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Islands in the Sun

The solar power deployment initiative at the University of the Virgin Islands.

THIS ARTICLE DISCUSSES THE DISTRIBUTED SOLAR power deployment initiative at the University of the Virgin Islands (UVI). It is an ongoing project that will deploy 3.3 MW of solar power at UVI. The project needs, benefits, design, and financing for the initiative are discussed. UVI is located in the U.S. Virgin Islands. A brief introduction to the U.S. Virgin Islands is presented first, providing background information on the energy need and why the solar power deployment initiative is necessary for UVI.

The U.S. Virgin Islands

The U.S. Virgin Islands are an organized, unincorporated U.S. territory on the boundary of the North American plate and the Caribbean plate. About 40 mi east of Puerto Rico and immediately west of the British Virgin Islands, the U.S. Virgin Islands are geographically part of the Virgin Islands archipelago and are located in the Leeward Islands of the Lesser Antilles (Figure 1).

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The U.S. Virgin Islands are located in the Atlantic Standard Time zone and do not participate in Daylight Saving Time. When the mainland United States is on standard time, the U.S. Virgin Islands are 1 h ahead of Eastern Standard Time. When the mainland United States is on Daylight Saving Time, Eastern Daylight Time is the same as Atlantic Standard Time.

Geography

The U.S. Virgin Islands consist of the main islands of Saint (St.) Croix, St. John, and St. Thomas, along with the much smaller but historically distinct Water Island, and many other surrounding minor islands. The main islands have nicknames often used by locals: "Twin City" (St. Croix), "Rock City" (St. Thomas), and "Love City" (St. John). The combined land area of the islands is 133.73 mi^2, roughly twice the size of Washington, D.C. The U.S. Virgin Islands are known for their white-sand beaches. Most of the islands, including St. Thomas, are volcanic in origin and hilly. The highest point is Crown Mountain, St. Thomas (1,555 ft).

PPA is a financing arrangement that allows UVI to purchase solar electricity with little to no upfront capital cost.

Climate

The U.S. Virgin Islands have a tropical climate, moderated by easterly trade winds and with relatively low humidity. Natural hazards include earthquakes and tropical cyclones (including hurricanes). Temperatures vary little throughout the year. Statistical temperature and precipitation data are shown in Table 1 and Figure 2. In the capital city of Charlotte Amalie in St. Thomas, the typical daily maximum temperatures are around 91 °F in the summer and 86 °F in the winter, and the typical daily minimum temperatures are around 78 °F in the summer and 72 °F in the winter. Rainfall averages about 39 in per year. Rainfall can be quite variable, but the wettest months on average are September to November, and the driest months on average are February and March. The U.S. Virgin Islands are subject to tropical storms and hurricanes, with the hurricane season running from June to November. In recent history, substantial damage was caused by Hurricane Hugo in 1989 and Hurricane Marilyn in 1995.

Economy

The U.S. Virgin Islands are an independent customs territory from the mainland United States and operate largely as a free port. Tourism is the primary economic activity (Figure 3). The islands normally host 2 million visitors a year, many of whom visit on cruise ships. The manufacturing sector consists mainly of rum distilling. The agricultural sector is small, with most food being imported. International business and financial services are a small but growing component of the economy. To draw more technology-focused companies and expand this segment of the economy, the government founded and launched UVI Research and Technology Park in conjunction with private businesses and UVI.

The aggregate population of the U.S. Virgin Islands is estimated to be approximately 109,000. About 42% of the population is between the ages of 25 and 54. The median household income, adjusted for inflation, is approximately US$32,000, well below the current U.S. average of about US$50,000. The poverty rate is relatively high in the U.S. Virgin Islands. U.S. census data indicate approximately

IMAGE COURTESY OF WIKIMEDIA COMMONS/RYANSMITH714

Figure 1. The U.S. Virgin Islands: (a) St. Thomas and St. John and (b) St. Croix. (Images courtesy of Google Maps.)

29% of families and 33% of individuals live below the poverty line. This can be compared with a 2009 poverty rate of approximately 14% for the United States.

Electric Transmission and Distribution System

St. Thomas and St. John are part of one interconnected power system, with an installed capacity of 191 MW, a maximum load of approximately 88 MW, and a minimum load of about 50 MW. The island of St. Croix constitutes a second power system, with an installed capacity of 117 MW, a maximum load of approximately 55 MW, and a minimum load of about 35 MW. Although the topography of the ocean floor has prevented the direct interconnection of these two grid systems to date, studies are underway to examine the possibility of connecting both island systems with Puerto Rico and the British Virgin Islands (Figure 4). The grid infrastructure of the U.S. Virgin Islands consists primarily of subtransmission lines (25–115 kV). The two grid systems currently operate at

TABLE 1. Climate Data for St. Thomas, U.S. Virgin Islands. (Source: weather.com.)

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Record high (°F)	93	93	94	96	97	99	98	99	98	97	95	92	99
Average high (°F)	85	85	86	87	88	89	90	90	90	89	87	86	87.7
Average low (°F)	72	73	73	74	76	78	78	78	78	77	75	74	75.5
Record low (°F)	63	62	56	62	66	67	57	59	64	66	52	62	52
Precipitation (in)	2.38	1.48	1.42	2.74	3.06	2.53	2.85	3.74	5.58	5.42	5.23	2.96	39.39

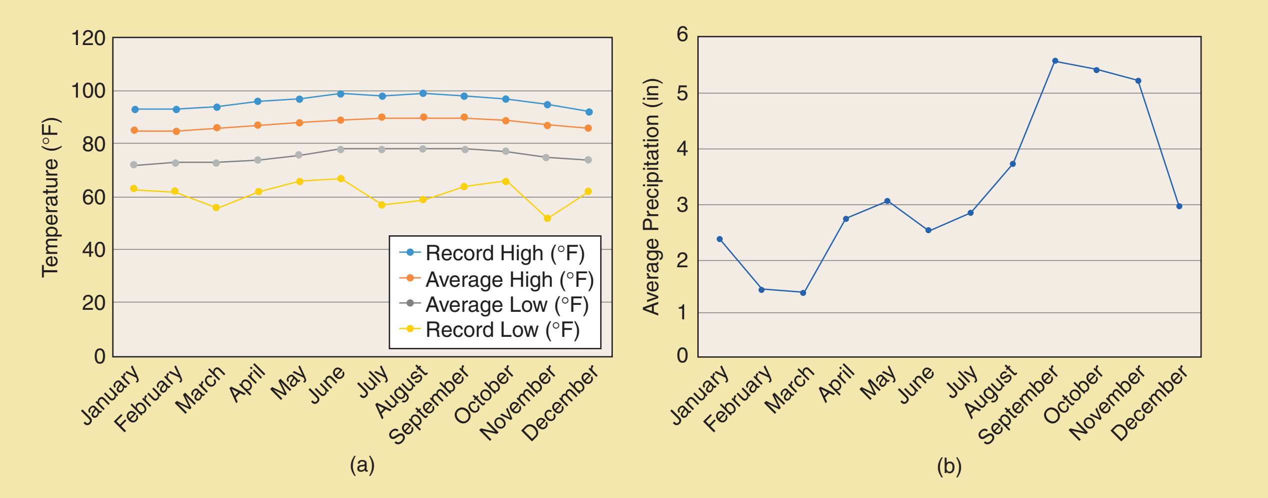

Figure 2. The monthly climate data for St. Thomas, U.S. Virgin Islands: (a) temperature and (b) precipitation. (Source: weather.com.)

24.9 and 34.5 kV for St. Thomas and St. Croix, respectively. St. Croix is currently in the process of upgrading parts of its system to operate at 69 kV. The distribution systems are typically operated at 13.8 kV. The total technical and nontechnical losses were estimated at 6% on the St. Thomas–St. John system and more than 13% on the St. Croix system.

Energy Cost

Similar to many island communities, the U.S. Virgin Islands are 100% dependent on imported fuel oil for electricity. Retail electricity rates in 2011 reached as high as US$0.49/kWh and were as high as US$0.52/kWh following the oil price spikes of 2008. The electricity generation and distribution systems in the U.S. Virgin Islands are owned, operated, and maintained by the Virgin Islands Water and Power Authority

Figure 3. Tourism is the primary economic activity in the U.S. Virgin Islands, which are known for their white-sand beaches. (Photo courtesy of http://www.imagebrowse.com/us-virgin-island-backgrounds/.)

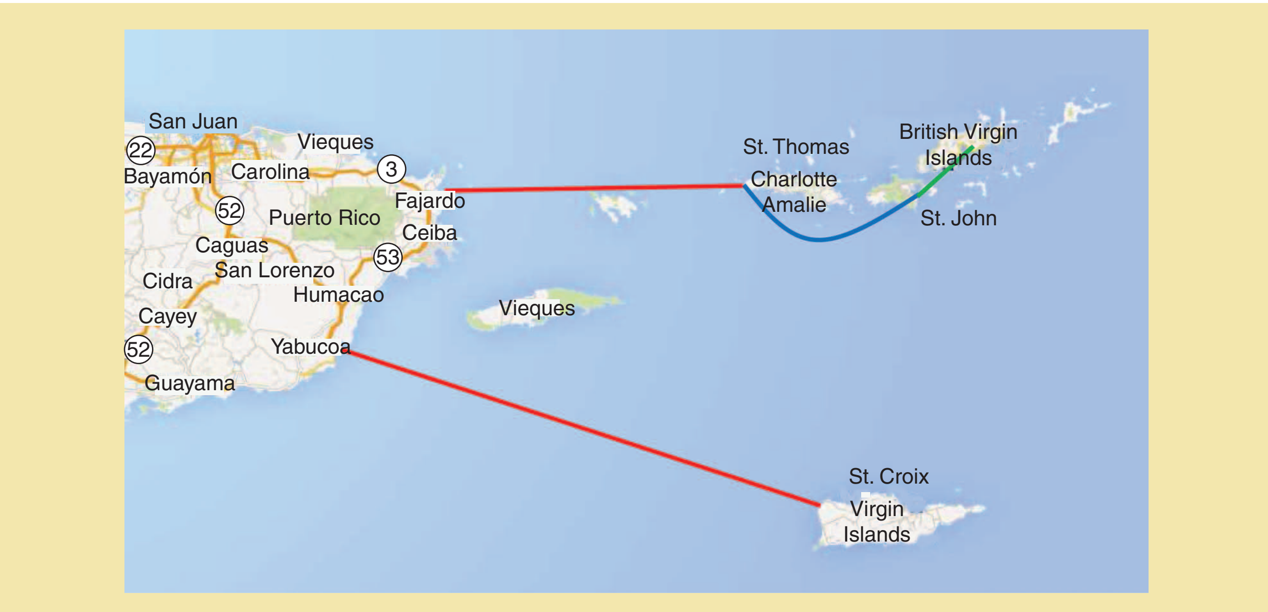

Figure 4. The conceptual interconnection between the U.S. Virgin Islands, Puerto Rico, and the British Virgin Islands. (The line information is from a public report: http://www.viwapa.vi/AboutUs/Projects/ProjectDetails/11-08-02/USVI-BVI-Puerto_Rico_Interconnection.aspx. Map image courtesy of Google Maps, illustration added.)

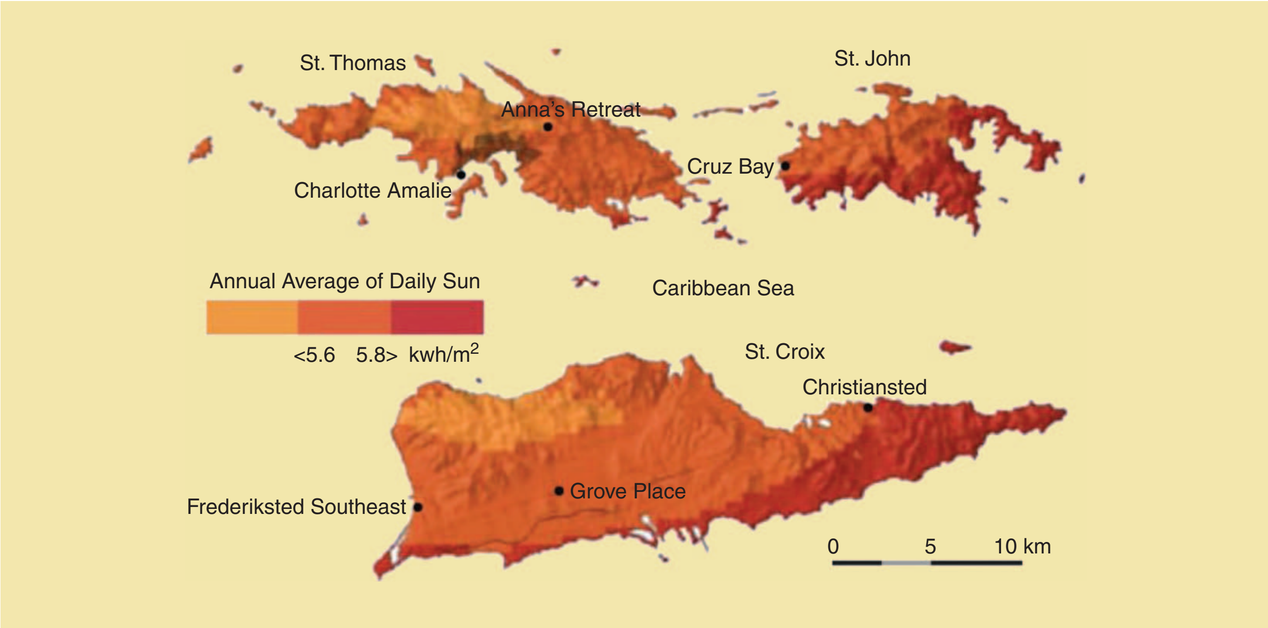

Figure 5. The solar radiation of the U.S. Virgin Islands. (Source: Clean Power Research.)

(WAPA). WAPA generation assets are primarily located on St. Thomas and St. Croix and consist of steam turbines operating on number 6 fuel oil, combustion turbines operating on number 2 fuel oil, and a limited amount of internal combustion (diesel) generation. Capacity is derived primarily from combustion turbines (72%) and steam turbines (28%). The mean household size in the U.S. Virgin Islands is 2.2 people. The total per-capita electricity consumption, including losses and water production, is estimated to be the equivalent of 8,000 kWh per person per year. Thus, the total annual household electricity consumption is about 17,600 kWh. With an average price of US$0.51/kWh for electricity, the total annual household electricity expenditure amounts to US$8,976, which is about 28% of the median household income (US$32,000). This extremely high cost of energy has seriously stifled the economic development of the U.S. Virgin Islands.

Solar energy has the potential to make a meaningful contribution to the U.S. Virgin Islands' energy future if it is deployed widely.

Generation Efficiency

Because of the use of low- and high-pressure steam for desalination, coupled with outmoded controls and nonstandardized operations procedures, WAPA's generation fleet operates at a relatively inefficient heat rate (greater than 15,000 Btu/kWh). This can be compared with the heat rate for Guam, an island in the South Pacific that also relies on number 6 and number 2 fuel oil and had a system average heat rate of 9,720 Btu/kWh, or Hawaii, whose heat rate has been estimated at 10,500 Btu/kWh. To enhance the efficiency of existing generation assets, WAPA installed waste heat recovery steam generators (HRSGs) in St. Thomas in 1997 and St. Croix in 2010. WAPA intends to upgrade the St. Thomas HRSGs to increase efficiency but has not yet established a time frame in which to complete these upgrades.

Solar Energy

The sun in the U.S. Virgin Islands is strong. The solar radiation map in Figure 5 shows that the U.S. Virgin Islands have a good solar resource for solar photovoltaic (PV) generation, with an average solar irradiation greater than 5.7 kWh/m^2/day. Thus, solar energy has the potential to make a meaningful contribution to the U.S. Virgin Islands' energy future if it is widely deployed. The National Renewable Energy Laboratory estimates that, under a base case scenario, 10 MW of solar PV will be deployed by 2025, which represents between 7% and 10% of peak load.

Wind Energy

The consistency of the trade winds from the east provides an excellent source of untapped power in the U.S. Virgin Islands. This resource is particularly pronounced along the southern coastline and exposed ridges of the islands (Figure 6). The National Renewable Energy Laboratory estimates that, under a base case scenario, 22.5 MW of wind will be deployed by 2025, which represents between 15% and 20% of peak load.

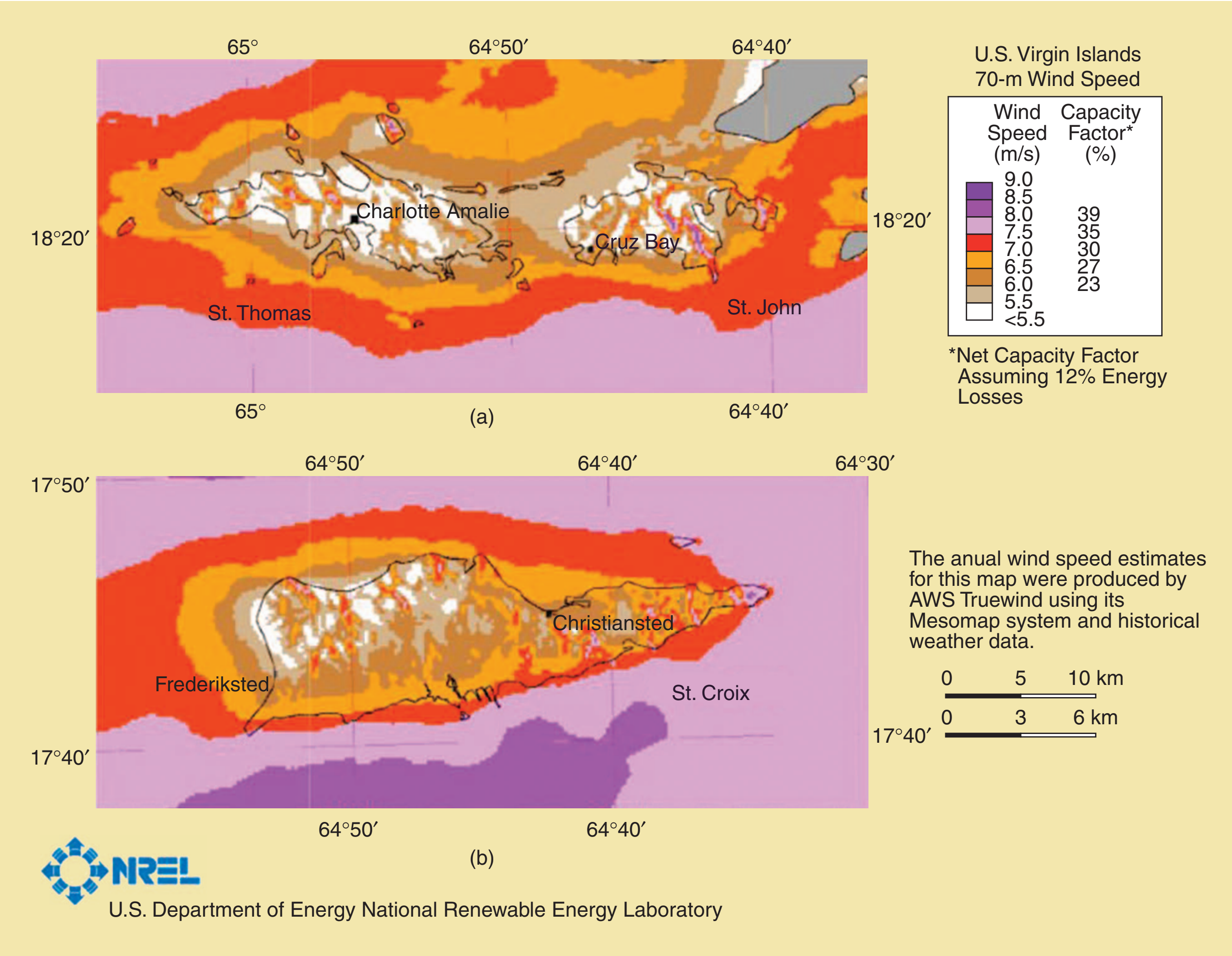

Figure 6. The annual wind speeds of the U.S. Virgin Islands: (a) St. Thomas and St. John and (b) St. Croix. (Source: National Renewable Energy Laboratory.)

A Look at UVI

Founded in 1962, UVI is a public, coed, land-grant, historically black university that lies in the heart of the beautiful Caribbean. Approximately 2,500 students are enrolled on the two campuses (Figure 7): the Albert A. Sheen Campus on St. Croix and the St. Thomas campus. UVI offers 38 undergraduate degree programs and seven graduate degree programs across its five colleges and schools. In a tropical climate, UVI students enjoy indoor and outdoor activities year round. Student entrepreneurs are rewarded with startup

Figure 7. The two campuses of UVI: (a) the Albert A. Sheen Campus, St. Croix, and (b) the St. Thomas Campus. (Images courtesy of UVI.)

funds. Students in the science, technology, engineering, and mathematics area present their research locally, nationally, and internationally. Internships give students hands-on field experience. Student clubs and organizations offer students the opportunity to lead, work as a team, network, and serve the community. The UVI experience is uniquely multicultural, international, entrepreneurial, and intellectually stimulating. UVI provides a vital and exciting environment for educating future leaders of the global 21st-century community. Table 2 summarizes the enrollment of UVI in fall 2012.

The Caribbean Green Technology Center (CGTC) at UVI was created in 2011 to advance energy and environmental sustainability in the U.S. Virgin Islands and their neighbors throughout the Caribbean Basin. In the face of severe economic pressures and energy and water insecurity, the CGTC serves as an important clearinghouse for information and processes geared toward supporting and protecting natural resources and the development of alternative and renewable-energy technologies. The CGTC serves as a vibrant intellectual hub for learning, networking, and innovation in and across the Caribbean, in all areas pertaining to green technology. Its main purpose is to foster research, education, and public service on sustainability; promote Caribbean interislands cooperation; advance interdisciplinary investigations and learning; collaborate with governmental agencies and industry partners; and research, develop, demonstrate, and monitor green technology. The CGTC addresses scientific, policy, and implementation issues around the topic of green technology and sustainability, especially as it pertains to living in the Caribbean. It brings together groups of researchers, industry leaders, and policy makers to address and solve problems and implement solutions that lead to better lives for the people of the Caribbean.

The Caribbean Green Technology Center at UVI was created in 2011 to advance energy and environmental sustainability in the U.S. Virgin Islands and their neighbors throughout the Caribbean Basin.

In an attempt to reduce energy consumption, UVI started examining firms to provide alternative renewable- energy solutions. In the field of renewable energies, there are solar, wind, biomass, water, geothermal, and hydrogen and fuel cells. Previously, wind turbines were researched. Because of the maintenance required for these units during hurricane season, it was determined that any wind project would not be feasible. Thus, a request for qualifications was advertized to explore firms that could provide a power purchase agreement (PPA) for a PV system. The PV systems could be ground mounted, rooftop mounted, carport integration, or a combination of all three. Any option would be rated to the Florida hurricane standards for 150-mi/h winds and gusts and would not require additional maintenance during hurricane season. The systems would tie into the UVI power grid to support as much electrical consumption as possible.

TABLE 2. UVI Enrollment by Level, Campus, Status, and Gender, Fall 2012. (Source: UVI.)

	All			Full Time			Part Time		
Level	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**
UVI (All)									
Undergraduate	2,271	1,589	682	1,423	969	454	848	620	228
Undergraduate	184	145	39	50	33	17	134	112	22
Graduate	2,455	1,734	721	1,473	1,002	471	982	732	250
St. Croix									
Undergraduate	860	617	243	475	334	141	385	283	102
Graduate	67	55	12	7	4	3	60	51	9
Total	927	672	255	482	338	144	445	334	111
St. Thomas									
Undergraduate	1,411	972	439	948	635	313	463	337	126
Graduate	117	90	27	43	29	14	74	61	13
Total	1,528	1,062	466	991	664	327	537	398	139

UVI's Partners

Veriown

Veriown, Inc. is an innovative energy company that helps businesses, universities, governments, and other institutions harness their on-site distributed solar and other forms of distributed energy as well as lock in long-term, predictable energy rates with little to no capital expense. Veriown has developed and is further developing clean tech energy systems that are based around providing power to areas that currently have high energy costs due to a lack of production and/or distribution.

The Robert W. Galvin Center

The Robert W. Galvin Center for Electricity innovation at the Illinois Institute of Technology (IIT) has pursued groundbreaking work in renewable-energy deployment and microgrid design over the last decade. It has completed the first phase of a next-generation smart solar installation on the IIT microgrid test bed. The demonstration consisted of a distributed smart solar photovoltaic system with battery installation on the IIT smart microgrid. The project included building roof sites of various size systems and was designed to support the demonstration of novel solar power systems in residential, commercial, and microgrid environments. The Galvin Center is pursuing the full scope of its smart solar installation across 17 buildings on the IIT microgrid.

The Solar Power Deployment Initiative at UVI

Veriown, Inc., the Robert W. Galvin Center for Electricity Innovation at Illinois Institute of Technology (IIT), and UVI will deploy 3.3 MW of solar power at UVI's two campuses. (See "UVI's Partners.") By the end of 2015, this solar power deployment initiative will reduce UVI's dependence on fossil fuel by 50%. The PV system will use approximately 5.7 acres on the St. Thomas Campus and 3.9 acres on the Albert A. Sheen Campus on St. Croix. This system is expected to produce 5.9 million kWh annually at the St. Thomas facility and 2.4 million kWh annually at the St. Croix facility.

The U.S. Virgin Islands, where UVI is located, have just 110,000 residents, but energy prices are four to five times higher than those in the continental United States. Like many islands, the U.S. Virgin Islands are almost 100% dependent on imported oil for electricity and water generation. Residents pay about US$0.57/kWh to light their homes and run their appliances, which is 275% higher than the national average per unit cost benchmark of US$0.33/kWh. The solar power deployment initiative will reduce UVI's electricity price to US$0.34/kWh (a 33% reduction) via distributed solar power and an advanced storage system. The savings are expected to be about US$11 million for the first eight years (a 39% reduction) and about US$37 million for the first 25 years (a 52% reduction).

> ***The U.S. Virgin Islands have a tropical climate, moderated by easterly trade winds and with relatively low humidity.***

The solar power deployment initiative is also in line with UVI's Goes Green Initiative, which is a sustainable, environmentally friendly initiative that promotes responsible environmental policies and practices. The Goes Green Initiative currently includes recycling, reusable to-go containers for food, green cleaning, electric vehicles, and alternative energy. Through the Goes Green Initiative, UVI is exploring various opportunities for the production of solar energy on campus. The initiative signifies an opportunity to unshackle energy consumers from the grips of traditional models of energy generation and distribution by using distributed solar. It represents the beginning of a new future leading to cleaner, more efficient, reliable, and lower-cost energy solutions for the U.S. Virgin Islands. As UVI President David Hall says, "Energy consumption and costs are crippling challenges facing the Virgin Islands and the broader Caribbean, and this initiative creates a pathway for addressing the problems." The solar power deployment initiative is "a historic and transformative development for the university and the Virgin Islands," notes Hall, and "once this project is completed, UVI will have blazed a trail that many universities throughout the world are destined to follow."

Project Design for the Solar Power Deployment Initiative

Project Sites

A summary of the sites and their corresponding solar capacities is shown in Table 3. A bird's-eye view of the installation site at the St. Thomas Campus is shown in Figure 8. The site is next to the UVI sports complex, as shown in Figure 9.

Technological Design

In the solar power deployment initiative, Veriown will use solar production to lower the cost of energy to UVI by more

TABLE 3. The Project Sites and Capacities.

Site Location	ft^2	KW
UVI St. Thomas Campus	243,936	2,099
UVI St. Croix Campus	173,673	1,200
Total	417,609	3,299

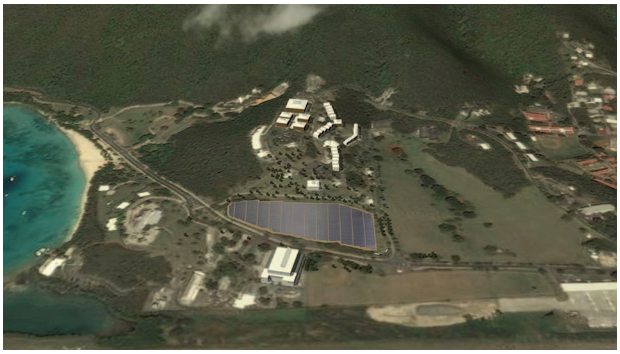

Figure 8. A bird's-eye view of the UVI St. Thomas Campus 2,099-kW dc solar array.

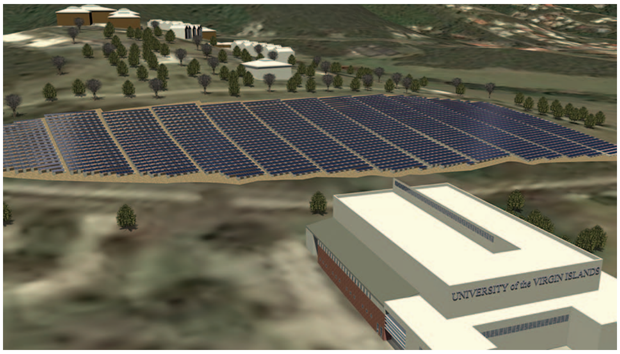

Figure 9. The UVI St. Thomas Campus 2,099-kW dc solar array.

than 40% during peak production hours, defined as the period of time when the solar system is producing power. Because solar is not a base load power source, the solar system is oversized based on electricity consumption requirements during peak production hours and stores the energy for off-peak production hours, the period of time when the solar system is not producing power, using advanced energy storage. The system is also designed to eliminate the inherent inability of renewable power production to load-follow due to the peak power design or constantly changing input power levels from variations in the sun, wind, or other production sources. The solar power deployment initiative will develop a 3.3-MW ground-mount crystalline PV system with a single-axis tracker. The system will include the components listed in Table 4.

This system design is an ideal platform into which new-technology battery storage should be introduced. Table 5 shows the requirements for the energy-storage system. A fully integrated energy-storage system that satisfies those requirements should be delivered to the site containerized, prewired, and pretested, reducing site work and installation time. One such solution is available from S&C Electric and summarized in Table 6. A more detailed description of each component follows.

TABLE 4. The Proposed PV System Components.

System Component	Quantity
Yingli/LDK-watt crystalline PV modules	10,920
Fixed-tilt solar panels (5°)	2
260-kW commercial Inverter with complete setup	9
16-circuit subcombiners with 100-A fuses	9
12-circuit combiner boxes	90
Data acquisition system gateways for each inverter	9

TABLE 5. The Requirements for the Energy-Storage System.

Element	Requirement
Power	St. Thomas: 1 MW St. Croix: 500 kW
Energy	3–4 h of storage at rated power
System life	10+ years
Battery functions	Time-shifting solar generation
Ambient conditions	Tropical/salt in the air
Containerized or indoor	Containerized

Power Electronics

S&C's Storage Management System (SMS) is an example of a utility-grade power-conversion system. It provides four-quadrant control, acting as either a voltage or current source (adjustable on the fly), with the ability to absorb or provide real and reactive power. As illustrated in Figure 10, the four-quadrant design allows the SMS to manage a wide range of real and reactive power requirements (the points along and within the red dashed line). The control algorithms within the SMS support a wide variety of energy-storage use cases, including peak shaving, dynamic islanding, renewable-energy integration, energy arbitrage, ancillary services (including frequency regulation), load following, and voltage control.

The SMS includes the inverters, ac and dc breakers, and controls mounted within each international organization for standardization (ISO) container. The building block of the SMS is an individually controlled ±1.25-MVA/1.0-MW inverter, with a dedicated 480-V breaker for each inverter, as shown in Figure 11. Up to four 1-MW inverter blocks can be combined into a single ISO container, and a total of 20 MW can be managed under a single control. The insulated gate bipolar transistor (IGBT) is the major power electronic component within the 1-MW inverter block. Each 1-MW inverter block contains 12 IGBTs and has its own local control and small ac filter components to ensure harmonic-free sine waves at the output terminals of the inverter. The SMS includes ±500-kW, dc-to-dc converter chopper blocks, which take the variable dc voltage

TABLE 6. The Integrated Energy-Storage System Solution.

Item	St. Thomas Installation	St. Croix Installation
Power Electronics	S&C PureWave SMS 1.25 MVA/1.0 MW	S&C PureWave SMS-250 263 kVA/250 kW
Battery	Lithium-ion 3,000 kWh or sodium–nickel–chloride (NaNiCl) 2,400 kWh (Total of 3,000-kWh embedded energy, but limited to 80% depth of discharge)	Lithium-ion 2,000 kWh

from the battery and create the fixed dc link voltage for the inverter system. The SMS controls the chopper circuits to allow charging or discharging of the batteries within the rigorous requirements provided by the battery manufacturer. The choppers are controlled to determine the direction of power flow and are current-limited by the controls in accordance with the battery controller's commands.

The digital signal processing–based SMS controls provide efficient operation across a wide range of power levels, which is a benefit for variable-power applications, as shown in Figure 12. All of the SMS subsystems are housed in a custom enclosure mounted inside an ISO container. A typical SMS ISO container without the transformer and batteries is shown in Figure 13.

Battery

The world of energy-storage choices can be complicated. Each energy-storage technology presents its own set of pros/cons, maturity level, and costs. Table 7 provides a summary the different technologies available today. Based on the project requirements, a lithium-ion battery system has been considered for the St. Croix site, and options of both the lithium-ion battery system and a sodium–nickel–chloride (NaNiCl) battery system were considered for the St. Thomas site. Lithium-ion batteries, with their combination of high discharge rates, excellent energy density, modularity, and low

Figure 11. The ±1.25-MVA SMS inverter and two choppers. (Image courtesy of S&C Electric, "Storage Management System," http://sandc.com/products/energy-storage/sms.asp.)

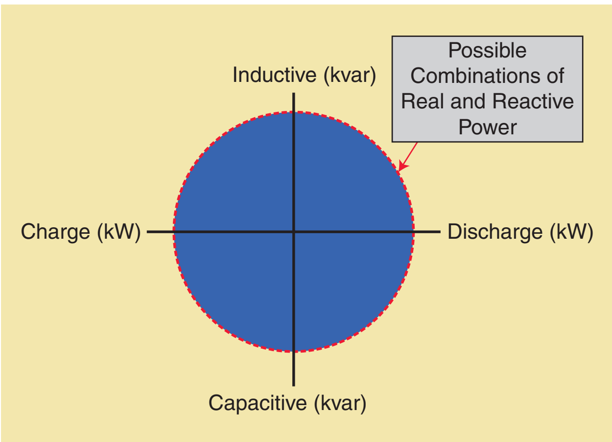

Figure 10. A conceptual four-quadranat power-conversion system. (Image courtesy of S&C Electric, "Storage Management System," http://sandc.com/products/energy-storage/sms.asp.)

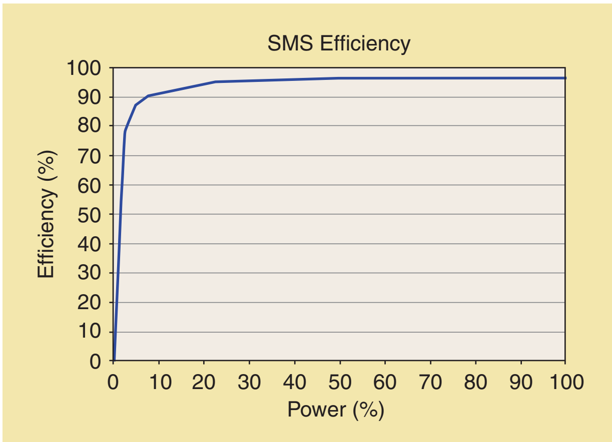

Figure 12. An SMS efficiency curve. (Image courtesy of S&C Electric, "Storage Management System," http://sandc.com/products/energy-storage/sms.asp.)

TABLE 7. A Summary of Currently Available Energy-Storage Technologies.

Technology	Maximum Current Rate	Energy Density	Cycle Life	Calendar Life	Maintenance Requirements	Technology Maturity	Minimum Scale
Lithium-ion	High	High	Medium	Medium	Low	High	1 kW
Lead-acid	Medium	Low	Low	Low	High	High	1 kW
Sodium-sulfur	Low	Medium	Medium	High	Low	High	1 kW
NaNiCl	Medium	Medium	Medium	High	Low	Medium	100 kW
Flow battery	Low	Low	High	High	High	Low	100 kW
Flywheel	High	Medium	High	High	Low	Medium	200 kW

maintenance requirements, are a flexible energy-storage technology appropriate for a variety of applications. NaNiCl technology provides an excellent energy density and cycle life without the need for heating, ventilating, and air conditioning systems or other auxiliary loads. In both cases, battery modules are combined into a sophisticated energy-storage system with multiple levels of control and protection. Each container includes a dedicated battery-management system (BMS), circuit breaker, and contactors as well as current and voltage sensors. A master BMS provides control across multiple racks and/or modules. The specifications of the complete battery systems are shown in Table 8.

S&C's Storage Management System is an example of a utility-grade power-conversion system.

Project Performance Measures

Table 9 shows the quantifiable project performance measures that will be achieved as a result of the solar power deployment initiative.

Project Financing for the Solar Power Deployment Initiative

In the solar power deployment initiative, Veriown will use solar production to lower the cost of energy to UVI by more than 40% during peak production hours, defined as the period of time when the solar system is producing power. Because solar is not a base load power source, the solar system is oversized based on electricity consumption requirements during these peak production hours and store the energy for off-peak production hours, the period of time when the solar system is not producing power, using advanced energy storage. The system is also designed to eliminate the inherent inability of renewable power production to load-follow due to peak power design or constantly changing input power levels from variations in the sun, wind, or other production sources.

The total budget of the solar power deployment initiative is US$13.136 million, of which US$3 million is sponsored by a U.S. Department of Agriculture grant and the remaining US$10.136 million is cost-shared by Veriown. Upon the completion of the initiative, 3.3 MW of solar PVs will be installed and operational at UVI's two campuses. Veriown will enter into a PPA with UVI. The PPA is a financing arrangement that allows UVI to purchase solar electricity with little to no upfront capital cost. To achieve this, UVI provides unused rooftop, land, or parking lot space as a location for a solar installation. Veriown pays for the cost of the solar installation and assumes all responsibility for ownership, operation, and maintenance once the solar

TABLE 8. The Desired System-Level Battery Specifications.

Item	St. Croix	St. Thomas	St. Thomas
Technology	Lithium-ion	Lithium-ion	NaNiCl
Total embedded energy (beginning of life)	2,000 kWh	3,000 kWh	2,400 kWh usable 3,000 kWh embedded
Cycle life	6,000 cycles	6,000 cycles	4,500 cycles
Round-trip dc efficiency	At least 90%	At least 90%	At least 90%
Operating temperature range (to be maintained by high-voltage ac system)	23 ± 5 °C	23 ± 5 °C	−10 °C to +40 °C

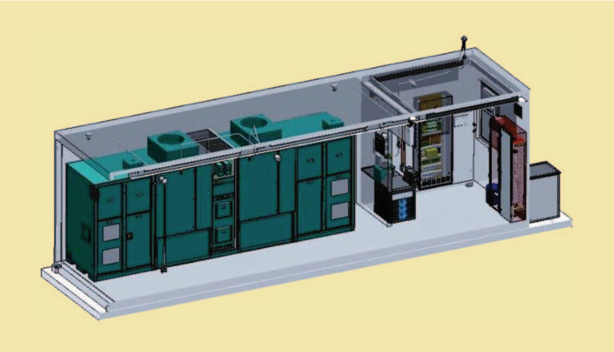

Figure 13. A 2-MW SMS in a 30-ft ISO container. (Image courtesy of S&C Electric, "Storage Management System," http://sandc.com/products/energy-storage/sms.asp.)

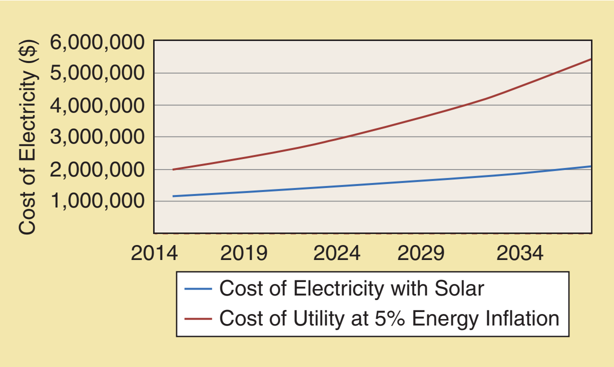

Figure 14. The PPA reducing the UVI cost of electricity relative to increasing utility energy cost.

project is complete. The well-structured PPA allows UVI to reduce electricity costs immediately (from US$0.51/kWh to US$0.34/kWh, a 33% reduction) and realize increased savings over time as grid electricity prices rise.

Figure 14 shows a detailed PPA cash flow analysis over the next 25 years, assuming an initial PPA rate of US$0.34/kWh, a PPA escalator of 3%, and an annual utility electric rate increase of 5%. In summary, the avoided electricity cost for the first ten years is US$11,057,098 (a 46% reduction) and for the first 25 years is US$47,577,968 (a 58% reduction). Additional benefits of the PPA include 1) no initial capital investment because UVI only pays for the solar electricity that is produced after installation, 2) fixed energy rates as the PPA provides a powerful hedge against volatile electricity prices, 3) UVI is not responsible for system operation or maintenance, and 4) a benefit from solar tax credits in the form of a lower PPA rate.

TABLE 9. Project Performance Measure.

Performance Measure	Target
Renewable energy installed capacity (kW)	3,300
Renewable energy produced (kWh annually)	5,900,000
UVI electricity price (cents/kWh)	34
Potential for CO_2 reduction (metric tons annually)	2,000
Jobs created	10
Jobs retained	20
U.S. Department of Agriculture funds (US$)	3,000,000
Funds leveraged (US$)	10,136,000

For Further Reading

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