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Final Assessment: U.S. Virgin Islands (USVI) Industrial Development Park and Adjacent Facilities Energy-Efficiency and Micro-Grid Infrastructure

December 2015

J.M. Petersen
P.A. Boyd
R.T. Dahowski
G.B. Parker, Project Manager

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99352

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Executive Summary

The purpose of this assessment was to undertake an assessment and analysis of cost-effective options for energy-efficiency improvements and the deployment of a micro-grid to increase the energy resilience at the U.S. Virgin Islands (USVI) Industrial Development Park (IDP) and adjacent facilities in St. Croix.

The Economic Development Authority (EDA) sought assistance from the U.S. Department of Energy to undertake this assessment undertaken by Pacific Northwest National Laboratory (PNNL). The assessment included 18 buildings plus the perimeter security lighting at the Virgin Islands Bureau of Correctional (BOC) Facility, four buildings plus exterior lighting at the IDP, and five buildings (one of which is to be constructed) at the Virgin Islands Police Department (VIPD) for a total of 27 buildings with a total of nearly 323,000 square feet. Table ES.1 is a description of the buildings included in the assessment. Figure ES.1 is an aerial view of a portion of St. Croix with the buildings included in the assessment circled in red.

Table ES.1. Buildings included in the Energy-Efficiency and Micro-Grid Assessment

Building Group	Building Use Type	Number of Buildings in Group	Date Built	Area (ft^2)
BOC Administration	Office	1	1972	5,504
BOC Building A	Cell blocks (lodging)	5	1972	24,110
BOC Chapel	Worship	1	1972	3,519
BOC Education	Education	1	1972	6,468
BOC Perimeter Lighting	Exterior lighting	N/A	N/A	0
BOC Holding Cells G/H	Cell Blocks (lodging)	6	2000	65,202
BOC Kitchen, Laundry	Food Service/laundry	1	1972	11,960
BOC Medical	Health care	1	1972	7,852
BOC R&D	Office	1	1972	7,176
BOC Warehouse	Storage	1	2014	6,724
IDP Exterior Lights	Exterior lighting	N/A	1995	N/A
IDP Building 1	Administration/manufacturing	1	1984	31,878
IDP Building 2	Administration/storage	1	1988	40,001
IDP Building 3	Administration/Storage	1	1988	40,001
IDP Building 4	Administration/storage	1	1986	40,001
VIPD Headquarters[a]	Administration	1	2016[a]	24,800
VIPD K9	K9 Kennels and administration	1	2015	1,148
VIPD Pavilion	Administration	1	1970	512
VIPD Special Operations	Administration	1	2015	2,380
VIPD Training	Administration and education	1	1970	3,063
Total		27		322,299

N/A= Not Applicable.
a. This building has yet to be constructed.

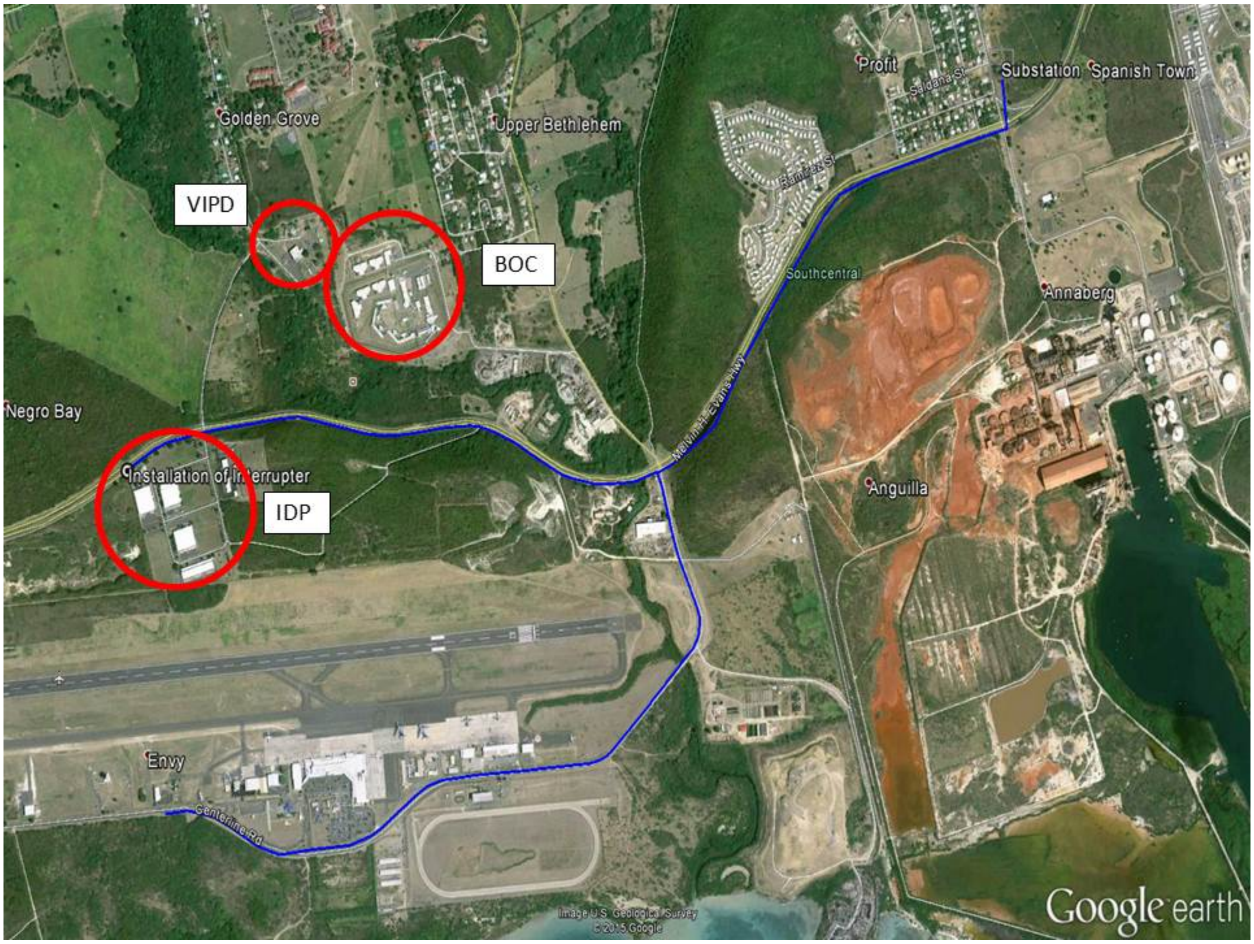

Figure ES.1. Aerial View of the Buildings included in the Assessment

The assessment was undertaken using data and information provided by the site points of contact and supplemented during a visit to St. Croix that occurred August 10-14, 2015. During that site visit, staff from PNNL conducted a detailed audit of the buildings and other site-specific information used in the assessment.

Based on the assessment, the estimated energy savings for the retrofit of all 27 buildings would be 1,966 MMBtu/yr (~576,000 kWh/yr) and the estimated load savings would be 101 kW (11%). The estimated electricity and operations and maintenance cost savings from cost-effective efficiency retrofit measures in the assessed buildings would be approximately $185,300/year with an investment of ~$1.75 million in retrofit technologies. The overall savings-to-investment ratio is 1.9 with a 9.4 year payback period. This estimated savings and capital investment in this assessment should be considered a conservative estimate.

PNNL evaluated the energy load profiles, utility electrical costs, and energy security issues to specify a micro-grid configuration for the 27 buildings that would provide power to the buildings during loss of utility grid power or when renewable energy sources will be in a micro-grid islanding mode of operation. A walk-down audit was performed on the three sites to determine the condition of existing electrical infrastructure, locate and assess site generators, and acquire available operational data. The site visit also included a meeting with representatives of the Virgin Island Water and Power Authority (WAPA) to determine reliability, stability, and availability of energy sources and review the existence and applicability of any renewable energy incentive programs.

As with most sites, there were a few challenges to the design of a micro-grid. The IDP and VIPD both are plagued with power lines running through the sites with multiple distribution points and pole-mounted transformers. The IDP has no existing generators that could provide backup electrical service to the entire site, but does have small generators that serve individual businesses and portions of the facility. The VIPD has sites with new generators, and there is a large, operable generator that is also connected to the nearby Department of Motor Vehicles but could not supply the entire site and the planned (new) VIPD administration building. These generators currently are used for backup generation for individual buildings. The BOC was the best choice to provide a micro-grid tie-in point because a single feed to the main transformer serves the whole site. The BOC's main generator has a good engine but it needs a radiator, and the electrical generator is inoperable. The second generator is too small to service the whole site, and is dedicated to providing backup electrical service to the medical clinic; however, that generator needs a wiring update.

Photovoltaic (PV) systems were specified for each building group (BOC, IDP. and VIPD) totaling 1500 kW at an installed cost of ~$6.117 million. The PV-generated electricity will lower net energy consumption with savings estimated at ~2.8 million kWh/year (~$900,000/year). No backup battery storage is included as battery storage is deemed to be too costly to be included in this micro-grid. The sites have adequate sunshine, but they suffer from cloud effect. Therefore, in this region, the PV output capacity is assumed at only 20% of the total capacity installed.

The capital cost to construct a micro-grid (PV arrays, generators, and infrastructure/controls) that connects and 'islands' the 27 buildings in this assessment is estimated to be ~$8.650 million, with an annual operating cost (maintenance plus fuel costs) of ~$76,000/year. The micro-grid costs assume that all recommended cost-effective retrofits are installed in the 27 buildings, thus reducing the building electricity consumption and average and peak loads.

The total project cost (i.e., building retrofits plus micro-grid) for 27 buildings is estimated to be ~$10.40 million.

The total capital cost for building retrofits and construction of a micro-grid (PV arrays, generators, and infrastructure/controls) for just the four buildings at the IDP is estimated to be ~$3.869 million. This includes ~$504,000 for the building retrofits and ~$3.365 million for the micro-grid.

Energy-Efficiency Assessment

Table ES.2 is a summary of the estimated energy and operations and maintenance savings for implementing the efficiency recommendations, the capital investment required, the simple payback, and the savings-to-investment ratio (SIR) by building. Table ES.3 summarizes the results of the energy-efficiency assessment over all 27 buildings by retrofit measure category.

There are environmental benefits to retrofitting the buildings in this assessment. Those benefits are quantified in Table ES.4 as reduction in carbon dioxide emissions at the thermal energy generation plant on the island. Total carbon dioxide emissions reduction at the three sites resulting from implementation of the recommended retrofits are estimated to be 422 metric tons/year, which is equivalent to removing nearly 90 passenger vehicles from the roads of St. Croix or eliminating ~150 tons/year of waste to the St. Croix landfill.[1]

Table ES.2. Summary of Savings, Investment, Payback, and SIR for Each Building in the Assessment

Building Group	Electricity Savings		Annual O&M[a] Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	MMBtu/yr	$/yr					
BOC Administration	134	$12,610	($547)[a]	$12,063	$100,438	8.3	2.3
BOC Building A	106	$9,985	($1,138)[a]	$8,847	$100,309	11.3	1.7
BOC Chapel	136	$12,780	($256)[a]	$12,524	$89,633	7.2	2.5
BOC Education	125	$11,704	$171	$11,875	$106,556	9.0	1.8
BOC Perimeter Lighting	50	$4,710	$1	$4,711	$57,950	12.3	1.5
BOC Holding Cells	157	$14,779	$217	$14,996	$105,546	7.0	2.7
BOC Kitchen, Laundry	175	$16,521	($701)[b]	$15,820	$175,801	11.1	1.5
BOC Medical	72	$6,813	($392)[b]	$6,421	$40,846	6.4	2.3
BOC R&D	199	$18,598	$422	$19,020	$161,973	8.5	2.1
BOC Warehouse	3	$239	$71	$310	$5,378	17.3	1.1
Total BOC	*1,157*	*$108,739*	*($2,152)*[b]	*$106,587*	*$944,430*	*8.8*	*2.0*
IDP Exterior Lighting	0	$0	$0	$0	$0	0.0	0.0
IDP Building 1	217	$20,299	$907[b]	$21,206	$271,026	12.8	1.5
IDP Building 2	62	$5,867	($28)[b]	$5,839	$50,571	8.7	2.2
IDP Building 3	179	$16,873	($247)[b]	$16,626	$165,973	10.0	1.9
IDP Building 4	27	$2,554	($142)[b]	$2,412	$16,714	6.9	2.7
Total IDP	*485*	*$45,593*	*$490*	*$46,083*	*$504,284*	*10.9*	*1.7*
VIPD Headquarters[c]	176	$16,494	$1,235	$17,729	$179,651	10.1	1.7
VIPD Administration/K9	15	$1,364	$160	$1,524	$17,349	11.4	1.6
VIPD Pavilion	19	$1,753	($20)[b]	$1,733	$12,837	7.4	2.4
VIPD Special Operations	21	$1,888	$167	$2,055	$31,076	15.1	1.2
VIPD Training	93	$8,718	$849	$9,567	$59,812	6.3	2.9
Total VIPD	*324*	*$30,217*	*$2,391*	*$32,608*	*$300,725*	*9.2*	*1.9*
Total	1,966	$184,549	$729	$185,278	$1,749,439	9.4	1.9

[a] O&M = operations and maintenance.
[b] Numbers in parentheses represent costs rather than savings.
[c] This building is to be constructed. Retrofits were based on preliminary design specifications for the building.

[1] See http://www2.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Table ES.3. Summary of Energy-Efficiency Retrofits by Retrofit Measure Category for 27 Buildings in the Assessment

Measure Category	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	MMBtu/yr	$/yr					
Building Envelope	700	$65,510	$0	$65,510	$654,954	10.0	1.9
Air Conditioning	233	$21,846	($322) [a]	$21,524	$198,259	9.2	1.2
Lighting	1,003	$94,307	$1,094	$95,401	$890,352	9.3	2.0
Domestic Hot Water	30	$2,886	($43) [a]	$2,843	$5,874	2.1	3.7
Total	1,966	$184,549	$729	$185,278	$1,749,439	9.4	1.9

[a] Numbers in parentheses represent a cost rather than a savings.

Table ES.4. Carbon Dioxide Reduction from Implementation of Energy-Efficiency Recommendations

Site	Carbon Dioxide Reduction (metric tons/year)
BOC	251
IDP	102
VIPD	69
Total	422

Typical load profiles from the Facility Energy Decision System (FEDS) energy modeling analyses for all 27 buildings at the three combined sites (i.e., BOC, IDP, and VIPD) after all retrofits have been implemented are shown in Figure ES.2. The average demand for the three sites after retrofits is estimated to be 382 kW with a peak demand estimated to be 838 kW (occurring in September). The annual energy use in the 27 buildings after retrofits is estimated to be 3,350,715 kWh/yr.

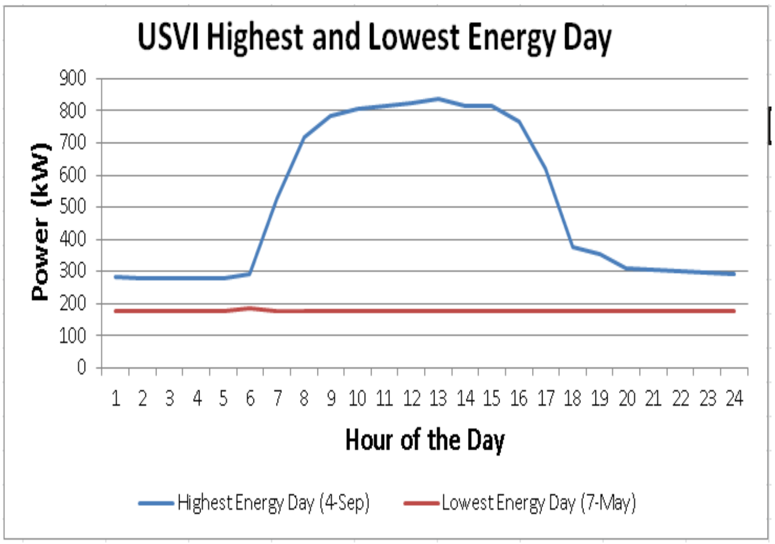

Figure ES.2. Average and Peak Load for the Combined 27 Buildings after Recommended Retrofits

Micro-Grid Conceptual Design

New backup generators were sized to serve the average load at the least operating cost. These generators will serve all 27 buildings in the event of loss of WAPA power and without benefit of the PV-generated electricity.

The configuration of the suggested micro-grid developed for this assessment is shown in Figure ES.3. This configuration will tie all 27 buildings together and be able to operate in an 'islanding' configuration.[1] Figure ES.3 shows the buildings and building clusters considered in this assessment, new PV arrays for each building or building cluster, battery for voltage control, backup fossil fuel generators and their 'smart' controllers, the energy management system, and the hard wiring that will tie the system to the WAPA feeder (9B) and to each of the buildings. Also noted are isolation points for 'islanding' the micro-grid from WAPA generation.

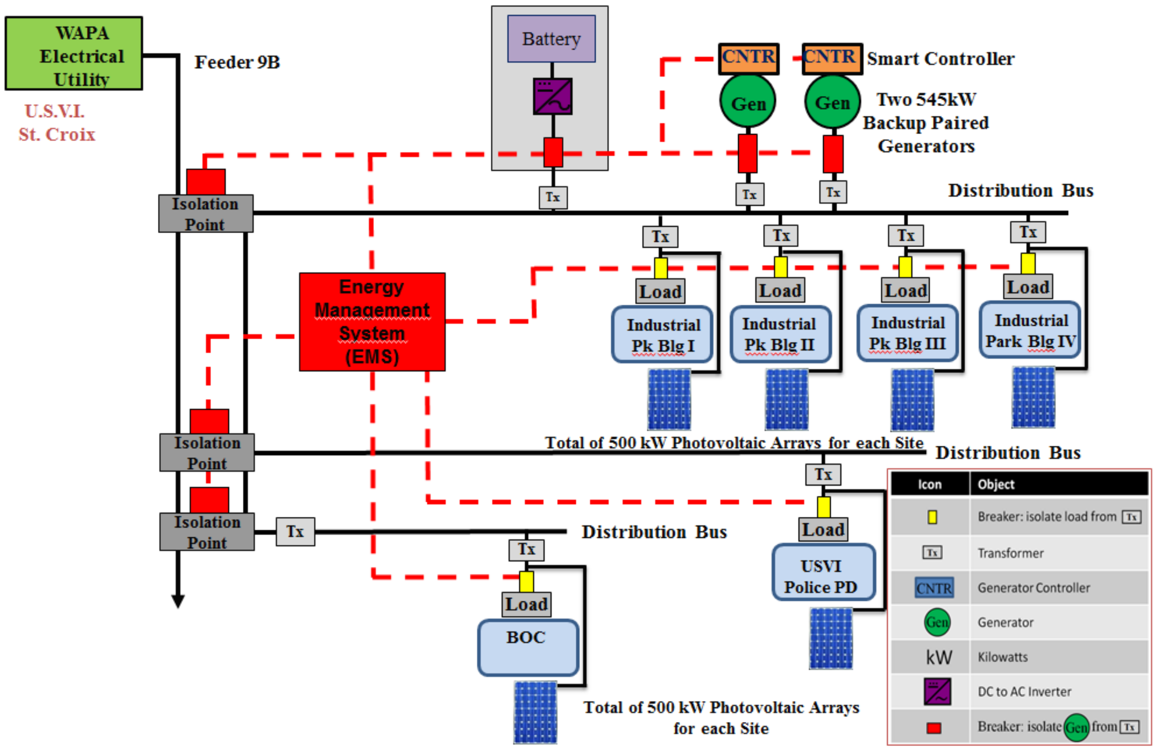

Figure ES.3. Diagram of the Proposed Micro-Grid for the Buildings in this Assessment

Table ES.5 provides a summary description of the PV system for the micro-grid, and Table ES.6 summarizes the micro-grid infrastructure (i.e., generators, cabling, controllers, and energy management system) for the micro-grid configuration shown in Figure ES.3. Table ES.7 summarizes the PV system for the four IDP buildings, and Table ES.8 summarizes the micro-grid infrastructure for just the four buildings at the IDP. The tables show the installed capital cost for equipment and annual operating cost of the systems.

[1] A diagram showing the configuration of a micro-grid for just the four buildings at the IDP is shown in Figure 3.2.

Table ES.5. Summary of the PV System for the Micro-Grid for all 27 Buildings

Description	Energy Savings (MMBtu/yr)	Energy Savings ($/y)r	Maintenance Cost ($/y)r	Total Savings ($/yr)	Investment ($)	Payback (yr)	Required to Reduce Utility Energy?
1,500 kW roof- and ground-mounted PV system for 27 buildings 335,150 ft^2 1,992 MWh/year	9,590	$899,47 6	$30,776	$868,700	$6,116,827	7.0[a]	Yes

[a] Excluding yearly maintenance costs

Table ES.6. Description and Costs for the Diesel Generators and Micro-Grid Infrastructure for all 27 Buildings

Description	Installed Equipment Costs ($)	Energy Savings (MMBtu/yr)	Diesel Fuel Use (gal/yr)	Maintenance Cost ($/yr)	Total Annual Cost ($/yr)
Two C18 545-kW paired backup power diesel generators, fuel tank, shelters, energy management system , batteries for stability, inverters with container, switchgear, transfer switches, transformers, trenching, installation, wire and communications	$2,533,010	0	11,232	$1,028	$46,565

Table ES.7. Description and Costs for the PV System at the IDP for the Micro-Grid

Description[a]	Energy Savings MMBtu/yr	Energy Savings ($/yr)	Maintenance Cost ($/yr)	Total Savings ($/yr)	Investment ($)	SIR	Payback (years)
496 kW PV system on roof tops of 4 buildings at the IDP.	3,083	$289,165	$9,917	$279,248	$2,013,223	2.20	7.2

[a] 496 kW of PV can produce up to 3,083 MMBtu/yr. System is somewhat oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects. Estimated output is 904MWh/yr. PV system requires a roof area of 108,000 ft^2.

Table ES.8. Description and Costs for the Diesel Generators and Micro-Grid Infrastructure for the IDP

Description	Energy Savings (MMBtu/yr)	Diesel Fuel Use (gallons/yr)	Maintenance Cost ($/yr)	Total Annual Cost ($/yr)	Investment ($)
Two CAT 3412C 275 kW paired prime power diesel generators, fuel tank, shelters, energy management system, batteries, inverters with container, electrical protection, switchgear, transfer switches, transformers, trenching, installation, wire and communications.	0	3,068	$1,299	$13,878	$1,351,460

Recommendations

Recommendations based on this assessment are briefly described below:

- For the participating buildings, prepare and release a bid package to perform the identified energy saving retrofit recommendations based on the FEDS results. For all 27 buildings, these retrofits have a payback of less than 10 years and with a SIR of nearly 2. The retrofits will result in electricity cost savings of over $185,000/year and a demand reduction of greater than 100 kW. These building retrofits are important for reducing overall coincident peak and average load to be served by the micro-grid. Therefore, the micro-grid design and costs assume the retrofit measures are implemented. The savings in electricity cost from these retrofits can be used to service the debt for the installation of the retrofits if the project is undertaken with third-party/alternative financing. For the four buildings at the IDP, the retrofit could potentially be in partnership with future tenants and specified in the lease contract language.
- Require a robust measurement and verification plan as part of the retrofit project.
- Verify that suitable/available land and building roof space is available for the proposed PV arrays.
- Determine if the size/capacity of the PV arrays meet WAPA and other utility/USVI requirements.
- Undertake an engineering design of the conceptually designed micro-grid to refine the design and costs.
- Secure funding and/or financing for the micro-grid.
- Prepare and release a bid package for the micro-grid.
- Award bid and proceed with the project.

Acronyms and Abbreviations

BOC	Bureau of Corrections
DHW	domestic hot water
DOE	U.S. Department of Energy
EDA	Economic Development Authority
EDP	Economic Development Park
FEDS	Facility Energy Decision System
HPS	high-pressure sodium
HVAC	heating, ventilating, and air conditioning
IDP	Industrial Development Park
MSW	municipal solid waste
O&M	operations and maintenance
PNNL	Pacific Northwest National Laboratory
PV	photovoltaic
SIR	savings-to-investment ratio
USVI	U.S. Virgin Islands
VIPD	Virgin Islands Police Department
VIWMA	Virgin Islands Waste Management Authority
WAPA	Water and Power Authority

Contents

Figures

Tables

1.0 Background

The purpose of this project was to undertake an assessment and analysis of cost-effective options for energy-efficiency improvements and deployment of a micro-grid to increase the energy resilience at the U.S. Virgin Islands (USVI) Industrial Development Park (IDP) and adjacent facilities in St. Croix, USVI.

The William D. Roebuck Industrial Park, located between the historic towns of Christiansted and Frederiksted on the island of St. Croix, is the larger of the two industrial parks. Situated within four adjoining buildings, this park consists of 152,000 square feet of commercial space. This IDP is being considered as an anchor for future ‘Green’ business development. As such, the U.S. Virgin Islands Economic Development Authority (EDA) sought assistance from the U.S. Department of Energy (DOE). In this assessment, DOE’s Pacific Northwest National Laboratory (PNNL) quantified cost-effective efficiency measures to be retrofitted in all the buildings that would be part of the micro-grid to reduce the electrical load in buildings being served by the micro-grid.

A total of 27 buildings were assessed—18 buildings at the U.S. Virgin Islands Bureau of Corrections (BOC), four buildings at the IDP, and five buildings at the Virgin Islands Police Department (VIPD) adjacent to the BOC. The assessment was based on information collected from the building/site staff and a walkthrough building audit by PNNL staff during August 10-14, 2015. An assessment also was conducted on four buildings at the Virgin Islands Waste Management Authority (VIWMA). These builds were not included in the micro-grid as all of the buildings are served from a different WAPA feeder making connection to the micro-grid prohibitively expensive. The energy-efficiency assessment for the VIWMA buildings are given in Chapter 6.0 with detailed information provided in Appendix C

Figure 1.1 is an aerial view of the site with buildings included in this assessment circled in red. Table 1.1 provides descriptions of the buildings.

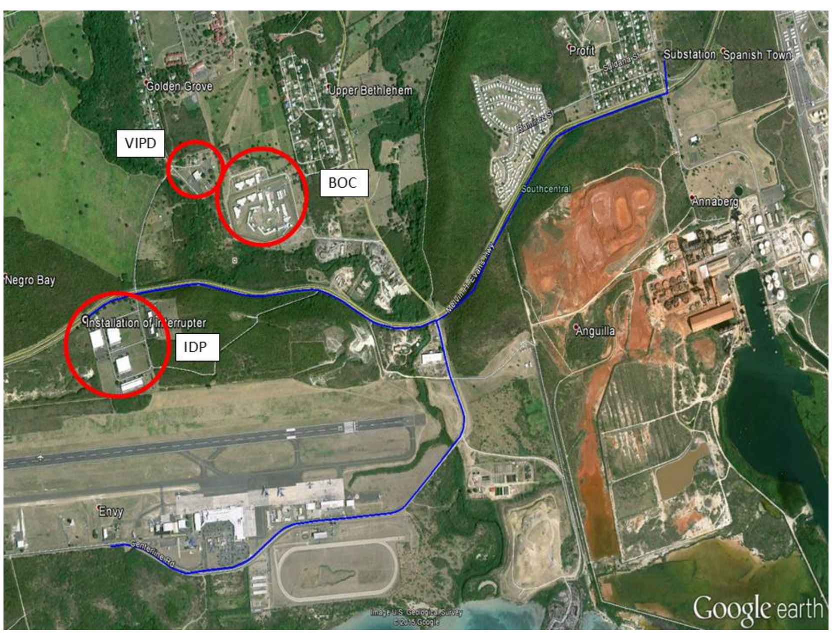

Figure 1.1. Aerial View of the IDP, BOC, and VIPD Buildings included in the Assessment

Table 1.1. Buildings included in the Facility Energy Decision System (FEDS) and Micro-Grid Assessment

Building Group	Building Use Type	Number of Buildings in Group	Date Built	Area (ft^2)
BOC Administration	Office	1	1972	5,504
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VIPD Special Operations	Administration	1	2015	2,380
VIPD Training	Administration and education	1	1970	3,063
Total		27		322,299

N/A= Not Applicable.
[a] This building has yet to be constructed.

2.0 Energy-Efficiency Assessment and Discussion

The buildings were analyzed for energy-efficiency technology retrofits using the FEDS software[1] to approximate energy performance and identify cost-effective efficiency retrofits. The FEDS output provides a prioritized list of energy saving measures on a life-cycle cost basis. In addition, details on the individual building and collective load profiles for the site also are developed. The micro-grid assessment assumes that the identified retrofit projects will be performed on the study buildings per the FEDS recommendations, and thus, the resulting electrical load in the critical buildings to be serviced by the micro-grid will be reduced.

Key input parameters were collected prior to and during the site visit. The key parameters used in the FEDS assessment are identified below:

- Blended electricity cost of $0.32/kWh with no separate demand charge[2]
- Building function (e.g., office, warehouse, classroom, common areas, food service, etc.)
- Building vintage
- Building square footage
- Building construction materials
- Building occupancy and hours of occupancy
- Building interior and exterior-lighting technologies
- Building air conditioning
- Building water heating equipment
- Presence of ‘other’ equipment such as laundry and kitchen equipment.[3]

The audit and retrofit assessment did not include recommendations for ‘control’ technologies such as heating, ventilating, and air conditioning) (HVAC system controls (e.g., setback thermostats, building automation-direct digital controls, etc.) and lighting controls (e.g., occupancy sensors or photo cells) nor any building re-commissioning (re-tuning of building operational systems) as that assessment was beyond the scope of this project. Because a majority of the cooling technology within the buildings audited was either ductless or standard split systems, basic programmable thermostats with scheduled setbacks will help reduce the cooling load. Decreasing the set point of the cooling technology during unoccupied periods not only increases the lifespan of the equipment but reduces the total load. There is no additional hardware cost to adjust or implement controls for this equipment. More advanced controls are not required based on the technology observed.

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[1] http://www.pnnl.gov/feds/

[2] This is the marginal/future ‘blended’ cost of electricity as indicated by WAPA and the U.S. Virgin Islands Energy Office that was deemed appropriate for use in the assessment. Given the very small demand charge, the kilowatts and kilowatt cost savings were not separated from the kilowatt-hour charge, and instead, the kilowatt cost was included into this ‘blended’ rate.

[3] Note that FEDS does not recommend retrofits for ‘other’ equipment given the unique characteristics and widely variable cost of such equipment. Additional savings can be acquired through such equipment retrofits.

In addition, lighting controls such as occupancy sensors in restrooms and storage rooms can be cost effective with minimal investment. An additional 10 to 25% savings can be realized with properly operated and/or retrofitted controls. It is recommended that any retrofit of HVAC equipment or lighting technologies also include new controls (e.g., a setback thermostat or occupancy sensor) if appropriate, and that the 'system' be commissioned to ascertain that the controls are operating properly. Based on the cost of electricity and large cooling and lighting load seen at all the facilities assessed in this project, inclusion of programmable thermostats with setback thermostats for all HVAC systems (both new or existing) and lighting occupancy sensors would have a conservative payback period of less than 2 years.

The audit and assessment also did not include a comprehensive water (commodity) savings estimate. However, given there was insufficient baseline water consumption data available and, for some buildings (such as the IDP buildings), water use is minimal a water commodity retrofit and savings estimate was not undertaken. The water use in the IDP buildings may change when the buildings are occupied by the tenants. A comprehensive water audit and water fixture retrofit measures assessment may therefore be justified at that time.

Given the recommended retrofits were only for technologies with a savings-to-investment ratio (SIR) >1, exterior-lighting (e.g., street lighting and perimeter lighting) retrofits for most high-pressure sodium (HPS) fixtures (e.g., at the IDP and the BOC) were not, by a very slim margin, found to be cost effective. The installed costs for high-quality, solid-state street lights in the USVI based on 2015 *RS Means Building Construction Cost Data* was sufficiently high that a stand-alone retrofit of HPS fixtures to solid-state fixtures was not cost effective (SIR <1) even at the $0.32/kWh marginal rate of electricity. However, costs for solid-state street lights continue to decrease, and it is likely that within the next 12 to 18 months, the fixture costs will decrease sufficiently to make this retrofit cost effective. In addition, these lighting retrofit measures could be bundled with other measures for a set of buildings and still achieve an overall SIR >1. Bundling of measures with SIRs <1 with those with a SIR >1 was not analyzed in this assessment.

Table 2.1 summarizes the energy savings identified by retrofit measure for the 27 buildings included in the FEDS assessment. Table 2.1 shows the electricity savings (reported in million [MM] Btu/year) and the associated cost savings. Also given in Table 2.1 are the operations and maintenance (O&M) savings for each measure category. The total installed equipment and materials investment costs (in 2015$) required to achieve those savings along with the associated simple payback (years) and SIR are listed for each measure category. Appendix A contains the detailed baseline and retrofit recommendations for each building set in the assessment.

The savings opportunities identified in Table 2.1 include building envelope improvements (insulation and windows), air conditioning system upgrades, lighting upgrades, and domestic hot water (DHW). There are no recommended measures with an SIR <1. The recommended improvements to the building envelopes have the longest payback at 10 years, and the shortest payback is DHW at 2.1 years.

The total dollar savings of $185,278 includes energy and O&M savings. The total investment required is $1,749,439 to achieve these savings with an overall simple payback of 9.4 years and a SIR of 1.9.

Table 2.1. Summary of Energy-Efficiency Retrofits by Retrofit Measure Category for the 27 Buildings Included in the Assessment

Measure Category	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	MMBtu/yr	$/yr					
Building Envelope	700	$65,510	$0	$65,510	$654,954	10.0	1.9
Air Conditioning	233	$21,846	($322)[a]	$21,524	$198,259	9.2	1.2
Lighting	1,003	$94,307	$1,094	$95,401	$890,352	9.3	2.0
DHW	30	$2,886	($43)[a]	$2,843	$5,874	2.1	3.7
Total	1,966	$184,549	$729	$185,278	$1,749,439	9.4	1.9

[a] Numbers in parentheses represent costs rather than savings.

Table 2.2 identifies the savings, investments, simple payback, and SIRs for each measure category specific to the buildings at the BOC. The recommended lighting retrofits for these buildings have the longest payback at 9.7 years, and the shortest payback is the DHW at 2.1 years.

Table 2.2. Summary of Energy-Efficiency Retrofits for the BOC by Retrofit Measure Category

Measure Category	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	MMBtu/yr	$/yr					
Building Envelope	383	$35,818	$0	$35,818	$291,713	8.1	2.3
HVAC	177	$16,581	($402)[a]	$16,179	$142,714	8.8	1.3
Lighting	568	$53,580	($1,707) [a]	$51,873	$504,678	9.7	1.9
DHW	29	$2,760	($43)[a]	$2,717	$5,325	1.9	4.1
Total	1,157	$108,739	($2,152)[a]	$106,587	$944,430	8.8	2.0

[a] Numbers in parentheses represent costs rather than a savings.

Table 2.3 identifies the savings, investments, simple paybacks, and SIRs for each measure category for only the four buildings at the IDP. The recommended building envelope retrofits for these buildings have the longest payback at 12.4 years, and the shortest payback is the DHW at 4.4 years. The recommended retrofits, savings, and paybacks may change as the currently unoccupied buildings are occupied and will be dependent upon the tenants and their activities. When occupied, the need for another audit and retrofit assessment can be substantially mitigated given the EDA is requiring the tenants to install energy efficient equipment (such as solid-state/LED lighting) as part of the lease terms and conditions.

Table 2.3. Summary of Energy-Efficiency Retrofits for the IDP by Retrofit Measure Category

Measure Category	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	(MMBtu/yr)	($/yr)					
Building Envelope	252	$23,673	$0	$23,673	$292,448	12.4	1.5
HVAC	0	$0	$0	$0	$0	N/A	N/A
Lighting	232	$21,794	$490	$22,284	$211,287	9.5	2.0
DHW	1	$126	$0	$126	$549	4.4	1.3
Totals	485	$45,593	$490	$46,083	$504,284	10.9	1.7

Table 2.4 identifies the savings, investments, simple paybacks, and SIRs for each measure category for only the buildings at the VIPD. The buildings included in this assessment are those adjacent to the BOC and also includes the yet-to-be constructed new Headquarters Administration building. The recommended building envelope retrofits for these buildings have the longest payback at 11.8 years, and the shortest payback is the lighting at 8.2 years. The retrofits for the yet-to-be constructed Headquarters Administration building are based on the design documentation. The new Headquarters Administration building and the newly constructed Special Operations and K9 buildings have solar-thermal water heating systems; therefore, the entire VIPD building set had insignificant water heating load. Thus, no DHW retrofits are recommended for the VIPD buildings.

Table 2.4. Summary of Energy-Efficiency Retrofits for the VIPD by Retrofit Measure Category

Measure Category	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	MMBtu/yr	$/yr					
Building Envelope	65	$6,019	$0	$6,019	$70,793	11.8	1.6
HVAC	56	$5,265	$80	$5,345	$55,545	10.4	1.2
Lighting	203	$18,933	$2,311	$21,244	$174,387	8.2	2.3
DHW	0	$0	$0	$0	$0	N/A	N/A
Totals for all measures	324	$30,217	$2,391	$32,608	$300,725	9.2	1.9

The peak load reductions for the sites included in the FEDS assessment are shown in Table 2.5 before and after all cost effective retrofits have been implemented. Also noted in Table 2.5 is the time (month/day) of the annual peak before-and-after retrofits. The overall peak savings of the three sites is 101 kW or 11%. The coincidental peak load for the combined buildings at the three sites will be shifted from August 28 at 12:00 hours to September 4 at 12:00 hours with the implementation of all the cost-effective retrofits.

Table 2.5. Peak Load Savings and Peak Shift with Implementation of Cost-Effective Retrofits in Buildings at the Three Sites

Site	Base Load Peak (kW)	Retrofit Load Peak (kW)	Peak Load Savings (kW)	Peak Load Decrease (%)	Base Load Peak (date/time)	Retrofit Load Peak (date/time)
BOC	314	261	53	17	08-01/13:00	08-01/13:00
IDP	536	506	30	6	08-28/12:00	09-04/12:00
VIPD	95	73	22	23	08-01/13:00	09-04/14:00
Totals for all buildings	939	838	101	11	08-28/12:00	09-04/12:00

Figure 2.1 shows typical load profiles from the FEDS analyses for all 27 buildings at the three combined sites (BOC, IDP, and VIPD) after all retrofits have been implemented. The average demand for the three sites after retrofits is estimated to be 383 kW with a peak demand estimated to be 838 kW (occurring at 12:00 on September 4). The annual energy use in the 27 buildings after retrofits from the FEDS analyses is estimated to be 3,350,715 kWh/yr. Appendix B provides details of the modeled load profiles for each site.

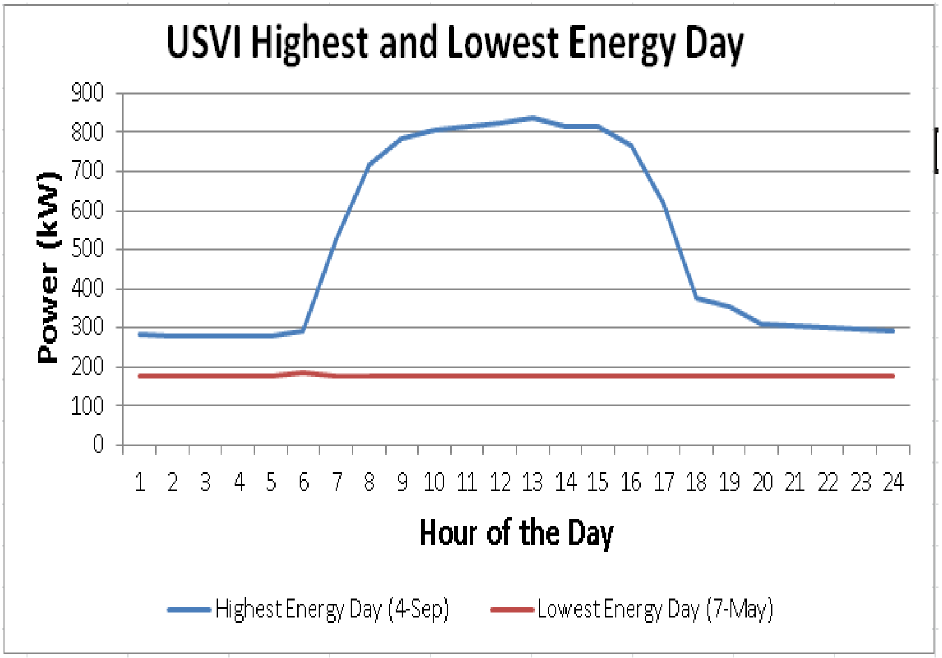


Figure 2.1. Average and Peak Load for the Combined 27 Buildings after Recommended Retrofits

There are environmental benefits to retrofitting the buildings considered in this assessment. Those benefits are quantified in Table 2.6 in terms of reduction in carbon dioxide emissions at the thermal energy generation plant on the island. Total carbon dioxide emission reduction at the three sites from implementation of the recommended retrofits are estimated to be 422 metric tons/year, which is equivalent to removing nearly 90 passenger vehicles from the roads of St. Croix or eliminating ~150 tons/year of waste to the St. Croix landfill.[1]

Table 2.6. Carbon Dioxide Reduction from Implementation of Energy-Efficiency Recommendations

Site	Carbon Dioxide Reduction (metric tons/year)
BOC	251
IDP	102
VIPD	69
Total	422

[1] See http://www2.epa.gov/energy/greenhouse-gas-equivalencies-calculator

3.0 Micro-Grid Infrastructure Assessment and Conceptual Design

A micro-grid is a distributed electrical generation system with defined electrical distribution boundaries that acts on a group of interconnected loads with a generation control system. PNNL evaluated energy load profiles, utility electrical costs, and energy security issues to specify the following micro-grid energy producing configurations with diesel generators for:

- *Stand-Alone (Prime/Continuous) Generators* **–** These generators have no electrical grid connection and are applicable for energy security considerations. They are used in areas where there is no grid access, poor grid power quality, or when the cost of energy (kWh) is larger than diesel/gas fuels consumed with generator maintenance.
- *Backup Generation* – These generators provide emergency power only when grid service is not present.

The following are the current diesel generators present at the micro-grid site:

- *IDP* – does not have backup generators; however that may change as the buildings are occupied depending upon tenant needs.
- *BOC* – the main generator needs a radiator; the second generator is too small and is currently used for the medical clinic.
- *VIPD* – the Special Operations and K9 buildings each have new (small) generators and there is a large generator for the rest of the site (including the abandoned old Administration building) that is also connected to the Department of Motor Vehicles building that is adjacent to the site. All these generators are for backup power.
- *Photovoltaics* – Electrical generation from PV systems was evaluated and recommended for deployment at each site. The PV systems are designed to lower the cost of electricity at the building compared to that supplied from the grid.

3.1 Micro-Grid Development Process

In the development of the micro-grid components and to prepare conceptual designs, PNNL requested data on the energy characteristics of the buildings of interest including at least 1 year of electrical bills, building construction and equipment and backup generation system characteristics, building electrical configuration, and one-line diagrams that show the external electrical distribution system and connections to the utility. Much of these data also are required for the FEDS retrofit assessment. The configuration and sizing of the micro-grid assumes that all identified cost-effective retrofits (described in the previous section) will be implemented in the assessed buildings thus reducing the loads

A micro-grid analysis model was used to determine the menu of possible micro-grid configurations. Key inputs to the model are described below:

- Condition of existing electrical infrastructure and utilization of any onsite generators
- Reliability, stability, and availability of energy sources and the characteristics of a renewable incentives program that may be available from the utility (WAPA) and/or USVI government

- Load profile for the buildings
- Cost of electricity (kWh) and #2 diesel oil
- Capital costs of new generation and storage on the USVI including PV, diesel generators, and batteries
- Capital cost of the infrastructure to support the micro-grid including controls, switches, cable, energy management system, and inverters
- O&M costs including cost of fuel for generators during the estimated hours of the operation of the micro-grid.

The backup generator simulator takes the load profile from the site and produces a list of the number of generators by size, runtime (hours), fuel consumed, and gallons per hour based on fuel curves for the generators considered. This allows the proper sized generator to be selected for a given site to minimize fuel and maintenance cost. For the 27 buildings in a micro-grid, the new backup generators at the sites will supply energy only to the buildings when the grid is offline, allowing the PV generation to restart during daylight hours. Operation of the generators then will ramp down to make up for total energy needs.

3.2 Proposed Micro-Grid Layout

Figure 3.1 is a line diagram showing the key components of the micro-grid for all 27 buildings considered in the assessment.

Selection of the new backup 545 kW paired generators allows a 65 to 85% loading for the first generator at the baseline load (383 kW) or the highest frequency of utilization, and the second generator is selected to meet the peak demand load (838 kW). Selection of generators is dependent on the cost for the generation that serves the (new) combined building load and the physical layout of the system (e.g., trenching, space/location of the generation, etc.) When undertaking the conceptual design, load growth is anticipated. When the site load grows, room (i.e., physical space) is noted for installation of another generator taking into account the electrical infrastructure is properly designed for the future electrical energy growth.

The selected batteries and bi-directional inverter are for reliability, stability and generator optimization. Batteries can be recharged using power from the grid when the grid is online and generator and/or PV power when the grid is offline.

Table 3.1 summarizes the generator and supporting infrastructure costs for the micro-grid in all 27 buildings considered in the study as shown in Figure 3.1. Figure 3.2 is a one-line diagram of the proposed micro-grid for the just the four buildings at the IDP, and identifies a proposed location for the generators and micro-grid components at the IDP. Figure 3.3 is an aerial view of the four IDP buildings showing the PV panels and micro-grid components.

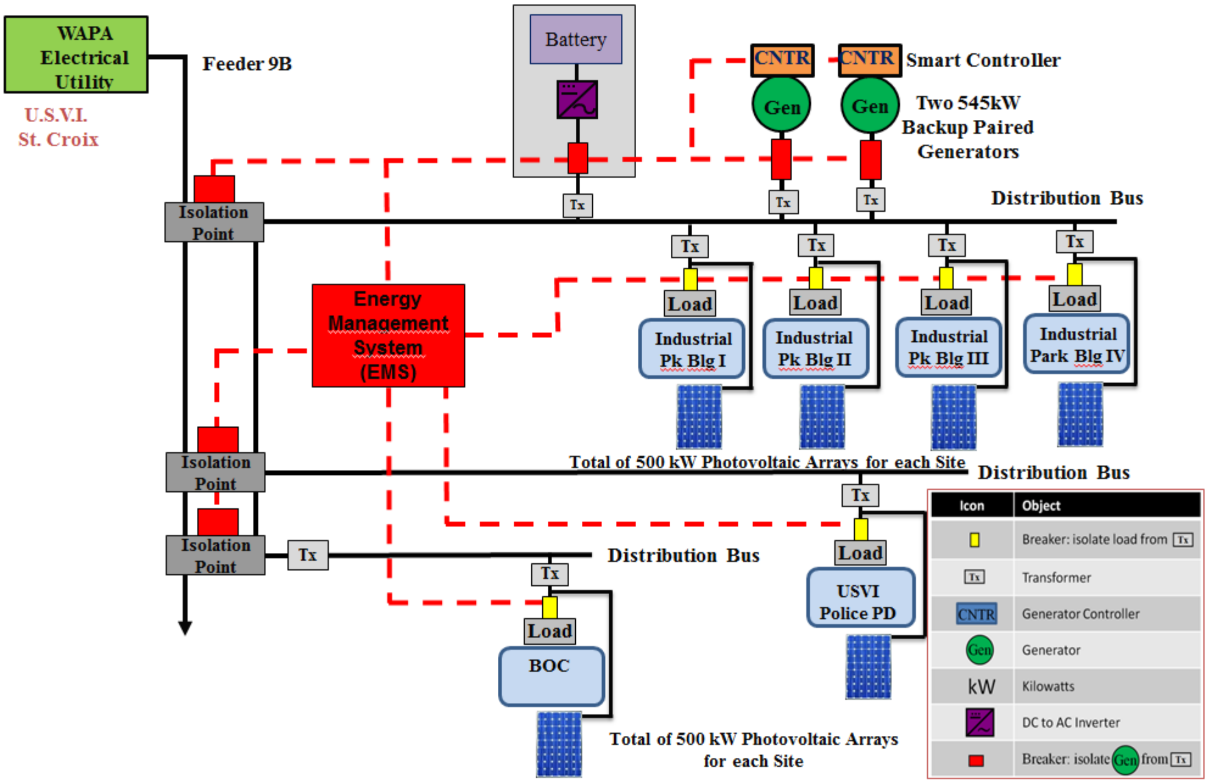


Figure 3.1. Diagram of the Proposed Micro-Grid for the 27 Buildings in this Assessment

Table 3.1. Description and Costs for the Diesel Generators and Micro-Grid Infrastructure for All 27 Buildings

Description	Installed Equipment Costs ($)	Energy Savings (MMBtu/yr)	Diesel Fuel Use (gal/yr)	Maintenance Cost ($/yr)	Total Annual Cost ($/yr)
Two C18 545-kW paired backup power diesel generators, fuel tank, shelters, energy management system, batteries for stability, inverters with container, switchgear, transfer switches, transformers, trenching, installation, wire, and communications	$2,533,010	0	11,232	$1,028	$46,565

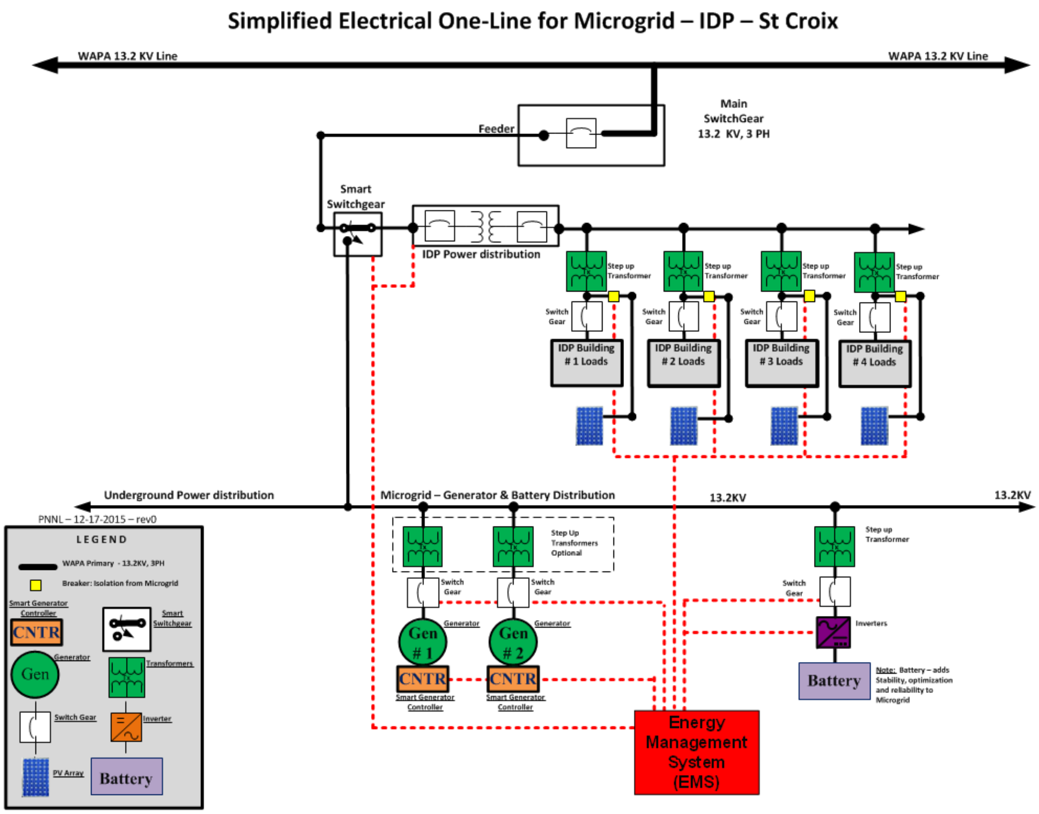


Figure 3.2. Diagram of the Proposed Micro-Grid for the Four IDP Buildings

Figure 3.3. Aerial View of the Four IDP Buildings showing the PV Panels and Micro-Grid Components

Table 3.2 summarizes the micro-grid components for just the four buildings at the IDP. Appendix B provides the details and costs of the generators and supporting infrastructure for this micro-grid.

Table 3.2. Description and Costs for the Diesel Generators and Micro-Grid Infrastructure for the IDP

Description	Energy Savings (MMBtu/yr)	Diesel Fuel Use (gallons/yr)	Maintenance Cost ($/yr)	Total Annual Cost ($/yr)	Investment ($)
Two CAT 3412C 275 kW paired prime power diesel generators, fuel tank, shelters, energy management system, batteries, inverters with container, electrical protection, switchgear, transfer switches, transformers, trenching, installation, wire and communications.	0	3,068	$1,299	$13,878	$1,351,460

Selection of the PV system size and location focuses on lowering the cost of energy for each of the three sites (IDP, BOC, and VIPD). While connected to the grid, the energy supplied to the site is lower because of the PV-system generation, and when the PV-system generates more than the individual load, the energy will be returned to the grid. In accordance with requirements implemented by WAPA, generation by the PV system is limited to 500 kW per site. Table 3.3 summarizes the collective cost for PV system at all three sites (27 buildings).

Table 3.3. Description of Costs for the PV System at the Three Sites (IDP, BOC, VIPD) for the Micro-Grid

Description	Energy Savings (MMBtu/yr)	Energy Savings ($/y)r	Maintenance Cost ($/y)r	Total Savings ($/yr)	Investment ($)	Payback (yr)	Required to Reduce Utility Energy?
1,500 kW roof- and ground-mounted PV system for 27 buildings 335,150 ft^2 1,992 MWh/year	9,590	$899,476	$30,776	$868,700	$6,116,827	7.0[a]	Yes

[a] Excluding yearly maintenance costs

Table 3.4 summarizes the costs for the PV system at just the IDP. Appendix B provides details of the PV sizing and costs by site. Figure 3.4 to Figure 3.6 show the PV panel and micro-grid layout at the three sites. Figure 3.7 shows the cabling and communications.

Table 3.4. Description and Costs for the PV System at the IDP for the Micro-Grid

Description[a]	Energy Savings MMBtu/yr	Energy Savings ($/yr)	Maintenance Cost ($/yr)	Total Savings ($/yr)	Investment ($)	SIR	Payback (years)
496 kW PV system on roof tops of four buildings at the IDP.	3,083	$289,165	$9,917	$279,248	$2,013,223	2.20	7.2

[a] 496 kW of PV can produce up to 3,083 MMBtu/yr. System is somewhat oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects. Estimated output is 904MWh/yr.

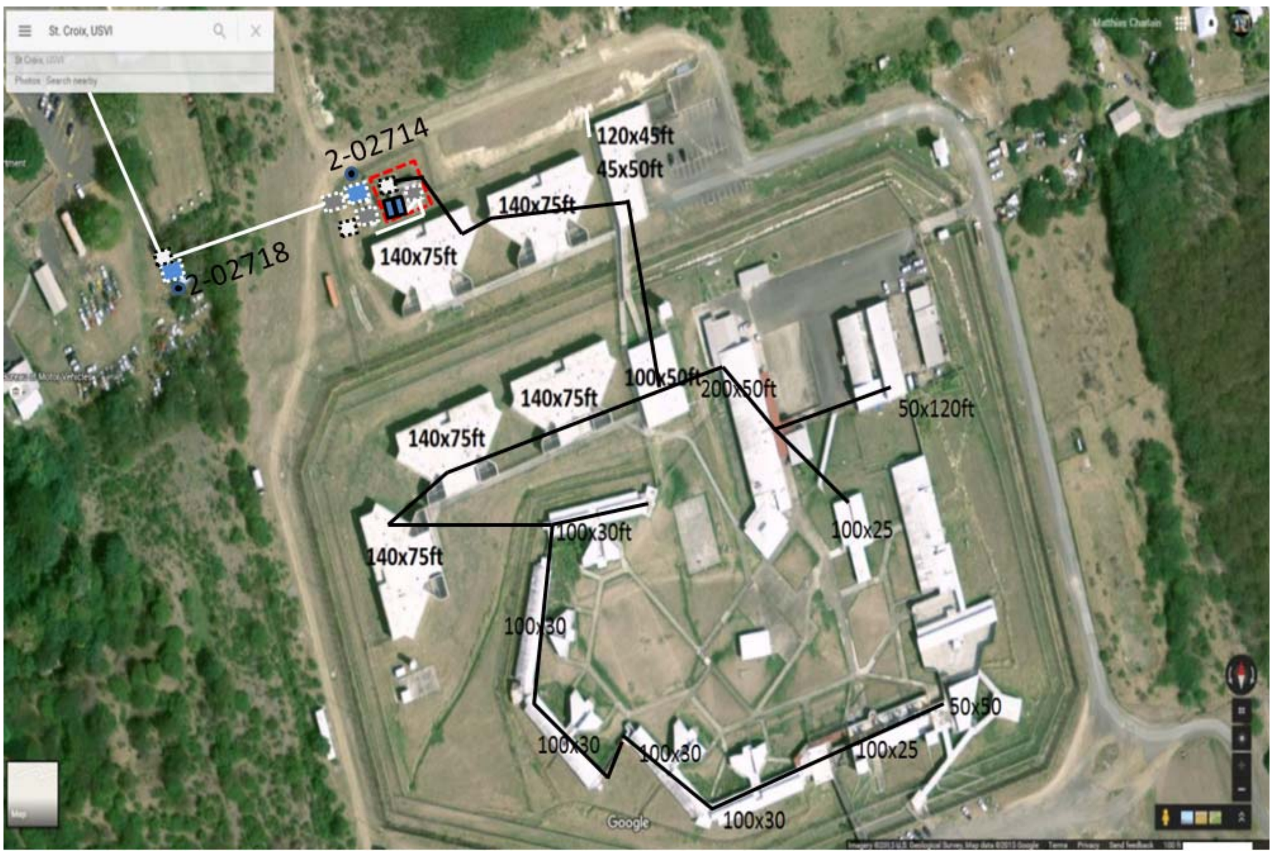


Figure 3.4. Micro-Grid and PV Panel Layout at the BOC

Figure 3.5. Micro-Grid, PV Panel, and Generator Layout for the Micro-Grid at the IDP

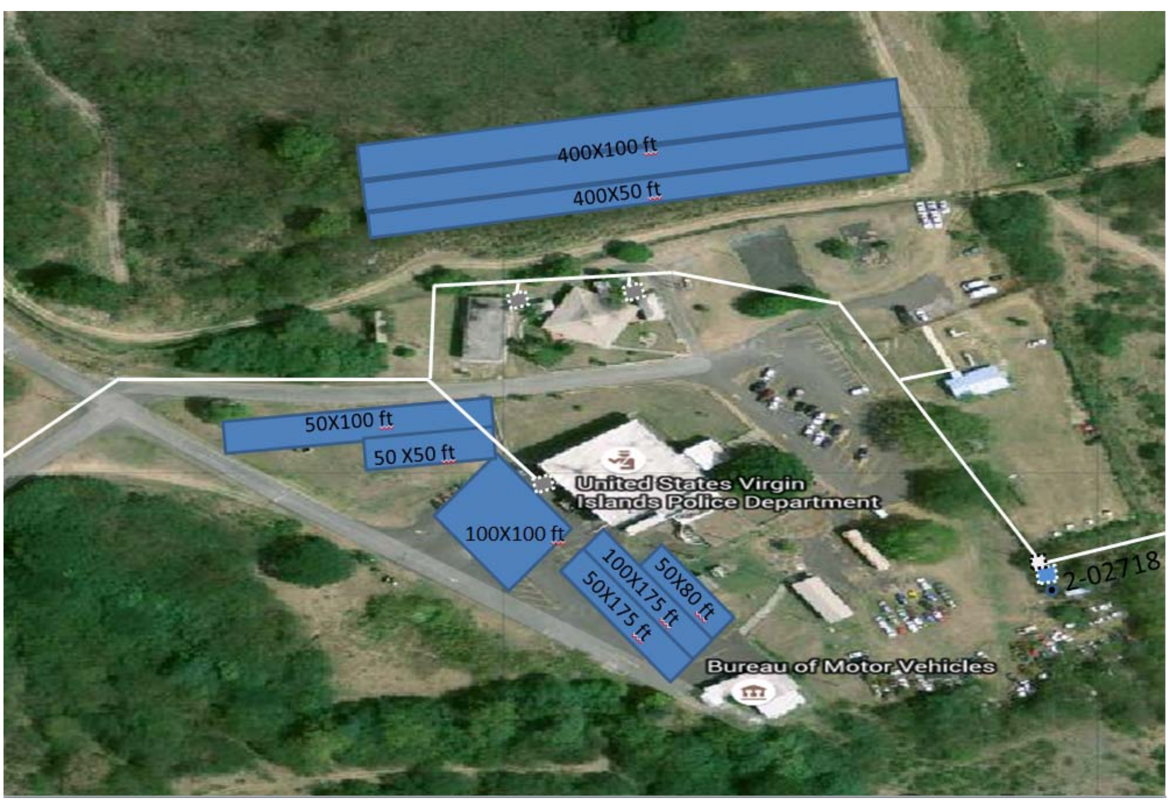


Figure 3.6. Micro-Grid and PV Panel Layout at the VIPD

Figure 3.7. Layout of the Underground Cabling and Communications for the Micro-Grid

4.0 Conclusions and Recommendations

4.1 Conclusions

The energy-efficiency retrofit and micro-grid assessment for the 27 buildings at three sites in St. Croix resulted in cost-effective retrofit measures for building envelope, HVAC, lighting and DWH that will save an estimated $185,000/year in electricity and more than 100 kW of capacity (peak demand). The estimated cost for the retrofits would be $1.75 million with a payback period of ~9.3 year and SIR of ~2. These building retrofits are important for reducing overall coincident peak and average load to be served by the micro-grid. Therefore, the micro-grid design and costs assume the retrofits would be implemented. The savings in electricity cost from these retrofits could be used to service the debt for the installation of the retrofits if the project were undertaken with third-party or alternative financing mechanisms. These retrofits also would significantly reduce greenhouse gas emissions on the order of 460 tons/year of CO_2.

The micro-grid design is relatively straightforward given that the buildings are in close proximity, they are all served by the same feeder from WAPA, and there appears to be sufficient and available roof and land space for the new infrastructure. The micro-grid incorporates 1500 kW of roof- and ground-mounted PV arrays at an estimated cost of $6.117 million and two 545 kW off-the-shelf diesel generators combined with batteries, cabling, and controls that will allow the micro-grid to ‘island’ the 27 buildings (see Appendix B for summary cost tables). The total estimated cost for the micro-grid system (PV arrays, generators plus infrastructure/controls) is estimated to be $8.650 million. The estimated payback of the PV system at all sites from electricity cost savings is ~7 years.

An energy efficiency retrofit and micro-grid infrastructure for just the four IDP buildings in St. Croix could be undertaken as a stand-alone project and would provide significant electricity cost savings and energy security/resiliency for these four buildings. The energy savings from the building retrofit is estimated to be ~$46,000/year (485 MMBtu/year), and the energy savings from the PV system (arrays and inverters) is estimated to ~$279,000/year (3,083 MMBtu/year) for a total energy savings of ~$319,000/year (3,568 MMBtu/year). The cost of the building retrofits are estimated to be ~$504,000 (see Table 2.3), and the cost of the PV system is estimated to be ~$2.013 million (see Table 3.4). The simple payback for the building retrofits and PV system (~$2.517 million) is ~7.9 years. The cost of the diesel generators and micro-grid for the four IDP buildings is ~$1.351 million (see Table 3.2). The total cost for an efficient and resilient infrastructure at the IDP is estimated to be ~$3.869 million.

4.2 Recommendations

Our recommendations are described below:

- Prepare and release a bid package to undertake the retrofit recommendations for the participating sites/buildings. The efficiency retrofits can be self-financed or financed through an Energy Services Company or other alternative/third-party financing. For the IDP, the retrofits could potentially be in partnership with future tenants and included in lease contract terms and conditions.
- Require a robust measurement and verification plan as part of the retrofit project.

- Determine if the size/capacity of the PV arrays in the participating sites/buildings meets WAPA and other utility/island requirements, and verify that suitable/available land and building roof space is available for the proposed PV arrays.
- Undertake an engineering design of the conceptually designed micro-grid in the participating sites/buildings to refine the design and costs.
- Secure funding and/or financing for the micro-grid in the participating sites/buildings.
- Prepare and release a bid package for the micro-grid.
- Award bid, and proceed with the project.

5.0 Capacity Building: Education and Training

The USVI EDA Economic Development Commission is charged with promoting the growth, development, and diversification of the economy of the USVI by developing the human and economic resources, preserving job opportunities for residents of the USVI, and promoting capital formation to support industrial development in the Territory. As a resource in business development, the USVI EDA has a Memorandum of Understanding with the University of the Virgin Islands Research and Technology Park to provide a framework for collaborative efforts to achieve complementary, beneficial outcomes for the USVI.

After undertaking the recommended efficiency retrofits and constructing the proposed micro-grid, the William D. Roebuck Economic Development Park (EDP) will be an efficient (i.e., green) and resilient infrastructure. As such it will be a highly attractive location for businesses seeking reliable and sustainable facilities. And, given the potential for businesses to engage in the development and/or application (installation, maintenance) of green and sustainable technologies (e.g., PV, water heating, solid-state lighting, HVAC, controls, etc.), the Economic Development Commission should consider establishing a 'living laboratory' located at the EDP. The living laboratory would be designed for education and training to develop skills needed to specify, install, and maintain this technology within the USVI as well as the entire Caribbean region. In the future, the living laboratory could be expanded to become a regional resource for certification and testing of equipment.

The laboratory would be a combination of classroom, web-based, and hands-on training providing education and certification programs. It would include fully functional HVAC and lighting systems using both existing and state-of-the-art, leading-edge technology. The living laboratory would be operated in collaboration with the Virgin Islands Research and Technology Park and potentially other educational and training institutions including, but not limited to, the University of the West Indies, the Association of Energy Engineers, the American Society of Heating Refrigeration and Air Conditioning Engineers, the Association of Mechanical Engineers, and the Institute of Electrical and Electronics Engineers.

6.0 Waste Management Authority Facilities

Staff at VIWMA have been very responsive to all data requests, and escorted the team on the site visit to see all VIWMA facilities (Figtree pump station, wastewater treatment plant, transfer station/landfill). A full audit day was spent at the facility as a courtesy to the site staff. During the audit, several energy-efficiency retrofit recommendations were identified and verbally provided to the VIWMA staff. In addition, existing generator sets were inspected. The wastewater treatment plant, transfer station, and Figtree pump station each had individual backup generators that were installed with extended fuel tanks. These backup generators are used when the electrical grid is not energized during power outages. The audit team found the generators to be well maintained and sized appropriately for each site.

Although the facility managers and staff are motivated to connect the wastewater treatment plant, transfer station, and Figtree pump station to the proposed micro-grid, physical infrastructure factors limit and prohibit connection. The greatest barrier to overcome would be physical connection of the Figtree pump station and wastewater treatment facility to the micro-grid. Trenching and conduit placement would need to run from the industrial park to the waste management facility; however, but the St. Croix airport is located between the two facilities. Analysis of trenching both under and around the airport runway determined that both scenarios were too expensive to pursue. Also, the potential to temporarily halt or delay incoming and outgoing flights from the island, during the trenching process, would likely receive pushback from the Federal Aviation Administration.

6.1 Energy-Efficiency Assessment

While it was determined that it would not be practical to include VIWMA facilities in the current micro-grid, the PNNL team conducted a FEDS assessment for the VIWMA buildings to identify cost-effective retrofits. A summary of the recommended retrofits, costs, and savings are given in Table 6.1.

Table 6.1. Summary of Energy-Efficiency Retrofits for the VIWMA Building by Retrofit Measure Category

Measure Category	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	MMBtu/yr	$/yr					
Building Envelope	34	$3,274	$0	$3,274	$27,502	8.4	2.2
HVAC	71	$6,714	$767	$7,481	$57,935	7.7	1.5
Lighting	259	$24,211	($538)[a]	$23,673	$141,925	6.0	3.1
DHW	1	$66	$0	$66	$158	2.4	3.6
Motors	116	$10,964	$0	$10,964	$58,918	5.4	2.2
Totals	481	$45,229	$229	$45,458	$286,438	6.3	2.7

[a] Represents a $538 increase in cost per year for lighting.

Table 6.2 summarizes retrofit savings identified for each VIWMA building. Appendix C provides additional details of the recommended retrofit measures by building.

Table 6.2. Summary of Energy-Efficiency Retrofits by VIWMA Building

Building	Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	Savings-to-Investment Ratio (SIR)
	(MMBtu/yr)	($/yr)					
Wastewater Treatment Plant	292	$27,496	$142	$27,638	$173,948	6.3	2.5
Control Building	77	$7,239	($370)[a]	$6,869	$73,397	10.7	1.6
Greenhouse	28	$2,596	($88)[a]	$2,508	$12,342	4.9	3.0
Transfer Station	84	$7,898	$545	$8,443	$26,751	3.2	5.9
Totals	481	$45,229	$229	$45,458	$286,438	6.3	2.7

[a] Represents cost increases of $370 per year and $88 per year for the Control Building and Greenhouse, respectively.

The overall estimated investment for the retrofits is ~$286K with energy savings of 145,920 kWh (8%) giving a 6.3-year payback period for the retrofits. The coincidental peak load for the four buildings is 245 kW, and the peak load savings from the retrofits is estimated to be 27 kW (11%). The largest savings are in lighting, cooling, and motor retrofits. Greenhouse gas emission reductions resulting from these energy saving projects are expected to be 117 tons of carbon dioxide per year.

Detailed retrofit recommendations for each building are found in Appendix C.

6.2 Waste-to-Energy Assessment

As a courtesy to the VIWMA and with their permission, an assessment was undertaken to estimate the capital and operating cost for a combustion and gasification waste-to-energy plant based on the annual municipal solid waste (MSW) feed and tipping fee. The VIWMA was in the process of issuing a request for proposals for a waste-to-energy plant so this analysis was provided as a potential benchmark for comparison with the proposals received.

As with many island communities, an environmentally friendly and safe MSW disposal system becomes problematic as the community grows. Waste Management in the USVI is in the process of issuing a request for proposals for a waste-to-energy facility located at the Waste Management transfer station. The onsite landfill was initially constructed in the early 1960s and is expected to reach full capacity by 2017. Currently, no gas-to-energy projects are being implemented at the landfill because of underground fires that have reduced the potential to produce off-gas. Servicing an estimated 12,500 homes on St. Croix, the Waste Management facility receives approximately 150 tons per day of MSW from the community and an estimated 40 tons per month from bio-solids removed from the landfill. Although Waste Management currently does not charge for waste pickup, there is a $50/ton tipping fee that is charged for waste disposal at the site.

PNNL developed a cost estimate for a combustion and gasification waste-to-energy plant based on the annual MSW feed and tipping fee. This estimate is shown in Table 6.3. The costs are generalized and should only be used as an initial guide. A detailed feasibility study would need to be done at the USVI Waste Management facility to understand the environmental and economic impact of each combustion and gasification waste-to-energy project before implementation.

Table 6.3. Cost Estimate of a Waste-to-Energy Plant for the VIWMD

Attribute	Combustion	Gasification
Capacity (MW)	5.4	8.0
Annual Feed (ton MSW/yr)	55,115	55,115
Total Capital Cost ($/kW)	$9,253	$9,905
• Base Capital Cost ($)	$49,970,000	$79,240,000
• Site Preparation ($)	$100,000	$100,000
• Environmental Impact Study ($)	$1.5 million	$1.5 million
• Owner Costs ($)	$6,960,00	$11,210,000
• Electrical Interconnection ($)	$500,000	$500,000
Fixed O&M Cost ($/kW)	378	329
Variable O&M Cost (/kWh)	0.5	0.5
Payment for Feedstock ($/ton)	50	50

Appendix A

Building-Level Baseline and Energy-Efficiency Retrofit Measure Recommendations

Appendix A

Building-Level Baseline and Energy-Efficiency Retrofit Measure Recommendations

This appendix provides recommendations for retrofit measures for each of the building groups identified in Table 1.1. A number of life-cycle, cost-effective building retrofit projects have been identified, including, but not limited to, building envelope improvements, ventilating and air conditioning (HVAC)[1] system upgrades lighting upgrades, and improvement in delivery efficiency of domestic hot water (DHW).

Below is information for interpreting the building audit findings and retrofit recommendations:

- In the "Existing Technology" table, R-value = 0.00 indicates that there is no insulation in the roof, floor, or wall. However, the envelope construction and materials of the envelope component itself offer their own thermal resistance, which is not reported here, but is accounted for in the energy model.
- Motors used to drive air-handling units in buildings were not audited, and thus these motors are not included or considered as a retrofit measure.
- ( ) = costs.

[1] Given there is no heating with these systems, the definition of HVAC is "ventilation and air conditioning".

The tables below show abbreviations used in the detailed retrofit tables.

Water Abbreviations	
DHW	domestic hot water

Lamp Type Abbreviations	
CFL	compact fluorescent lamp
ELC	Electronic ballast
HAL	halogen
HPS	high-pressure sodium
INC	incandescent
LED	light-emitting diode
LPS	low pressure sodium
MH	metal halide
PAR	parabolic aluminized reflector
ST8	super fluorescent T8 linear tube
STD	Standard magnetic ballast
T12	fluorescent T12 linear tube
T5	fluorescent T5 linear tube
T8	fluorescent T8 linear tube

Lighting Fixture Abbreviations	
1x4	1 foot by 4 foot fixture
2x4	2 foot by 4 foot fixture
BLST	ballast
CEIL	ceiling
EEF	energy efficient magnetic ballast
ELEC“X”	fixture with electronic ballasts driving X lamps each
FIXT	fixture
Fix Repl	fixture replacement
PEND	pendant mount
POLE	pole mount
REF	reflector
STD“X”	fixture with magnetic ballasts driving X lamps each
WALL	wall mount

Building	BOC Administration
Site Name	Administration
Date Constructed	1972
Total Area (sq. ft.)	5,504
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 8.90
	Floor	Slab on grade with perimeter insulation, Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.20
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 4F32T8 ELC2, FL 1X4 1F32T8 ELC1, FL 1X4 2F32T8 ELC2, MH 100 WALL, INC 60 CAN, FL 2X4 2F32T8 ELC2
DHW	Hot Water	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Re-Roof and add R-10	94	$8,804	0	$0	$0	$8,804	$71,611	8.1	2.3
	Floor	None recommended									
	Wall	R-12.4									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 71W 2x4 Fixture (7000 Lumens), LED 23Wx1 4' 30W ST8/32W T8 Lamp Repl. (2550 Lumens/Lamp), LED 34W 1x4 Fixture (3300 Lumens), LED 56W Wall Pack (6000 Lumens), LED 11W A-Line (850 Lumens), LED 34W 2x4 Fixture (3300 Lumens)	40	$3,806	0	$0	($547)	$3,259	$28,827	8.8	2.1
DHW	Hot Water	N/A									
Total			***134***	***$12,610***	***0***	***$0***	***($547)***	***$12,063***	***$100,438***	***8.3***	***2.3***

Building	BOC Building A
Site Name	5 Holding cells
Date Constructed	1972
Total Area (sq. ft.)	24,110
Use Type	Lodging
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 0.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 0.00
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 1X4 2F32T8 ELC2, FL 2X4 2F32T8 ELC2, CFL 13 INTEGRAL UNIT ELC, HPS 150 WALL, EXIT - LED
DHW	Hot Water	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 34W 1x4 Fixture (3300 Lumens), LED 34W 2x4 Fixture (3300 Lumens), LED 11W A-Line (850 Lumens), LED 111W Wall Pack (10000 Lumens)	106	$9,985	0	$0	($1,138)	$8,847	$100,309	11.3	1.7
DHW	Hot Water	N/A									
Total			***106***	***$9,985***	***0***	***$0***	***($1,138)***	***$8,847***	***$100,309***	***11.3***	***1.7***

Building	BOC Chapel
Site Name	Chapel
Date Constructed	1972
Total Area (sq. ft.)	3,519
Use Type	Worship
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	**Subcategory**	**Existing Technology**
Building Envelope	Roof	Built Up Roof Insulation R-Value 8.90
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.20
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 1X4 2F32T8 ELC2, EXIT - LED
DHW	Hot Water	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended	84	$7,862	0	$0	$0	$7,862	$43,906	5.6	3.3
	Floor	None recommended									
	Wall	None recommended									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	Single Zone Packaged AC Unit (high efficiency, small)	40	$3,761	0	$0	($39)	$3,722	$30,226	8.1	1.5
Lighting	Lights	LED 34W 1x4 Fixture (3300 Lumens)	12	$1,157	0	$0	($217)	$940	$15,501	16.5	1.2
DHW	Hot Water	N/A									
Total			***136***	***$12,780***	***0***	***$0***	***($256)***	***$12,524***	***$89,633***	***7.2***	***2.5***

Building	BOC Education Building
Site Name	Administration Education
Date Constructed	1972
Total Area (sq. ft.)	6,468
Use Type	Education
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	**Subcategory**	**Existing Technology**
Building Envelope	Roof	Built Up Roof Insulation R-Value 8.90
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.20
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 2F32T8 ELC2, EXIT - LED, HPS 150 WALL
DHW	Hot Water	None

Measure Category	**Subcategory**	**Measures**	**Electricity Savings**		**Non-electric Energy Savings**		**Annual O&M Savings ($/yr)**	**Total Savings ($/yr)**	**Investment ($)**	**Simple Payback (yr)**	**SIR**
			MMBtu/yr	**$/yr**	**MMBtu/yr**	**$/yr**					
Building Envelope	Roof	Increase Insulation by R-38	30	$2,813	0	$0	$0	$2,813	$24,408	8.7	2.2
	Floor	None recommended									
	Wall	None recommended									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	Single Zone Packaged AC Unit (high efficiency, small)	43	$4,045	0	$0	$237	$4,282	$27,148	6.3	1.9
Lighting	Lights	LED 34W 2x4 Fixture (3300 Lumens), LED 111W Wall Pack (10000 Lumens)	52	$4,846	0	$0	($66)	$4,780	$55,000	11.5	1.6
DHW	Hot Water	N/A									
Total			***125***	***$11,704***	***0***	***$0***	***$171***	***$11,875***	***$106,556***	***9.0***	***1.8***

Building	BOC Exterior Lights
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Lighting	Lights	HPS 400 POLE, HPS 880 REP FOR MV POLE, HPS 200 POLE

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Lighting	Lights	LED 160W Pole Lamp (16000 Lumens)	50	$4,710	0	$0	$1	$4,711	$57,950	12.3	1.5
Total			***50***	***$4,710***	***0***	***$0***	***$1***	***$4,711***	***$57,950***	***12.3***	***1.5***

Building	BOC G and H holding cells
Site Name	6 Holding cells
Date Constructed	2000
Total Area (sq. ft.)	65,202
Use Type	Lodging
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 0.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 0.00
	Window	None
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 3F32T8 ELC1,2, FL 2X4 4F32T8 ELC2, FL 2X4 2F32T8 ELC2, HPS 400 WALL, EXIT - LED
DHW	Hot Water	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	FL 2X4 2F32ST8 ELC2 REF, FL 2X4 3F30ST8 ELC3 REF, LED 34W 2x4 Fixture (3300 Lumens)	157	$14,779	0	$0	$217	$14,996	$105,546	7.0	2.7
DHW	Hot Water	N/A									
Total			***157***	***$14,779***	***0***	***$0***	***$217***	***$14,996***	***$105,546***	***7.0***	***2.7***

Building	BOC Kitchen, Laundry
Site Name	Kitchen/Laundry/Commissary/Shop
Date Constructed	1972
Total Area (sq. ft.)	11,960
Use Type	Food service/laundry
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 0.00, Built Up Roof Insulation R-Value 8.90
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 0.00, Masonry Frame Wall Insulation R-Value 3.20
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 2F32T8 ELC2, FL 2X4 3F32T8 ELC1,2, HPS 150 WALL, EXIT - LED, FL 1X4 2F40T12 ELC2, FL 1X4 2F32T8 ELC2, FL 1X8 1F96T8 ELC1, EXIT - FL 1-PL9, HPS 150 POLE
DHW	Hot Water	Electric Water Heater

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended	57	$5,336	0	$0	$0	$5,336	$62,559	11.7	1.6
	Floor	None recommended									
	Wall	R-12.4									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	Single Zone Packaged AC Unit (high efficiency, small), Single Zone Packaged AC Unit (very high efficiency, medium)	56	$5,224	0	$0	($371)	$4,853	$53,901	11.1	1.1
Lighting	Lights	LED 34W 2x4 Fixture (3300 Lumens), FL 2X4 2F32ST8 ELC2 REF, LED 111W Wall Pack (10000 Lumens), LED 34W 1x4 Fixture (3300 Lumens), EXIT - LED RETRO KIT, LED 120W Pole Lamp (12000 Lumens)	58	$5,569	0	$0	($330)	$5,239	$57,641	11.0	1.7
DHW	Hot Water	Wrap Tank with Insulation and Insulate Pipe Near Tank	4	$392	0	$0	$0	$392	$1,700	4.3	1.3
Total			***175***	***$16,521***	***0***	***$0***	***($701)***	***$15,820***	***$175,801***	***11.1***	***1.5***

Building	BOC Medical
Site Name	Medical administration
Date Constructed	1972
Total Area (sq. ft.)	7,852
Use Type	Health care
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 0.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 0.00
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 1X4 2F32T8 ELC2, FL 1X8 2F96T12 ELC2, EXIT - LED, FL 2X4 2F32T8 ELC2, FL 1X4 2F40T12 ELC2, MH 150 HE WALL
DHW	Hot Water	Electric Water Heater, Electric Central Boiler

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 34W 1x4 Fixture (3300 Lumens), FL 1x8 4F32T8 ELC4, LED 34W 2x4 Fixture (3300 Lumens), LED 56W Wall Pack (6000 Lumens)	47	$4,449	0	$0	($349)	$4,100	$37,237	9.1	2.1
DHW	Hot Water	Heat Pump Water Heater, LFSHs	25	$2,364	0	$0	($43)	$2,321	$3,609	1.6	6.6
Total			***72***	***$6,813***	***0***	***$0***	***($392)***	***$6,421***	***$40,846***	***6.4***	***2.3***

Building	BOC R&D and Health Services
Site Name	Administration Assembly
Date Constructed	1972
Total Area (sq. ft.)	7,176
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	**Subcategory**	**Existing Technology**
Building Envelope	Roof	Built Up Roof Insulation R-Value 8.90
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.20
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 3F32T8 ELC1,2, EXIT - LED, HPS 150 POLE
DHW	Hot Water	Electric Water Heater

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Increase Insulation by R-38	118	$11,003	0	$0	$0	$11,003	$89,229	8.1	2.3
	Floor	None recommended									
	Wall	R-12.4									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	Single Zone Packaged AC Unit (very high efficiency, medium), Single Zone Packaged AC Unit (high efficiency, small)	38	$3,551	0	$0	($229)	$3,322	$31,439	9.5	1.3
Lighting	Lights	FL 2X4 2F32ST8 ELC2 REF, LED 120W Pole Lamp (12000 Lumens)	43	$4,040	0	$0	$651	$4,691	$41,289	8.8	2.1
DHW	Hot Water	Wrap Tank with Insulation	0	$4	0	$0	$0	$4	$16	4.0	1.3
Total			***199***	***$18,598***	***0***	***$0***	***$422***	***$19,020***	***$161,973***	***8.5***	***2.1***

Building	BOC Warehouse
Site Name	Warehouse
Date Constructed	2014
Total Area (sq. ft.)	6,724
Use Type	Storage
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Engineered Metal Roof Insulation R-Value 30.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 5.00
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2x4 6F28T5 ELC3, CFL 32 INTEGRAL UNIT ELC, EXIT - LED
DHW	Hot Water	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 136W High Bay Fixture (15000 Lumens)	3	$239	0	$0	$71	$310	$5,378	17.3	1.1
DHW	Hot Water	N/A									
Total			***3***	***$239***	***0***	***$0***	***$71***	***$310***	***$5,378***	***17.3***	***1.1***

Building	IDP Exterior Lighting
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Lighting	Lights	HPS 250 POLE

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Lighting	Lights	None recommended									
Total			***0***	***$0***	***0***	***$0***	***$0***	***$0***	***$0***	***0.0***	***0.0***

Building	IDP Building 1
Site Name	Administration Manufacturing
Date Constructed	1984
Total Area (sq. ft.)	31,878
Use Type	Office
Date Audited	08/2015
Audited By	Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Engineered Metal Roof Insulation R-Value 11.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry on Steel Frame Wall Insulation R-Value 11.00
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X2 2F32T8U ELC2, MH 175 WALL, EXIT - LED, CFL 7 CAN, FL 2X4 4F32T8 ELC2
DHW	Hot Water	Electric Water Heater

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	4 inches Fiberglass	116	$10,915	0	$0	$0	$10,915	$157,249	14.4	1.3
	Floor	None recommended									
	Wall	None recommended									
	Window	Install High Performance Aluminum Frame Double Pane Low-Gain Low-e Windows									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 34W 2x2 Retrofit Panel (3430 Lumens), LED 75W Wall Pack (8000 Lumens), FL 2X4 3F30ST8 ELC3 REF	100	$9,333	0	$0	$907	$10,240	$113,558	11.1	1.7
DHW	Hot Water	Wrap Tank with Insulation and Insulate Pipe Near Tank	1	$51	0	$0	$0	$51	$219	4.3	1.3
Total			***217***	***$20,299***	***0***	***$0***	***$907***	***$21,206***	***$271,026***	***12.8***	***1.5***

Building	IDP Building 2
Site Name	Administration Storage
Date Constructed	1986
Total Area (sq. ft.)	20,467
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Engineered Metal Roof Insulation R-Value 11.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry on Steel Frame Wall Insulation R-Value 11.00
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 3F32T8 ELC1,2, EXIT - LED, FL 2X4 2F32T8 ELC2, MH 175 WALL, CFL 105 INTEGRAL UNIT ELC, FL 2X4 4F32T8 ELC2
DHW	Hot Water	Electric Water Heater

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	FL 2X4 2F32ST8 ELC2 REF, LED 34W 2x4 Fixture (3300 Lumens), LED 75W Wall Pack (8000 Lumens), LED 52W A-Line (5800 Lumens), FL 2X4 3F30ST8 ELC3 REF	62	$5,842	0	$0	($28)	$5,814	$50,461	8.7	2.2
DHW	Hot Water	Wrap Tank with Insulation and Insulate Pipe Near Tank	0	$25	0	$0	$0	$25	$110	4.4	1.3
Total			***62***	***$5,867***	***0***	***$0***	***($28)***	***$5,839***	***$50,571***	***8.7***	***2.2***

Building	IDP Building 3
Site Name	Administration Storage
Date Constructed	1988
Total Area (sq. ft.)	40,001
Use Type	Storage
Date Audited	08/2015
Audited By	Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Engineered Metal Roof Insulation R-Value 11.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry on Steel Frame Wall Insulation R-Value 11.00
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 3F32T8 ELC1,2, MH 175 WALL, EXIT - LED, FL 2X4 2F32T8 ELC2, HPS 100 POLE, HPS 400 PEND
DHW	Hot Water	Electric Water Heater

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	4 inches Fiberglass	136	$12,758	0	$0	$0	$12,758	$135,199	10.6	1.8
	Floor	None recommended									
	Wall	None recommended									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	None recommended									
Lighting	Lights	FL 2X4 2F32ST8 ELC2 REF, LED 75W Wall Pack (8000 Lumens), LED 34W 2x4 Fixture (3300 Lumens), LED 60W Pole Lamp (6000 Lumens)	43	$4,090	0	$0	($247)	$3,843	$30,664	8.0	2.4
DHW	Hot Water	Wrap Tank with Insulation and Insulate Pipe Near Tank	0	$25	0	$0	$0	$25	$110	4.4	1.3
Total			***179***	***$16,873***	***0***	***$0***	***($247)***	***$16,626***	***$165,973***	***10.0***	***1.9***

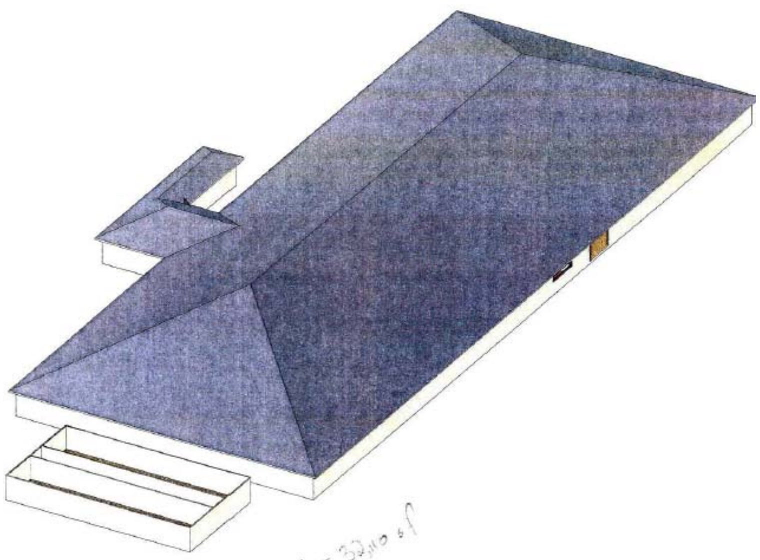
Building	Industrial Park Building 4
Site Name	Administration Storage
Date Constructed	1986
Total Area (sq. ft.)	40,001
Use Type	Warehouse/storage
Date Audited	08/2015
Audited By	Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Engineered Metal Roof Insulation R-Value 11.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry on Steel Frame Wall Insulation R-Value 11.00
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 3F32T8 ELC1,2, MH 175 WALL, EXIT - LED, HPS 100 POLE, LED 56W Wall Pack (6000 Lumens)
DHW	Hot Water	Electric Water Heater

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	FL 2X4 2F32ST8 ELC2 REF, LED 75W Wall Pack (8000 Lumens), LED 60W Pole Lamp (6000 Lumens)	27	$2,529	0	$0	($142)	$2,387	$16,604	7.0	2.7
DHW	Hot Water	Wrap Tank with Insulation and Insulate Pipe Near Tank	0	$25	0	$0	$0	$25	$110	4.4	1.3
Water	Plumbing	N/A									
Motors	Motors	N/A									
Other	Other	N/A									
Renewable	Renewable	N/A									
Total			***27***	***$2,554***	***0***	***$0***	***($142)***	***$2,412***	***$16,714***	***6.9***	***2.7***

Building	VIPD HQ Building
Site Name	Administration
Date Constructed	2016 (New)
Total Area (sq. ft.)	24,800
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 38.00
	Floor	Slab on grade with perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 15.00
	Window	Aluminum with Thermal Break Frame Double Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X2 2F32T8U ELC2, EXIT - LED, CFL 32 INTEGRAL UNIT ELC, HPS 250 POLE, FL 2X4 2F32T8 ELC2
DHW	Hot Water	Other Fuels Water Heater



Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended									
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	Single Zone Packaged AC Unit (very high efficiency, large)	56	$5,265	0	$0	$80	$5,345	$55,545	10.4	1.2
Lighting	Lights	LED 34W 2x2 Retrofit Panel (3430 Lumens), LED 34W 2x4 Fixture (3300 Lumens)	120	$11,229	0	$0	$1,155	$12,384	$124,106	10.0	1.9
DHW	Hot Water	None recommended									
Total			***176***	***$16,494***	***0***	***$0***	***$1,235***	***$17,729***	***$179,651***	***10.1***	***1.7***

Building	VIPD K9 Bldg.
Site Name	Administration
Date Constructed	2015
Total Area (sq. ft.)	1,148
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 38.00
	Floor	Slab on grade with perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.50
	Window	None
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X2 2F32T8U ELC2, EXIT - LED, CFL 32 INTEGRAL UNIT ELC
DHW	Hot Water	Other Fuels Water Heater (Solar-thermal)

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended	6	$532	0	$0	$0	$532	$9,933	18.7	1.0
	Floor	None recommended									
	Wall	R-12.4									
	Window	none									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 34W 2x2 Retrofit Panel (3430 Lumens)	9	$832	0	$0	$160	$992	$7,416	7.5	2.5
DHW	Hot Water	None recommended									
Total			***15***	***$1,364***	***0***	***$0***	***$160***	***$1,524***	***$17,349***	***11.4***	***1.6***

Building	VIPD Pavilion
Site Name	Administration
Date Constructed	1970
Total Area (sq. ft.)	512
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 0.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 0.00
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 1X4 2F32T8 ELC2, CFL 32 INTEGRAL UNIT ELC, EXIT - LED
DHW	Hot Water	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Re-Roof and add R-15	17	$1,603	0	$0	$0	$1,603	$11,247	7.0	2.6
	Floor	None recommended									
	Wall	R-12.4									
	Window	Add Low-e Exterior Storm Windows									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 34W 1x4 Fixture (3300 Lumens)	2	$150	0	$0	($20)	$130	$1,590	12.2	1.5
DHW	Hot Water	N/A									
Total			***19***	***$1,753***	***0***	***$0***	***($20)***	***$1,733***	***$12,837***	***7.4***	***2.4***

Building	VIPD Special Operations
Site Name	Administration education
Date Constructed	2015
Total Area (sq. ft.)	2,380
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 38.00
	Floor	Slab on grade with perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.50
	Window	High Performance Aluminum Frame Triple Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X2 2F32T8U ELC2, EXIT - LED, CFL 32 INTEGRAL UNIT ELC
DHW	Hot Water	Other Fuels Water Heater (Solar-thermal)

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	None recommended	10	$902	0	$0	$0	$902	$14,063	15.6	1.2
	Floor	None recommended									
	Wall	R-12.4									
	Window	None recommended									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 34W 2x2 Retrofit Panel (3430 Lumens)	11	$986	0	$0	$167	$1,153	$17,013	14.8	1.3
DHW	Hot Water	None recommended									
Total			***21***	***$1,888***	***0***	***$0***	***$167***	***$2,055***	***$31,076***	***15.1***	***1.2***

Building	VIPD Training Building
Site Name	Administration education
Date Constructed	1970
Total Area (sq. ft.)	3,063
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker/Paul Boyd/Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 8.90
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 3.20
	Window	Aluminum Frame Single Pane Window (Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 4F40T12 EEF2, EXIT - FL 1-PL9, INC 100 FLD

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Increase Insulation by R-38	32	$2,982	0	$0	$0	$2,982	$35,550	11.9	1.5
	Floor	None recommended									
	Wall	R-12.4									
	Window	Add Low-e Exterior Storm Windows									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 59W 2x4 Retrofit Panel (6227 Lumens), EXIT - LED RETRO KIT, CFL 27 INTEGRAL FLOOD ELC, FL 2X4 3F28ST8 ELC3 REF	61	$5,736	0	$0	$849	$6,585	$24,262	3.7	5.0
DHW	Hot Water	N/A									
Total			***93***	***$8,718***	***0***	***$0***	***$849***	***$9,567***	***$59,812***	***6.3***	***2.9***

Appendix B

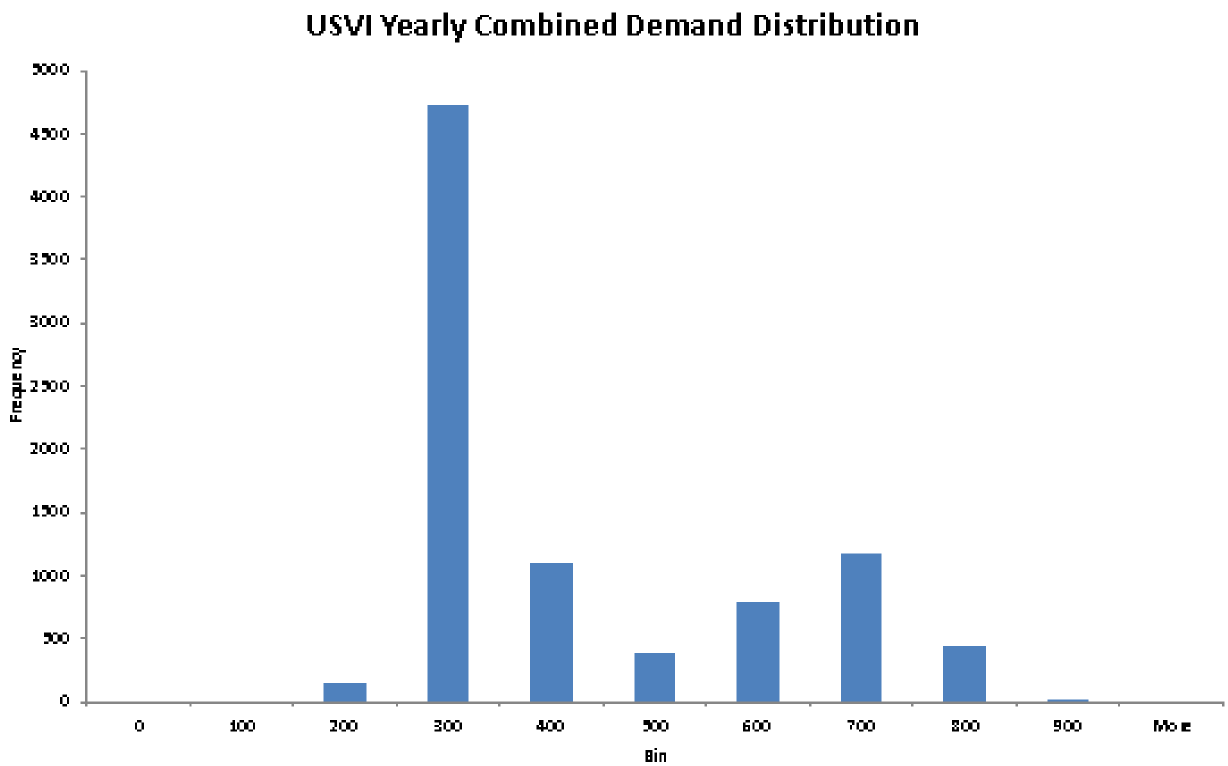
Micro-Grid Load Profiles and Recommended Equipment Specifications

Appendix B

Micro-Grid Load Profiles and Recommended Equipment Specifications

This appendix contains the detailed data used to design the micro-grid. Load data from the Facility Energy Decision System (FEDS) analysis and data and information for sizing and costing the equipment are included.

Load profiles generated from FEDS based on equipment retrofits in the 27 buildings are shown in Figures B.1 and B.2. Figure B1 shows the load demand distribution over a year. Figure B.2 shows the load profile over a typical day. The load frequency in Figure B.1 is based on the output shown in Table B.1.



Demand, kW

Figure B.1. Yearly Estimated Demand (kW) Frequency (hours) for the Combined 27 Buildings in the Micro-Grid

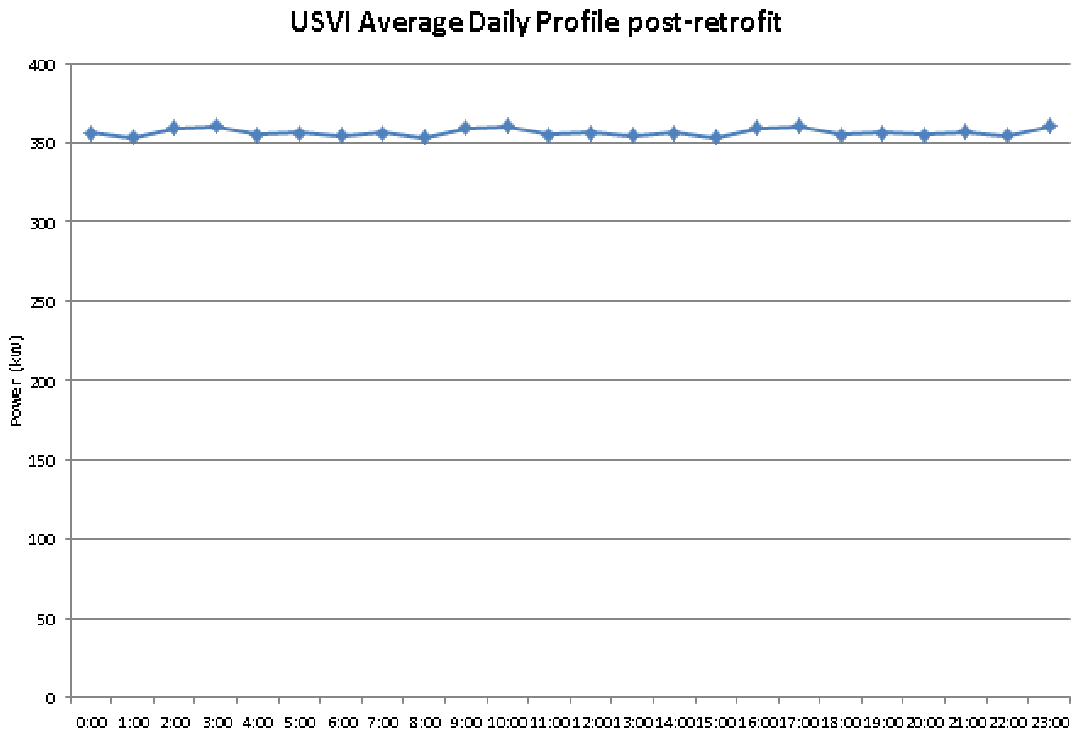


Figure B.2. Estimated Daily (0:00 to 24:00 hours) Average Load (kW) Profile for the Combined 27 Buildings in the Micro-Grid

Table B.1. Yearly Frequency Distribution of the Estimated Load for the Combined 27 Buildings in the Micro-Grid

Load (kW)	Frequency (hours/year)
0	0
100	0
200	143
300	4722
400	1093
500	386
600	788
700	1,172
800	449

The annual load (demand) distribution profiles developed based on the FEDS assessment for the Bureau of Corrections (BOC), Industrial Development Park (IDP), and Virgin Islands Police Department (VIPD) buildings are shown below is Figures B.3, B.4, and B.5, respectively.

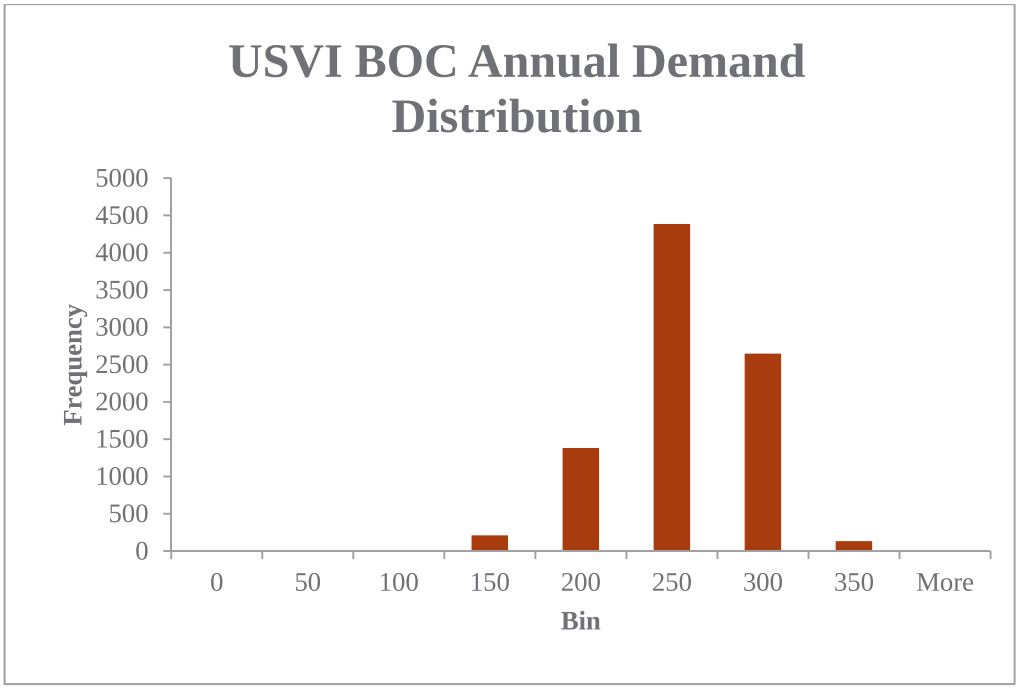


Figure B.3. Modeled Demand Frequency for Buildings at the BOC after Efficiency Retrofits

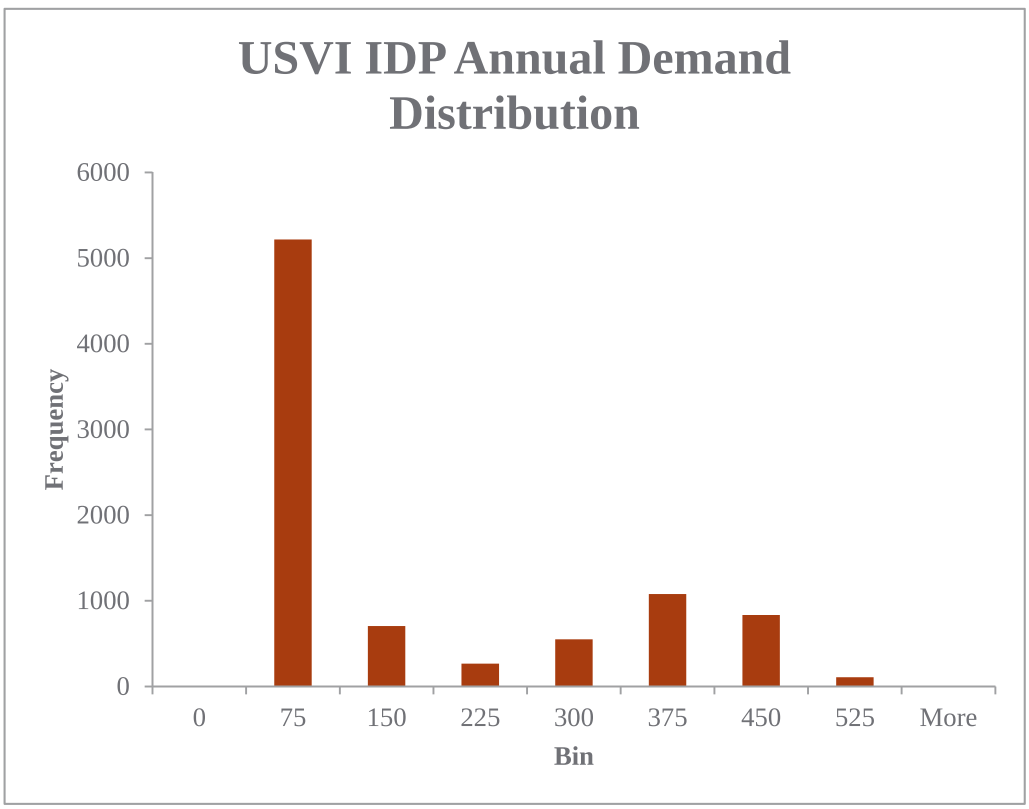


Figure B.4. Modeled Demand Frequency for Buildings at the IDP after Efficiency Retrofits

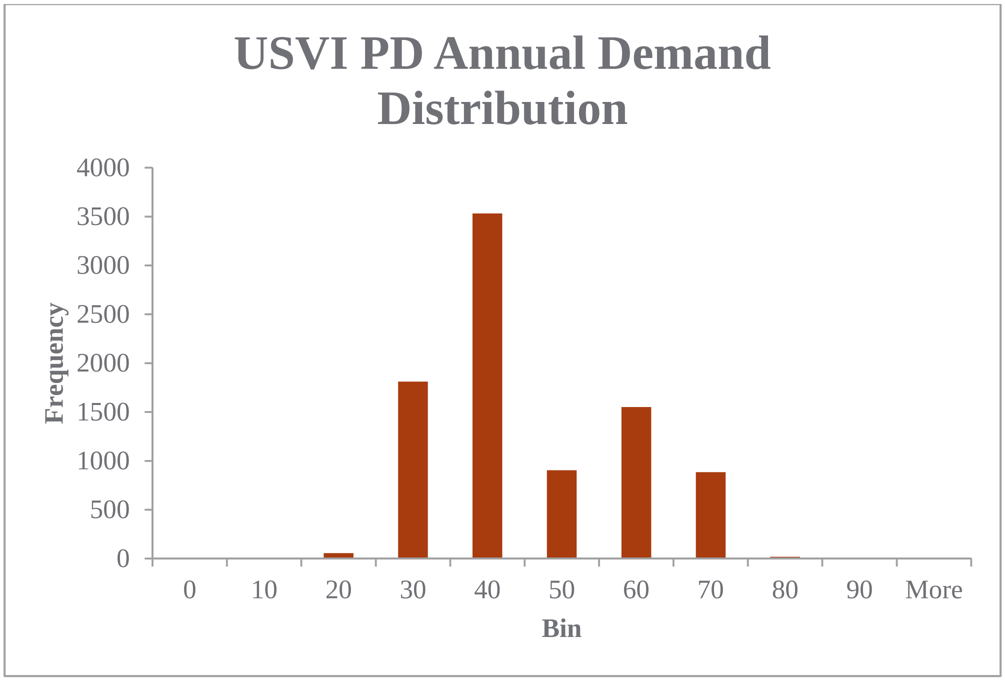


Figure B.5. Modeled Demand Frequency for Buildings at the VIPD after Efficiency Retrofits

The selection of the pair of backup generators was based on the generator fuel curves, the combined load profile of the 27 buildings (post-retrofit), and the cost to produce electricity. The cost of diesel fuel is assumed to $4.10 a gallon. Table B.2 shows the generator options for one to four generators and highlights the generator pair selected. During operation, one generator will be dispatched and run at 70% loaded for the average load of 383 kW. This is an optimal loading condition for the generator to operate and consume fuel.

Table B.2. Backup Generator Characteristics for the USVI Micro-Grid showing the Selected Generator

	Generator 1		Generator 2		Generator 3		Generator 4				
Generator Options	Fuel (gal)	Hours	Fuel (gal)	Hours	Fuel (gal)	Hours	Fuel (gal)	Hours	Total Fuel (gal)	Total Fuel Cost	Cost per kWh
100 C4 100 kW	51,561	8,760	51,561	8,760	51,561	8,760	45,839	7,799	200,523	$822,143	$0.25
114 C6.6 114 kW	61,240	8,760	61,240	8,760	61,240	8,760	44,125	6,466	227,844	$934,159	$0.28
135 C6.6 135kW	76,562	8,760	76,562	8,760	71,939	8,251	34,061	3,330	259,125	$1,062,410	$0.32
158 C6.6 158 kW	87,727	8,760	87,727	8,760	70,268	7,076	32,478	2,658	278,199	$1,140,617	$0.34
180 C9 180 kW	98,587	8,760	98,587	8,760	52,173	4,634	30,800	2,397	280,146	$1,148,600	$0.34
275 C9 275 kW	128,723	8,760	124,869	8,528	34,376	1,909	135	8	288,102	$181,219	$0.35
275 3406C 275 kW	121,405	8,760	117,788	8,528	32,713	1,909	127	8	272,032	$1,115,333	$0.33
320 3406C 320 kW	134,827	8,760	119,563	7,861	10,360	574	0	0	264,750	$1,085,477	$0.32
365 3406C 365 kW	147,021	8,760	93,670	5,733	197	12	0	0	240,888	$987,640	$0.29
320 C15 320 kW	129,967	8,760	115,126	7,861	10,062	574	0	0	255,156	$1,046,138	$0.31
365 C15 365 kW	152,095	8,760	96,276	5,733	206	12	0	0	248,577	$1,019,164	$0.30
410 C15 410 kW	168,925	8,760	73,092	3,734	0	0	0	0	242,017	$992,271	$0.30
455 C15 455 kW	175,244	8,760	65,967	3,158	0	0	0	0	241,211	$988,963	$0.30
500 C18 500 kW	181,304	8,760	63,290	2,882	0	0	0	0	244,594	$1,002,835	$0.30
545 C18 545 kW	183,847	8,760	62,059	2,777	0	0	0	0	245,907	$1,008,217	$0.30
680 C27 680 kW	207,554	8,760	59,699	2,368	0	0	0	0	267,253	$1,095,737	$0.33
725 C27 725 kW 480 V	209,633	8,760	54,626	2,152	0		0	0	264,289	$1,083,584	$0.32

	Generator 1		Generator 2		Generator 3		Generator 4				
Generator Options	Fuel (gal)	Hours	Fuel (gal)	Hours	Fuel (gal)	Hours	Fuel (gal)	Hours	Total Fuel (gal)	Total Fuel Cost	Cost per kWh
725 C27 725 kW 600 V	209,633	8,760	54,626	2,152	0	0	0	0	264,289	$1,083,584	$0.32
591 3412C 591 kW	198,416	8,760	64,109	2,654	0	0	0	0	262,525	$1,076,351	$0.32
635 3412C 635 kW	200,737	8,760	61,568	2,514	0	0	0	0	262,304	$1,075,448	$0.32
680 3412C 680 kW	204,605	8,760	58,993	2,368	0	0	0	0	263,597	$1,080,748	$0.32
725 3412C 725 kW	205,652	8,760	53,677	2,152	0	0	0	0	259,328	$1,063,247	$0.32
910 C32 910 kW	231,483	8,760	17,458	658	0	0	0	0	248,941	$1,020,658	$0.30
1010 3512 A 1,010 kW 12.47 kV	276,116	8,760	3,064	96	0	0	0	0	279,180	$1,144,637	$0.34

Selection of generators for the four IDP buildings was based on generator fuel curves, the combined load profile (Figure B.4) for the buildings (post-retrofit), and the cost to produce electricity. The two 275-kW prime generators will be connected in parallel, and each will be controlled by an onboard controller to efficiently provide generation to the site, and they will be tied into the Energy Management System (EMS). A maximum-allowable PV array of 500 kW is recommended for the site to provide generation during the day and to meet the 506.4 kW peak demand (after the efficiency retrofit), provide future growth for the IDP, and reduce the cost electricity that will in turn provide an attractive operational cost for existing and new tenants. When PV generation exceeds the IDP load, the energy could either be used at the site or could flow back onto the WAPA grid depending on WAPA requirements and restrictions.

A battery is installed in the micro-grid to provide stability and reliability to the site during WAPA electrical outages. The IDP buildings are automatically switched to micro-grid operation during an electrical outage. The micro-grid is able to supply electricity to the site during all loading conditions. Because the PV system has the capacity to supply 500 kW of generation during peak production, there must be an operational strategy for micro-grid operation.

Without service from the grid (during outages) and when the micro-grid is online, there will be no load for the PV energy once the PV's output exceeds the IDP load. Therefore, the micro-grid design has incorporated PV array switches/breakers so the site can be controlled by the EMS during micro-grid operations to provide no PV generation during this time or just enough from building 1, 2, 3, or all 4 buildings PV arrays as load requires. The prime generators will be the main source of backup generation during an outage. Power generation by the PV system will have to be curtailed during an outage so that it does not add to and conflict with the generators electrical output.

The micro-grid equipment selected and their costs are given in Table B.3 for the 27 buildings and in Table B.4 for the four IDP buildings. The selection and sizing of the PV systems for each site are found in Tables B.5, B.6 and B.7 for the BOC, IDP, and VIPD, respectively.

Table B.3. Micro-Grid Equipment Costs for All 27 Buildings at the Three Sites

Equipment & Installation	Unit Cost ($)	Quantity	Total Cost ($)
Generator Equipment			
Generators, Caterpillar-C18 545 kW	$128,000	2	$256,000
Transfer switch and gear	$30,000	7	$210,000
Installation	$64/hour	10,400	$665,600
6,000 gallon diesel fuel tank – single wall	$12,500	1	$12,500
1,500 kVA transformer, 480V, 3-phase to 13.2 kV, oil-filled, pad-mounted	$21,900	1	$21,900
500 kVA transformer, 480V, 3-phase to 13.2kV, oil-filled, pad-mounted	$18,500	7	$129,500
Generators enclosure – concrete and steel construction with roll-up doors and ventilation	$162,000	1	$162,000
Battery and enclosure with inverter, battery cells and ventilation	$350,000	1	$350,000
EMS-to-SCADA/HMI interface with the tridium building automation system (BAS/EMS)	$75,500	1	$75,500
Trenching and power cable: 6,330 ft @ $85/foot	$538,050	1	$538,050
Subtotal Generator Equipment			*$2,421,050*
EMS Equipment			
JACE 600	$6,500	3	$19,500
Human interface machine touch screen	$5,500	1	$5,500
Power meter	$6,000	7	$42,000
CATS cabling 100 meters	$350	3	$1,050
Switches	$2,250	1	$2,250
Wireless Ethernet (secure)	$3,500	1	$3,500
Shielded cable	$1.50/foot	1,000	$1,500
Fiber optic cable,	$2.00/foot	6,330	$12,660
Equipment installation	$50/hour	480	$24,000
Subtotal EMS equipment			*$111,960*
Total investment for micro-grid			$2,533,010

Table B.4. Micro-Grid Equipment Costs for the Four Buildings at the IDP

Equipment & Installation	Unit Cost ($)	Quantity	Total Cost ($)
Generator Equipment			
Generators, Caterpillar-3406C Prime 275kw	$75,000	2	$150,000
Transfer switch and gear	$35,000	4	$140,000
Installation	$64/hour	640 hours	$40,960
3,000 gallon diesel fuel tank – single wall	$6,850	1	$6,850
1,500 kVA transformer, 480V, 3-phase to 13.2 kV, oil-filled, pad-mounted	$24,900	1	$24,900
750 kVA transformer, 480V, 3-phase to 13.2kV, oil-filled, pad-mounted	$18,500	5	$92,500
Generators enclosure – concrete and steel construction with roll-up doors and ventilation	$162,000	1	$162,000
Battery and enclosure with inverter, battery cells and ventilation	$350,500	1	$350,500
EMS-to-SCADA/HMI interface with the tridium building automation system (BAS/EMS)	$4,800	1	$4,800
Trenching and power cable: 2,065 ft. @ $85/foot	$175,500	1	$175,500
Subtotal Generator Equipment			***$1,148,010***
Generation protection; relay (SEL-700GT	$2,500	1	$2,500
Shunt trip breaker	$250	4	$1,000
Design/install of protection	$10,500	1	$10,500
Battery Protection; Basic relay	$2,500	1	$2,500
Design/install of relay	$25,000	1	$7,500
Battery Transformer; 750 kw transformer	$50,000	1	$50,000
Installation cost	$25,000	1	$25,000
Transformer Protection; Relay for Generator Tx (SEL-787)	$3,000	1	$3,000
Tx relay protection battery	$7,000	1	$7,000
Design and Install	$30,000	1	$30,000
Subtotal Microgrid Protection			***139,000***
EMS Equipment	$6,500	3	$19,500
JACE 600	$5,500	1	$5,500
Human interface machine touch screen	$6,000	3	$18,000
Power meter	$350	3	$1,050
CATS cabling 100 meters	$5,000	1	$5,000
Switches	$3,500	1	$3,500
Wireless Ethernet (secure)	$1.50/foot	1,000	$1,500
Shielded cable	$50/hour	208 hours	$10,400.00
Equipment installation			***$64,450.00***
Subtotal EMS equipment			
Total investment for micro-grid			**$1,351,460**

Table B.5. PV Selection and Sizing for the BOC

Measure ID	Measure	Description	Energy Savings (MMBtu/yr)	Energy Savings ($/yr)	Maintenance Costs ($/yr)	Total Savings ($/yr)	Investment ($)	SIR	Simple Payback (yrs)	Comments
REN1C	PV on roof tops 99,150 ft^2 830 MWh/yr	Install 455 kW PV system on roof tops of buildings at BOC	2,831	$265,469	$9,105	$256,364	$1,848,251	2.2	7.2	455 kW of PV can produce up to 3,083 MMBtu/yr; system is oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects.
REN1C	PV on ground 12,000 ft^2; 101 MWh/yr	Install 55 kW PV system, ground-mounted adjacent to the BOC	344	$32,346	$1,102	$31,244	$287,603	1.7	9.2	55 kW of PV can produce up to 345 MMBtu/yr; system is oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects
Total	111,150 ft^2 931 MWh/yr	Install 510 kW PV at BOC	3,175	$297,815	$10,207	$287,608	$2,135,854	2.0	7.4	Cost effective @ marginal rate of $0.32/kWh

Table B.6. PV Selection and Sizing for the IDP

Measure ID	Measure	Description	Energy Savings (MMBtu/yr)	Energy Savings ($/yr)	Maintenance Costs ($/yr)	TBattelle@78 Botal Savings ($/yr)	Investment ($)	SIR	Simple Payback (yrs)	Comments
REN1A	PV on roof tops 108,000 ft^2 84 MWh./year	Install 496 kW PV system on rooftops of buildings at the IDP.	3,083.0	$289,165	$9,917	$279,248	$1,735,537	1.9	7.2	496 kW of PV can produce up to 3,083 MMBtu/yr; system is oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects. Cost effective @ marginal rate of $0.32/kWh.

Table B.7. PV Selection and Sizing for the VIPD

Measure ID	Measure	Description	Energy Savings (MMBtu/yr)	Energy Savings ($/yr)	Maintenance Costs ($/yr)	Total Savings ($/yr)	Investment ($)	SIR	Simple Payback (yrs)	Comments
REN1B	PV on ground around new building or as carport; 106,000 ft^2; 893 MWh/yr	Install 487 kW PV system on ground	3,047	$285,722	$9,734	$275,988	$2,032,397	1.9	7.4	487 kW of PV can produce up to 3047 MMBtu/yr; system is oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects.
REN1B	PV on new building roof top; 10,000 ft^2; 84 MWh/yr	Install 46 kW PV system on ground	285	$26,774	$918	$25,856	$213,039	1.6	8.2	46 kW of PV can produce up to 285 MMBtu/yr; system is oversized because St Croix conditions place PV capacity at 21% of unit rating due to cloud effects.
Total	116,000 ft^2; 977 MWh/yr	Install 533 kW at VIPD	3,332	$312,496	$10,652	$301,844	$2,245,436	1.8	7.4	Cost effective @ marginal rate of $0.32/kWh.

Appendix C

VIWMA Building Baseline and Retrofit Tables

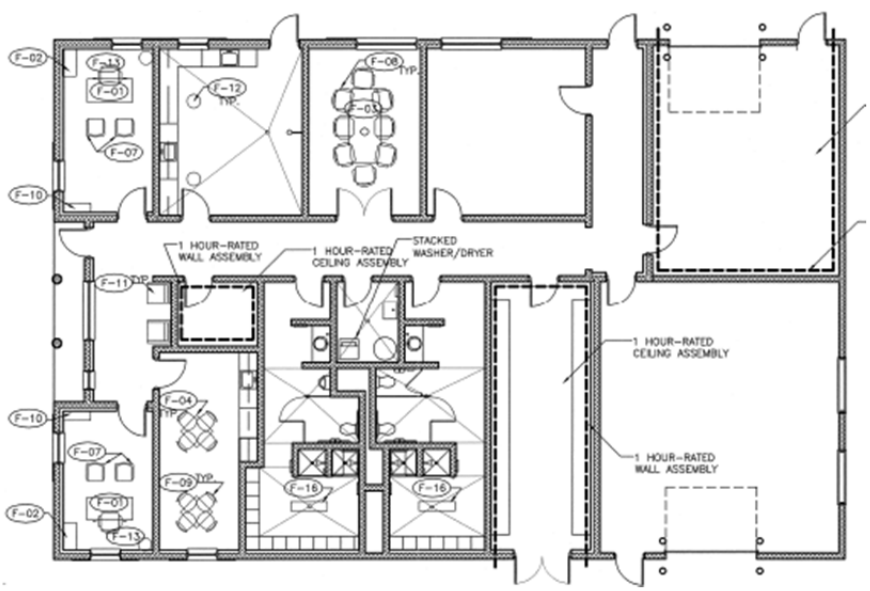
Building	Wastewater Treatment Plant
Site Name	Administration and shop
Date Constructed	2006
Total Area (sq. ft.)	4,872
Use Type	Office and warehouse/storage
Date Audited	08/2015
Audited By	Graham Parker, Paul Boyd, and Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 11.00
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 11.00
	Window	Aluminum with Thermal Break Frame Double Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X2 2F32T8U ELC2, FL 2X4 2F32T8 ELC2, EXIT - FL 2-PL9, MH 400 POLE, LED 40W A-Line (4000 Lumens), FL 1X4 2F32T8 ELC2, CFL 32 INTEGRAL UNIT ELC, MH 175 WALL, MH 175 POLE
DHW	Hot Water	Electric Water Heater
Motors	Motors	7.5 hp ODP motor(460V/1800rpm), 30.0 hp ODP motor(460V/1800rpm), 75.0 hp TEFC motor(200V/1800rpm)

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Increase Insulation by R-19	8	$781	0	$0	$0	$781	$8,407	10.8	1.7
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	Single Zone Packaged AC Unit (high efficiency, small), Single Zone Packaged AC Unit (very high efficiency, medium)	32	$3,064	0	$0	$707	$3,771	$27,575	7.3	1.6
Lighting	Lights	LED 34W 2x2 Retrofit Panel (3430 Lumens), LED 34W 2x4 Fixture (3300 Lumens), EXIT - LED, LED 240W Pole Lamp (24000 Lumens), LED 75W Wall Pack (8000 Lumens), LED 80W Pole Lamp (8000 Lumens)	135	$12,621	0	$0	($565)	$12,056	$78,890	6.5	2.9
DHW	Hot Water	Wrap Tank with Insulation, Insulate Pipe Near Tank, LFSHs, Lower Tank Temperature	1	$66	0	$0	$0	$66	$158	2.4	3.6
Motors	Motors	Replace motor with Premium Efficiency (91.7%) 7.5 hp motor, Replace motor with Premium Efficiency (94.1%) 30 hp motor, Replace motor with Premium Efficiency (95.4%) 75 hp motor	116	$10,964	0	$0	$0	$10,964	$58,918	5.4	2.2
Total			***292***	***$27,496***	***0***	***$0***	***$142***	***$27,638***	***$173,948***	***6.3***	***2.5***

Building	Control Building
Site Name	Administration
Date Constructed	2004
Total Area (sq. ft.)	4,953
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker, Paul Boyd, and Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 11.13
	Floor	Slab on grade with no perimeter insulation
	Wall	Masonry Frame Wall Insulation R-Value 4.80
	Window	Aluminum with Thermal Break Frame Double Pane Window (Fixed, Non-Operable)
HVAC	Heating	None
	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 2F32T8 ELC2, EXIT - FL 2-PL9, MH 175 WALL, EXIT - LED
DHW	Hot Water	Electric Water Heater
Motors	Motors	None



Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Increase Insulation by R-19	9	$870	0	$0	$0	$870	$8,547	9.8	1.9
	Floor	None recommended									
	Wall	None recommended									
	Window	None recommended									
HVAC	Cooling	Single Zone Packaged AC Unit (high efficiency, small)	30	$2,802	0	$0	$60	$2,862	$28,690	10.0	1.2
Lighting	Lights	LED 34W 2x4 Fixture (3300 Lumens), EXIT - LED, LED 75W Wall Pack (8000 Lumens)	38	$3,567	0	$0	($430)	$3,137	$36,160	11.5	1.6
DHW	Hot Water	None recommended									
Motors	Motors	N/A									
Total			***77***	***$7,239***	***0***	***$0***	***($370)***	***$6,869***	***$73,397***	***10.7***	***1.6***

Building	Greenhouse
Site Name	WM Green House Administration
Date Constructed	1995
Total Area (sq. ft.)	480
Use Type	Office
Date Audited	08/2015
Audited By	Graham Parker, Paul Boyd, and Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Built Up Roof Insulation R-Value 11.13
	Floor	Crawlspace Floor Insulation R-Value 11.00
	Wall	Engineered Metal Wall Insulation R-Value 9.60
	Window	Aluminum Frame Single Pane Window (Fixed, Non-Operable)
HVAC	Cooling	Electric Package Unit
Lighting	Lights	FL 2X4 2F32T8 ELC2, CFL 32 INTEGRAL UNIT ELC
DHW	Hot Water	None
Motors	Motors	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	Increase Insulation by R-38	14	$1,321	0	$0	$0	$1,321	$7,696	5.8	3.2
	Floor	None recommended									
	Wall	4 inches Fiberglass									
	Window	Install High Performance Aluminum Frame Double Pane Argon/Low-Gain Low-e Windows									
HVAC	Cooling	Window unit (very high efficiency)	9	$848	0	$0	$0	$848	$1,670	2.0	6.1
Lighting	Lights	LED 34W 2x4 Fixture (3300 Lumens)	5	$427	0	$0	($88)	$339	$2,976	8.8	2.2
DHW	Hot Water	N/A									
Motors	Motors	N/A									
Total			***28***	***$2,596***	***0***	***$0***	***($88)***	***$2,508***	***$12,342***	***4.9***	***3.0***

Building	Transfer Station
Site Name	WM waste processing and break room
Date Constructed	2012
Total Area (sq. ft.)	22,050
Use Type	Warehouse/storage
Date Audited	08/2015
Audited By	Graham Parker, Paul Boyd, and Joe Petersen

Measure Category	Subcategory	Existing Technology
Building Envelope	Roof	Engineered Metal Roof Insulation R-Value 0.00, Engineered Metal Roof Insulation R-Value 14.60
	Floor	Slab on grade with no perimeter insulation
	Wall	Engineered Metal Wall Insulation R-Value 0.00, Engineered Metal Wall Insulation R-Value 9.60
	Window	None
HVAC	Cooling	Electric Package Unit
Lighting	Lights	MERC 400 PEND, LED 75W Wall Pack (8000 Lumens), EXIT - LED, FL 2X4 2F32T8 ELC2, FL 1X4 2F32T8 ELC2, CFL 42 INTEGRAL UNIT ELC
DHW	Hot Water	Electric Water Heater
Motors	Motors	None

Measure Category	Subcategory	Measures	Electricity Savings		Non-electric Energy Savings		Annual O&M Savings ($/yr)	Total Savings ($/yr)	Investment ($)	Simple Payback (yr)	SIR
			MMBtu/yr	$/yr	MMBtu/yr	$/yr					
Building Envelope	Roof	4 inches Fiberglass	3	$302	0	$0	$0	$302	$2,852	9.4	2.0
	Floor	None recommended									
	Wall	4 inches Fiberglass									
	Window	None									
HVAC	Cooling	None recommended									
Lighting	Lights	LED 136W High Bay Fixture (15000 Lumens), LED 34W 2x4 Fixture (3300 Lumens)	81	$7,596	0	$0	$545	$8,141	$23,899	2.9	6.3
DHW	Hot Water	None recommended									
Motors	Motors	N/A									
Total			***84***	***$7,898***	***0***	***$0***	***$545***	***$8,443***	***$26,751***	***3.2***	***5.9***

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