water and Sewage Company Ltd

EC$-Eastern Caribbean Dollars

EE – Energy Efficiency

EEO's – Energy Efficiency Opportunities

EOI – Energy-efficient Options

ESO – Energy Saving Opportunities

Exchange Rate - 1$USD = $2.70 EC

GED – Dominica Electrical Engineering Department

GENSET – Generator System

GHG – Green House Gas

GUI – Graphic User Interface

IEC - International Electro-technical Commission

IEEE - Institute of Electrical and Electronics Engineers

IP – Waterproof and Dustproof rating IP67, IP68

IRC –Independent Regulatory Commission of Dominica

KVA – Kilo Variance

kW - Kilowatt

KWh – Kilowatt-hour

KWp – Kilowatt Peak

LCOE – Levelized Cost of Electricity

MDP – Main Distribution Panel

MIGD – Million Imperial Gallons per day

MPPT/MPP – Maximum Power Point Tracking/ Maximum PowerPoint

MTS – Manual Transfer Switch

MWh- Megawatt-hour

NEC – North America Electric Code

NRW- Non-Revenue Water

Ø – Phase

OCPD – Overcurrent Protection Devices

P 1-29 – Valve and Distribution Connection points

PCU – Power Conditioning Unit/Inverter

Pf – Power factor

PS – Pumping Station

PV – Photovoltaic

REO – Renewable Energy Options

RET Screen – Renewable Energy Economic Analysis Tool

STC – Standard test conditions

T&D - Transmission and Distribution

TUV - Technical Inspection Association of Germany

UL - Underwriters Laboratories

USD$ – United States dollar

VFD/VSD – Variable Speed Drives

Technical Assessment and electrical/energy audit were conducted at three (3) sites: Jimmit Pump station, Warner Pumping station and the Tete Morne/Grand Bay Pump station under the supervision of DOWASCO engineer and the operational guidance of the stations pump operators. To collect the data the consultant supplied and used Amprobe dm- II plus 1000a power quality analyzer, which measures all of the electrical characteristics – Kilowatts- KW, Kilo Variance- KVARs, Current – I, Power Factor – pft, Harmonics, Voltages- V, Kilo Voltage Amperes- KVA and waveform of the Current and voltages. The Consultant also thought it necessary to analyze PV shading of each site given the topography of the island of Dominica, this shading analysis was performed using the 'Solar Pathfinder' analyzer.

The site visit was conducted during the period of 3rd December 2019 to 8th December 2019. Data collection and the station's technical electrical assessment and energy analysis were staggered over this period because of safety and ground access to the sites. Additionally, data collected from the Chief Engineer along with information shared from the Finance and Operations Department for the economic years of 2018 and 2019 revealed that the total cost of energy for the budget for these time periods amounted to $EC 1.1M and $EC 1.3M respectively.

From the onset of this technical assignment which will generate REO's more specifically recommended grid-interactive photovoltaic systems, the Consultant recognized that it was prudent to have detailed technical discussion(s) with the grid operator DOMLEC, in order to determine the correct protocol, procedures and technical requirements to ensure successful grid interconnection. Furthermore, the Consultant noted that grid-interactive systems required licensing from the IRC (Independent Regulatory Commission); thus, a detailed technical meeting was conducted. This information will be critical to ensure the process of grid interconnection for DOWASCO.

For the specific purpose of this technical needs assessment for DOWASCO RE options, several energy economic drivers were extrapolated from DOWASCO power utility data. The following values were derived:

- Cost of Energy (including fuel surcharge and VAT) = ~ 1.244 EC$/kWh[1] or [2]USD$0.46/kWh
- KVA Demand Cost = 1.00 EC$/KVA Month[3]
- Energy Index Tete Morne = 0.65kWh/M^3
- Energy Index Jimmit = 0.36kWh/M^3
- Energy Index Warner = 0.21kWh/M^3
- Monthly energy average for Tete Morne Station = 5366 kWh
- Monthly energy average for Jimmit Station = 8009kWh
- Monthly energy consumption for Warner Station =430.9kWh

The main results are:

1. Jimmit Booster Station

a. The potential area that can be used for PV installations ~ 3250ft2 ± 10%
b. Overall shading is less than 10% for all months

[1] This Value is based on calculated averages for year 2018/2019
[2] Exchange rate 1$USD = $2.70 EC
[3] Consultant noted that KVA for each station was 1 no matter the demand

c. Inverter size recommended for the array is any combination 50kW$_{ac}$
d. Gross annual GHG emission reduction of 51.6tons of CO_2/yr.
e. Spec. energy yield (approx.) 1305 kWh/kWp

2. Tete Morne Booster Station

a. The potential area that can be used for PV installations ~ 2087 ft2 ±10%
b. Overall shading is less than 10% for all months
c. Inverter size recommended for the array is any combination 50kW$_{ac}$
d. Gross annual GHG emission reduction tons of CO^2 approximately 55tons/yr.
e. Spec. energy yield (approx.): 1312 kWh/kWp
f. After expansion Tete Morne facility energy demand will increase from 5366kWh/month to ~ 23,940kWh/month with an estimated average cost of $EC 29,782/month (current cost is ~ EC$6,670.92)

The results of the recommendations were based on several activities that included:

- Conducting a physical site visit to DOWASCO's three (3) water pumping stations, namely, an inspection of each site, Jimmit, Warner and Tete Morne booster Stations and Data Collection

- Interviewing key facility personnel to establish operating characteristics of the facilities, operating and maintenance procedures, unusual operating constraints, and anticipated future expansions or changes to the facility, specifically for the **Tete Morne** facility/station

- Inspecting and observing the facility in order to map energy use flows and operations
- Reviewing all available documentation, including all structural building drawings, mechanical and electrical drawings

- Analyzing information generated by RetScreen software specific to Clean Energy projects that provides engineering economic data along with avoided CO_2/GHG.

One of the challenges faced during this assignment was the lack of flow meters at the station and access to the main power cables. Flow meters would be appropriate for engineering analysis to get a clear indication of each station energy index, which is one of the useful indicators to understand the energy consumed in the pumping process; thus, an engineering estimated calculation was made based on operational flow rate and tank sizes. Access to power cables through the facility presented a high electrical shock risk factor to the Consultant, the current and voltage at the industrial level can result in death or serious injury.

In summary, the technical assessment and evaluation conducted at the three (3) pumping facilities, revealed that DOWASCO engineering selection and the use of appropriate pumps to meet demand and elevations '*head'* requirements, were well selected and the pumping engineering distribution system within each station was set up to achieve maximum and efficient operation based on the current electrical infrastructure. Such precise pump engineering and pump selection will continue to integrate well with DOWASCO's goal of achieving the best possible energy-efficient operation which will complement the Company's renewable energy framework.

DOWASCO Energy and Water Sector of Commonwealth of Dominica

Dominica is situated in the eastern Caribbean, south of Guadeloupe and north of Martinique. With an area of 751 km² (289.5 sq. mi), the island has a coastline of 148 km, its landscape is mountainous and of volcanic origin, the highest peak is Morne Diablotins, at 1,447 m (4,747 ft.), the dormant volcano is the second highest mountain in the Lesser Antilles, after La Grande Soufriere in Guadeloupe. The Windward Islands includes Dominica, Grenada, Martinique, Saint Lucia, and St. Vincent and the Grenadines. Dominica is the most northern of the Windward Islands has a population of 71,808 inhabitants (2019), with Roseau as its capital and largest city.

Figure 1 General Map of Dominica

The island has significant eco-tourism potential, but poor infrastructure and the absence of an international airport which has impeded the industry's growth. The country is also vulnerable to hurricanes, notably Tropical Storm Erika in 2015 and Hurricane Maria 2017, thus climate change has negatively impacted this island far more significant than some of its neighbouring counterparts. The Dominica Water and Sewage Company Limited –DOWASCO, a government-owned company provides 100% of the islands potable water supply. Dominica has 2,706 m³/person/year of water per inhabitant (2017)[4]. According to the Chief Engineer[5] for DOWASCO, water production average about 10MIGD, where source water is captured at various points of higher elevations from the mountainous regions via gravity and then boosted via strategically placed PS: Warner, Jimmit and Tete Morne as examples. Also noted during the engineering interview with the chief engineer, estimates from water production versus

[4] https://www.worldometers.info/water/dominica-water/
[5] Mr. Magnus Williams

billed water by DOWASCO indicated that unaccounted-for-water or commonly known as NRW is estimated to be around 58.5%. The Consultant also noted from the interview that the adverse climate conditions experienced by the country has also directly impacted DOWASCO and has damaged a large percentage of the distribution network, this has aggravated the NRW condition that exists today; needless to say, there is no program to counteract this NRW to date.

DOWASCO has installed 97.2kW PV system at its sewage treatment facility in its capital city Roseau, however, to date it has not been energized because of high harmonic intermittence mentioned by DOMLEC engineers. Thus prior to the above project, all the energy consumed by DOWASCO is generated by the Dominica Light & Power Utility Company, which EMERA Caribbean Inc., holds a 52% interest in Dominica Electricity Services Ltd-DOMLEC.

DOMLEC serves approximately 35,300 customers with a peak demand of about 18MWh[6]on the island of Dominica. The Independent Regulatory Commission (IRC)[7] which regulates the electricity industry in the Commonwealth of Dominica recently granted two licenses to the Company. The first is a non-exclusive generation license, and the second is an exclusive license to transmit, distribute and supply electricity within Dominica. These licenses came into effect on 1st January 2014. As is relates to DOMLEC generation capacity, the Company operates three run-of-the-river hydro plants on the Roseau River in the Roseau Valley and two diesel plants; however, noted during the interview process, two of the hydro plants are currently off-line as a result of the two major hurricanes that have affected the island, reducing load capacity from a peak of 18MWh to a peak of 14MWh to date. The engineers also highlighted that the loss of ROSS University, which was DOMLEC largest customers has affected the peak loading by approximately 30%. The hydro plants are the Laudat plant, the Trafalgar plant and the Padu plant with installed capacities of 1.24MW, 3.52MW and 1.8MW respectively. These three plants are automated and controlled from the System Control Center located in Fond Cole. The two diesel stations: Fond Cole and Sugar Loaf, have installed capacities of 13.3MW and 6.8MW respectively. However, Low Peak loading demand continues to hamper this utility Company, though, outside the scope of this consultancy, this has a direct effect on the amount and the quality of renewable penetration allowed by DOMLEC as the grid operator.

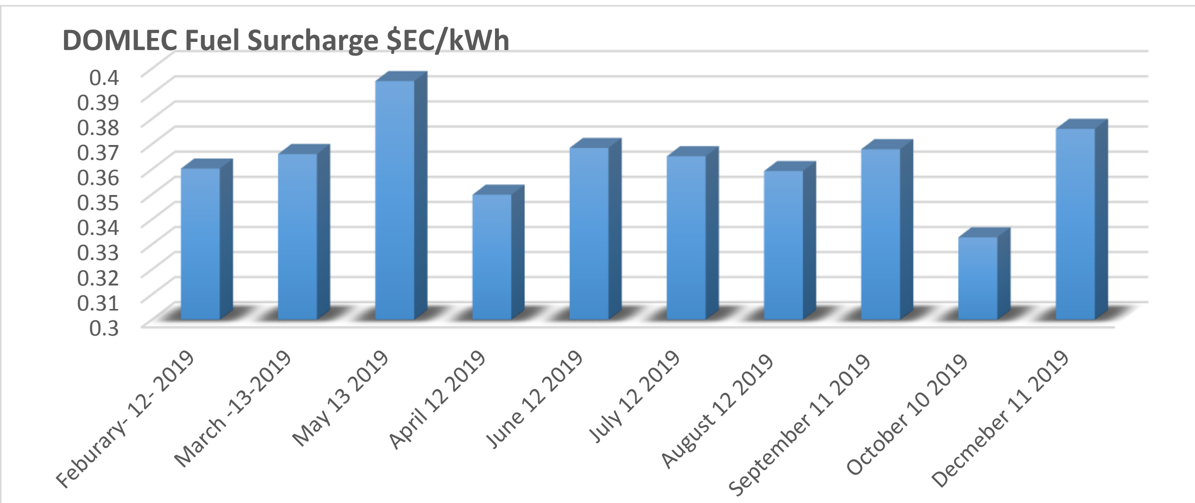
Electricity rates in Dominica are one of the highest, if not the highest, in the Caribbean, approximately $EC1.244/Kwh or $ US0.46/kWh. The transmission and distribution (T&D) network comprised of 403 kilometres of 11kV and 922 kilometres of 230/400V overhead lines. This current infrastructure serves a customer base of approximately 35,300 customers or about 98% of the island. All generation sources are linked via 11kV inter-connectors and, in some instances, via 33kV distribution feeders.

The DOWASCO pump stations that have been audited as result of this technical assessment conducted, are billed under commercial class by DOMLEC with varying monthly surcharge cost of EC$0.3499/kWh - $EC 0.3951/kWh, EC$4.32/KVA and commercial Block 1 Charge of EC $0.733/kWh, bringing the average cost of electricity at a commercial rate of ~EC$ 1.244/kWh.

[6] See Initial report for interviewed response from DOMLEC Engineers
[7] See Initial report for interviewed response from IRC Engineer

DOMLEC Tariffs			
Item	Residential	Commercial	Industrial
Fixed KVA Demand $EC/KVA	N/A	4.32	4.32
Power/ Energy $EC/kWh	1st bulk 0.578 up to 50kWh; 0.67 2nd bulk >50kWh	0.733	6:00am -10pm @0.633; 10:00pm-6:00am @0581
Fuel Surcharge $EC/kWh	Variable	Variable	Variable
Time of Use - TOU	N/A	Not requested by DOWASCO	yes
Penalty system Customer/Utility	No	No	No

Figure 2 Table showing DOMELC Tariff



[8]*Figure 3 Chart showing DOMLEC fuel Surcharge 2019 history*[9]

[8] For 2019 the average was 0.34$EC/kWh (Max 0.399-May 2019 ; Min 0.33 –October 2019)
[9] The rate is calculated monthly. Actual fuel charge depends on the KWHs consumed.

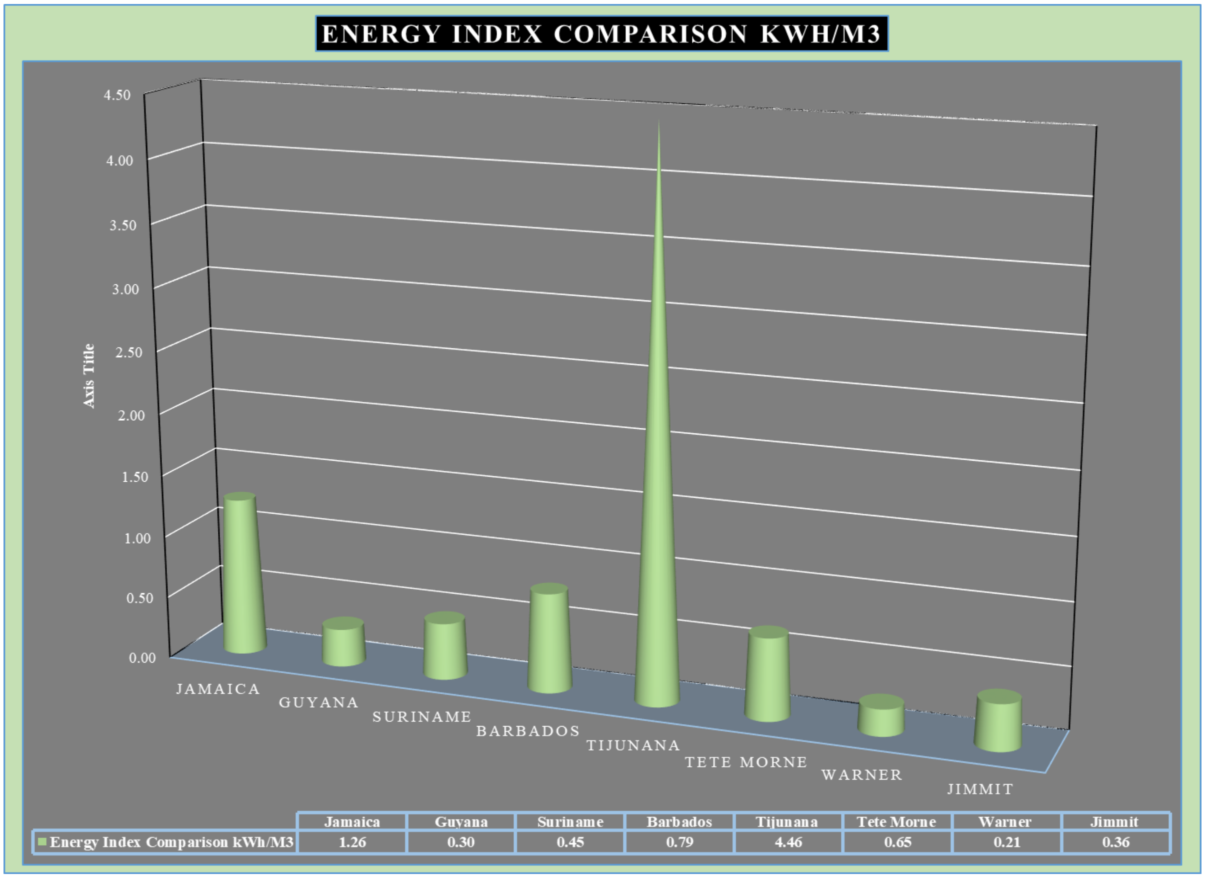


Figure 4 Chart showing Energy Index Comparison

Presentation of the DOWASCO Technical Assessment Report of the Renewable Energy Needs of Tete Morne, Jimmit & Warner Pumps Stations

Organization

DOWASCO is a statutory corporation that has the sole responsibility for the management and control of Dominica water resources for potable use. It is responsible for managing, allocating and monitoring the water resources of Dominica with a view to ensuring their best development, utilization, conservation and protection in the public interest. It is also responsible for the designing, construction, acquisition, provision, operation and maintenance of water and sewerage works for the purpose of supplying water for public purposes and the receiving, treating and disposing of sewage, respectively.

As a result, this technical assessment of the renewable energy needs of the DOWASCO pumping station Warner, Jimmit & Tete Morne under the guidance of the Caribbean Community Climate Change Centre feeds well into DOWASCO common goal of building a more climate-resilient utility infrastructure while consciously reducing its carbon footprint.

Energy Audit Methodology for the Technical Assessment

The technical assessment audit methodology used a set of techniques to determine the degree of electrical characteristics during the normal operational mode of each station with respect power quality and energy usage; as well as, to a certain degree determine areas of potentially wasted energy. The assessment will also follow through on the physical site characteristics to determine best REO's as it relates to photovoltaic application specific to each site. Conclusions drawn from the technical assessment audit include the identification and quantification of low-cost measures or profitable investments for saving energy through new PV installations, which will feed into and make up part of the project development of DOWASCO renewable energy plan and adds to a comprehensive energy efficiency project.

Based on the technical assessment of the energy audit at the water booster/pumping stations performance which relates to pumping and operation efficiency, the Consultant will make the following recommendations for improvement and REO's, based on the principle "energy-consuming systems" within each pump stations, which are:

- Motor and pump assembly, including efficiencies, operating conditions and maintenance aspects
- The Electrical distribution systems, including wires, pumps starters and OCPDs
- Electromotive system, including the transformers, metering units and Feeders

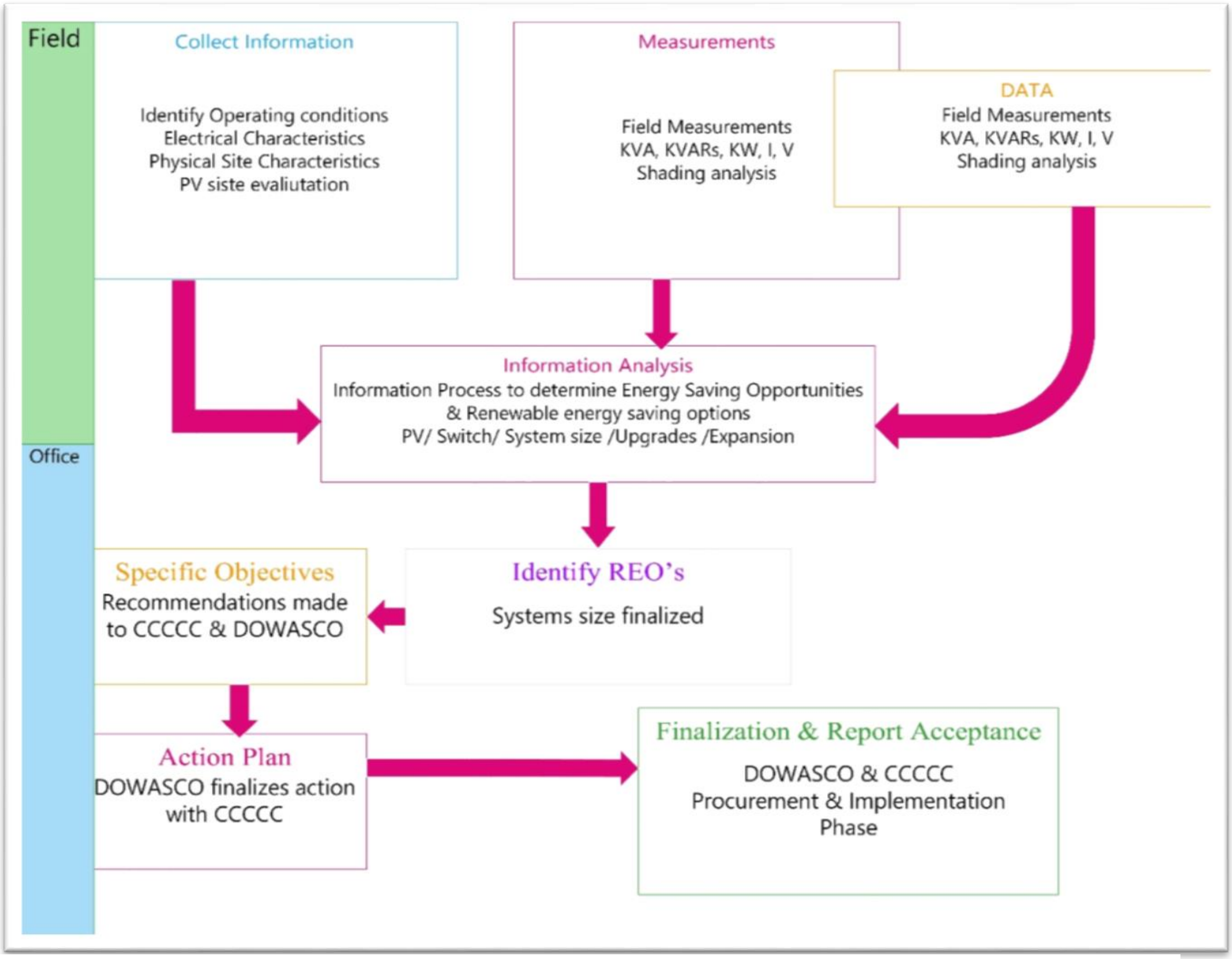


Figure 5 Diagram showing Audit Methodology

As it appears, the methodology is composed of two main tasks: fieldwork and office work.

Fieldwork consists of collecting all possible information on each pumps station system, electrical systems, including field measurements (KVA, KVARs, instant kW, I,-current, Voltages, pft-Power factor) data from the equipment plates, information on the process and operation maintenance provided by the pump operator and all the information which will help to make a correct technical analysis of each station system and equipment.

Office work consists of the analysis of the information collected in the field. It is used to first make a sound technical evaluation on the most practical REO's taking into constraints set out by policies of IRC[10] and DOMLEC[11] requirements. Site analysis coupled with the electrical characteristics of each station will feed into the overall best practice option in a report on the final renewable energy system to be implemented with a view to expanding on a modular level. It is very important to know what the largest energy consumption point at each station is, this would then guide the assessment to the areas, to implement the greatest savings opportunities through the best pathway for RE options. Once the

[10] IRC solar Application Form
[11] Decision – Renewable Energy Generation Policy – Dominica Electrical Services 2016 version 2.0

projects and recommendations are made, the Procurement and Action Plan may be integrated into the DOWASCO Climate Change Energy Efficiency and Renewable Energy Program.

The proposed methodology is focused on the following typical energy efficiency measures but not limited to:

- Power factor determination
- Pump characteristics
- Station Voltages, Operational Currents, KVA, KVARs,
- Electrical Waveform performance/characteristics
- Station switch gear orientations and OCPD devices
- Station supply and demand characteristics
- Selection of the optimal size of conductors

Other opportunities for energy savings that can result from this type of analysis may include tariff adjustments, operating equipment during off-peak hours, generation of onsite energy, during peak demand hours, application of variable frequency drives.

ENERGY AUDITS FIELDWORK

Fieldwork to audit systems consists of two main surveys to:

- Obtain the equipment characteristics
- Preform PV site Shading analysis
- Record all the field measurements of the equipment

The equipment characteristics are taken in the field by collecting information on the electrical system, the electrical motor plate, and the pump plates in all of the equipment. Additional data are taken from the operator that controls on the stations. This information is collected in a field format for all equipment.

Evaluating Technical Assessment of Energy-Saving Opportunities & Renewable Energy Options

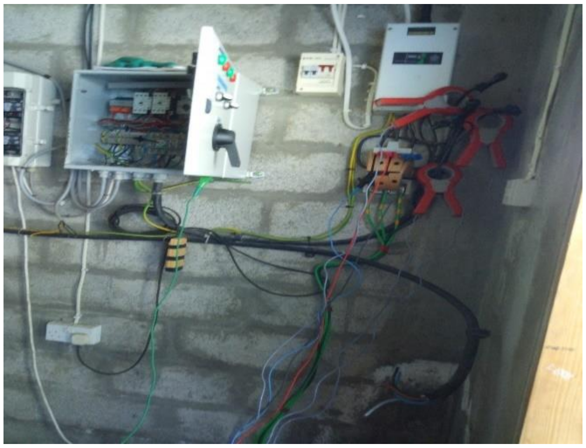


Figure 7 Showing Amprobe Meter for electrical measurements

Figure 6 Showing CT & VT around 400v system feeders

The final step of the methodology proposed is to determinate the energy savings opportunities of each station specific to photovoltaic technology in order to increase the energy efficiency and reduce power usage from traditional generation. These savings opportunities include the substitution of existing electrical equipment that will help determine the new equipment characteristics. Then, with the new equipment and savings proposals, the expected new energy reduction balance has to be processed to calculate the expected energy savings. Finally, a calculation of final economic savings, investment costs, and payback time have to be calculated as the final step of the energy efficiency audit methodology. (The latter is currently outside the scope of this contract project, however, it will form part of the recommendation for Monitoring and Evaluation).

Economic Evaluation for Saving Opportunities & Renewable Energy Options

Direct Economic Savings

The expected savings from reducing energy input from the grid via photovoltaic applications will result in a more efficient system. The amount of energy savings is obtained by multiplying the energy saved (kWh saved) by the cost of energy. For the purpose of this audit, a value of $EC1.244[12]/KWh is assumed.

RESULTS OF ENERGY AUDITS

[12] See figure 2 DOMELC Tariff

Audited Systems Process Description Jimmit Pump Station

Figure 8 Location of Jimmit Booster Pump Station

The Jimmit Pump station is located approximately 30 minutes drive from the main capital Roseau off the main access road that goes north to Portsmouth's. Based on an operational interview with engineering and the operation staff, the station operates for 13 hours per day each day of the week via set electronic timers, the times are:

- 1 am – 7 am
- 12pm – 3pm
- 7 pm – 11 pm

Electrical & Pumping Characteristics of Booster Pump Stations

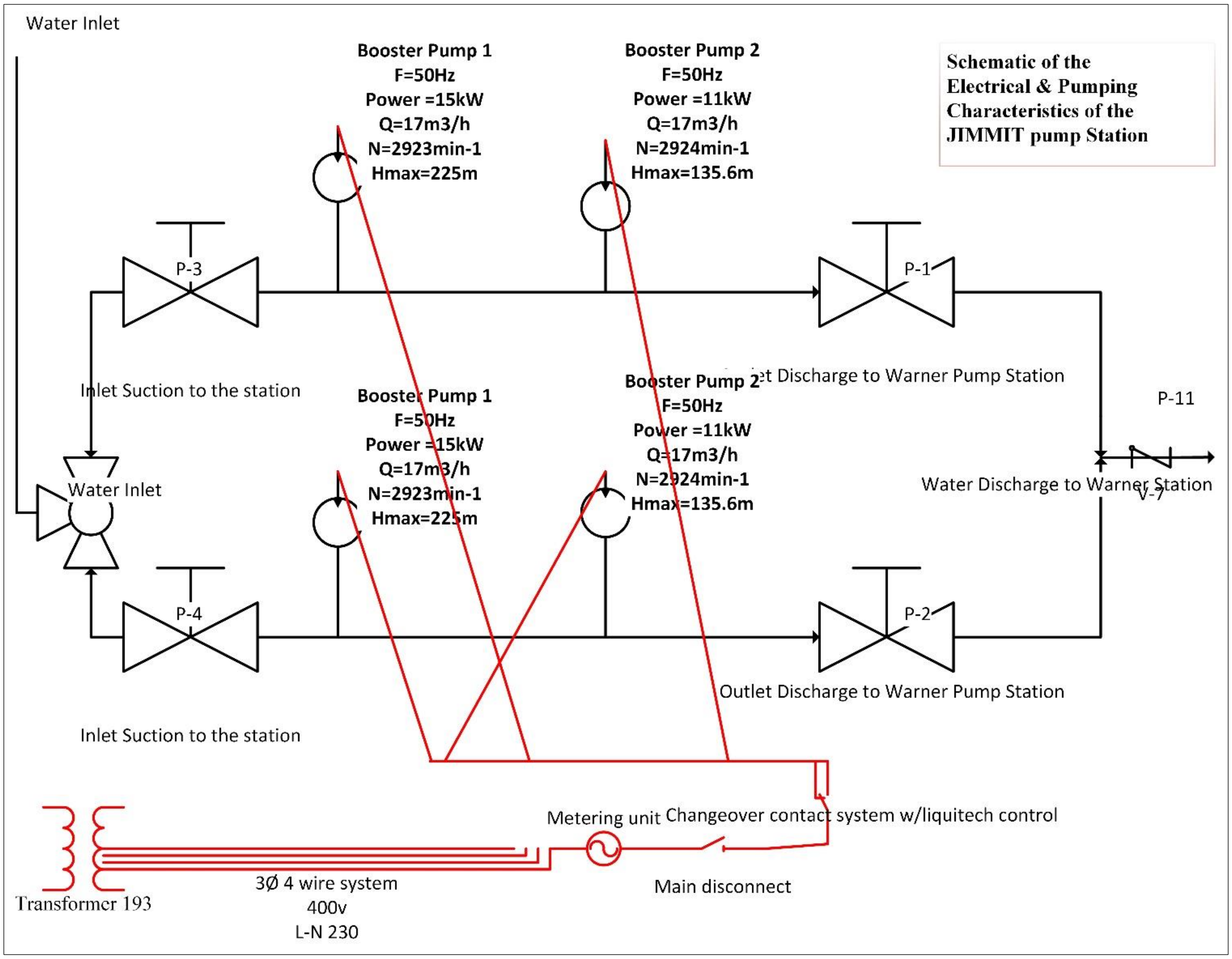


Figure 9 Schematic of Jimmit Electrical and Pumping arrangement

Jimmit Booster Pump Station

Jimmit booster station gets its supply of water from mains incoming from Mahuat area at a lower elevation. The station is comprised of four (4) GRUNDFOS[13] booster pumps. There are two CRN 15-16 SF and two CRN 15-12 A-FGJ-G-E HQQE. Figure 9 shows that the current orientation is one 15kW and one 11kW pumps each arranged in series to achieve relevant operational head[14] for DOWASCO operational needs. Each pair, which are in parallel, are rotated according to operation and maintenance needs by engineering an operational staff. The pumps operate direct online with LiqTec controls to prevent operational damage due to low or reduce suction rate.

[13] See figure 9 for JIMMIT booster pumps specification
[14] Max achievable height/elevation at which a pumps can raise water up

Electrical Characteristics of the Jimmit Booster Station

Figure 10 Pump Arrangement of Jimmit Booster Station

Figure 11 Jimmit Station controls system

The station is fed by from the utility through 11kVA transformer that steps the voltage down to 0.4KVA. Station incoming supply is 3Ø 400V, Line to Line 400V and Line to Neutral 230V. Service supply is 100AMP main feeder to stations electrical and control system via max 2AWG[15] electrical transmission lines. This Station does not have VFD/VSD[16], therefore the pumps run at full operational load at all times.

Parameter units	Results Thurs/5/19 10am	Results Thurs/5/19 11am	Results Thurs/5/19 12am	Thursday 5th 10am-12noon AVG	Average Results
Voltage L1-	228.10	228.00	228.20	228.1	228.10
Voltage L2	231.50	230.40	230.41	231.4	230.93
Voltage L3	228.50	229.10	229.10	229.5	229.05
Voltage L1,2	398.30	394.00	397.00	399	397.08
Voltage L2,3	398.30	399.00	398.10	397.3	398.18
Voltage L31	396.40	399.00	397.80	398.5	397.93
Current I1	33.30	33.00	32.45	33.29	33.01
Current I2	38.00	36.35	36.45	38	37.20
Current I3	36.75	36.61	36.67	36.75	36.70
Total Current I_n	72.32	70.42	71.34	72.32	71.60
Power Instantaneous KW	14.33	14.03	14.32	14.33	14.25
KVA	16.45	15.48	16.43	16.45	16.20
KVAR	8.05	8.094	8.015	8.045	8.05
Power Factor	0.87	0.86	0.87	0.87	0.87
Frequency Hz	50.10	50.10	50.1	50.1	50.10

Figure 12 Table Showing Collected Electrical Power Characteristics of Jimmit Booster Station

[15] AWG- America Wire Gauge
[16] Variable Speed Drive

Figure 12 shows the electrical performance characteristics of the Jimmit station, the result will vary little given the fact that pumps operate at full load during operation. Pumps work direct online through OCPD devices with LiqTec control flow rate devices that prevent a dry run in the event of loss of suction pressure. Smart control starters like soft-starts and VSD's can regulate power usage according to network demand, pressure and flows of which are outside of the scope of this consultancy.

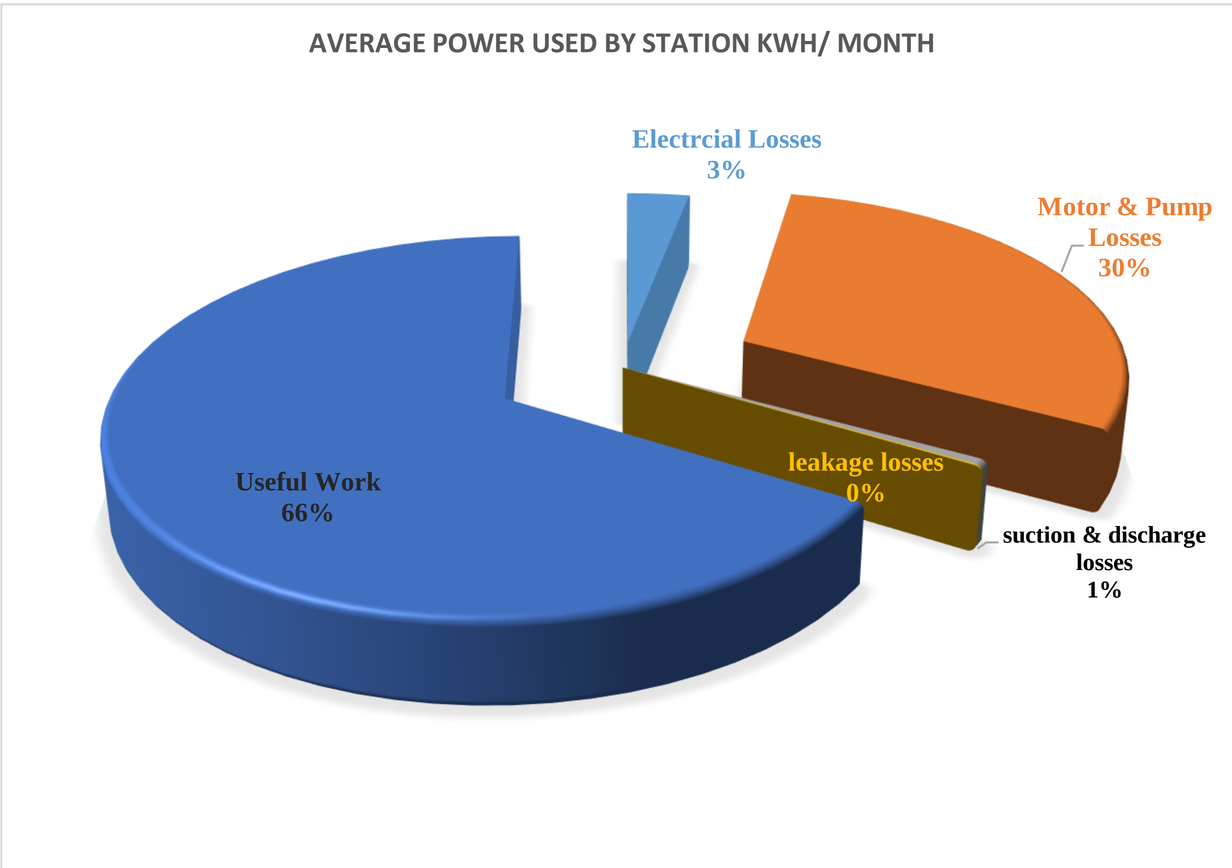


Figure 13 Chart Showing Energy Balance Jimmit Booster station

Figure 13 shows that 66% of the energy consumed by the station is used to deliver water into the distribution network. Leakage loss, suction/discharge loss and electrical losses are minimal. While motor and pump losses are within an acceptable range.

Comments:

- Electrical, suction & discharge and leakage losses are minimal
- The pump station is operating on the best possible efficiency it can with the current electrical infrastructure
- Operational power factor is good
- Without flow meters at the station, based on the electrical parameters recorded it can be assumed that the pumps are operating within pump characteristics

Physical Site Layout

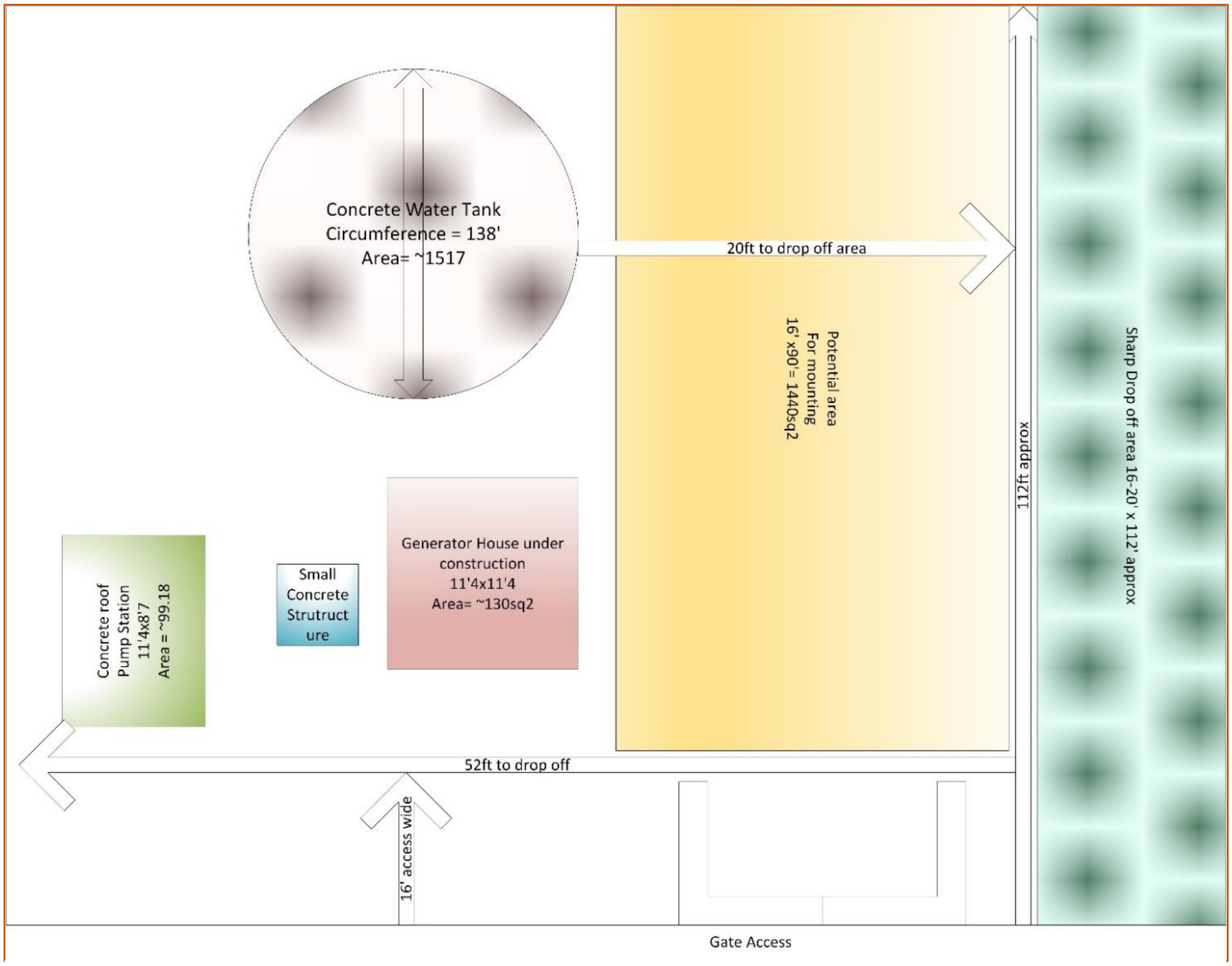


Figure 14 Physical site layout Jimmit Station

Comments

- Site is relatively small with a large concrete water tank area ~1517ft^2
- There are two structures with concrete roofs
- The area has a lot of external vegetation
- The potential area that can be used for PV installations ~ 3250ft^2 ± 10%
- PV systems can be mounted almost anywhere however good structural engineering will be recommended

PV Site shading analysis Jimmit Station

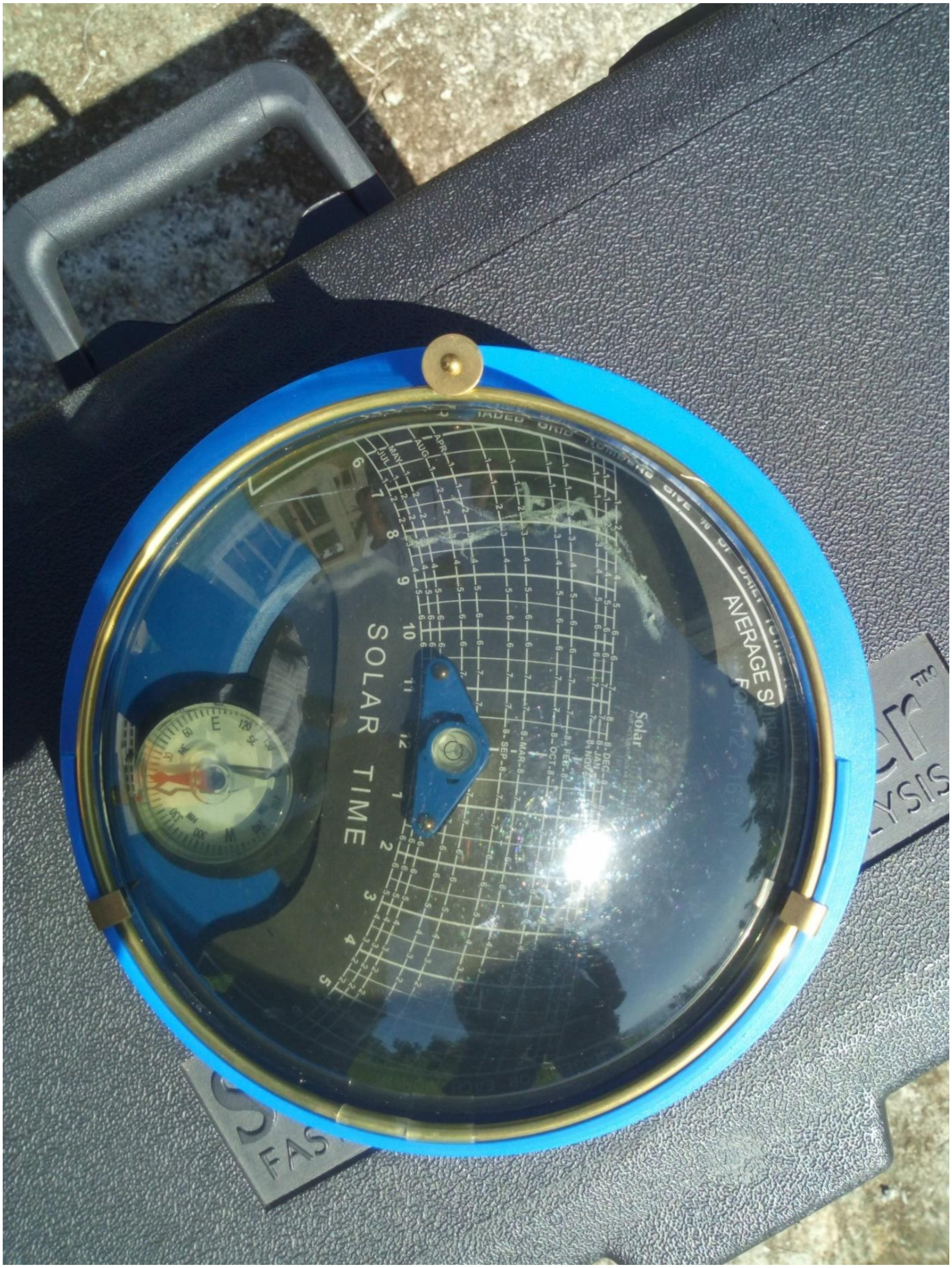


Figure 15 Jimmit Shading analysis pt. 1

Figure 16 Showing Jimmit Station area and solar analysis of site

Figure 17 PV solar site analysis of Jimmit Station Area

PV site area analysis- Jimmit

- Months May June July approximately 9% shading due to structures and vegetative growth
- Months April and August approximately 5% shading due to structures and vegetative growth
- Months November, December, January approximately 7% shading due to structures and vegetative growth
- Months February, March, September, October, approximately 4-5% shading due to structures and vegetative growth
- Shading occurs from between hours 6 am – 8:30 am & 5 pm – 6 pm
- The topography and geography of Dominica will have shading impact on any PV system
- Overall Shading is less than 10% for all months
- Good design and equipment with high efficiencies will compensate for losses due to shading issues

Site reference conditions

Select climate data location

Climate data location: Melville Hall A

Show data ☑

	Unit	Climate data location	Project location
Latitude	˚N	15.5	15.5
Longitude	˚E	-61.3	-61.3
Elevation	m	14	14
Heating design temperature	°C	19.7	
Cooling design temperature	°C	31.7	
Earth temperature amplitude	°C	1.3	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		24.9	71.9%	4.08	101.5	7.4	26.7	0	462
February		24.8	72.1%	4.61	101.5	6.9	26.3	0	414
March		25.1	73.2%	5.19	101.4	6.5	26.4	0	468
April		25.8	75.9%	5.61	101.4	5.8	26.9	0	474
May		26.6	77.8%	5.83	101.4	6.0	27.5	0	515
June		27.3	77.9%	5.72	101.5	6.8	27.8	0	519
July		27.4	78.6%	6.17	101.5	7.0	28.0	0	539
August		27.4	79.7%	5.94	101.4	6.2	28.5	0	539
September		27.1	80.2%	5.28	101.3	5.5	28.7	0	513
October		26.1	79.9%	4.86	101.2	5.3	28.6	0	499
November		26.2	77.6%	4.31	101.2	6.0	28.2	0	486
December		25.4	73.1%	4.19	101.4	6.8	27.4	0	477
Annual		26.2	76.5%	5.15	101.4	6.3	27.6	0	5,906
Measured at	m					10.0	0.0		

Figure 18 Climate and Solar irradiation data Dominica - RETSCREEN

TECHNICAL ASSESSMENT PHOTOVOLTAIC ENERGY SAVING OPPORTUNITIES FOR THE JIMMIT AUDITED SYSTEMS AND COST EVALUATION

Using all the data procured in the field: site analysis, station energy usage and supplied information as explained by methodology previously and constrained by budgetary capital the following photovoltaic saving opportunities are recommended:

- Total useable area for photovoltaic modules at the site assuming that DOWASCO will allow mounting on structures present on the site is approximately 3250ft^2
- Assuming standard module of 5'4 x 3'3 (65" x39"), the site can accommodate approximately max of 163 modules @ 60 cell technology
- Assuming higher wattage modules ≥ 300watts, PV array system based on 163 modules is approximately **48,900W_{dc} or 48.9kW_{ac} minimum**
- Inverter size recommended for the array is any combination 50kW≤ inverter ≤ 55kW
- Based on average the DOMLEC consumption of ~8,160kW, unless otherwise approved by DOMLEC, to be eligible to connect and operate in parallel with DOMLEC's Grid, the DG renewable must have a maximum aggregate capacity per facility of 1.5 times the Customer's current average usage up to a maximum of 150kW. This calculation result in the max size specified for Jimmit is 81.6kW. However, site analysis, budget and space allocation the Consultant recommends a system no larger than 55kW
- Number of modules for 30kW recommended assuming 60cell PV module modules≥ 300watts is **100 modules**
- See RETSCREEN analysis in figure 19 for economic engineering analysis
- Assumed 20% Capacity Factor
- Assumed Net Metering effect for calculation

30kW photovoltaic Jimmit Financial viability

Financial viability

- Pre-tax IRR - equity % 57.3%
- Pre-tax IRR - assets % 51.7%
- Simple payback yr 1.9
- Equity payback yr 1.8
- [17]Gross annual GHG emission reduction tons of CO_2 is approximate 51.6t

[17] There no CO^2 base case for Dominica. Base case was model after Jamaica CO^2 avoided Carbon foot print

RETScreen Energy Model - Power project

☐ Show alternative units

Proposed case power system					Incremental initial costs	
Technology		Photovoltaic				
Analysis type		⦿ Method 1 ○ Method 2				
Photovoltaic						
Power capacity	kW	31.72	117.8%		$ 145,938	*See product database*
Manufacturer		Sunpower				
Model		mono-Si - SPR-305-WHT		104 unit(s)		
Capacity factor	%	20.0%				
Electricity delivered to load	MWh	56	27.3%			
Electricity exported to grid	MWh	0.0				
Electricity rate - base case	$/MWh	1,244.00				
Fuel rate - proposed case power system	$/MWh	0.00				
Electricity export rate	$/MWh	1,244.00				
Electricity rate - proposed case	$/MWh	1,244.00				

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Power system fuel MWh	Operating profit (loss) $	Efficiency %
Full power capacity output	**56**	**0**	**148**	**0**	**69,133**	**-**
Power load following	56	0	148	0	69,133	-

Select operating strategy: Full power capacity output

☑ Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Dominica	All types			0.000

GHG emission					
Base case	tCO2	0.0			
Proposed case	tCO2	0.0			
Gross annual GHG emission reduction	tCO2	0.0			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	0.0	is equivalent to	0.0	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	$/tCO2				

Financial Analysis

Financial parameters			
Inflation rate	%	1.0%	
Project life	yr	25	
Debt ratio	%	10%	
Debt interest rate	%	3.00%	
Debt term	yr	10	
Initial costs			
Power system	$	145,938	96.7%
Other	$	5,000	3.3%
Total initial costs	$	150,938	100.0%
Incentives and grants	$		0.0%
Annual costs and debt payments			
O&M (savings) costs	$	5,000	
Fuel cost - proposed case	$	184,163	
Debt payments - 10 yrs	$	1,769	
	$		
Total annual costs	$	190,933	
Annual savings and income			
Fuel cost - base case	$	266,628	
	$		
Total annual savings and income	$	266,628	
Financial viability			
Pre-tax IRR - equity	%	57.3%	
Pre-tax IRR - assets	%	51.7%	
Simple payback	yr	1.9	
Equity payback	yr	1.8	

Cumulative cash flows graph

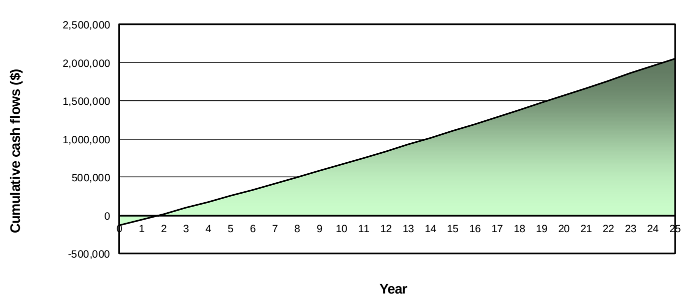


Figure 19 Financial Analysis for Jimmit Station PV performance

30kW Photovoltaic Technical Data recommendation for Jimmit Station

- Total number of PV modules: 102
- PV peak power: 31.11 kWp
- Number of inverters: 3
- Nominal AC power: 30.00 kW
- AC active power: 30.00 kW
- Active power ratio: 96.4 %
- Annual energy yield (approx.) 40586.40 kWh[18]
- Energy usability factor: 100 %
- Performance ratio (approx.): 82.9 %
- Spec. energy yield (approx.) 1305 kWh/kWp
- Line losses (in % of PV energy): 0.88 %
- Unbalanced load: 0.00 VA
- Self-consumption: 34475.12 kWh
- Self-consumption quota: 84.9 %
- [19]Performance and self-consumption data shows 84.9% of the total energy consumed
- Maximum losses due to shading at 6.5% is approximately 2638.116kWh/yr.

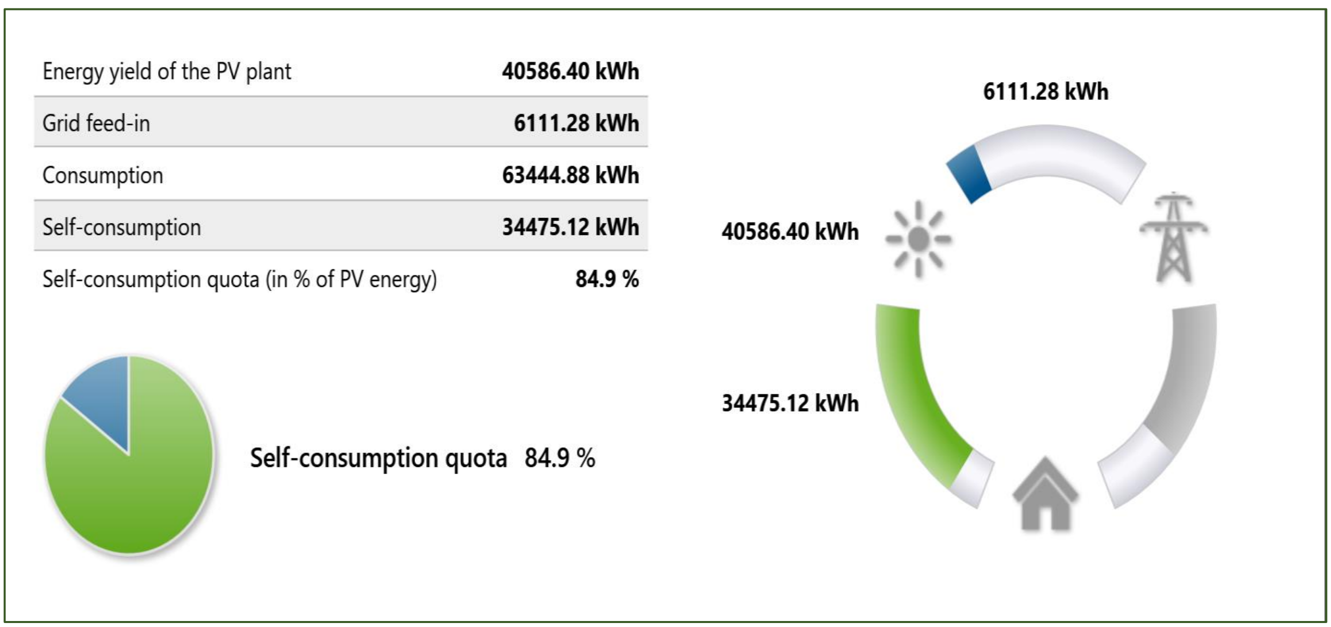
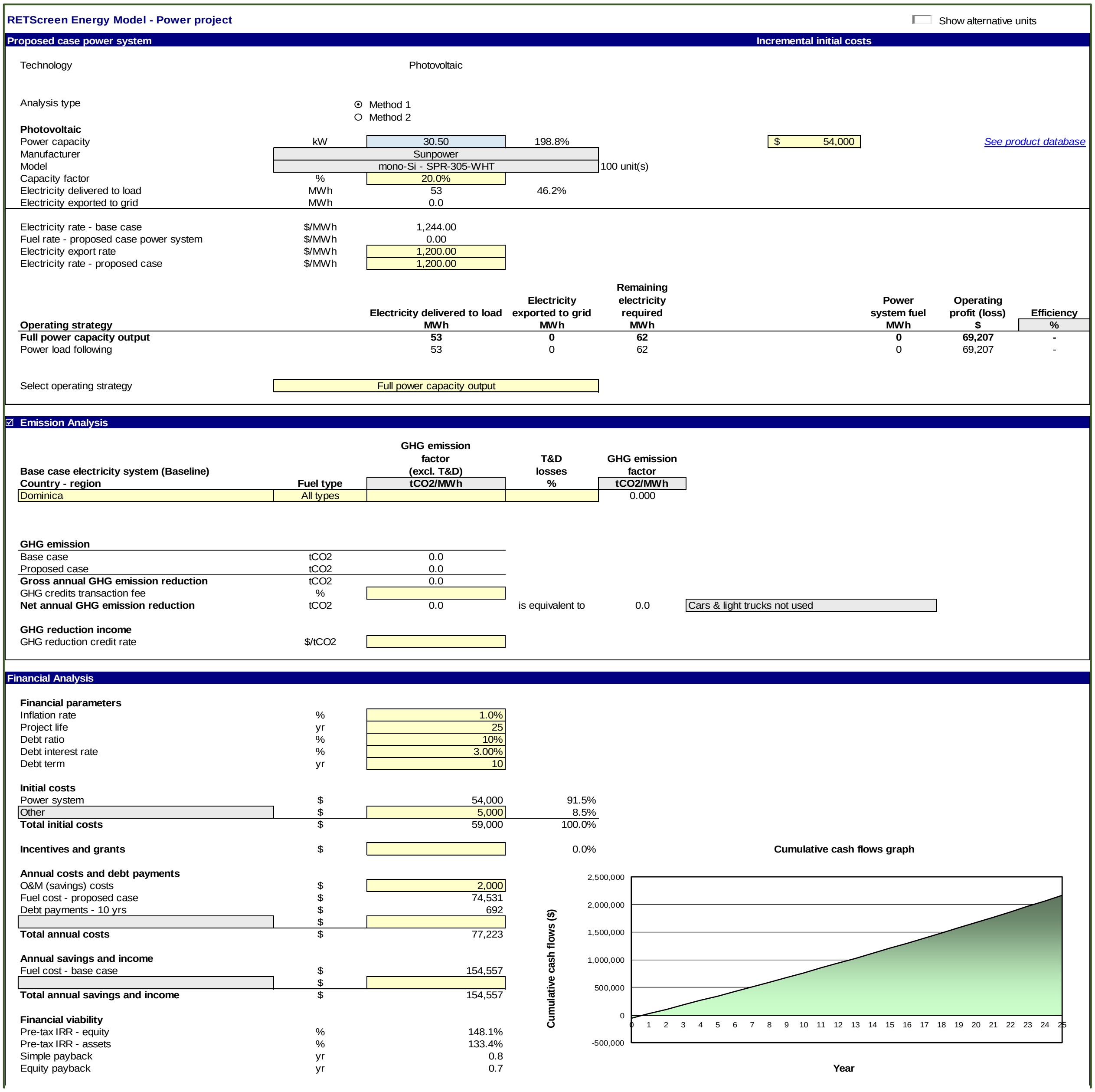


Figure 20 Performance & consumption yield of 30kW plant Jimmit Booster Station

[18] Important: The yield values displayed are estimates. They are determined mathematically. The Consultant accepts no responsibility for the real yield value which can deviate from the yield values displayed here. Reasons for deviations are various outside conditions, such as soiling of the PV Modules or fluctuations in the efficiency of the PV modules.

[19] The displayed results are estimated values which are derived mathematically. The Consultant accepts no liability for the actual self-consumption which may deviate from the values displayed here. The potential self-consumption essentially depends on individual load patterns, which may deviate from the load profile on which the calculation is based.



RETScreen Energy Model - Power project — Show alternative units

Proposed case power system — **Incremental initial costs**

Technology		Photovoltaic		
Analysis type		⦿ Method 1 / ○ Method 2		
Photovoltaic				
Power capacity	kW	30.50	198.8%	$ 54,000 — See product database
Manufacturer		Sunpower		
Model		mono-Si - SPR-305-WHT	100 unit(s)	
Capacity factor	%	20.0%		
Electricity delivered to load	MWh	53	46.2%	
Electricity exported to grid	MWh	0.0		
Electricity rate - base case	$/MWh	1,244.00		
Fuel rate - proposed case power system	$/MWh	0.00		
Electricity export rate	$/MWh	1,200.00		
Electricity rate - proposed case	$/MWh	1,200.00		

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Power system fuel MWh	Operating profit (loss) $	Efficiency %
Full power capacity output	**53**	**0**	**62**	**0**	**69,207**	**-**
Power load following	53	0	62	0	69,207	-

Select operating strategy: Full power capacity output

☑ Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Dominica	All types			0.000

GHG emission				
Base case	tCO2	0.0		
Proposed case	tCO2	0.0		
Gross annual GHG emission reduction	tCO2	0.0		
GHG credits transaction fee	%			
Net annual GHG emission reduction	tCO2	0.0	is equivalent to	0.0 Cars & light trucks not used
GHG reduction income				
GHG reduction credit rate	$/tCO2			

Financial Analysis

Financial parameters			
Inflation rate	%	1.0%	
Project life	yr	25	
Debt ratio	%	10%	
Debt interest rate	%	3.00%	
Debt term	yr	10	
Initial costs			
Power system	$	54,000	91.5%
Other	$	5,000	8.5%
Total initial costs	$	59,000	100.0%
Incentives and grants	$		0.0%
Annual costs and debt payments			
O&M (savings) costs	$	2,000	
Fuel cost - proposed case	$	74,531	
Debt payments - 10 yrs	$	692	
	$		
Total annual costs	$	77,223	
Annual savings and income			
Fuel cost - base case	$	154,557	
	$		
Total annual savings and income	$	154,557	
Financial viability			
Pre-tax IRR - equity	%	148.1%	
Pre-tax IRR - assets	%	133.4%	
Simple payback	yr	0.8	
Equity payback	yr	0.7	

Figure 21 Retscreen showing <1yr payback with Dominica kW/kW Net Metering arrangement

Final Recommendation for Jimmit Station

- 30kWp Photovoltaic System
- Total number of PV modules: 102
- PV peak power: 31.11 kWp
- Number of inverters: 3
- Nominal AC power: 30.00 kW
- Minimum system Spec. energy yield (approx.) 1305 kWh/kWp
- Procure & Install 3Ø 4wire 4pole IP67 MDP with main spares for expansion
- Medium-term recommendation outside the scope of this project is to install VSDs

AUDITED SYSTEMS PROCESS DESCRIPTION TETE MORNE PUMP STATION

Figure 23 Location of Tete Morne Booster Pump Station

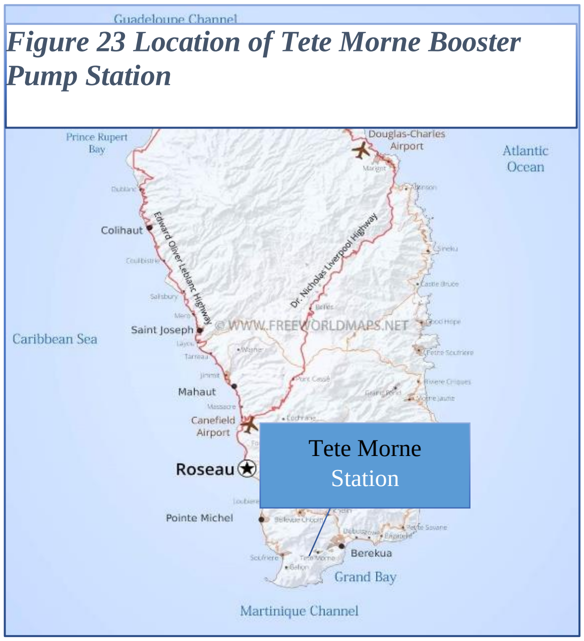


Figure 22 Tete Morne Primary School damage & derelict after Hurricane Maria with adjoining sub water tank

Figure 24 Pierre Charles Secondary School - Tete Morne

Figure 25 New tank under construction to be supplied from Tete Morne Station

The Tete Morne Pump station is located in the South of the island approximately 40 minutes drive heading south-east from the capital of Roseau Dominica. The coordinates of the station are approximately 15°14'12.8"N 61°19'31.6"W. The Station supplies areas/villages of Tete Morne, Mortin area and surrounding homes. Tete Morne/Mortin areas were one of the hard-hit villages during the passage of Tropical Storm Erika and Hurricane Maria 2015 & 2017 respectively. Tete Morne station supplies a high density of existing homes and new construction for homes for ongoing residential developments. The Consultant noticed that this section of the island can be isolated or cut off from general civilization due to limited access via the singular entrance through the Soufriere mountain path. If this public road access is severed in the event of a storm, Tete Morne and Mortin residents will be isolated. The PS is strategically located to supply the residents within this area, the station supplies approximately [20]25,000 gallons of water per day. Tete Morne booster station, as determined by the pump operator, pumps a via manual operation for four hours in the morning, 5 am -10 am, and for two hours in the evening, 4 pm -6 pm; This operation runs for 7days/week.

See Figure 36.

[20] This figure was mentioned during the interview process with the Pumping Operators

Energy cost at the Tete Morne Facility					
Date	Consumption kWh	Energy Cost $EC	KVA demand	Cost of Energy $EC/kWh	Daily Average Consumption KWh
February-12- 2019	3350	EC$4,218.06	1	1.259	111.67
March -13- 2019	6130	EC$7,753.07	1	1.265	204.33
April 12 2019	5790	EC$7,082.29	1	1.223	193.00
May 13 2019	5180	EC$6,605.92	1	1.275	172.67
June 12 2019	5370	EC$6,683.78	1	1.245	179.00
July 12 2019	4890	EC$6,068.98	1	1.241	163.00
August 12 2019	5280	EC$6,515.98	1	1.234	176.00
September 11 2019	6100	EC$7,588.19	1	1.244	203.33

October 10 2019	6200	EC$7,462.24	1	1.204	206.67
December 11 2019	5370	EC$6,730.71	1	1.253	179.00
Averages	5366	EC$6,670.92	1	1.244	178.867
Future Demand 2nd Quarter 2020	16098	EC$20,025.912	1	1.244	536.6

The station forms part on the integrated larger network which indirectly supplies the Pierre Charles Secondary School as highlighted by Chief Engineer, Mr. Magnus Williams. Physical inspection and mathematical extrapolation by the Consultant indicates that the station will increase its supply and demand by 3 to 4 times its current supply rate. The existing power demand is around 14kW -26kW instantaneous load, however, with 250,000gallon tank which is 95% completed at Mortin, which is 10 minutes drive uphill up to an extremely higher elevation, the station power capacity demand will increase from the existing 26kW max to 116kW when tank construction is completed. Mr. Williams highlighted that three (3) GRUNDFOS CRN 45-13-2A-F-A-V-HQQV are being prepared to be installed, with two of the three installed pumps coming online with existing [21]GRUNDFOS CRN 15-16 SF & CRN 15-14 A-FGJ-G-E HQQE 15kW and 11KkW respectively.

Increasing the supply at Tete Morne Station to meet the intended demand, will move the current monthly usage from 5366kWh to approximately 16098kWh. This increase in demand will also be as a result of the Tete Morne station taking on the demand of the Soufriere pumping station that will go offline permanently when Tete Morne station capacity increases. Tete Morne will add to its supply-demand network, the area of Soufriere which has a new hotel development completed and to supply the residents in the Soufriere area.

Figure 26 Table Showing Tete Morne current Usage and Future Demand and Consumption. Based on Mathematical extrapolation

Based on pump selection and energy requirements, the table above in Figure 37, gives basic expectations of economic and power demands that DOWASCO should expect. However, these calculation are based primarily on pumps running direct online without VSD starter controls, as with the existing case currently.

[21] See Appendix for Pumping Details

Electrical & Pumping Characteristics of Tete Morne Booster Pump Stations

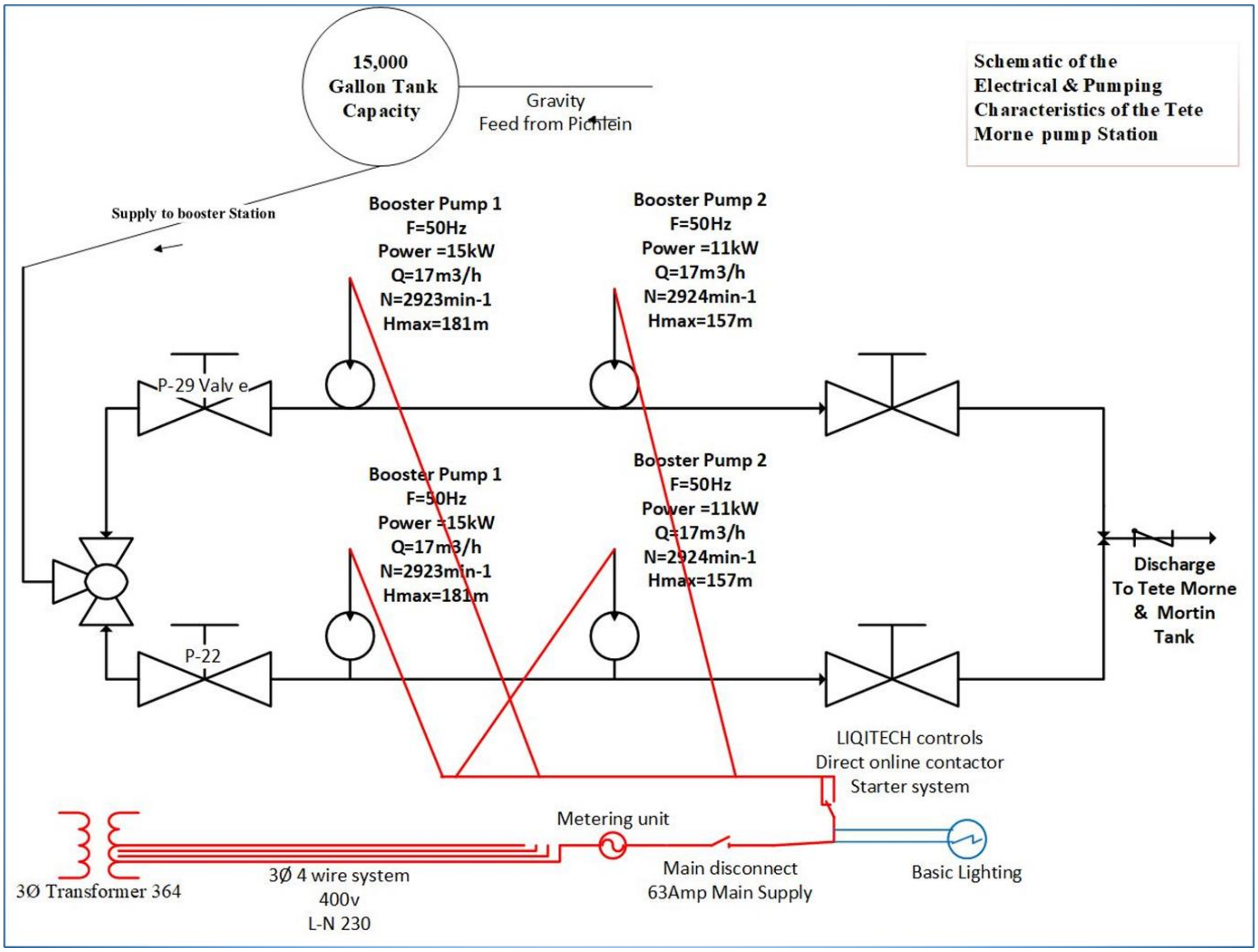


Figure 27 Diagram Showing Current Pumping & Electrical Arrangement of Tete Morne Station

Tete Morne booster station gets its supply water from mains which are gravity-fed sourced from the mountainous area of Pichelin. The station is comprised of four pumps, two 15kW GRUNDFOS CRN 15-16 SF and two 11kW GRUNDFOS CRN 15-14 A-FGJ-G-E HQQE booster pumps. Each pair set (which are in parallel) is rotated according to operation and maintenance needs by engineering and the operational staff. Pumps are controlled by LiqTec for lower suction pressure pump protection and powered via contactor which is direct online through the OCPD. The station operates within the best operational efficiencies as seem from data collected. Pumps and motor are performing around 70.4 % efficiency for actual work done.

Electrical Characteristics of Tete Morne Booster Station

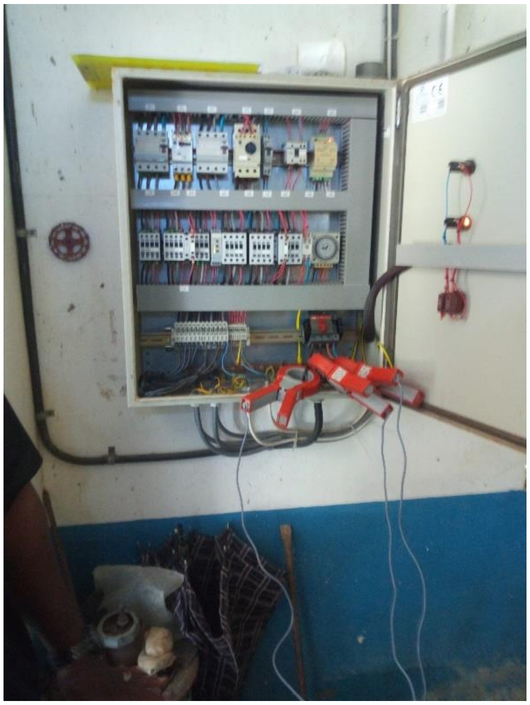


Figure 28 Electrical Control Panel

Figure 29 showing the station pump and electrical set up

The station is fed from the DOMLEC utility through the 11kVA pole-mounted transformer that steps the voltage down to 0.4KVA. Station incoming supply is 3Ø 400V, Line to Line 400V and Line to Neutral 230V. Service supply is currently 63AMP, the main feeder to the stations electrical and control system via max 2AWG electrical transmission lines. This Station does not have VFD/VSD, therefore the pumps run at full operational load at all times. Unlike the Warner and Jimmit Stations, Tete Morne station is manually controlled by the pump operator, there are no control timers within the control switchgear mounted on the walls. See Figure 39 & 40.

Tete Morne Electrical characteristics					
Parameter units	Results Sat/7/19 10am	Results Sat/7/19 2 pm	Results Sat/7/19 5pm	Results Sat 7th 10am-5pm	Average Results
Voltage L1-	224.7	224.50	225.9	225.3	225.10
Voltage L2	231.2	231.30	229.7	229.5	230.43
Voltage L3	238.82	227.90	223.3	222.6	228.16
Voltage L1,2	394.9	394.7	394.5	393.9	394.50
Voltage L2,3	397.9	394.7	392.5	391.6	394.18
Voltage L31	391.2	391.8	392.4	387.9	390.83
Current I1	37.47	37.63	43.48	43.23	40.45
Current I2	39.25	39.29	42.21	42.43	40.80
Current I3	30.56	30.45	33.23	33.43	31.92
Total Current In	77.01	77	85.1	85.23	81.09
Power Instantaneous KW	14.11	14.09	15.09	14.19	14.37
KVA	15.52	15.50	15.52	15.51	15.51
KVAR	6.45	6.43	6.37	6.37	6.40
Power Factor	0.92	0.91	0.91	0.92	0.92
Frequency Hz	50.1	50.10	50.1	50.1	50.10
Harmonics I1 %	5.1	5.1	5.2	5.1	5.13
Harmonics I2 %	3.2	3.2	4	3.9	3.58
Harmonics I3 %	7.3	7.3	7.2	6.9	7.18

Figure 30 Table Showing the Electrical Characteristic of Tete Morne Station

Figure 41 shows the electrical performance characteristics of the Tete Morne station, the result will vary little given the fact that pumps operate at full load during operation. The pumps work direct online through OCPD devices with LiqTec flow rate devices that prevent a dry run in the event of loss of suction pressure. The interview process highlighted that with the ongoing construction of the extension to the pumping facility, VSDs drive will be incorporated as part of the PS upgrade and the introduction of the three CRN 45-13-2A-F-A-V-HQQV booster pumps. With the increase of power usage expected at this facility and the cost of electricity to DOWASCO, all energy efficiency opportunities should be considered.

Tete Morne Energy Balance			
Parameters	Amount or Percentage/fraction	Average Power Used by Station KWh/ Month	Notes
Monthly Energy Consumption kWh	5366	6,514.20	This result calculated on energy bill 2nd result is a power meter
Motor & Pump Efficiency average	0.704	3,777.66	This result is concurrent with actual analysis
Electrical Losses	0.03	160.98	Assumed nominal wire losses 2-5%
Motor & Pump Losses	0.26	1,395.16	Data
suction & discharge losses	0.005	26.83	assumed nominal wire losses >1%
leakage losses	0.001	5.37	assumed nominal wire losses >1%
Useful Work		3,777.66	Based on calculations
Total	**100%**	**5,366.00**	**Energy Balance**

Figure 31 Table Showing energy usage within Tete Morne Station

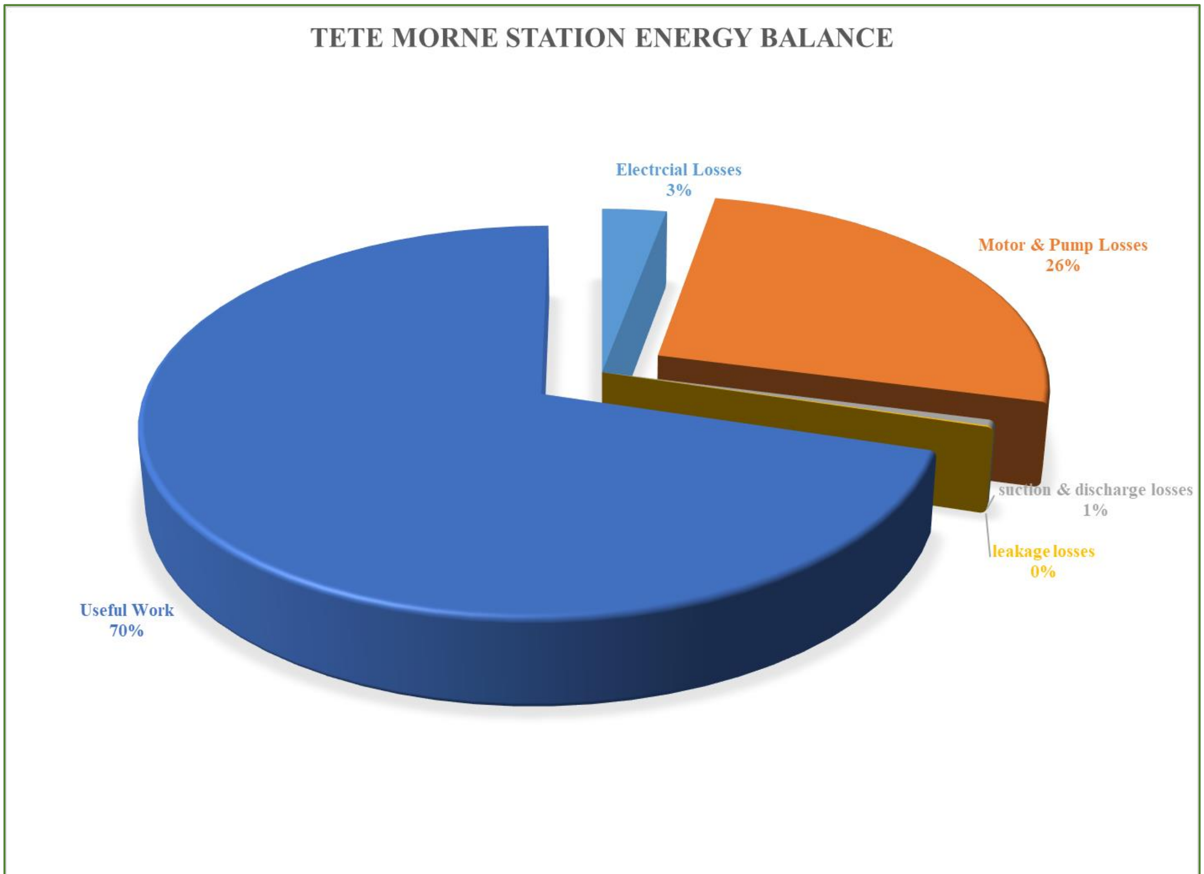


Figure 32 Showing Energy balance for power used within the Station per Month

Technical Comments on Energy Balance

- Electrical, suction & discharge and leakage losses are minimal
- The pump station is operating on the best possible efficiency it can with current electrical infrastructure
- Operational power factor is excellent, high-efficiency drives should be installed at this facility to maintain optimum power factor at Pf ≥ .90
- GRUNDFOS pumps and motors are some of the most efficient and reliable pumps on the market; DOWASCO needs to continue with this excellent track record of good pump selection and design, this has ensured that 70% of energy is used for useful work- water delivery.
- Without flow meters at the station, based on the electrical parameters recorded it can be assumed that the pumps are operating within pump characteristics based on the instantaneous current draw

Physical Layout of Tete Morne Site

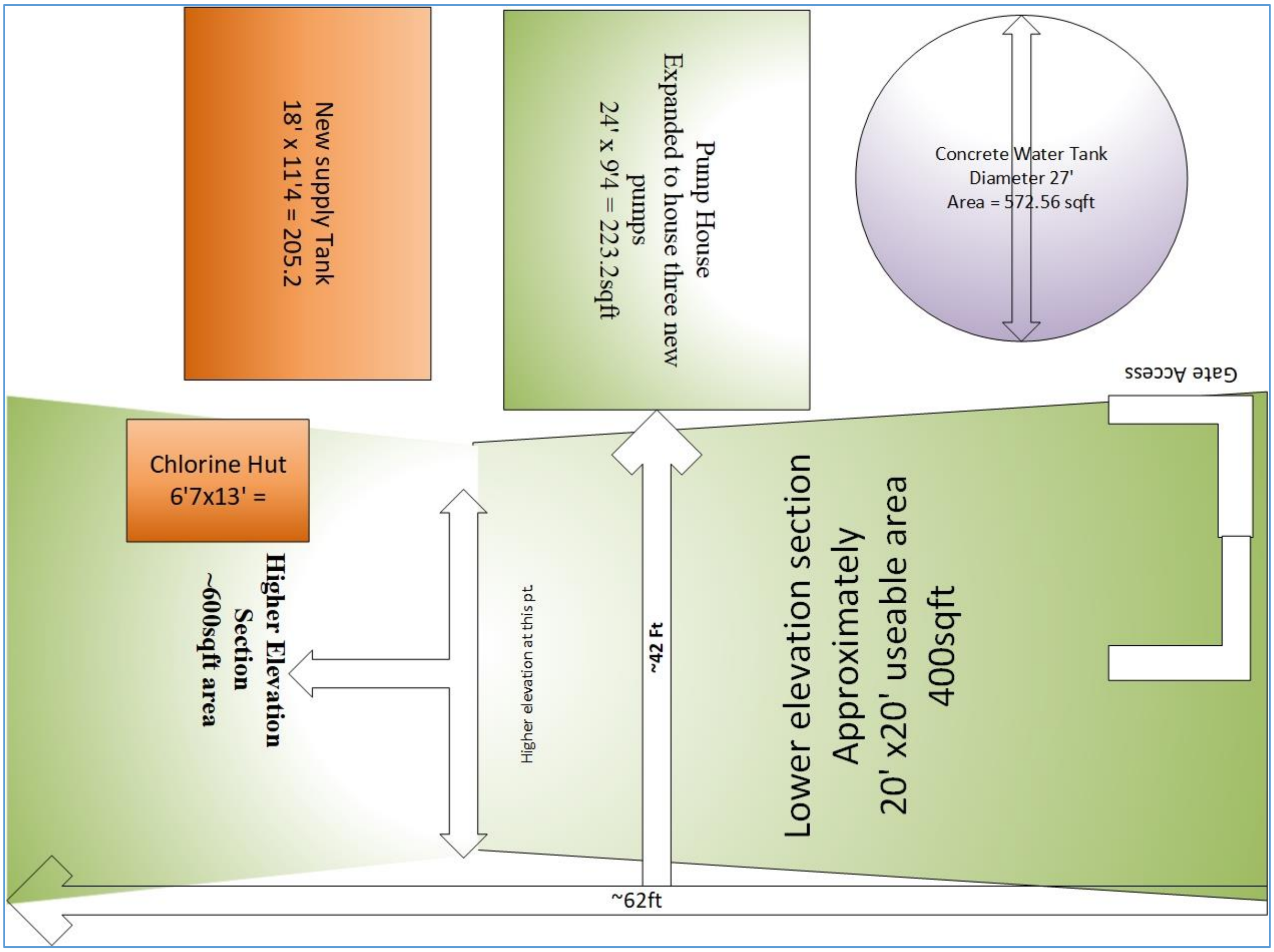


Figure 33 Diagram Showing Tete Morne Site layout

Tete Morne Site Layout Comments

- Site is the largest of the 3 stations investigated with a concrete water tank area ~572ft^2
- There are three (3) structures with concrete roofs totaling 515.5ft^2
- The area has a lot of external vegetation which will need attention to reduce shading and obstruction

Figure 34 Piping network close to the potential area for PV mounting

- The potential area that can be used for PV installations ~ 2087ft2 ± 10%
- PV systems can be mounted almost anywhere however good structural engineering will be recommended
- The site has a lot of scrap metal that will need to be disposed of before any construction can occur.
- The site has two distinct elevation patterns, an upper area close to the chlorine house and the lower area at the pump house
- The change in elevation between these two areas is sharp and will present a challenge when constructing at this site.
- Tete Morne site will need an upgrade to its perimeter security infrastructure
- With an increase to power consumption at the station within the first quarter of 2020, DOWASCO should consider the leasing and or purchasing of the land area close to this station.
- This site has the best potential for EEO's an REO's, giving its demand, power consumption and the potential to expand RE options at this site.

Figure 36 Shading analysis Test at point 1

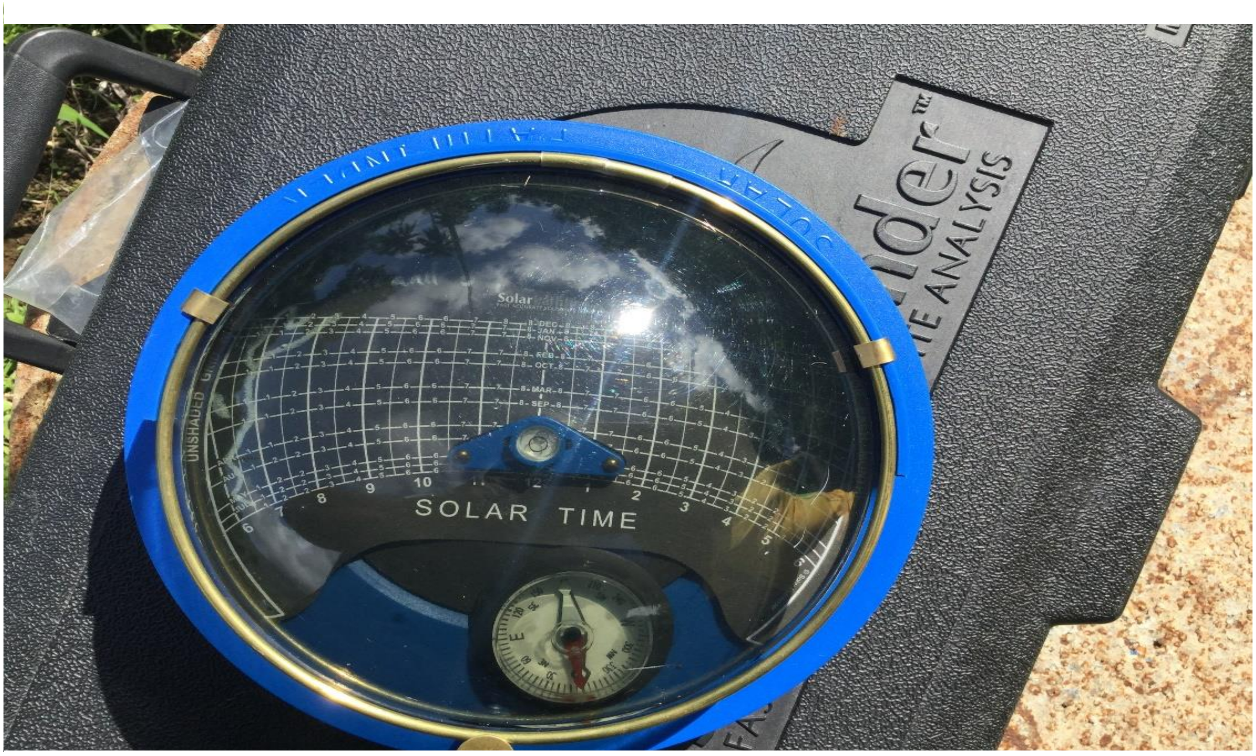


Figure 36 Shading analysis results from Tete Morne site

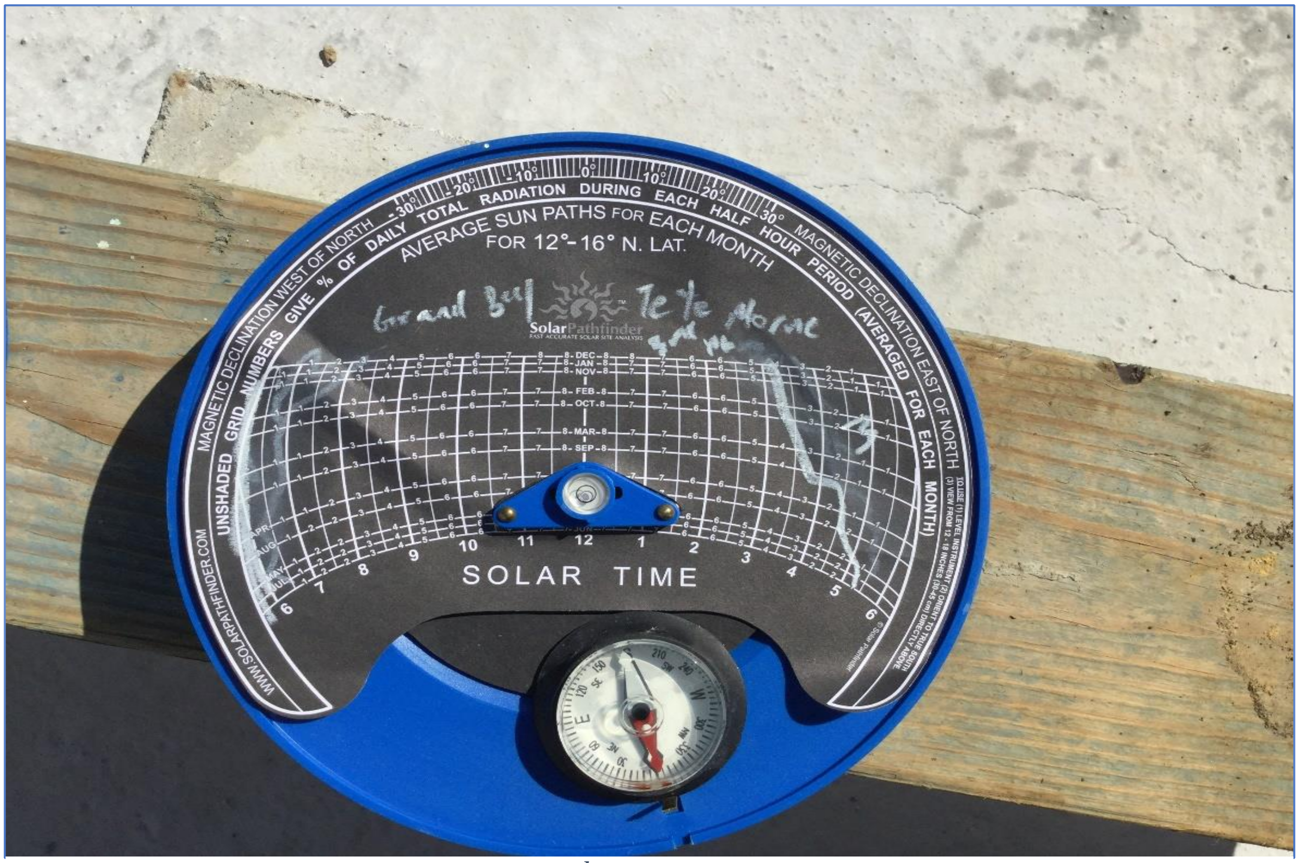


Figure 38 Tete Morne 2nd shading analysis on Concrete tank

Site reference conditions

Select climate data location

Climate data location: Melville Hall A

Show data ☑

	Unit	Climate data location	Project location
Latitude	°N	15.5	15.5
Longitude	°E	-61.3	-61.3
Elevation	m	14	14
Heating design temperature	°C	19.7	
Cooling design temperature	°C	31.7	
Earth temperature amplitude	°C	1.3	

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	24.9	71.9%	4.08	101.5	7.4	26.7	0	462
February	24.8	72.1%	4.61	101.5	6.9	26.3	0	414
March	25.1	73.2%	5.19	101.4	6.5	26.4	0	468
April	25.8	75.9%	5.61	101.4	5.8	26.9	0	474
May	26.6	77.8%	5.83	101.4	6.0	27.5	0	515
June	27.3	77.9%	5.72	101.5	6.8	27.8	0	519
July	27.4	78.6%	6.17	101.5	7.0	28.0	0	539
August	27.4	79.7%	5.94	101.4	6.2	28.5	0	539
September	27.1	80.2%	5.28	101.3	5.5	28.7	0	513
October	26.1	79.9%	4.86	101.2	5.3	28.6	0	499
November	26.2	77.6%	4.31	101.2	6.0	28.2	0	486
December	25.4	73.1%	4.19	101.4	6.8	27.4	0	477
Annual	26.2	76.5%	5.15	101.4	6.3	27.6	0	5,906

Figure 38 Climatic Data used for the Tete Morne Site

Tete Morne Shading Analysis

- January, February, October, November, and December there is 6%-9% shading at the eastern section of the site
- April, May, July and August shading is less than 2%
- March & September shading at this eastern point is 3%-4%
- Topography & southern mountainous region of the Soufriere will present shading.
- 2^{nd} Shading analysis west of the site layout showed that the months of the year: January, February March, September, October, November, and December shading will reduce performance by 4%-7% area on the site.
- Overall the shading analysis is less than 9% at each point on the site, thus apart from the high vegetative growth, the PV system performance will be satisfactory and will still result in favourable kW/kW_p.
- Good design and equipment with high efficiencies will compensate for losses due to shading issues
- Climatic data shows that PV analysis will be based on solar Irradiance of $5.15kWh/m^2/d$ at this elevation, assuming a minimum elevation of 300 meters above sea level
- Dominica has a relatively constant high humidity of 76.5% or greater therefore at this location the site will tend to display higher scattered diffusion of sunlight. See Figure 47

TECHNICAL ASSESSMENT PHOTOVOLTAIC ENERGY SAVING OPPORTUNITIES FOR THE Tete Morne AUDITED SYSTEMS AND COST EVALUATION

Using all the data procured in the field, site analysis, station energy usage and supply information as explained by methodology previously and constrained by budgetary capital the following photovoltaic saving opportunities is recommended:

- Total useable area for photovoltaic modules at the site assuming that DOWASCO will allow mounting on structure present on Tete Morne site is approximately **2087 ft^2 ±10%**

- Assuming standard module of 5’4 x 3’3 (65” x39”), the site can accommodate approximately max of 104 modules of 60 cell technology

- Assuming higher wattage modules ≥ 300watts, PV array system based on 104 modules is approximately **$31200W_{dc}$ or $31.2kW_{ac}$**

- Inverter size recommended for the array is any combination or **30kW≤ inverter ≤ 50kW**

- Based on average DOMLEC consumption of **~ 5366kW**, unless otherwise approved by DOMLEC, to be eligible to connect and operate in parallel with DOMLEC’s Grid, the DG renewable must have a maximum aggregate capacity per facility of 1.5 times the Customer’s current average usage up to a maximum of 150kW. This calculation result in the max size specified for Tete Morne is **53.66kW.** However, site analysis, budget and space allocation the

Consultant recommends system no larger than 50kW, however, for the scope of this project, the Consultant recommends **<u>30kW$_{ac}$ Photovoltaic system</u>**.

- Even though expansion will be completed within 1st quarter of 2020, DOMLEC requirements are based on 12month full operational schedule of average power consumption, thus, currently only max of **53.66kW** will be allowed on the grid network.

- Number of modules for 30kW recommended assuming 60cell PV module modules≥ 300watts is 104 modules

- See RETSCREEN analysis in the appendix for economic engineering analysis

- See SMA PV calculation analysis for in-depth technical assessment in appendix

- Assumed 20% Capacity Factor

- Assumed Net Metering effect for calculation

30kW photovoltaic Tete Morne Financial viability

Financial viability		
Pre-tax IRR - equity	%	57.3%
Pre-tax IRR - assets	%	51.7%
Simple payback	yr.	1.9
Equity payback	yr.	1.8

[22]Gross annual GHG emission reduction tons of CO_2 approximately 55.0t

- Alternatively, for the system expansion, which will result in higher energy demand the Consultant recommends a minimum 105kW Photovoltaic system to meet the new demand load, which would require approximately 12,000ft^2 – 15,000ft^2 of relatively flat surface area for a ground-mounted application

[22] There no CO2 base case for Dominica. Base case was model after Jamaica CO2 avoided Carbon foot print

RETScreen Energy Model - Power project

Show alternative units

Proposed case power system | **Incremental initial costs**

Technology		Photovoltaic			
Analysis type		⦿ Method 1 ○ Method 2			
Photovoltaic					
Power capacity	kW	31.72	117.8%	$ 145,938	See product database
Manufacturer		Sunpower			
Model		mono-Si - SPR-305-WHT	104 unit(s)		
Capacity factor	%	20.0%			
Electricity delivered to load	MWh	56	27.3%		
Electricity exported to grid	MWh	0.0			
Electricity rate - base case	$/MWh	1,244.00			
Fuel rate - proposed case power system	$/MWh	0.00			
Electricity export rate	$/MWh	1,244.00			
Electricity rate - proposed case	$/MWh	1,244.00			

Operating strategy	Electricity delivered to load MWh	Electricity exported to grid MWh	Remaining electricity required MWh	Power system fuel MWh	Operating profit (loss) $	Efficiency %
Full power capacity output	**56**	**0**	**148**	**0**	**69,133**	**-**
Power load following	56	0	148	0	69,133	-

Select operating strategy: Full power capacity output

☑ Emission Analysis

Base case electricity system (Baseline) Country - region	Fuel type	GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Dominica	All types			0.000

GHG emission					
Base case	tCO2	0.0			
Proposed case	tCO2	0.0			
Gross annual GHG emission reduction	tCO2	0.0			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	0.0	is equivalent to	0.0	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	$/tCO2				

Financial Analysis

Financial parameters			
Inflation rate	%	1.0%	
Project life	yr	25	
Debt ratio	%	10%	
Debt interest rate	%	3.00%	
Debt term	yr	10	
Initial costs			
Power system	$	145,938	96.7%
Other	$	5,000	3.3%
Total initial costs	$	150,938	100.0%
Incentives and grants	$		0.0%
Annual costs and debt payments			
O&M (savings) costs	$	5,000	
Fuel cost - proposed case	$	184,163	
Debt payments - 10 yrs	$	1,769	
	$		
Total annual costs	$	190,933	
Annual savings and income			
Fuel cost - base case	$	266,628	
	$		
Total annual savings and income	$	266,628	
Financial viability			
Pre-tax IRR - equity	%	57.3%	
Pre-tax IRR - assets	%	51.7%	
Simple payback	yr	1.9	
Equity payback	yr	1.8	

Cumulative cash flows graph

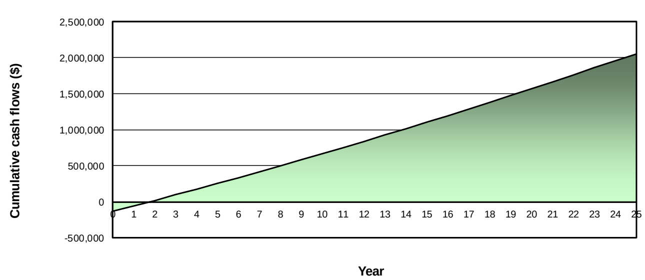


Figure 39 Engineering & Financial Analysis of Tete Morne PV system performance

30kW Photovoltaic Technical Data recommendation for Tete Morne Station

- **Total number of PV modules: 105**
- **PV peak power: 32.03 kWp**
- Number of inverters: 3
- Nominal AC power: 30.00 kW
- AC active power: 30.00 kW
- Active power ratio: 93.7 %
- **Annual energy yield (approx.)*: 42004.30 kWh**
- Energy usability factor: 100 %
- Performance ratio (approx.)*: 82.6 %
- **Spec. energy yield (approx.)*[23]: 1312 kWh/kWp**
- Line losses (in % of PV energy): ---
- Unbalanced load: 0.00 VA
- **Self-consumption: 26237.44 kWh**
- Self-consumption quota: 62.5 %
- **PV peak power: 32.03 kWp**
- Total number of PV modules: 105
- Number of inverters: 3
- Max. DC power (cos φ = 1): 10.20 kW
- Max. AC active power (cos φ = 1): 10.00 kW
- Grid voltage: 230 V
- Nominal power ratio: 96 %
- Displacement power factor cos φ: 1

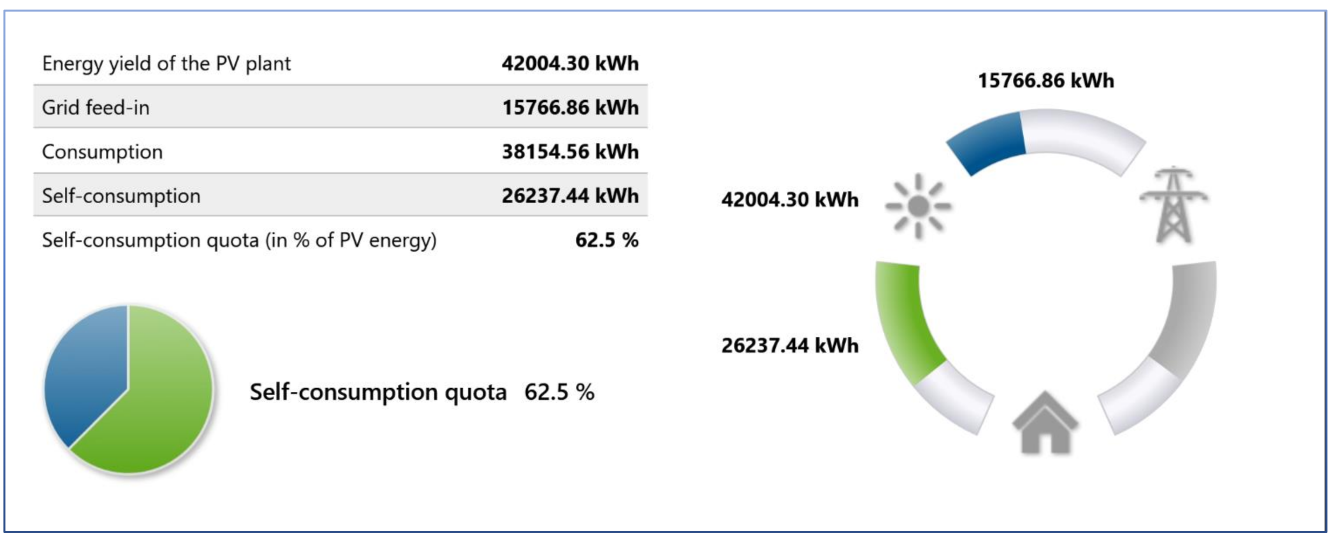


Figure 40 PV System Performance & Consumption yield of the potential 30kW Plant Tete Morne Booster Station

[23] The displayed results are estimated values which are derived mathematically. The consultant accepts no liability for the actual self-consumption which may deviate from the values displayed here. The potential self-consumption essentially depends on individual load patterns, which may deviate from the load profile on which the calculation is based.

Recommendations

Photovoltaic clearly makes environmental and economic sense as a renewable energy option for DOWASCO. Dominica, through the IRC and DOMLEC already have an established path for the implementation of the commercial-grade interconnection of grid-tied photovoltaic systems. In order to carry out a successful infrastructural renewable energy option – REO, a fundamental upgrade to current electrical infrastructure is necessary to ensure proper integration of the PV systems with the electrical and pump equipment. The following process should be followed to ensure smooth incorporation of photovoltaic options at each station:

- Jimmit Booster Station recommendation
  - Application to IRC for the interconnection of 30kW system
  - Application to DOMLEC for the interconnection of 30kW system
  - Application of GED
  - The installation of 3Ø IP67/68 MDP with 150amp incoming 4 pole breaker, four (4) 60amp to control existing pumps, one 50amp breaker to control the photovoltaic system, one 150amp breaker for BMS and one spare 50amp breaker for future expansion
  - Installation of Manual Transfer Switch rated at 200amp – MTS
  - Installation of flow meter at the discharge point
  - Installation of perimeter security to protect the investment
  - Cleaning and removal of extraneous material from the site
  - Proper structural reinforcement for the installation of the mounting brackets for the PV modules
  - The installation of one (1) three-phase 30kW photovoltaic system
  - <u>An alternative recommendation will be 20kW Photovoltaic System</u>
- Future recommendation Jimmit Booster Station outside the scope of this assessment
  - Installation of Variable Speed Drives to control pumps
  - Installation suction and discharge flow meters
  - Installation of pressure sensors at the discharge point for the station
  - Prepare a comprehensive master plan to guide maintenance of the electrical system inclusive of any photovoltaic system that is integrated
  - <u>Lithium-ion 800kWh Battery Bank assuming 50% DOD and 2days capacity.</u>

Tete Morne Booster Station recommendation

- Application to IRC for the Interconnection of 30kW system

- Application to DOMLEC for the interconnection of 30kW system
- Application of GED
- The installation of 3Ø IP67/68 MDP with 400amp incoming 4 pole breaker, four (4) 60amp to control existing pumps, three (3) 100amp breakers for expansion of new pump system, one (1) 50amp breaker to control the photovoltaic system, one (1) 400amp breaker for BMS and one spare 100amp breaker for future expansion
- Installation of Manual Transfer Switch rated at 400amp – MTS
- Installation of flow meter at the discharge point
- Installation of perimeter security to protect the investment
- Cleaning and removal of extraneous material from the site
- Proper structural reinforcement for the installation of the mounting brackets for the PV modules
- The installation of one (1) 3Øphase 30kW photovoltaic system

- Future recommendation Tete Morne Booster Station outside the scope of this assessment
  - Installation of Variable Speed Drives to control pumps
  - Installation suction and discharge flow meters
  - Installation of pressure sensors at the discharge point for the station
  - Prepare a comprehensive master plan to guide maintenance of the electrical system inclusive of any photovoltaic system that is integrated
  - Lithium-ion 2.394MWh Battery Bank assuming 50% DOD and 2days for current capacity with expansion (cost may not warrant this capacity). Lithium Nickel Cobalt Aluminum Oxide or Lithium Titanate more commonly used for grid storage.

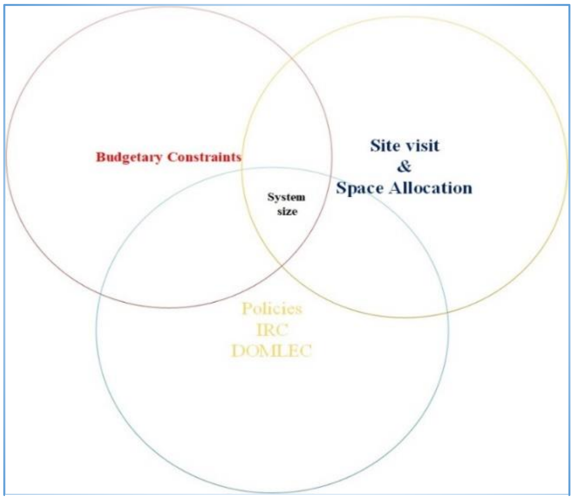


Figure 41 Diagram Showing linkage of all Critical data that fed into the final design and recommendation

Overall the factors that contribute to the critical decision of system recommendation and size were budgetary constraints, space allocation and most importantly the policies and technical requirements set out by the Independent Regulatory Commission -IRC and DOMLEC will determine successful grid interconnection. Figure 52 shows the overall linkage of each component that fed into the final design and Renewable Energy Opportunities, namely the photovoltaic system, for each station audited. In conclusion, any step made towards energy efficiency and clean energy alternative is always the best decision for the environment, the economy, the country/citizens and overall this will undoubtedly contribute to the reduction of a Caribbean climate footprint of CO_2 as a central eco-environmental goal.

Recommendation on System Specifications, Warranties and Required Electrical Codes

Photovoltaic Modules

2 Photovoltaic (PV) Modules and Arrays

- All PV modules must meet or exceed the requirements of IEEE Standard 1262-1995-Recommended Practice for Qualification of Photovoltaic (PV) Modules and Underwriters Laboratories (UL) Standard 1703 Standard for Safety for Flat-Plate Photovoltaic Module, or equivalent standards.

- Only monocrystalline silicon flat-plate PV modules should be supplied.

- The power output of the PV module must be reported under standard test conditions (STC).

- The use of the highest quality materials in the construction/manufacture/production of its modules, to ensure a long service life and high energy output over time is highly recommended.

- Efficiency should be ≥ 18%. The panels must have less than two percent (2%) mismatch from the nameplate data. The PV modules must be made of lightweight cells, resistant to abrasion, rain, water, saline humid air and environmental pollution. The PV modules must be provided with the anti-reflection coating and back surface field (BSF) structure to increase conversion efficiency. The bidder should provide saline mist certificate

- The terminal box on the module must have a provision for an opening for replacing the cable if required.

- The standard deviation of module power rating for All modules must be less than five percent (<5%) of the mean value of the module's power.

- Due to expected high wind loads, and subsequent potential for damage from flying debris, all PV arrays must be securely installed to the structure as dictated by site conditions.

- PV module interconnects wiring must be sunlight-resistant USE-2 (90°C wet or dry) or equivalent rated conductor and must be attached to module junction boxes using weather-tight strain relief. The module wiring interconnections must use a connector device that allows quick assembly and disassembly of the arrays under no-load conditions. These connectors must be UL-listed, and be weather-sealed, guarded and polarity protected.

- All series-connected strings of modules (source circuits) must include a series fuse as required by UL and NEC to prevent excessive reverse current flow through modules in source circuits under fault conditions, and the diodes must be contained in a listed junction/combiner box. Parallel connections of modules in individual source circuits are discouraged and are only allowed as long as the module listing allows for a series fuse with high enough capacity required for this configuration. All series source circuit fuses must be rated for at (1.56) times the source circuit short-circuits current rating and no greater than that specified on the module listing. Blocking diodes for array source circuits are optional. If used, these diodes must have voltage and current ratings (at temperature) at least twice the open-circuit voltage and short-circuit ratings of the source circuits.

- The PV modules must have a multi-year guarantee/warranty to maintain ninety percent (90%) of their initial rated output for fifteen years (15 yrs.) and eighty-five percent (85%) of their initial rated output for twenty-five years (25 yrs.). These performance guarantees/warranties must be on the DC power rating. The contractor must provide certification from approved bodies, for example, UL 1741, TUV or internationally recognized equivalent standard.

Inverter - Power Conditioning Unit (PCU)

- Surge suppression on the DC and AC side of the inverter must be provided.

- AC power must be fed to the grid at three-phase four hundred volts (3Ø,400 V) AC bus.

- The output of the inverter must synchronize automatically its AC output to the exact AC voltage and frequency of the grid.

- The injection of DC power into the grid must be avoided by using an isolation transformer or Transformerless unit at the output of the inverter. It is proposed to limit DC injection within one percent (1%) of the rated current of the inverter as per IEC 61727.

- The inverter must continuously monitor the condition of the grid and in the event of grid failure; the inverter must shut down within two to five seconds (2s -5s). The solar system is resynchronized with the grid within two minutes or otherwise determined by the grid operator after the restoration of the grid. This means that the PV system must be provided with synchronizing equipment having two (2) inputs for comparison, i.e. grid supply vs. solar output so as to connect it in synchronism with the grid

- The inverter control unit must be so designed so as to operate the PV system near its Maximum Power Point (MPP), the operating point where the combined values of the current and voltage of the solar modules result in maximum power output.

- The inverter must be a true sine way inverter for a grid-interactive PV system.

- Typical technical features of the inverter must include at a minimum the following:

- Nominal AC Output Voltage and Frequency: 400V, 3 Phase, 50Hz, Grid Voltage Tolerance: -20% to +15%, Continuous inverter Output Rating: Equal to the capacity of the PV system. To be mentioned in kVA, Output Wave Form: Pure Sine Wave Output, Total Harmonic Distortion: < 3% with resistive load, Total Voltage Harmonic Distortion: 5%, Individual Voltage Harmonic Distortion: 3%, Total Current Harmonic Distortion: 8%,Output Voltage: 415 ±3% ,Accuracy of AC Voltage Control: ±1% , Grid Frequency Control Range: ±3Hz

- Accuracy of Frequency Control: ±0.5% ,Power Factor Control: 0.95 inductive to 0.95 capacitive, Inverter/PCU efficiency: 96% minimum ,No-Load Losses: < 1% of rated power

- Overload Features: 150% for 1-minute Cooling: Forced Air cooling, with temperature-controlled cooling fan Ambient temperature: 0 – 40°C

- Relative Humidity: 100% non-condensing (maximum).

- If the inverter is supplied with LED/LCD Display Indications: Display must indicate system functional parameters and protection functional indicators

- Data monitor and display controls: Ethernet connectivity

- [24]Anti Islanding Protection as per the standard. It must comply with UL 1741 and complies with utility FRT requirements. This standard is in harmony with DOMLEC distributed renewable energy generation policy 2016 version 2.0 Category I & Category II Type A-3-Inverter must comply with UL 1741 or equivalent. Photovoltaic inverters must comply with IEEE 929 or equivalent.

- Enclosure Protection: IP 21(for indoor) as per IEC 529. The inverter must have IP65 (outdoor mounting) as per the UL 1703 requirements

- Safety -IEC 62103, IEC 62109 Part 1 & 2

- Galvanic Isolation at input & output through a transformer or transformerless topology

- Solar irradiation/isolation – UL/CE/TUV

- The nuts & bolts and the inverter enclosure must be adequately protected taking into consideration the atmosphere and weather prevailing in the area.

- Night or sleep mode: where the Inverter is almost completely turned off, with just the timer and control system still in operation, losses must be less than two watts per five kilowatts (2 W per 5 kW).

- Standby mode: where the control system continuously monitors the output of the solar generator until a pre-set value is exceeded.

[24] DOMLEC DISTRIBUTED RENEWABLE ENERGY GENERATION POLICY 2016 VERSION 2.0

- Operation of MPP tracking mode: the control system continuously adjusts the voltage of the generator to optimize the power available. The power conditioner must automatically re-enter standby mode if the input power reduces below the standby mode threshold. The front panel must provide a display of the status of the inverter.

- The inverter must have a minimum of Dual MPPT with independent strings as a minimum with

- A fifteen year (15 yr.) guarantee/warranty must be provided for the inverter(s). If an inverter fails, it must be replaced or repaired within two (2) weeks of notification

Balance of System – BOS

- The system must be adaptable. Materials must be corrosion resistant and have adequate structural support for the arrays and attachment to the structure, and any attachment points and penetrations must be properly weather sealed using accepted practice.

- The mechanical structures, electrical works including power conditioners/inverters /maximum power point tracker units/distribution boards/ digital meters/switchgear, etc. and overall workmanship of the PV system must be guaranteed or warranted against any manufacturing/material/design/installation defects for a minimum period of five (5) years.

- Structural Array mounting hardware supplied for this installation must be compatible with the site considerations and environment. Special attention must be paid to minimizing the risk from exposed fasteners, sharp edges, and potential damage to the modules or support structure. Corrosion resistance and durability of the mechanical hardware is emphasized. All materials must be selected to avoid corrosion and degradation. The use of ferrous metals, contact of dissimilar metals and the use of any wood or plastic components are strongly discouraged. Aluminum/Galvanized Iron and stainless steel components and hardware are preferred.

- The array mounting systems and overall installation must meet all applicable local building codes; and be capable of withstanding from back side of module hurricane-force winds of Category 3 (one hundred and seventy-five kilometres per hour (175km/hr.) or greater, for all attachment points, which are consistent with the module manufacturer’s installation instructions, and the requirements of ANSI/ASCE 7-98. Calculations and certifications from a licensed professional engineer or test lab verifying that the system can withstand these wind forces must be provided.

- All materials for the BOS must be new and both workmanship and materials must be of the very best quality, entirely suitable for the service to which the system is to be subjected and must conform to all applicable sections of this specification and all other relevant international or national regulations/specifications/standards. All parts of a duplicate of machines and mounting structure must be interchangeable without modification.

- The system installation and equipment layout must be considered with respect to the need for access, maintenance and future expansion of the system as needed by the DOWASCO.

System Spares

- Spare modules must be provided at a minimum quantity equal to three percent (3%) of the number of modules installed in the array field.

- All spares (electrical, electronic and mechanical) necessary for the satisfactory operation, routine maintenance and testing of the equipment for at least three (3) years.

- Spares must be readily interchangeable with the parts they replace and must comply with these Specifications.

- A complete and detailed spare parts list for all equipment supplied must be submitted.

Conclusion

The Dominica Water and Sewage Authority- DOWASCO undertakes the essential tasks of providing potable water to households and removing wastewater for safe disposal. Despite the impact of severe hurricanes in recent years, the island of Dominica continues to pursue its strategic goal of achieving 90% renewable energy target by 2029, among others subset goals of reducing the annual cost for diesel by 94%, tapping into geothermal energy and reduction of the overall cost of electricity generation.

[25]Very rarely, the link is made between water supply, wastewater treatment and energy as these are presented to the public as very separate systems. However, like all systems that function to sustain a nation, these three entities are interrelated and interdependent. However, while DOWASCO is not the DOMLEC largest customer, no doubt, an energy bill at ~ USD $407,023/yr with an estimated demand of 884,244kWh/yr via traditional fuel, contributes significantly to the Caribbean Community overall GHG climate output. Thus, this project, 'Technical Assessment of Renewable Energy Needs for DOWASCO' will lead to the successful installation of two or three photovoltaic systems which will contribute to the country's national goal of 90% renewables by 2029.

Despite the current economic and adverse climatic conditions that have impacted the island, energy efficiency and renewable energy projects will undoubtedly impact positively on the operational cost DOWASCO making it a more efficient and sustainable Company, while conscientiously reducing its carbon footprint. Renewable energy has its place within the framework of the water and wastewater industry. It is imperative that the ad-hoc approach of *"slapping a bunch of solar panels on the roof of a building is not taken, but true engineering is used"* to achieve the most efficient results. If a sequential path is followed, as laid out within the framework of this technical assessment document, along with due diligence and careful implementation in conjunction with the integration of an improved electrical switchgear system, this project will lead to a successful installation of the PV systems at the intended pumping facilities audited.

Stemming from the technical assessment of this assignment, the recommended action plan for DOWASCO was generated by the Consultant should run concurrently for each pump station as follows:

- The installation of 30kW_{ac} Photovoltaic system at Jimmit Booster Station
- The installation of 30kW_{ac} Photovoltaic system at Tete Morne Booster Station

  Competent procurement with good engineering using the best technology, skilled/trained human resource, coupled with adhering to an already developed Renewable Energy framework by the IRC, while following the guidelines set out by Distributed Renewable Energy Generation Policy of DOMLEC, will ensure that the installation of the potential photovoltaic systems positively affect DOWASCO strategic RE plans while helping to stabilize its financial cost of operations where clean energy projects are a viable option in today's economic climate; now that the technology is more readily available and cost-effective.

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[25] Paper submitted by the Consultant CWWA 2015 –' The application of renewable energy at the Barbados Water Authority Facilities'

Grant funding projects such as the “Italian/Dominica/CCCCC – Partnership Program” helps Caribbean countries to achieve goals of generating ‘*your own’* power safely and cleanly, with sustainability as core criterion.

Appendices

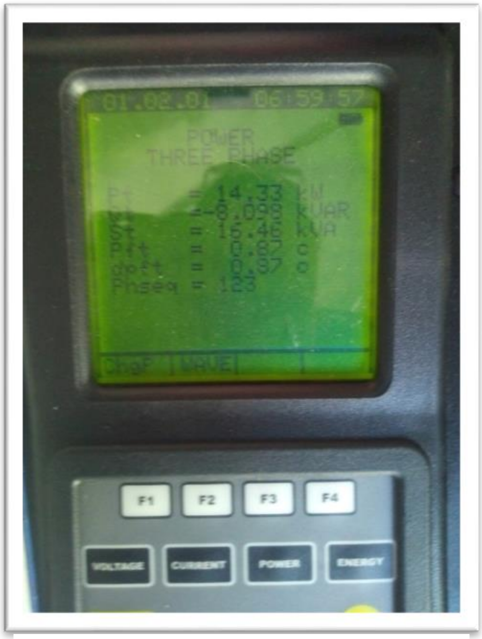

Figure 42 Extract of Jimmit Electrical Audited Results

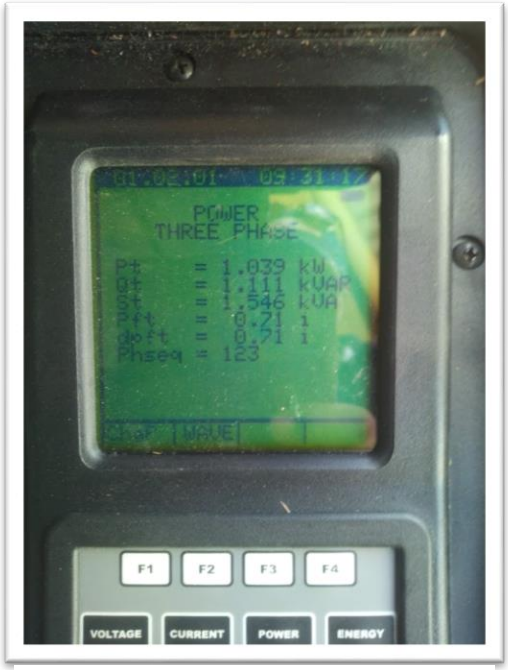

Figure 43 Warner Electrical and Power Results

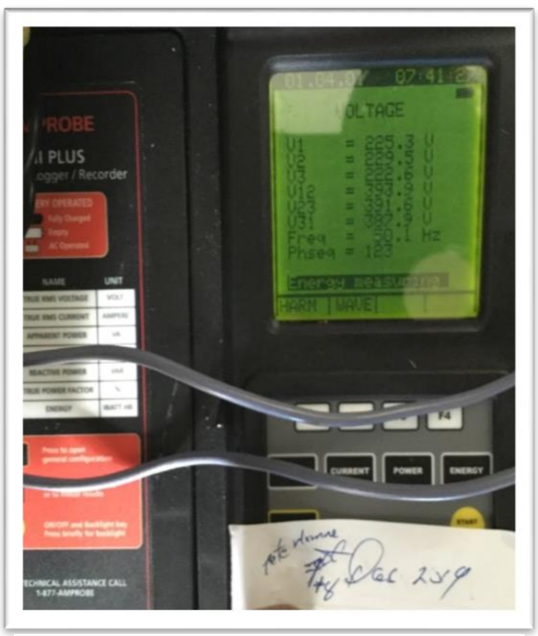

Figure 44 Extract of Tete Morne Electrical Results

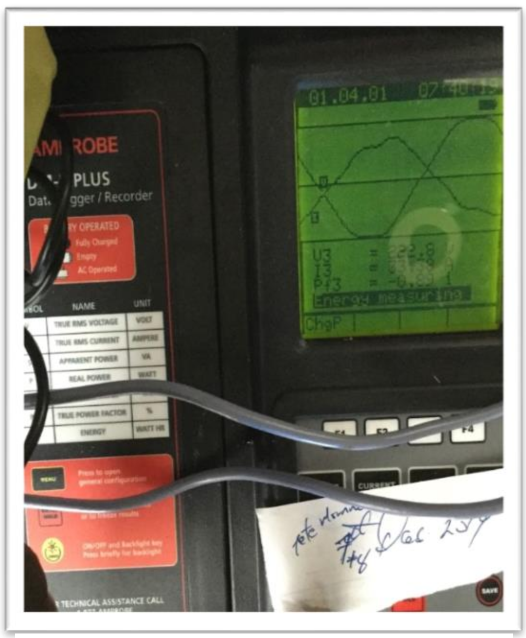

Figure 45 Extract showing Tete Morne Harmonics Wave Form

Tete Morne Facility Energy Cost					
Date	**Consumption kWh**	**Energy Cost $EC**	**KVA demand**	**Cost of Energy $EC/kWh**	**Daily Average Consumption KWh**
February-12- 2019	3350	EC$4,218.06	1	1.259	111.67
March -13-2019	6130	EC$7,753.07	1	1.265	204.33
April 12 2019	5790	EC$7,082.29	1	1.223	193.00
May 13 2019	5180	EC$6,605.92	1	1.275	172.67
June 12 2019	5370	EC$6,683.78	1	1.245	179.00
July 12 2019	4890	EC$6,068.98	1	1.241	163.00
August 12 2019	5280	EC$6,515.98	1	1.234	176.00
September 11 2019	6100	EC$7,588.19	1	1.244	203.33
October 10 2019	6200	EC$7,462.24	1	1.204	206.67
December 11 2019	5370	EC$6,730.71	1	1.253	179.00
Averages	5366	EC$6,670.92	1	1.244	178.867

Jimmit Facility Energy Cost					
Date	Consumption kWh	Energy Cost $EC	KVA demand	Cost of Energy $EC/kWh	Daily Average Consumption KWh
Feb- 12- 2019	8350	10,506.26	1	1.258	278.3
March- 13- 2019	7380	9,333.03	1	1.265	246.0
April - 12- 2019	7250	8,861.91	1	1.222	241.7
May- 13- 2019	9070	11,563.01	1	1.275	302.3
June- 11- 2019	7550	9,395.10	1	1.244	251.7
July- 11- 2019	7520	9,329.24	1	1.241	250.7
August- 12- 2019	8160	10,067.43	1	1.234	272.0
sept - 11- 2019	8200	10,198.20	1	1.244	273.3
Oct- 11- 2019	8110	9,759.55	1	1.203	270.3
Nov- 11- 2019	8620	10,739.76	1	1.246	287.3
Dec 11-2019	7890	9,886.92	1	1.253	263.0
Average	8009	9967.31	1	1.24	266.97

Surcharge Rate Fluctuations DOMLEC	
Date	$EC/kWh
February- 12- 2019	0.3603
March -13-2019	0.3661
May 13 2019	0.3951
April 12 2019	0.3499
June 12 2019	0.3685
July 12 2019	0.3652
August 12 2019	0.3593
September 11 2019	0.368
October 10 2019	0.3329
December 11 2019	0.3761

Glossary of Terms

COMPANY - Corporation or utility responsible for the operation of the pumping system.

CURRENT (I) - Computes the average current in accordance with the measures the current average imbalance of each phase measurements, and places a description of the imbalances according to the imbalance calculated between phases.

EFFICIENCY - The manufacturer or new motor efficiency in percentage (%).

ELECTRIC DIAGRAM - It is extremely important to outline the single-line diagram connections of the electric equipment, intake, cabling, transformer, main switch, and starter, if applicable.

ELECTRICAL LOSES - Energy losses due to electrical items, in this case, due to the conductor's energy losses.

ENERGY CONSUMPTION. - The total energy consumed by the electrical system in a year of operation, calculated as the sum of the average active power at all stages. The result is total energy consumption in kWh.

EQUIPMENT – Name of Equipment.

HARMONIC DISTORTION - This single parameter can be measured if harmonic analyzer equipment is available.

HEAD - The pump load due to the physical and topographic elevations; the vertical distance between the suction and highest point of delivery, expressed in water column meters or feet.

LEAKAGES LOSSES - The estimate of water lost through leaks in the distribution network, according to previous studies of the network.

MOTOR EFFICIENCY - The real motor efficiency percentage.

MOTOR LOSSES - Energy losses in the motor, according to the real motor efficiency.

NETWORK HEAD LOSSES - Total pumping load losses calculated by the difference between the net pumping load and the corresponding pressure gap.

POWER (kW) - Computes the average active power, the average active power imbalance and calculated average and the voltage measured at each phase.

POWER FACTOR - Computes the average power factor according to the measurements of each phase. It places a description of the imbalances calculated between phases.

POWER SUPPLY - Refers to the provider of electrical service and details of the contract with this company.

PUMP EFFICIENCY - The pump efficiency percentage.

PUMP EVALUATION -Pump evaluation determines the efficiency of the pump. The total efficiency of the operating pump is calculated as the ratio between the hydraulic power output and the mechanical power absorbed.

PUMP LOSSES - Energy losses due to the pump inefficiency.

STARTER – Equipment that controls the pump

SUCTION & DISCHARGE PIPE LOSSES - Energy losses caused by friction of the fluid in piping suction and discharge.

SYSTEM - Hydraulic system to which the pumping system belongs.

TARIFF - The key or name of the fare schedule associated with Utility companies.

TRANSFORMER – An electrical device that converts voltages and currents.

USEFUL WORK - The real work expressed in units of energy actually needed by the pumping

VOLTAGE (V) - Computes the average voltage measured, the imbalance of tension between the calculated average and the voltage measured at each phase.