GOVERNMENT OF THE VIRGIN ISLANDS

VIGILATE

British Virgin Islands ELECTRICITY CORPORATION

BRITISH VIRGIN ISLANDS RESILIENT NATIONAL ENERGY TRANSITION STRATEGY

ROCKY MOUNTAIN INSTITUTE

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ABOUT US

ABOUT THE MINISTRY OF COMMUNICATIONS AND WORKS

The Ministry of Communications and Works is dedicated to ensuring the continued development and maintenance of public infrastructure in keeping with international standards so that public utilities are reliable and affordable in support of an enhanced community life for every resident and visitor in the Virgin Islands.

ABOUT THE MINISTRY OF NATURAL RESOURCES AND LABOUR

The Ministry of Natural Resources and Labour endeavours to effectively manage and administer the natural resources of the Territory in a manner that ensures long term sustainability, and to ensure that the supply of labour is commensurate with the level of development in all sectors of the economy under working conditions which preserve the individuals' health, safety, and welfare.

ABOUT BRITISH VIRGIN ISLANDS ELECTRICITY CORPORATION

The main goal and objective of the British Virgin Islands Electricity Corporation (BVIEC) is to provide the best possible service to its customers, and to aid in the development of the Territory's electrical infrastructure by adequately supplying a reliable and continuous electrical supply to the entire British Virgin Islands population at an affordable cost.

ABOUT ROCKY MOUNTAIN INSTITUTE

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; the San Francisco Bay Area; Washington, D.C.; and Beijing.

FOREWORD

On September 6, 2017, the British Virgin Islands took a direct hit from Hurricane Irma—a Category 5 hurricane. Irma caused winds in excess of 185 miles per hour that led to severe coastal and inland flooding and widespread destruction to critical infrastructure. Over 80 per cent of the housing stock was destroyed. On September 19, less than two weeks later, BVI was hit by Hurricane Maria—also a Category 5 hurricane. The two hurricanes caused historical destruction throughout the BVI. Four lives were lost and 125 persons injured.

The hurricanes also significantly impacted the electricity sector—damaging the Territory's only power plant and destroying approximately 90 per cent of the electrical grid.

With any destruction of this magnitude, there lies an opportunity to build stronger, smarter, greener and better. The Government of the British Virgin Islands is committed to rebuilding a new, more resilient and sustainable Territory. In particular, the Government has taken this opportunity to redesign the electricity system to one that is more resilient, cleaner, and affordable for its citizens. With support from Rocky Mountain Institute (RMI), the Government has taken a whole-systems approach to ensure the pursuit of a low-cost and resilient electricity system for the British Virgin Islands.

The British Virgin Islands Resilient National Energy Transition Strategy (R-NETS) process was undertaken in late 2017 and early 2018 by the Ministry of Communications and Works, the Ministry of Natural Resources and Labour, and the British Virgin Islands Electricity Corporation (BVIEC). The R-NETS provides the architecture for the future of the electricity sector in the British Virgin Islands. More specifically, it outlines the process undertaken, results, and recommendations for near, medium, and long-term actions that will ensure a pathway for the territory to meet our shared priorities for the electricity sector.

—Premier Dr. the Honourable D. Orlando Smith, OBE

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EXECUTIVE SUMMARY

On September 6, 2017, the British Virgin Islands (BVI) took a direct hit from Hurricane Irma— a category 5 hurricane. On September 19, less than two weeks later, BVI was hit by Hurricane Maria—also a category 5 hurricane. The two hurricane events caused widespread destruction in many of the BVI islands, and tragically led to numerous deaths. However, the devastation caused by Hurricanes Irma and Maria offer an important window of opportunity to leapfrog from the current electricity system architecture characterized by centralized diesel generation transmitted through a highly vulnerable transmission and distribution (T&D) system to a 21st-century electrical grid characterized by high levels of decentralized renewable energy and energy efficiency. Under the auspices of the economy-wide Recovery and Development Plan, it was recognized that an immediate and whole-systems process was required to ensure the pursuit of a low-cost and resilient electricity system for the BVI in the aftermath of recent weather events. To meet this need, the BVI government commissioned the Resilient National Energy Transition Strategy (R-NETS) process to identify the optimal investments in clean energy infrastructure that can be incorporated into the rebuilding process.

The R-NETS process offers an important step forward in better understanding the opportunity and options for the BVI to achieve the shared goals of stakeholders for the future electricity system. The results provide BVI decision makers with a sequenced, prioritized, and flexible action plan designed to guide future investment decisions and transition to an electricity system that is resilient, reliable, low-cost, values environmental stewardship, and promotes job and industry creation.

More importantly, the R-NETS serves as a tool to build consensus by developing a common fact base among key stakeholders. The R-NETS was developed through an inclusive process in partnership with the Ministry of Communications and Works (MCW), the Ministry of Natural Resources and Labour (MNRL), and the British Virgin Islands Electricity Corporation (BVIEC) with support from Rocky Mountain Institute (RMI).[i]

[i] Rocky Mountain Institute supported the data gathering, analysis, and consultations as an independent and objective third party.

RECOMMENDED PATHWAY CREATES ECONOMIC AND SOCIAL BENEFITS

The R-NETS indicates an opportunity for the BVI to:

- reduce volatility of electricity costs by up to 9 per cent by reducing diesel fuel use by 21.7 million litres annually;
- diversify sources of technology by increasing renewable penetration by up to 34 per cent;
- reduce generation costs by up to 27 per cent; and
- create over two times as many jobs and spur local investment by over $150 million compared to business-as-usual (BAU) operation.

BENEFITS CAN BE CAPTURED THROUGH IMMEDIATE ACTIONS

To capture these benefits, the BVI should:

- aggressively pursue energy efficiency;
- investigate energy storage;
- expedite regulatory changes; and
- investigate the national wind resource.

Specifically, the BVI should pursue tangible projects that will bring benefit today, while kick-starting the BVI on the optimal pathway towards a more resilient and prosperous future. These projects include:

- **Immediate-term:** LED Street lighting, Cox Heath Solar Project, Ground-Mount and Rooftop Solar, Continued Energy Efficiency Programmes
- **Medium-term:** Solar for Schools (and Government Buildings) Project, Paraquita Bay Integrated Energy Project, Anegada Hybrid Microgrid Project
- **Long-term:** Anegada Generation Expansion Project

RECOMMENDED PATHWAY IS ROBUST FOR A BROAD RANGE OF ASSUMPTIONS

The RMI technical team used assumptions agreed upon with the MCW, MNRL, and BVIEC. Where data did not exist, or was not available, the RMI technical team carefully considered assumptions based on similar electricity systems in the Caribbean. In addition, RMI carried out a sensitivity analysis to test the robustness of the R-NETS recommendations.

The analysis concluded that a generation mix with significant energy efficiency and renewable energy penetration between 30 to 40 per cent remains beneficial under changing conditions for fuel price and technology costs. Further, an increase in load leads to a dramatic increase in optimal new resource sizes. However, the high modularity and short lead time necessary to deploy battery storage, as well as solar PV, well-positions the BVI to quickly scale technology sizes should future load growth exceed expectations. The R-NETS results indicate that adopting the identified recommendations would put theBVI in a better position to manage costs, reduce volatility, and meet renewable policy targets.

THE BENEFITS ARISE FROM AN OBJECTIVE FACT-BASED PROCESS

The key stakeholders from the MCW, MNRL, and BVIEC established a set of priorities, supporting strategic objectives, and indicators. Table 1 includes the priorities and strategic objectives used to evaluate options.

The first step in the R-NETS analysis was forecasting future electricity demand. The results indicate an estimated annual growth in electricity consumption ranging from 1.39 to 2.53 per cent for the different scenarios. The team then reviewed existing resource assessments to determine which technology options and sizes to include in the scenarios. The team tested and scored the five discrete scenarios shown in Table 2 against the evaluation criteria. The results show that all renewable scenarios move the BVI's electricity system closer to national priorities compared to the BAU scenario.

Table 3 depicts the results of the five scenarios tested. All scenarios analysed that include renewables and energy efficiency, outperform BAU across all priorities with the following exceptions:

- BAU outperforms renewables scenarios for the reliability priority due to a higher score related to the N minus 2 criteria (the electricity system's ability to meet hourly load during the year if the two largest generating units are out of service); and

- BAU significantly outperforms the Aggressive SS scenario in the low-cost category.

These results indicate that there are several options for the BVI to transition to an electricity system that meets the territory's priorities and goals; the BAU scenario receives the lowest overall score of 57, highlighting the clear business case for a transition to new resources.

TABLE 1

R-NETS OBJECTIVES AND STRATEGIC OBJECTIVES

PRIORITY	STRATEGIC OBJECTIVE
RESILIENCY	Build a robust electricity system that can withstand, respond, and adapt to external shocks
RELIABILITY	Improve reliability of electricity delivered by BVIEC
LOW-COST	Reduce generation costs
ENVIRONMENTAL STEWARDSHIP	Increase renewable penetration and energy efficiency savings
JOBS AND INDUSTRY CREATION	Increase job creation and economic development

TABLE 2

OVERVIEW OF TECHNOLOGIES INCLUDED IN FIVE SCENARIOS ASSESSED IN R-NETS

1	2	3	4	5
BAU	SS	SWS	SSEE	AGGRESSIVE SS
Business As Usual	Solar, Storage	Solar, Wind, Storage	Solar, Storage, Aggressive Energy Efficiency	Aggressive Solar, Storage

TABLE 3
FINAL SCORES FOR FIVE R-NETS SCENARIOS

PRIORITY	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
RESILIENCY	26	14	20	23	22	22
RELIABILITY	26	26	15	16	15	16
LOW-COST	20	14	16	18	19	8
ENVIRONMENTAL STEWARDSHIP	14	0	6	6	13	7
JOBS AND INDUSTRY CREATION	14	3	8	8	6	14
TOTAL	100.	57	65	71	75	67

01 CONTEXT

CONTEXT

1.1 RECENT WEATHER EVENTS

The British Virgin Islands (BVI) experienced three unprecedented weather events in less than six weeks in 2017: extreme floods on August 7, followed by Hurricanes Irma and Maria—both category 5 hurricanes, on September 6 and September 19 respectively. The storms caused significant damage to the BVI electricity system. All power plants suffered damage, incapacitating the utility's ability to generate power across the islands. The storms destroyed approximately 90 per cent of the transmission and distribution grid—approximately 12,000 poles, 400 miles of conductor, 2,200 pole-mounted transformers, and 3,500 streetlights. The storms also caused significant structural damage to buildings leading to a large loss of customer accounts. Peak demand in January 2018 was approximately 17 MW, compared to a high of 34 MW prior to Hurricane Irma.[1]

Under the auspices of the economy-wide Recovery and Development Plan, it was recognized that an immediate and whole-systems process was required to ensure the pursuit of a low-cost and resilient electricity system for the BVI in the aftermath of recent weather events. To meet this need, the BVI government commissioned the Resilient National Energy Transition Strategy (R-NETS) process to identify the optimal investments in clean energy infrastructure that can be incorporated into the rebuilding process. The R-NETS was initiated in late 2017 and early 2018 by the Ministry of Communications and Works, the Ministry of Natural Resources and Labour, and the British Virgin Islands Electricity Corporation (BVIEC).

This document outlines the R-NETS process and results, and provides recommendations for near-term actions that will ensure a pathway for the BVI to meet shared priorities related to the electricity sector. Following sections describe the methodology, results, and recommendations.

1.2 BVI'S CURRENT ELECTRICITY SYSTEM

BVIEC, a statutory corporation owned by the Government of the BVI, is responsible for electricity generation, transmission, and distribution throughout the islands of the BVI. Standby generation by other parties is permitted, but BVIEC is solely responsible for providing continuous supply.

BVIEC operates a diesel-based system that generates the majority of electricity in the BVI at the Pockwood Pond power station on the main island of Tortola. This station supplies Tortola and Beef Island, as well as the islands of Virgin Gorda, Jost van Dyke, Little Thatch, Buck Island, Little and Great Camanoe, Scrub Island, and Marina Cay via undersea cables. Additionally, BVIEC operates a small diesel station on the island of Anegada.

The BVI's ten-year energy vision includes significant expansion of renewable generation and energy efficiency. Specifically, it includes the following targets:

- Supplying 30 per cent of electricity from renewable sources by 2023
- Decreasing fossil fuel imports by 20 per cent by 2021
- Ensuring that 50 per cent of consumers adopt energy efficiency measures and/or distributed renewable technologies by 2021
- Reducing 80 per cent of inputs to fossil-fuel based generation in Anegada by 2021

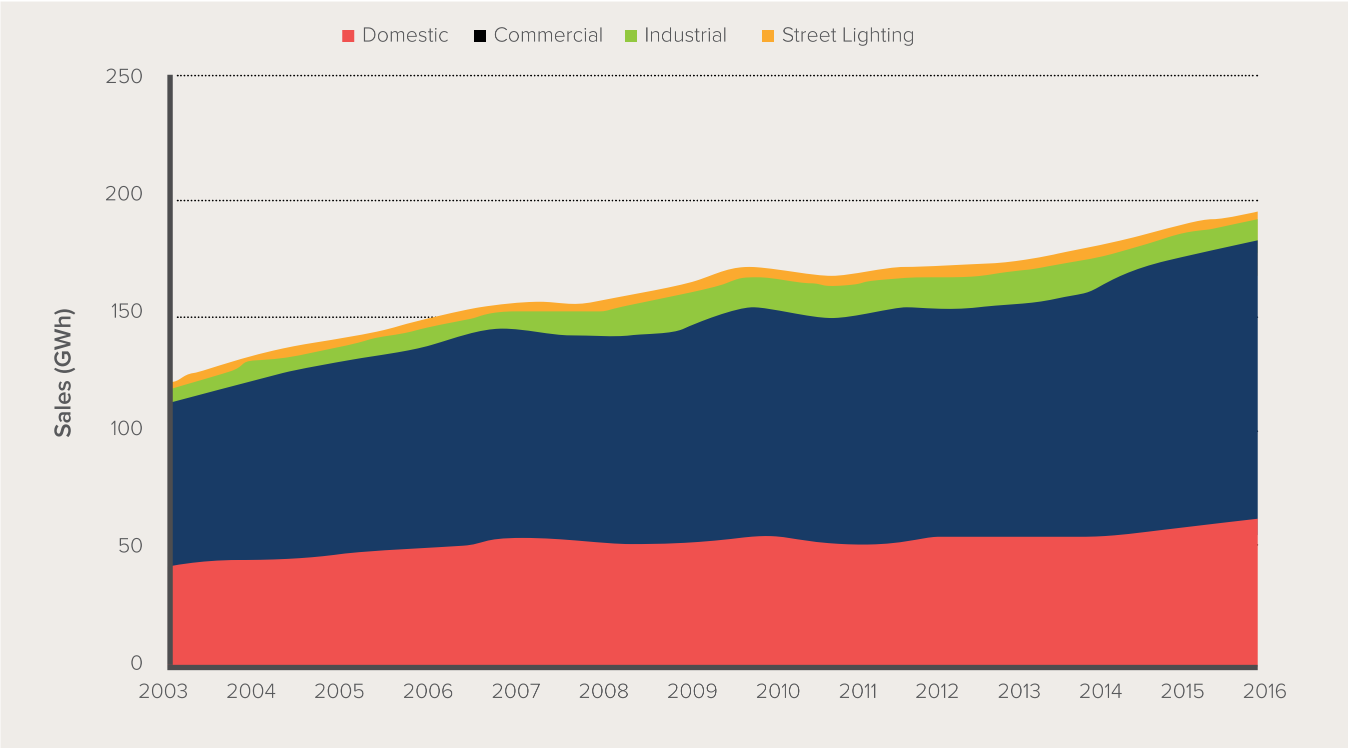
A subset of privately owned islands within the BVI are well on their way towards significant renewable penetration, highlighting the potential for the rest of the territory. Peter Island generates approximately 70 per cent of its electricity from two 250 kW hybrid turbines, backed by diesel generators. Cooper Island generates more than 75 per cent of its electricity from solar and uses solar water heating. Necker Island is planning to build a renewable microgrid that would include 900 kW of wind, 300 kW of solar, and 500 kWh of energy storage.[2]

1.2.1 HISTORICAL RELIABILITY

Over the decades, diesel generation has provided reliable and flexible electricity to the BVI. Apart from planned and corrective maintenance, the generation units had reliability factors of over 90 per cent on average from 2011 to 2016.[3] However, by 2016 demand exceeded available capacity for portions of the year causing problems with reliability. In 2017 BVIEC completed the Phase V project, installing three new 8.5 MW Wärtsilä gensets at the Pockwood Pond power station. These units provided the necessary generation capacity to meet electricity demand and increase reliability of the system. Increasing the available capacity of the system also improved the resiliency of the system. Hurricane Irma damaged some of the older Wärtsilä generating units installed at Pockwood Pond.[ii] However, Pockwood Pond resumed operations quickly after Hurricane Irma because it had enough available capacity to continue operations without the damaged generating units.

FIGURE 1

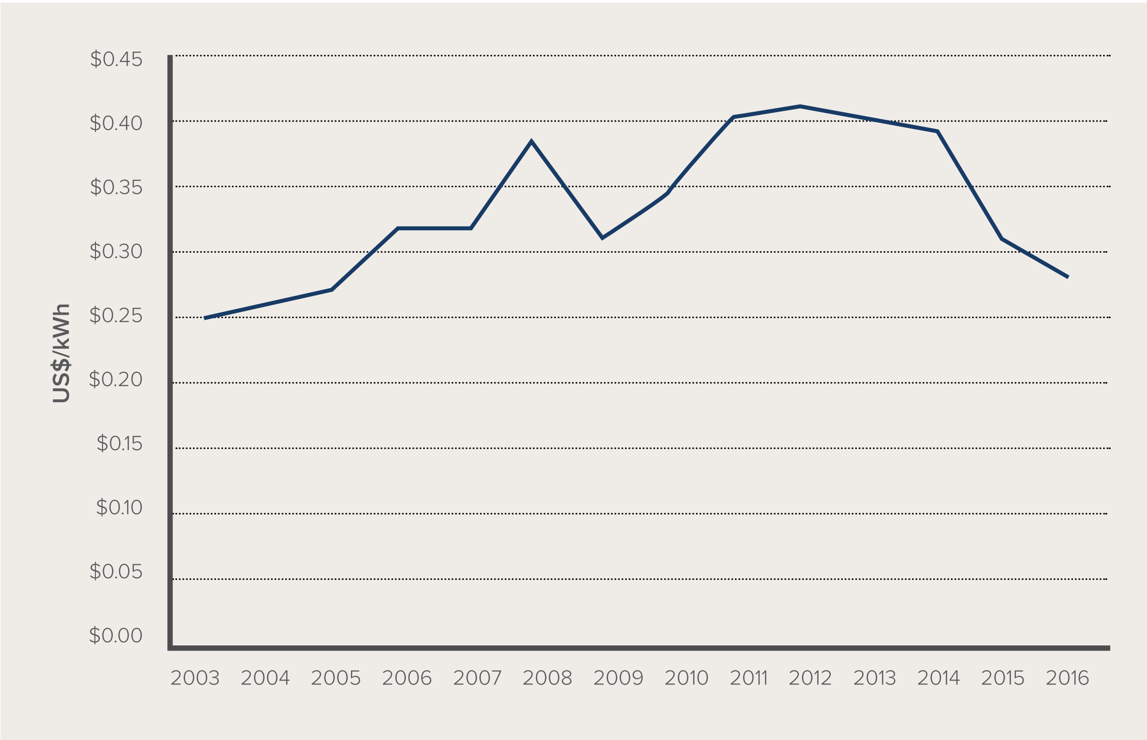
BVIEC HISTORICAL SALES PER CUSTOMER CATEGORY (2003-2016)



[ii] In February 2018 only two of the older Wärtsilä generating units were in operation (not including units commissioned under the Phase V project).

FIGURE 2

BVIEC HISTORICAL ELECTRICITY TARIFF FOR DOMESTIC CUSTOMERS (2003–2016)



1.2.2 HISTORICAL ELECTRICITY TARIFFS AND SALES

The BVI's electricity tariff was designed to promote economic productivity. The tariff was structured to include "declining block rates" so that customers are charged a rate according to the amount of electricity they use. The blocks decrease in price so customers who use higher amounts of electricity are billed less for each incremental unit.

BVIEC has four consumer categories: domestic, commercial, industrial, and street lighting. Figure 1 shows BVIEC's historical sales per customer type from 2003 to 2016, while Figure 2 shows historical annual electricity tariffs for domestic customers for the same period (other customer types follow a similar historical tariff trend). Forecasting of electricity demand following the storms and the importance of maintaining low a nd stable electricity tariffs, are both key components of the R-NETS process and are discussed further in this document.

1.3 FUTURE OPPORTUNITIES

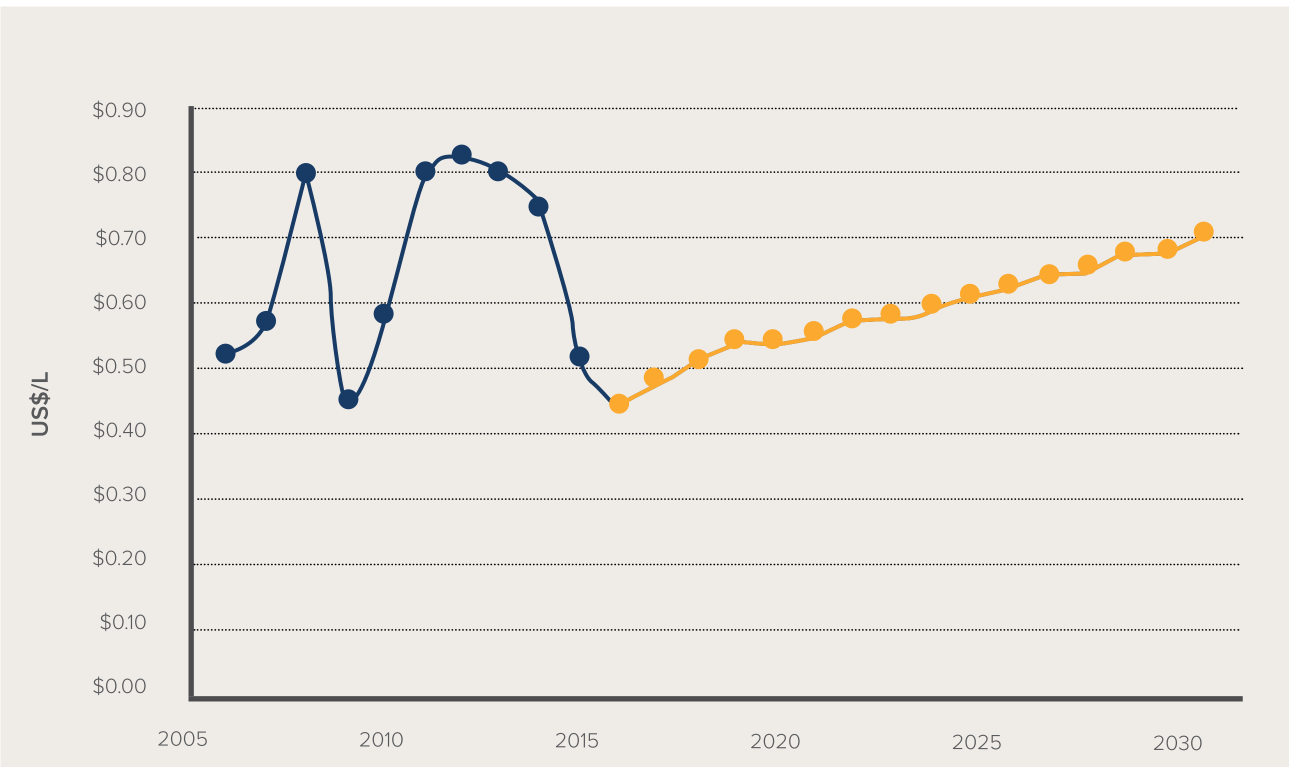
Global trends in energy-related costs coupled with a changing economic environment show renewable energy options will become increasingly favourable to the BVI. As BVIEC and other stakeholders install or purchase renewable energy at competitive prices, the opportunity to more cost-effectively serve electricity needs is apparent, resulting in lower and more stable electricity costs for BVI residents. In addition, reducing fossil fuel use can help to meet stated targets and establish the territory as a worldwide leader. This section describes relevant trends in terms of fuel prices, renewable energy prices, and resiliency.

1.3.1 FUEL PRICE TRENDS

Recent trends of low-cost diesel are predicted to reverse—with a 40 per cent increase projected over the next decade. Figure 3 shows historical cost of diesel fuel for the BVI, as well as projections for fuel cost in the coming years. This baseline projection informed the core modelling and analysis of the R-NETS; in addition, two alternative fuel projections were tested through sensitivity analysis and are discussed in Section 4. The baseline fuel cost forecast does not capture historical price volatility, given the difficulty in accurately forecasting and predicting price fluctuations over time; the potential impact of cost volatility is considered in the R-NETS.[iii]

FIGURE 3

HISTORICAL AND PROJECTED DIESEL FUEL COST FOR BVI



[iii] The R-NETS evaluates the impact of a 25 per cent increase to the price of diesel on the generation costs of each scenario. Scenarios that have a higher percentage of diesel fuel use receive a lower score related to resiliency due to the potential for impact from an external shock (significant fuel price increase).

1.3.2 RENEWABLE ENERGY PRICE TRENDS

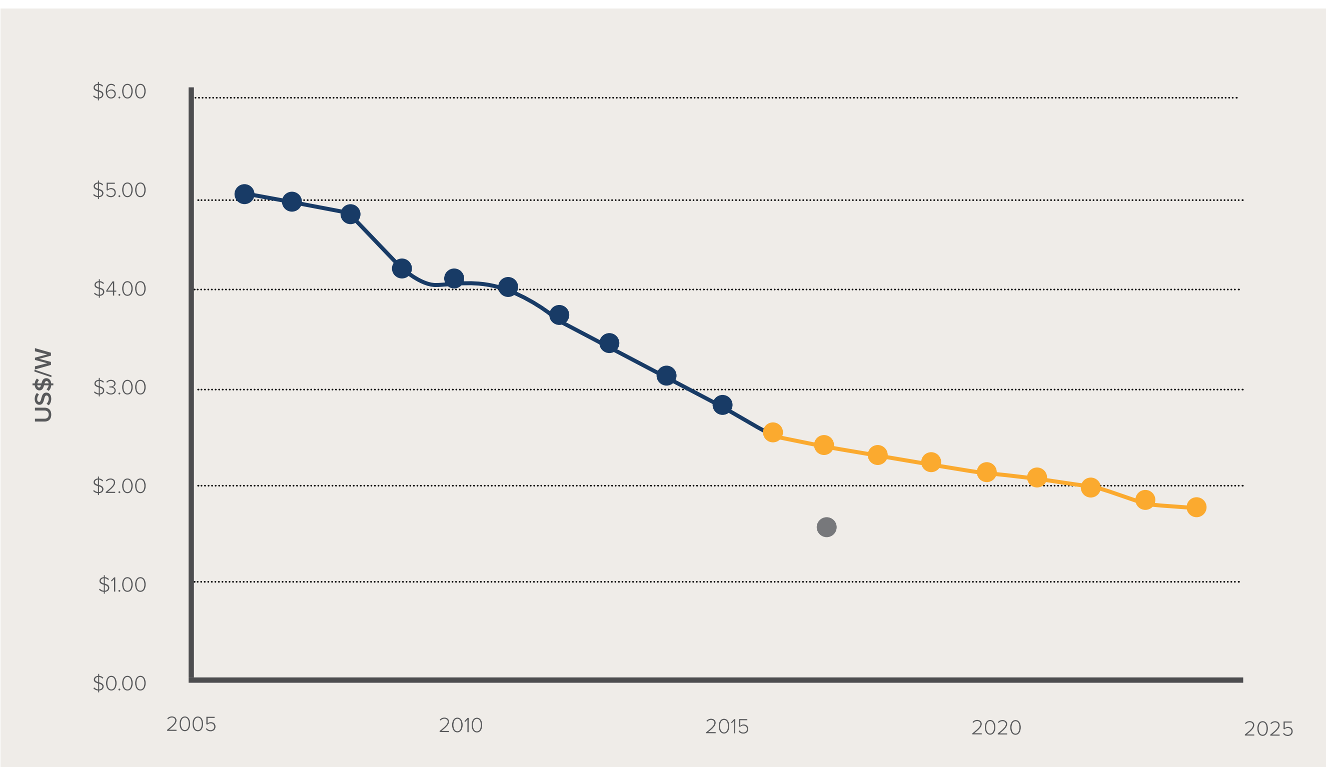
The BVI's goal of 30 per cent renewable penetration by 2023 could become easier to accomplish given the projected 24 per cent decrease in solar costs, 13 per cent decrease in wind power costs, and 44 per cent decline in battery costs by 2024. Figure 4 to Figure 6 show historical installed costs for solar PV, wind power, and lithium-ion battery storage, as well as projections for installed costs in the near future for these three technologies.[iv] Figure 4 includes the actual cost for a utility-scale solar project in the Caribbean, contract signed in 2017.

1.3.3 RESILIENCY

The impact of Hurricanes Irma and Maria in September 2017 highlight the importance of enhancing resiliency in the Caribbean region. The destruction caused by these storms was unprecedented, and demonstrated the underlying vulnerability of an electricity system that relies on centralized generation in one location. While the main generation station at Pockwood Pond survived the storms with minimal damage, significant damage throughout the grid left residents without power. With generation resources located in only one place, significant repairs have to be made throughout

FIGURE 4

HISTORICAL AND PROJECTED SOLAR PV INSTALLED COST



[iv] Cost projections were taken from leading industry projections from Greentech Media and Bloomberg New Energy Finance, although these cost projections are generally conservative.

the electricity grid network before power can reach customers.

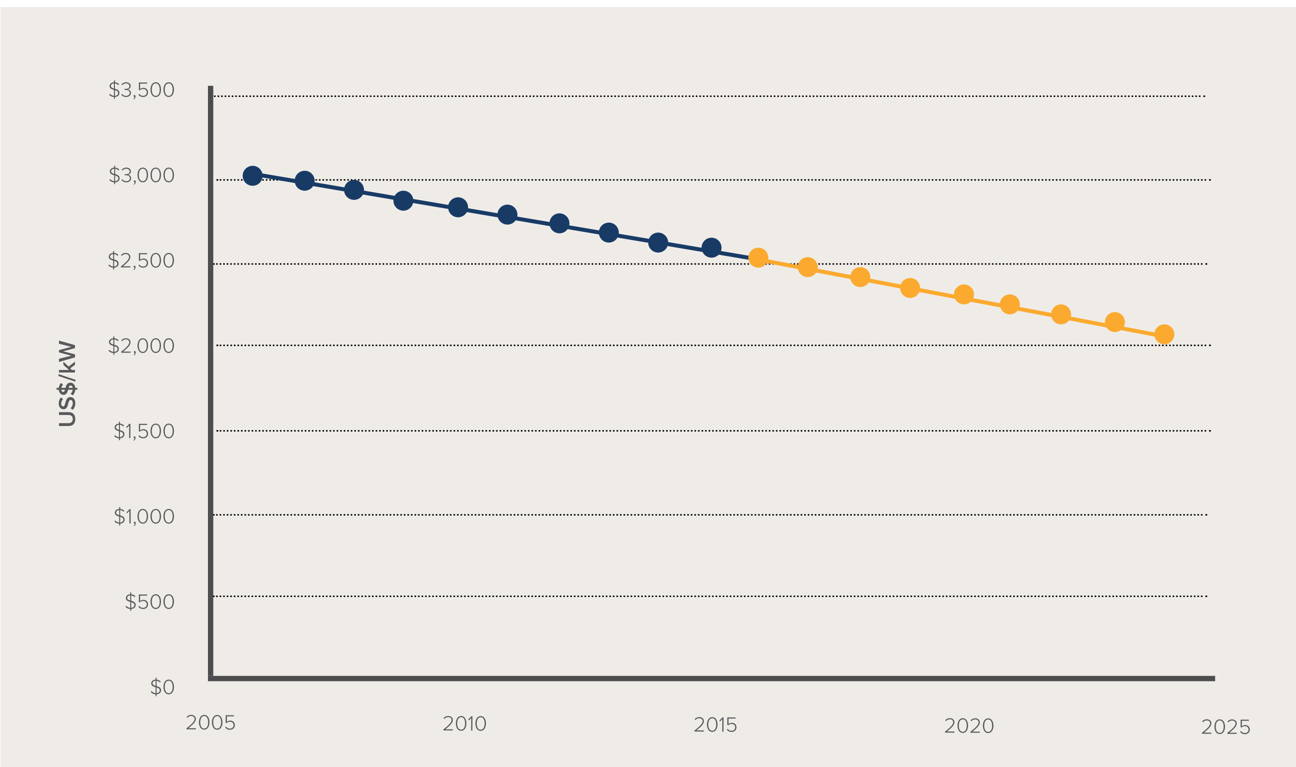
Predicted severe weather will impact the livelihoods of many people as global climate patterns continue to shift. In particular, fossil-fuel-based generation systems will represent a greater source of risk to small isolated systems that must import fuel. As energy is the lifeblood of the economy, and especially so on islands, a more resilient electricity system is essential to ensuring continued economic development.

A focus on resiliency is therefore warranted in the coming years, as island nations continue to prepare their infrastructure and systems to face future storm threats. While there are multiple ways to define resiliency, for the R-NETS process it is considered to be the ability to anticipate, absorb, adapt, and recover from a disruptive event or external shock in a timely manner. Various metrics exist for considering resilience, although there is not one set of commonly agreed-upon metrics. Resilience can be examined with respect to electricity generation resources, as well as the transmission and distribution grid; measures such as diversifying resource types, moving to a more distributed rather than centralized system, and installing all components to Category 5 Hurricane specifications contribute to increased resiliency.

To evaluate options for the future of the electricity

FIGURE 5

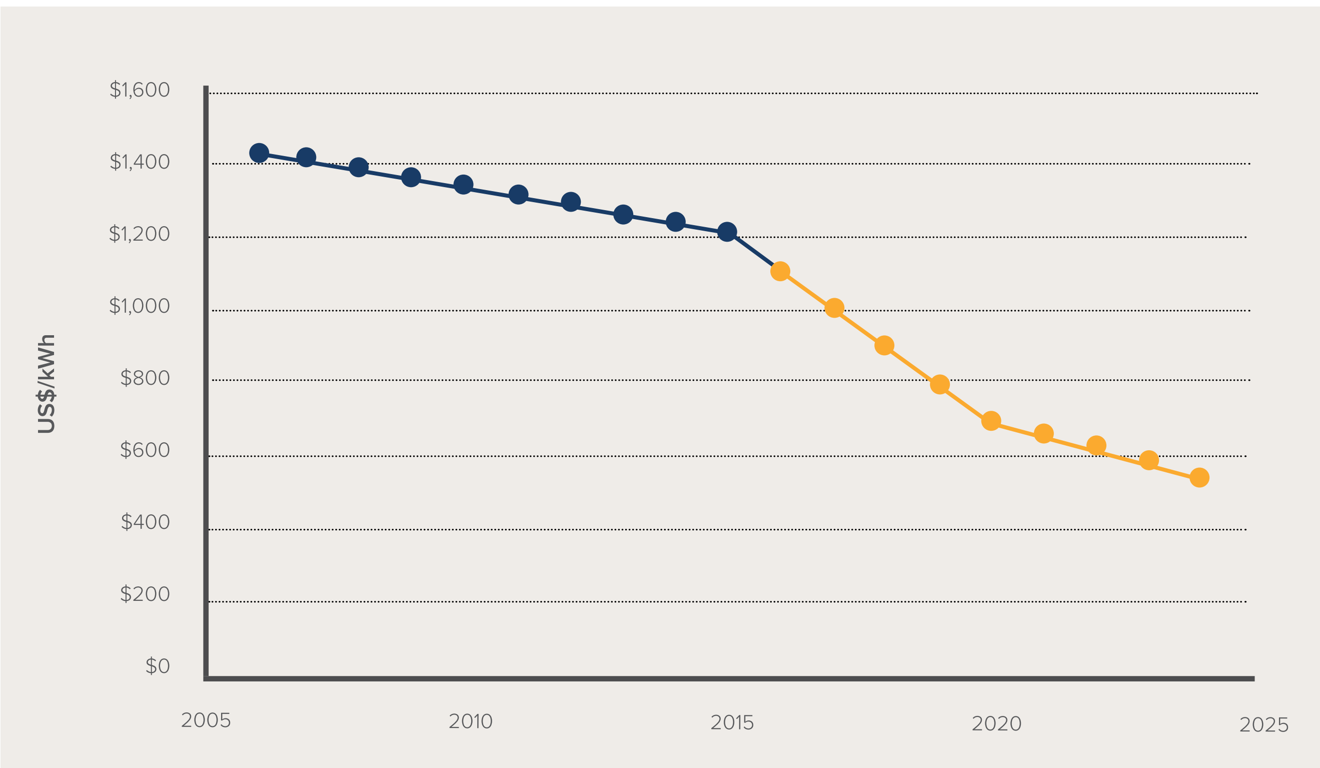
HISTORICAL AND PROJECTED WIND POWER INSTALLED COST



sector, the R-NETS includes considerations of resiliency related to the diversity of technology types, the cost volatility of various options, and the adaptability of different technologies in terms of their lead time to implement, modularity of installation size, and opportunity to deploy in diverse locations. While improving resiliency is a key objective within the R-NETS process and appears in its name, there are other priorities as well such as providing affordable electricity; this process seeks to balance multiple priorities to find the overall optimal pathway for the BVI in pursuit of the territory's overarching objectives.

FIGURE 6

HISTORICAL AND PROJECTED LITHIUM-ION BATTERY STORAGE INSTALLED COST



02 OVERVIEW AND METHODOLOGY

OVERVIEW AND METHODOLOGY

2.1 PURPOSE AND TIMING

Given the devastating impact of severe weather events in September 2017, and the recent reductions in costs for solar, wind, and energy storage technology, leaders in the BVI recognized an opportunity to undergo an integrated and objective R-NETS process. The unfortunate impact of Hurricane Irma did result in an opportunity to rebuild an electricity system that is more resilient, cost-effective, and sustainable.

The R-NETS was completed in partnership with the Ministry of Communications and Works, the Ministry of Natural Resources and Labour, and the British Virgin Islands Electricity Corporation (BVIEC)—the national electric utility company. The team from Rocky Mountain Institute (RMI) completed the analysis as an independent and objective third party. Additional technical support was provided by engineering firm DNV GL and GIS experts NepCol International. This section describes the general R-NETS approach as well as the methodology and specific analysis components that came together in this process.

2.2 KEY QUESTIONS EXPLORED IN THE R-NETS PROCESS

Partners embarked on the R-NETS process to determine the pathway forward to transition the BVI's electricity system towards and beyond its stated targets and goals. To do so, the R-NETS process explores options and aligns stakeholders along a common group of priorities and next steps for the BVI electricity sector. Specifically, the objectives included:

- Exploring potential options for electricity production and consumption
- Identifying a mix of resources that meets priorities and goals for the BVI electricity sector
- Aligning stakeholders around requirements and next steps needed to achieve their shared goals for the BVI electricity sector

To achieve these objectives, the R-NETS team followed six key steps in an iterative process. The first step was to forecast electricity demand from 2018 to 2037. In parallel, the RMI team facilitated alignment with stakeholders on the key priorities for the BVI energy sector. Next, the team conducted a detailed inventory and review of existing studies to assess the potential of resources and define the scenarios to explore. These scenarios were modelled from a technical and economic perspective to refine and distil the final five scenarios. Lastly, to test the performance of the five scenarios, the team assessed and evaluated the requirements needed to ensure that the transmission grid can absorb the generation mixes related to each scenario.

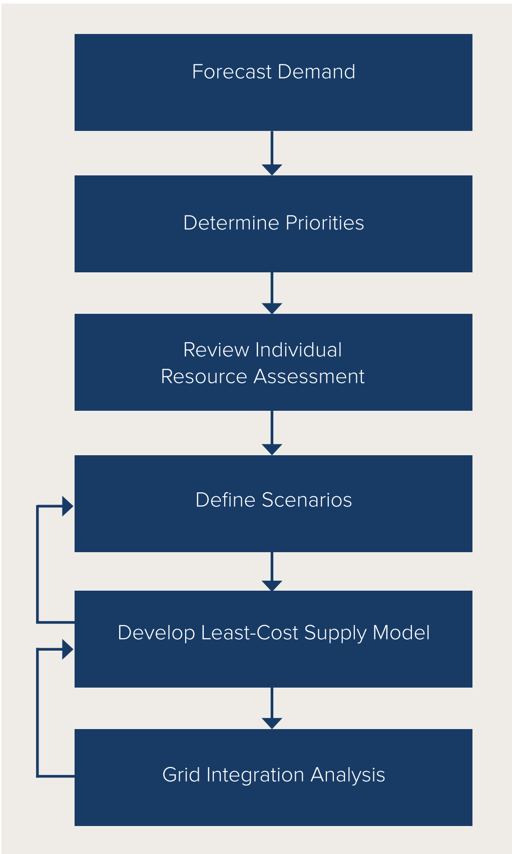
Figure 7 presents the process followed to undertake the R-NETS analysis. The following sections describe each of the components presented in the figure. While each component uses inputs from the previous step and the analysis flows from one to the next, there was iteration in R-NETS process, particularly where the results of the preliminary least-cost model affected the scenarios considered.

2.3 DEMAND FORECAST

The objective of the demand forecast model is to determine electricity needs from 2018 to 2037 using assumptions agreed upon during the February 2018 R-NETS meeting. The model estimates a baseline, high, and low demand forecast both with and without considering the implementation of energy efficiency (EE). Figure 8 includes the baseline, low, and high demand forecasts including EE, and the business-as-usual (BAU) demand forecast, which represents the baseline demand forecast without EE. The four demand

FIGURE 7

PROCESS FOLLOWED TO DEVELOP R-NETS



predictions grow rapidly for a reconnection and regrowth period through 2023, followed by a period of slower but continued growth through 2037.

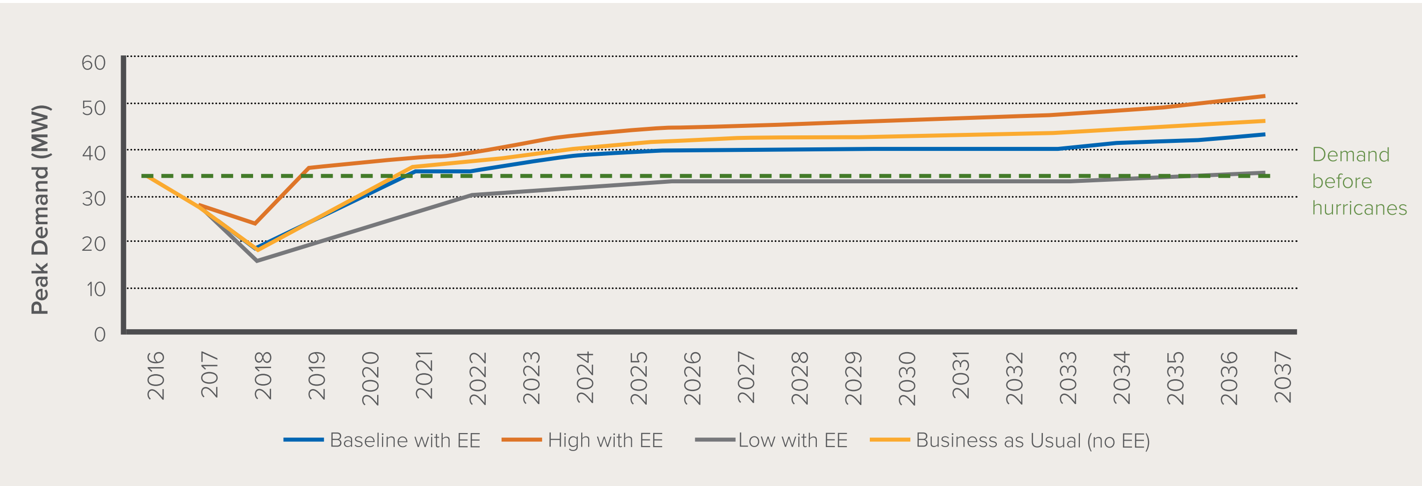
The reduction in demand from year 2016 to 2018 indicates Hurricane Irma's impact on electricity load. The four demand forecasts show different consumption levels in 2018. The model estimates load in 2017 equally for all forecasts, accounting for the reduction in customers and average consumption during the last three months of the year following the storms. The reduced number of customers and average consumption affects load during all of 2018—leading to a dip in load compared to 2017. The dip is more pronounced for the low and baseline demand forecasts because they include more conservative growth rates in consumption and customer reconnection that lead to a smaller bounce-back than the higher growth rate does. For more details on the demand forecast methodology and assumptions, please see Appendix A.

2.4 R-NETS SHARED PRIORITIES

The team convened a meeting among key stakeholders early in the process to discuss priorities for the future of the electricity sector in the BVI. This discussion built upon prior work completed in establishing the Virgin

FIGURE 8

BASELINE, LOW, HIGH, AND BUSINESS-AS-USUAL DEMAND FORECAST FOR R-NETS



Islands energy policy; the team did not begin at square one for the R-NETS, but instead used the foundation of prior work, and focused on synthesizing and collating critical information to develop a common fact base to inform decision-making.

The outcome of the meeting resulted in a set of five priorities, and a weighting value for each to reflect their relative importance. The RMI technical team suggested the selection of specific indicators to evaluate how well each priority and strategic objective would be met, based on past experience with similar island electricity systems. Table 4 shows the R-NETS priorities, strategic objectives, indicators, and points assigned to each.

2.5 INDIVIDUAL RESOURCE ASSESSMENT

Several studies assessing the potential of renewable resources in the BVI have been carried out in the past. These studies assessed renewable technologies including solar, waste to energy, and wind. Solar studies found a high-quality resource and identified potential locations on Tortola and Virgin Gorda including roof-mount, ground-mount, and carport systems. Based on these findings, the least-cost model places no cap on the amount of solar PV considered in each scenario. To validate this assumption, the R-NETS includes a geospatial assessment of the BVI to determine the space that exists for solar PV in ground and rooftop locations, and to ensure that the PV penetration included in the scenarios is possible; technical experts at NepCol International developed the SpatialEdge tool for the BVI to assess site viability for solar PV deployment. The SpatialEdge tool enables users to filter land parcels and rooftops based on various factors such as landslide risk in order to identify optimal sites that can be explored in more detail. More information on the SpatialEdge tool is included in Appendix B.

Previous studies assessing the potential of wind do not include the requisite level of detail to accurately determine the resource potential. The BVI Airports Authority measured wind speeds from January 2009 to December 2011 and found a good quality resource; however, this would need to be verified across multiple sites and the appropriate height required to optimize

TABLE 4

R-NETS PRIORITIES, STRATEGIC OBJECTIVES, INDICATORS, AND WEIGHTING

PRIORITY	STRATEGIC OBJECTIVE	INDICATORS	POINTS
RESILIENCY (26 TOTAL)	Build a robust electricity system that can withstand, respond, and adapt to external shocks	Diversity of resource mix; standard deviation of resource mix (%)	10
		Volatility; annual change in cost to generate (%) and fuel savings compared to BAU (litres)	4
		System adaptability (qualitative)	12
RELIABILITY (26 TOTAL)	Improve reliability of electricity delivered by BVI	Meeting N minus 2 criteria	13
		Meeting load and 10% operating reserve	13
LOW-COST (20 TOTAL)	Reduce generation costs	Cost to generate ($/kWh)	18
		Annual operating expense ($/y)	2
ENVIRONMENTAL STEWARDSHIP (14 TOTAL)	Increase renewable penetration and energy efficiency savings	Percentage penetration of renewables (%)	2
		EE Savings compared to BAU (MWh/y)	12
JOBS AND INDUSTRY CREATION (14 TOTAL)	Increase job creation and economic development	Increase in jobs (number)	12
		Increase in local investment ($)	2
TOTAL			100

the resource and site potential. In addition, the limited availability of land in Tortola limits the potential size of the wind resource in the BVI unless islands outside of Tortola are considered. As a result, the least-cost model places a cap of 8.2 MW (30 x 275 kW units) on the size of wind potential that can be developed.

Further, studies assessing the potential of waste to energy found that the volume of waste produced was insufficient to be commercially and economically viable for electricity generation. As such, the R-NETS does not consider waste to energy as a viable resource.

2.6 SCENARIOS

With individual resource options understood, six discrete scenarios were agreed upon to test through the R-NETS modelling efforts. The RMI technical team refined and narrowed these to five total scenarios to identify the least-cost mix of resources within each. Table 5 shows the resources explored within these five scenarios.

The core scenarios (SS, SWS, and SSEE) represent the economically optimal solutions for different resource

TABLE 5

OVERVIEW OF RESOURCES INCLUDED FOR BVI IN FIVE SCENARIOS

1	2	3	4	5
BAU	SS	SWS	SSEE	AGGRESSIVE SS
Business As Usual	Solar, Storage	Solar, Wind, Storage	Solar, Storage, Aggressive Energy Efficiency	Aggressive Solar, Storage

mixes and load sizes. That is, for a specific demand size and combination of resources, the core scenarios represent the least-cost systems. Alternatively, in the Aggressive SS scenario, renewables represent the largest generation source. The RMI technical team first determined the solar PV size needed to meet demand in a 100 per cent renewable system. Then the team introduced one 8.5 MW Wärtsilä genset to the model and optimized the storage size to determine the least-cost system with the solar installed capacity determined in the previous step. The BAU scenario represents a diesel-based system that meets future demand and operating reserves.

All scenarios except for Aggressive Solar Storage (Aggressive SS) include the three new 8.5 MW Wärtsilä generators installed under the Phase V project, and assume the retirement of the older existing Wärtsilä units. The BAU scenario includes three additional 6 MW diesel generators needed to meet forecasted demand.

All scenarios except for BAU also include different mixes of new resources in the BVI. These resources are not modelled at the project level; instead the model determines the economically optimal resource size to meet demand and operating reserves.[v]

The BAU scenario assumes growth in demand per the baseline forecast, resulting in an average 2.53 per cent growth per year. All other scenarios include energy efficiency (EE) measures such as efficient lighting and solar water heaters. Three of the scenarios—Solar Storage (SS), Solar Wind Storage (SWS), and Aggressive SS—assume an average 2.15 per cent demand growth per year given the implementation of EE. The SSEE scenario considers implementation of an aggressive EE program leading to an additional 10 per cent reduction in demand compared to BAU by 2023, and a 20 per cent reduction by 2037. This results in an average annual growth rate of 1.39 per cent. Table 6 summarizes the assumptions of demand growth for each scenario.

[v] Resources are not included in the least-cost model based on the sizes and characteristics of specific projects. Instead, the least-cost model optimizes for the total optimal amount of the resource using the characteristics of the resource and technology found in the region.

All demand estimates include electricity system losses; all scenarios include a reduction in net electricity losses (technical and non-technical) from 13 per cent (the 2017 actual) to 11 per cent in 2027.[vi] This estimated reduction is driven by a reduction in distribution losses to their 2015 levels (8 per cent).

2.7 LEAST-COST MODEL

With the type of resources in each of the scenarios defined, the RMI technical team used the HOMER Pro software to determine the economically optimal installed capacity of each resource per scenario. The HOMER Pro software completes an hourly dispatch of resources, to ensure that the basic requirements of load and operating reserves are met in every hour of the year. Due to the lack of hourly load data, the RMI technical team modelled hourly demand based on electricity demand in countries in the region with comparable power systems. The RMI technical team used HOMER Pro to run multiple simulations of different resource mixes to meet load and operating reserves; the least-cost option was selected that contains the resources specified for each scenario. Appendix C includes details on the key assumptions included in the least-cost model.

Table 7 and Figure 9 show the optimal amount of new resources by 2023 for each scenario. Table 8 and Figure 10 show the annual electricity generation by resource in year 2023.

TABLE 6
ASSUMPTIONS OF DEMAND GROWTH RATES FOR EACH SCENARIO

SCENARIO	2017 TO 2037 (%)	2017 TO 2023 (%)	2023 TO 2037 (%)
BAU	2.53	5.52	1.27
SS	2.15	4.77	1.05
SWS	2.15	4.77	1.05
SSEE	1.39	3.68	0.42
AGGRESSIVE SS	2.15	4.77	1.05

[vi] Electricity losses represent the electricity lost in delivering electricity to consumers through the transmission and distribution (T&D) system. There are two types of losses: technical and non-technical losses. Technical losses represent electricity dissipated due to the characteristics of the T&D system and how it is operated. Non-technical losses represent losses due to non-metered consumption (such as electricity theft) and billing errors.

TABLE 7

INSTALLED CAPACITY BY SCENARIO BY 2023 (MW)

SCENARIO	NEW DIESEL (MW)	NEW SOLAR (MW)	NEW STORAGE (MWH)	NEW WIND (MW)
BAU	18	-	-	-
SS	-	75	145	-
SWS	-	69	65	8
SSEE	-	57	30	-
AGGRESSIVE SS	-	328	620	-

FIGURE 9

INSTALLED CAPACITY BY 2023 FOR EACH SCENARIO

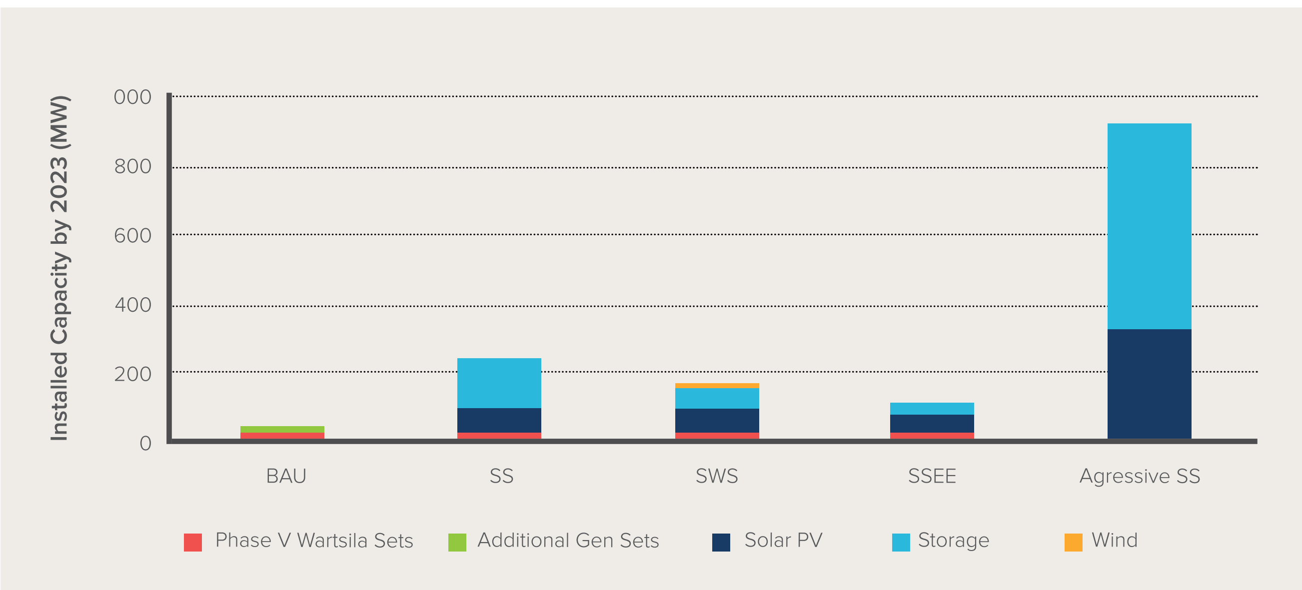
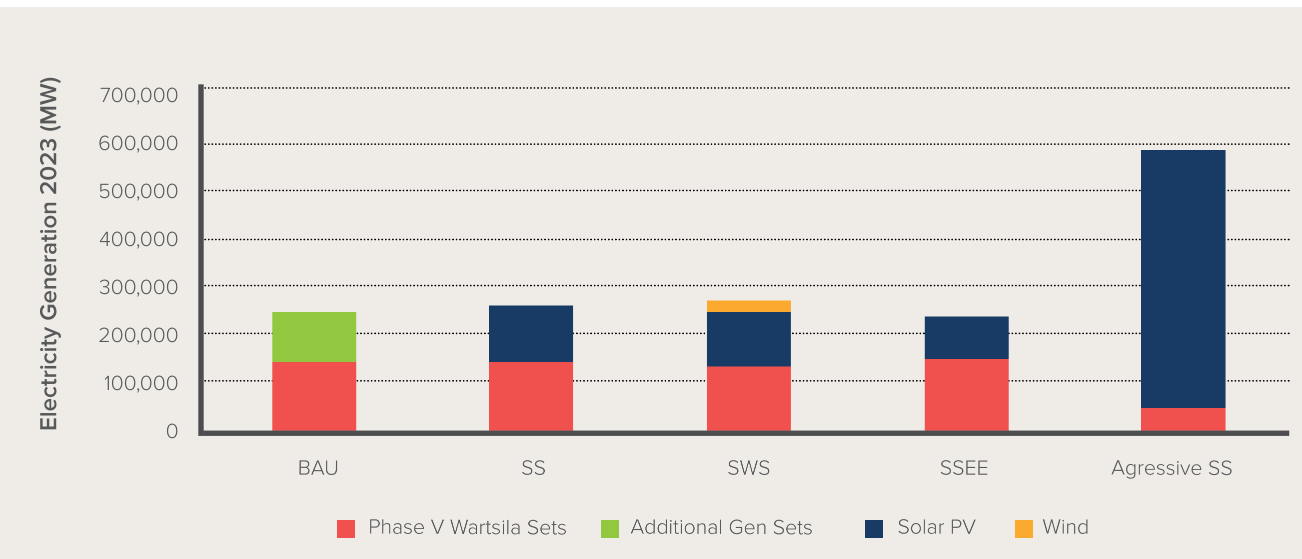


TABLE 8
ANNUAL GENERATION BY SCENARIO IN 2023 (MWH)

SCENARIO	ANNUAL DEMAND (MWH)	DIESEL (MWH)	SOLAR (MWH)	WIND (MWH)
BAU	249,761	249,761	-	-
SS	239,252	141,335	123,315	-
SWS	239,252	136,979	112,726	21,663
SSEE	224,786	148,773	94,142	-
AGGRESSIVE SS	239,252	50,827	538,100	-

FIGURE 10
ANNUAL GENERATION IN 2023 FOR EACH SCENARIO



2.8 GRID INTEGRATION ANALYSIS

Technical experts at DNV GL completed a preliminary transmission-level study. The grid integration analysis assesses the capacity limits of the transmission system to safely transmit higher levels of generation. The results indicate how much capacity is available at each of the main BVI substations to interconnect new generation resources. These results provide initial insights on potential locations for interconnecting new projects, and can be utilized together with the SpatialEdge tool, which focuses on space availability for new projects. However, new projects will require targeted analysis at the distribution grid level to determine whether any grid upgrades would be required to interconnect new resources.

2.9 SCENARIO EVALUATION

After incorporating the grid integration results into the overall analysis described in this section, the team completed the R-NETS process by evaluating the five scenarios against the shared priorities. The results of that evaluation form the recommendations of the R-NETS process described in the following section.

03 RESULTS

RESULTS

The R-NETS analysis examined various options for the BVI to realize economic benefits, obtain greater resiliency, and increase renewable penetration. The results indicate that moving forward with identified renewable projects and adopting energy efficiency measures enables the BVI to meet its goals and priorities for the electricity system. Specifically, moving towards greater renewable penetration and energy efficiency provides the BVI an opportunity to:

- Reduce volatility of electricity costs by up to 9 per cent by reducing diesel fuel use by 21.7 million litres annually.
- Diversify sources of technology by increasing renewable penetration by up to 34 per cent.
- Reduce generation costs by up to 27 per cent.
- Create over two times as many jobs and spur local investment by over $150 million compared to BAU.

Table 9 shows the final results for the five scenarios. The SSEE scenario received the highest score—75 out of the possible 100. The R-NETS results show that all scenarios including renewables and energy efficiency outperform BAU across all priorities with the following exceptions:

- BAU outperforms renewable scenarios in the reliability priority due to a higher score in the N minus 2 criteria (see Section 3.2 for further detail on reliability scores).
- BAU outperforms the Aggressive SS scenario in the low-cost category due to the significant investments required in the Aggressive SS scenario.

These results indicate that there are several options for the BVI to transition to an electricity system that meets the territory's priorities and goals. The BAU scenario receives the lowest overall score of 57, highlighting the opportunity to transition to new resources.

TABLE 9

FINAL SCORES FOR FIVE R-NETS SCENARIOS

PRIORITY	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
RESILIENCY	26	15	20	23	22	22
RELIABILITY	26	26	15	16	15	16
LOW-COST	20	14	16	18	19	8
ENVIRONMENTAL STEWARDSHIP	14	0	6	6	13	7
JOBS AND INDUSTRY CREATION	14	3	8	8	6	14
TOTAL	100	57	65	71	75	67

Scenarios containing renewable resources outperform BAU in terms of resiliency. Scenarios with higher renewable penetration provide a greater hedge against volatility in fuel costs; in scenarios with higher renewable penetration, diesel accounts for a smaller percentage of generation and so electricity costs are less affected by changes in fuel price. Similarly, scenarios with a greater number of and more equal spread across technology sources perform better in terms of diversity of technology. Both of these factors are part of the resiliency priority result.

All renewable scenarios receive similar scores for reliability. However, the BAU scenario receives the highest score for the N minus 2 criteria so that its final score for reliability outperforms renewable scenarios' scores. The N minus 2 criteria ensures that load can be met even when the two largest generators are out of service—not due to a sudden external shock, but due to a routine issue such as requiring maintenance. The R-NETS analysis evaluates the ability to meet electricity demand without the two largest generators over one whole year, taking a very conservative approach to assessing this indicator. If there were an extended period requiring this mode of operation, measures could be taken on both the supply and demand sides to ensure reliable electricity service even in highly renewable scenarios.

All core scenarios (SS, SWS, and SSEE) including energy efficiency have lower electricity costs—energy efficiency is the lowest-cost individual option and requires the least amount of capital investment. Alternatively, the Aggressive SS scenario, which requires a larger capital investment in new installed capacity, leads to significantly higher generation costs compared to BAU. The larger investment also leads to higher job growth and local investment compared to the other scenarios. Nonetheless, the higher funding requirement of the Aggressive SS scenario uses funds that could be deployed elsewhere. Additionally, lower generation costs increase economic activity and jobs, and this job growth often dwarfs job growth related to the immediate construction of projects.

All renewable scenarios allow the BVI to meet and exceed its stated renewable targets of 30 per cent by 2023.

The following sections describe in more detail the results of the R-NETS analysis.

3.1 RESILIENCY

R-NETS results indicate an opportunity to increase the resiliency of the electricity system in the BVI. The destruction of the electricity system caused by Hurricanes Irma and Maria in September 2017 shows the importance of a resilient electricity system that can better withstand and recover from Category 5 hurricanes. Table 10 shows that renewable scenarios outperform the BAU scenario in the three indicators considered: diversity of technology, cost volatility, and system adaptability. The following sections describe each of these indicators.

3.1.1 DIVERSITY OF TECHNOLOGY

Introducing renewables diversifies the BVI's portfolio of electricity generation and increases the resiliency of the electricity system. Diversifying sources of generation leads to greater resiliency by strengthening the electricity system's ability to withstand external shocks. While an external shock may affect one resource, it is less likely to affect all resources to the same extent. Different technologies involve different levels of uncertainty related to price and availability. Diversifying a country's portfolio of generation technologies hedges the electricity system against volatility in price and availability of any one specific technology.

The diversity-of-technology indicator measures the standard deviation of the percentage-installed capacity of each technology. Standard deviation measures how

TABLE 10

FINAL SCORES FOR FIVE SCENARIOS FOR RESILIENCE PRIORITY

PRIORITY	INDICATOR	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
RESILIENCY	Diversity of Technology	10.00	3.59	6.90	10.00	8.61	5.79
	Cost Volatility	4.00	0.20	1.39	1.42	1.24	4.00
	System Adaptability	12.00	11.20	12.00	11.38	11.85	11.91
TOTAL		26.00	14.99	20.29	22.79	21.70	21.70

dispersed installed capacities for each technology are from an equal distribution across all technologies (diesel, solar, storage, and wind). The scenarios with lower standard deviation values receive higher scores.

Figure 11 shows the breakdown of installed capacities for each technology for all scenarios. A lower standard deviation value represents a system with a greater number and more even spread of technologies. The SWS scenario receives the highest score because it has the greatest number of technologies and a more even spread of installed capacities per technology. In general, renewable scenarios, which include diesel as well as renewable technologies, receive higher scores compared to the BAU scenario.

3.1.2 COST VOLATILITY

Cost volatility caused by rapid changes in fuel prices represent external shocks to the electricity system that can lead to instability in electricity rates or, if costs are not fully passed on to consumers, to the utility's ability to recover its costs. Cost volatility is a function of the amount of diesel used in a scenario and the price of diesel. Each scenario's score for the cost volatility indicator is based on diesel fuel savings and change in the cost to generate given a volatile fuel price.

Figure 12 shows a comparison of the amount of diesel fuel saved by scenario relative to BAU. The 2013 Energy Policy envisions reducing fossil fuel imports by 20 per cent by 2021. All scenarios that include renewables are less reliant on diesel, moving the BVI towards its stated target and leading to more predictable costs to generate.

Fuel price represents a major driver of change in system generating costs. The R-NETS analysis uses the baseline fuel price forecast for 2023 based on Energy Information Administration (EIA) projections. Through sensitivity analysis, the team also tested the impact of a more volatile diesel fuel price on costs to generate. Testing with more volatile fuel prices is helpful to

FIGURE 11

DIVERSITY OF TECHNOLOGY FOR EACH SCENARIO

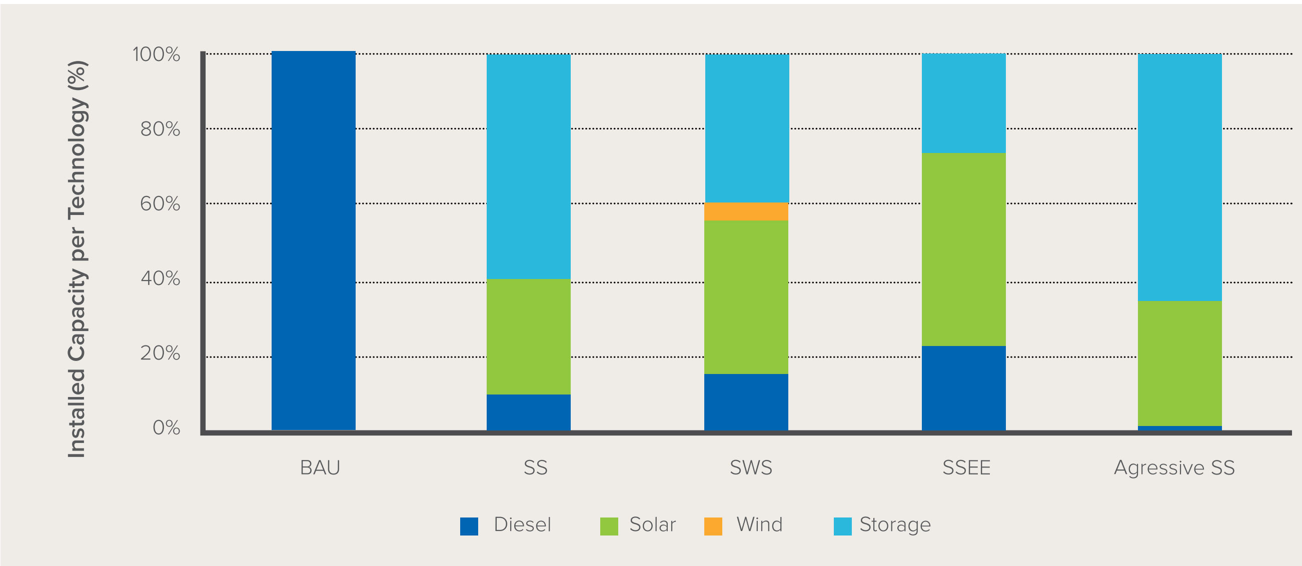


FIGURE 12

LITRES OF DIESEL SAVED PER YEAR BY SCENARIO COMPARED TO THE BAU SCENARIO

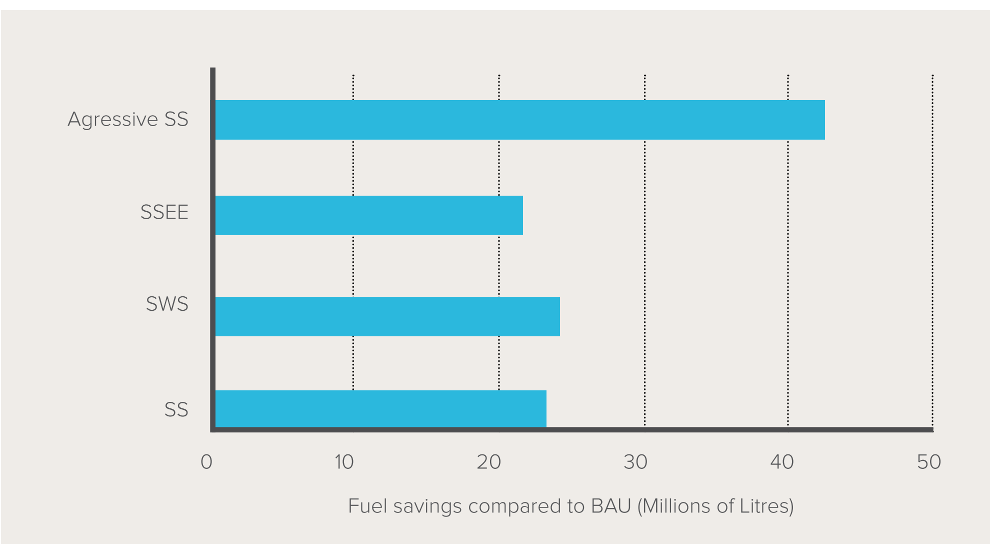
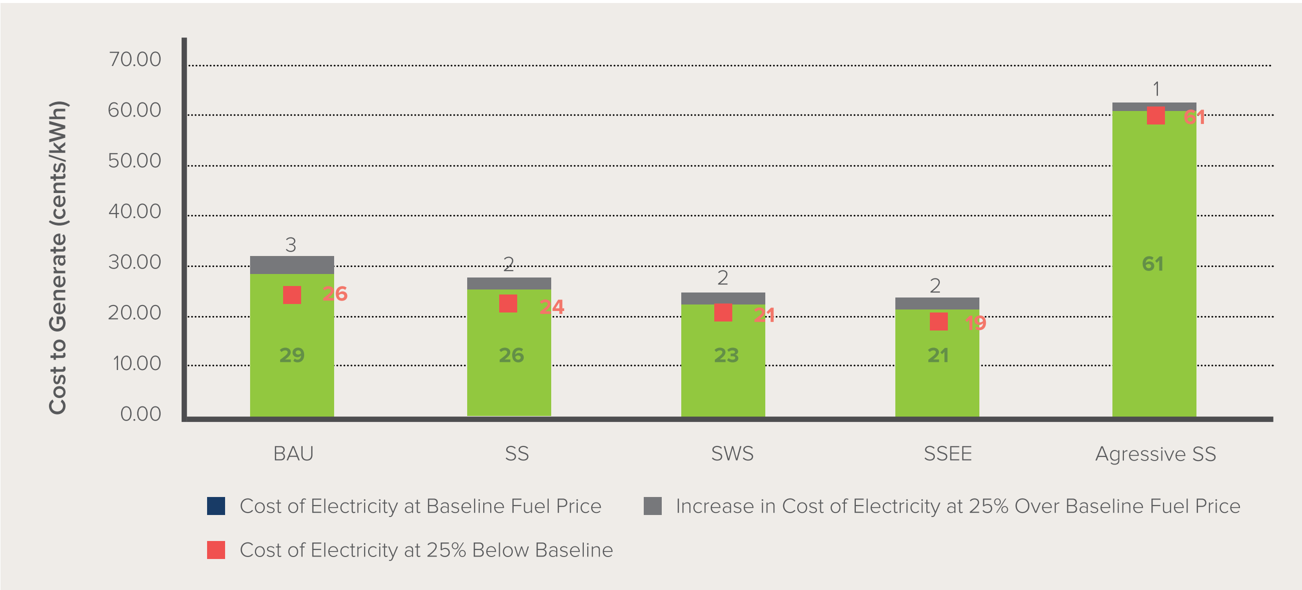


FIGURE 13

CHANGE IN GENERATING COSTS IN EACH SCENARIO DUE TO A 25% FUEL PRICE INCREASE AND DECREASE IN 2023



understand how the system reacts to sudden fuel price changes. Figure 13 illustrates the increase and decrease in generation costs resulting from increasing and decreasing fuel price by 25 per cent. Renewable scenarios that are less reliant on diesel reduce exposure to cost volatility and outperform the BAU scenario.

3.1.3 SYSTEM ADAPTABILITY

The team used the qualitative metric of system adaptability to evaluate the scenarios on how easy it is to adapt the selected pathway against changing conditions. Each scenario's score is based on three indicators. The indicators include the lead time to implement technologies, the modularity of the technologies, and the extent to which technologies can be spatially distributed. Modularity refers to the flexibility to tailor and modify total technology size to a system's needs. Lead time refers to the time between the beginning of a project and its completion—commissioning of the generating unit. Diversification of location refers to the potential of spatial diversification of a technology. Increasing spatial diversification reduces the vulnerability of the energy supply from a single event or a single location.

Making predictions to base decisions is more difficult in a context with a greater number of exogenous shocks. A measure that captures how easy it is to modify and tailor the selected pathway to changing conditions provides a valuable perspective to assess the five scenarios.

Table 11 presents the system adaptability scores for each scenario. All scenarios receive similar scores. SS, SSEE, and Aggressive SS receive marginally higher scores due to solar, energy efficiency, and storage's higher modularity and greater ability to spread out geographically compared to wind and diesel.

TABLE 11
SYSTEM ADAPTABILITY SCORES FOR EACH SCENARIO

INDICATORS	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
WEIGHTED MODULARITY SCORE	4.00	3.20	3.55	3.33	3.46	3.45
WEIGHTED LEAD TIME SCORE	4.00	4.00	4.00	3.84	3.92	4.00
WEIGHTED DIVERSIFICATION OF LOCATION SCORE	4.00	2.40	2.74	2.59	2.77	2.76
TOTAL	12.00	9.60	10.29	9.75	10.16	10.21

3.2 RELIABILITY

The R-NETS results show that all scenarios meet load and a 10 per cent operating reserve (generating capacity operating and available to meet a 10 per cent change in load, 25 per cent change in solar output, and 50 per cent change in wind output at any time). None of the scenarios can meet demand at all times during the year when the two largest generators are offline (representing an N minus 2 criteria), however BAU has the lowest unmet demand and receives the highest score. Given the conservative approach to evaluating the N minus 2 criteria in the R-NETS analysis, the renewable scenarios receive slightly lower scores for reliability. However, options are available to ensure electricity system reliability both under normal operations and in an N minus 2 situation, when renewable resources make up a large part of the generation mix. These include demand-side management to better align demand with production from renewable resources, and using new approaches for forecasting the expected output from renewable resources, among others.

Table 12 presents the final scores for each scenario for the reliability goal. Indicators include whether the scenarios meet the N minus 2 criteria as well as the load and operating reserve requirement. Given the time constraints of this analysis, the study does not consider other potentially useful indicators for reliability. However, the BVI should consider other indicators when developing new projects to determine the grid investment requirements needed to ensure the reliability of the electricity system. Examples of other analyses and indicators the BVI should consider include a power flow analysis, loss of load expectation (LOLE), system average interruption duration index (SAIDI), and system average interruption frequency index (SAIFI).

3.2.1 MEETING N MINUS 2 CRITERIA

The N minus 2 criteria illustrates the electricity system's ability to meet hourly load during the year if the two largest generating units are out of service. It is unlikely that the two largest generating units would be offline for a full year, but they could go offline for shorter periods of time to undergo maintenance. Running the test for a full year ensures it captures

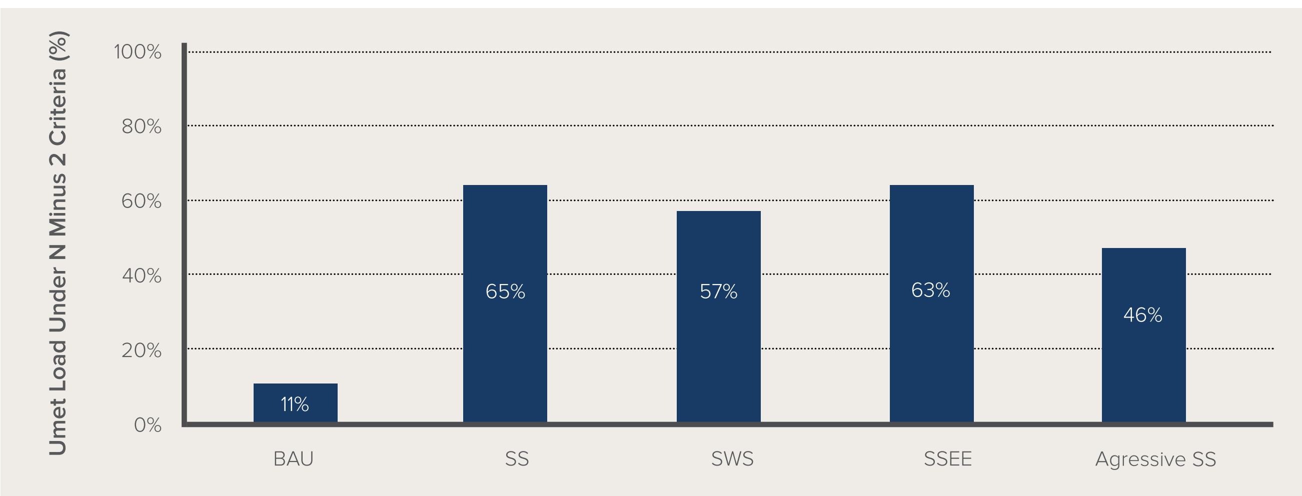
TABLE 12

FINAL SCORES FOR FIVE R-NETS SCENARIOS FOR RELIABILITY PRIORITY

PRIORITY	INDICATOR	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
RELIABILITY	Meeting N Minus 2 Criteria	13.00	13.00	2.22	2.53	2.27	3.10
	Meeting Load and Operating Reserve	13.00	13.00	13.00	13.00	13.00	13.00
TOTAL		26.00	26.00	15.22	15.53	15.27	16.10

FIGURE 14

N MINUS 2 CRITERIA FOR EACH SCENARIO



rainy days when the solar PV output is low, the storage cannot be fully charged, and the two largest generators are down for maintenance. Since the renewable scenarios do not include additional diesel capacity beyond the existing Phase V units, the lower dispatchability of renewable sources of generation may affect the reliability of the system.

The results show that none of the scenarios meet the N minus 2 criteria when it is tested using the conservative approach used here to assess one full year. However, the BAU scenario has the smallest amount of unmet demand and so receives the highest score. Figure 14 shows the percentage of unmet demand over one year when the two largest generating units are offline for each scenario.

3.2.2 LOAD AND OPERATING RESERVES

As part of the least-cost model, the team used the Homer Pro microgrid modelling software to model the hourly operation of the electricity system for each of the five scenarios. The model ensures that the electricity systems of all scenarios meet the load for every hour in the year plus a 10 per cent operating reserve margin. This modelling constraint ensures that generation capacity is available in each hour to instantaneously respond to a sudden change in electricity demand of up to 10 per cent, in addition to a sudden change in output from solar of up to 25 per cent, and a sudden change in output from wind of up to 50 per cent.

3.3 LOW COST

The R-NETS results indicate an opportunity to reduce both total generating costs and operating expenses. The results of the analysis conclude that energy efficiency leads to lower costs for both indicators. Increasing renewable penetration leads to lower operating expenses and lower total generating costs compared to BAU in all scenarios that economically optimize resource mixes (SS, SWS, and SSEE). Renewable penetration beyond optimal levels (Aggressive SS) increases generation costs significantly compared to BAU. Table 5 presents the final scores for each scenario; this section describes the R-NETS results related to the low-cost priority.

3.3.1 COST TO GENERATE

Renewables and energy efficiency reduce the cost to generate electricity. Figure 15 shows that except for the Aggressive SS scenario, every renewable scenario decreases the cost to generate compared to BAU. These results suggest that increasing renewable penetration lowers cost to generate as long as RE resource sizes do not exceed the sizes related to the economically optimal resource mixes (SS, SWS, SSEE) for the assumed demand levels.

Energy efficiency lowers the costs to generate. This intuitively makes sense—energy efficiency represents the lowest-cost option (LCOE of $0.07/kWh, estimated based on an assessment of EE potential and implementation cost for a comparable energy

TABLE 13
FINAL SCORES FOR FIVE R-NETS SCENARIOS FOR LOW-COST PRIORITY

PRIORITY	INDICATOR	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
LOW-COST	Cost to Generate ($/kWh)	18	13.16	14.78	16.88	18.00	6.21
	Operating Expense ($ millions/ year)	2	0.48	1.00	1.05	1.00	2.00
TOTAL		20	13.64	15.78	17.93	19.00	8.21

FIGURE 15

COST TO GENERATE FOR EACH SCENARIO BY 2023

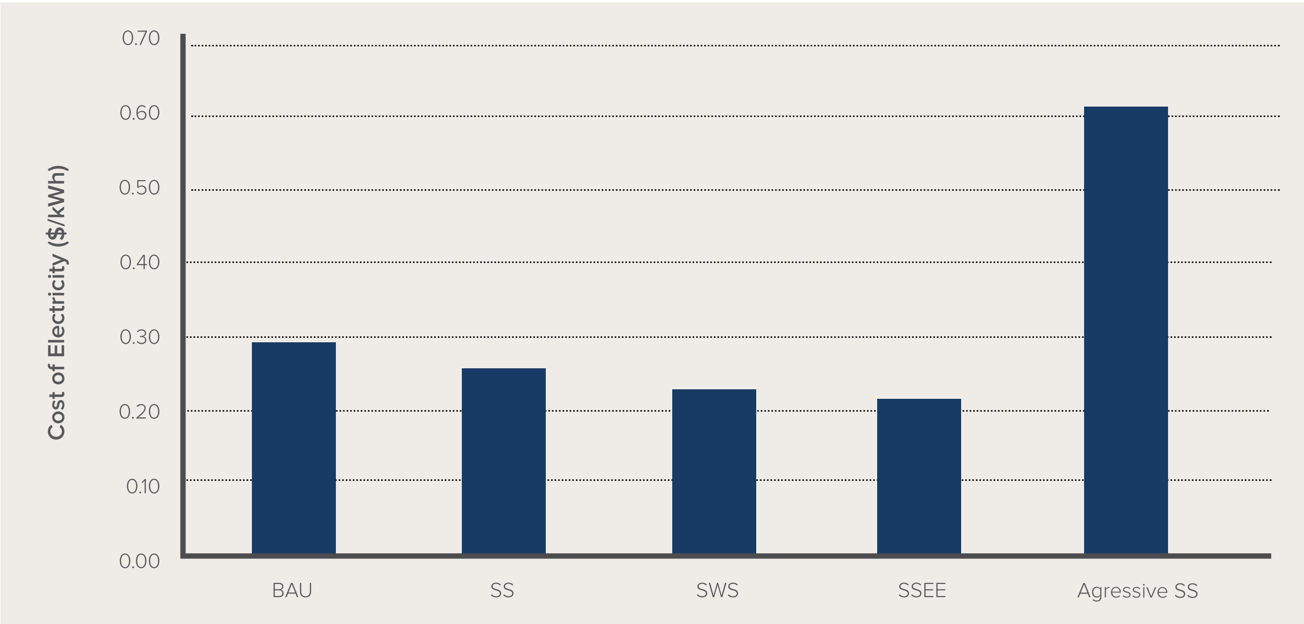
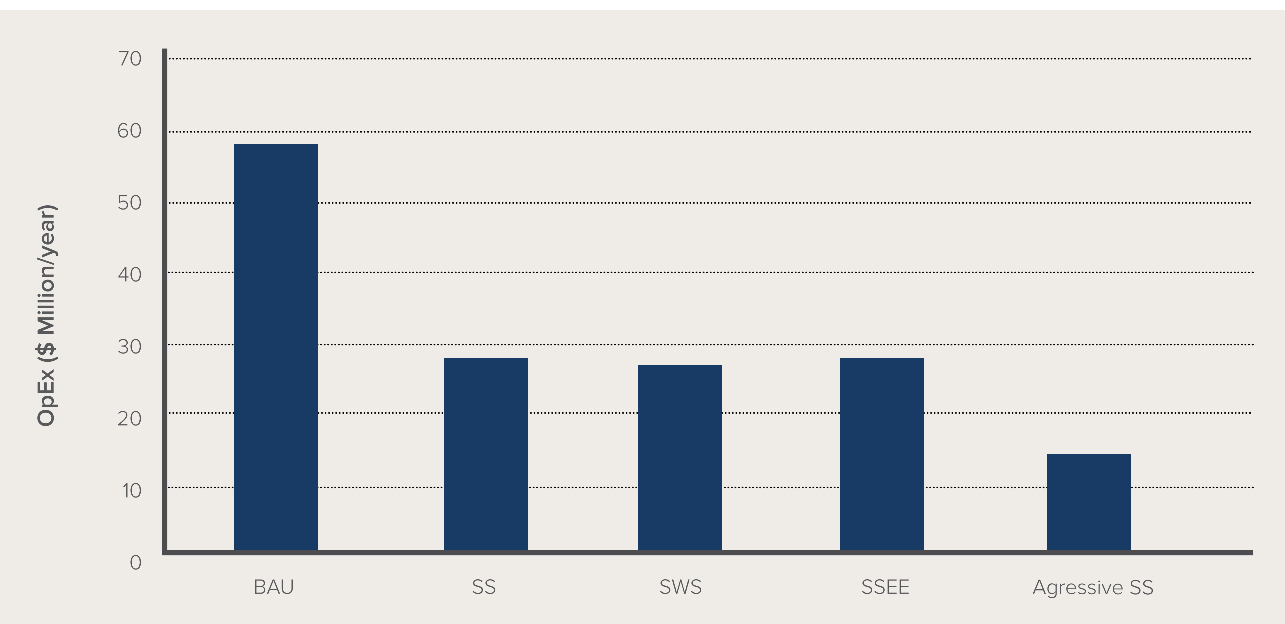


FIGURE 16

ANNUAL OPERATING EXPENSES FOR EACH SCENARIO BY 2023



efficiency program in Saint Lucia). Scenario SSEE, the only scenario with the aggressive EE program, leads to the lowest cost to generate. These results suggest that increasing energy efficiency savings (kWh) leads to a greater reduction in generation costs than increasing electricity supplied (kWh) by renewable sources.

3.3.2 OPERATING EXPENSES

Understanding the operating expenses of different scenarios represents an important measure of performance. Operating expenses (OpEx) reflects the operational efficiency of an electricity system by illustrating the costs necessary to operate the system. The inability of a utility to recover OpEx through revenue (under current tariff structures) indicates that the utility is unable to cover its day-to-day operations. A utility that is unable to recover OpEx is also unable to meet its debt obligations and is unlikely to obtain external funding to finance capital expenditures. Figure 16 shows the annual OpEx for each scenario.

The BVI R-NETS results indicate that the Aggressive SS scenario has the lowest OpEx while the BAU scenario has the highest. These results show that higher renewable penetration leads to lower OpEx. Renewable systems have lower operational and maintenance costs and require much less fuel, leading to a significant reduction in OpEx compared to diesel-based electricity systems.

3.4 ENVIRONMENTAL STEWARDSHIP

R-NETS results indicate an opportunity to achieve at least 34 per cent renewable energy penetration and up to 10 per cent electricity savings from energy efficiency by 2023. Table 6 shows the final scores for each scenario for the Environmental Stewardship priority, and this section describes the results related to this goal.

3.4.1 RE PENETRATION

The BVI established a target of supplying 30 per cent of electricity from renewable sources by 2023. Figure 17 shows the renewable penetration

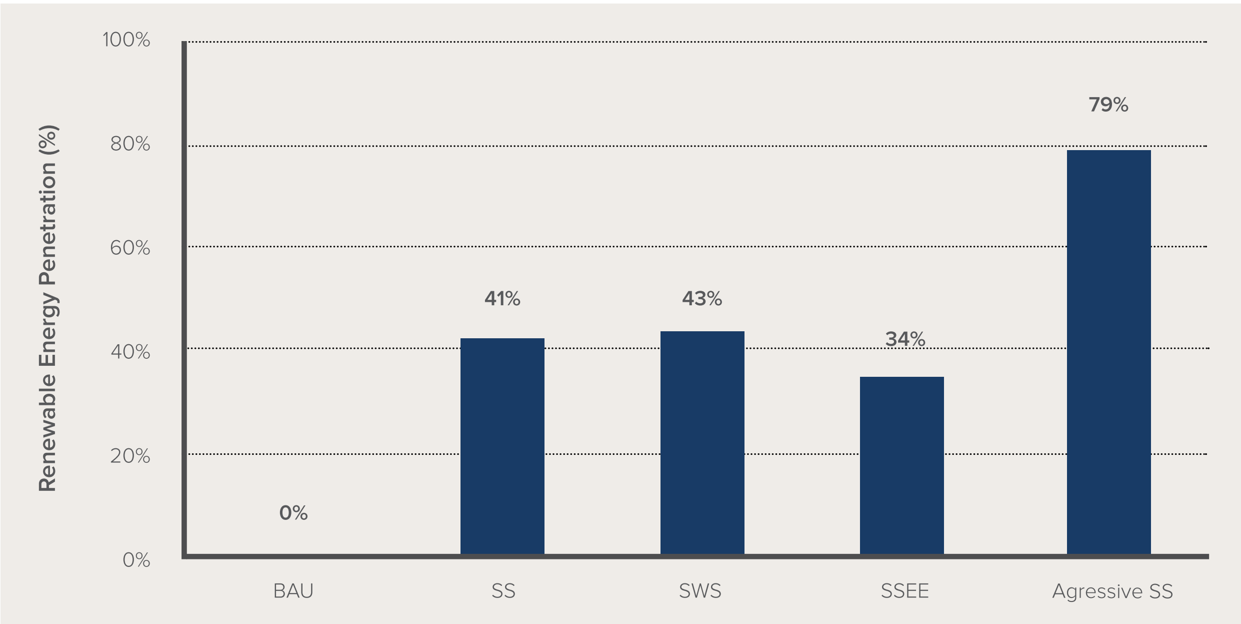
TABLE 14

FINAL SCORES FOR FIVE SCENARIOS FOR ENVIRONMENTAL STEWARDSHIP PRIORITY

PRIORITY	INDICATOR	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
ENVIRONMENTAL STEWARDSHIP	Renewable Energy Penetration	2.00	0.00	1.04	1.09	0.86	2.00
	Energy Efficiency Savings Compared to BAU	12.00	0.00	5.05	5.05	12.00	5.05
TOTAL		14.00	0.00	6.09	6.14	12.86	7.05

FIGURE 17

RENEWABLE PENETRATION FOR EACH SCENARIO BY 2023



for each scenario by 2023, demonstrating that all renewable scenarios meet the BVI's stated target for renewable penetration.

There are multiple ways to calculate renewable penetration. For this R-NETS, the team calculated renewable penetration as the per cent of annual energy demand met by renewable energy, shown in the equation below.

$$RE\% = \frac{\text{Total Annual kWh Demand - Diesel Annual kWh Generated}}{\text{Total Annual kWh Demand}}$$

Figure 17 shows that the Aggressive SS scenario reaches the highest renewable penetration of almost 80 per cent. The economically optimal amounts of resources in the SS and SWS scenarios lead to similar levels of renewable penetration ranging from 41 to 43 per cent. With an aggressive EE program in place, fewer new supply resources are required to meet demand. As such, the SSEE scenario reaches a lower renewable penetration of 34 per cent.

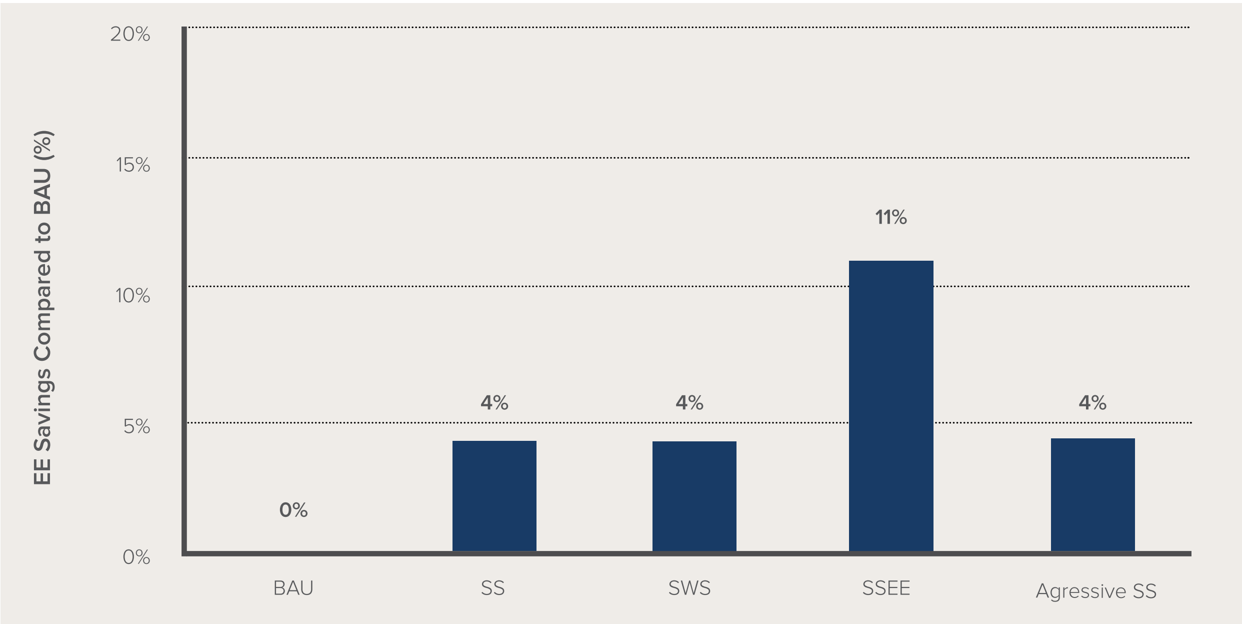
3.4.2 ENERGY EFFICIENCY SAVINGS COMPARED TO BAU

Energy efficiency represents the lowest-cost individual option. The 2013 Energy Policy envisions that 50 per cent of consumers will use energy conservation measures by 2021. Additionally, key stakeholders in the energy sector including representatives of the Ministry of Communications and Works and BVIEC have stressed the importance of achieving greater energy efficiency for the sector. Figure 18 shows the opportunities for savings in electricity from energy efficiency for each scenario by 2023.

Energy efficiency savings were calculated in two steps. First, the reduction in annual electricity demand compared to BAU for each scenario was conducted. Then, this number was divided by the annual

FIGURE 18

SAVINGS IN ELECTRICITY FROM ENERGY EFFICIENCY FOR EACH SCENARIO BY 2023



electricity demand for each scenario. The process is presented in the equation below.

$$\frac{\text{BAU Scenario Annual Demand-RE Scenario Annual Demand}}{\text{Total Annual kWh Demand}}$$

Figure 18 shows that the SSEE scenario achieves the highest energy efficiency savings of 11 per cent by 2023, whereas the other renewable scenarios achieve more moderate energy efficiency savings of 4 per cent.

3.5 JOB AND INDUSTRY CREATION

R-NETS results indicate an opportunity to increase the jobs in the energy sector and spur economic development in the BVI. Table 15 presents the final scores for each scenario for the priority related to job and industry creation. The table shows that renewable scenarios outperform BAU in this metric. Renewable scenarios include larger expansions in installed capacity and bigger investments leading to greater job creation and local investment. This section describes these findings in greater detail.

3.5.1 INCREASE IN JOBS

To test the objective of increasing the number of jobs available in the energy sector, the team drew on existing international models and reports on job creation across different energy technologies. Further investment in locally generated renewable energy stands to produce higher job growth than fossil-fuel-based technologies, across all assessed technologies. This is a trend that has been well documented by the United States Department of Energy (DOE) and other large organizations.

The 2017 US Energy and Employment Report notes that roughly five times as many people are employed

TABLE 15

FINAL SCORES FOR FIVE SCENARIOS FOR JOBS AND INDUSTRY CREATION PRIORITY

PRIORITY	INDICATOR	POSSIBLE	BAU	SS	SWS	SSEE	AGGRESSIVE SS
JOBS AND INDUSTRY CREATION	Increase in Jobs	12.00	2.52	7.48	8.10	5.71	12.00
	Increase in Investments (CapEx)	2.00	0.01	0.46	0.35	0.22	2.00
TOTAL		14.00	2.53	7.94	8.45	5.93	14.00

in the US renewable energy sector compared with the conventional energy sector. While the BVI is subject to a different set of constraints and opportunities in terms of job growth potential, this analysis utilized the best available data from the US to assess differences in job creation potential between scenarios.

The analysis drew from the Jobs and Economic Development Impact (JEDI) model developed by the National Renewable Energy Lab (NREL) to estimate the potential for both temporary (construction) and permanent job growth. The JEDI model takes a wide set of inputs and metrics into consideration to estimate the amount of jobs that can be created per unit of installed capacity. For technologies and scenarios where the JEDI estimates were incomplete, this analysis drew on reports from the US DOE, the International Energy Agency (IEA), the Solar Energy Industries Association (SEIA), and others to complete calculations. In the analysis, permanent jobs were weighted as 50 per cent more valuable than construction jobs to determine the total number of jobs generated for the new installed capacity in each scenario. Construction jobs were also weighted based on the duration of the construction time period ranging from one to three years for solar, diesel, and wind.

FIGURE 19

RELATIVE INCREASE IN JOBS FOR EACH SCENARIO

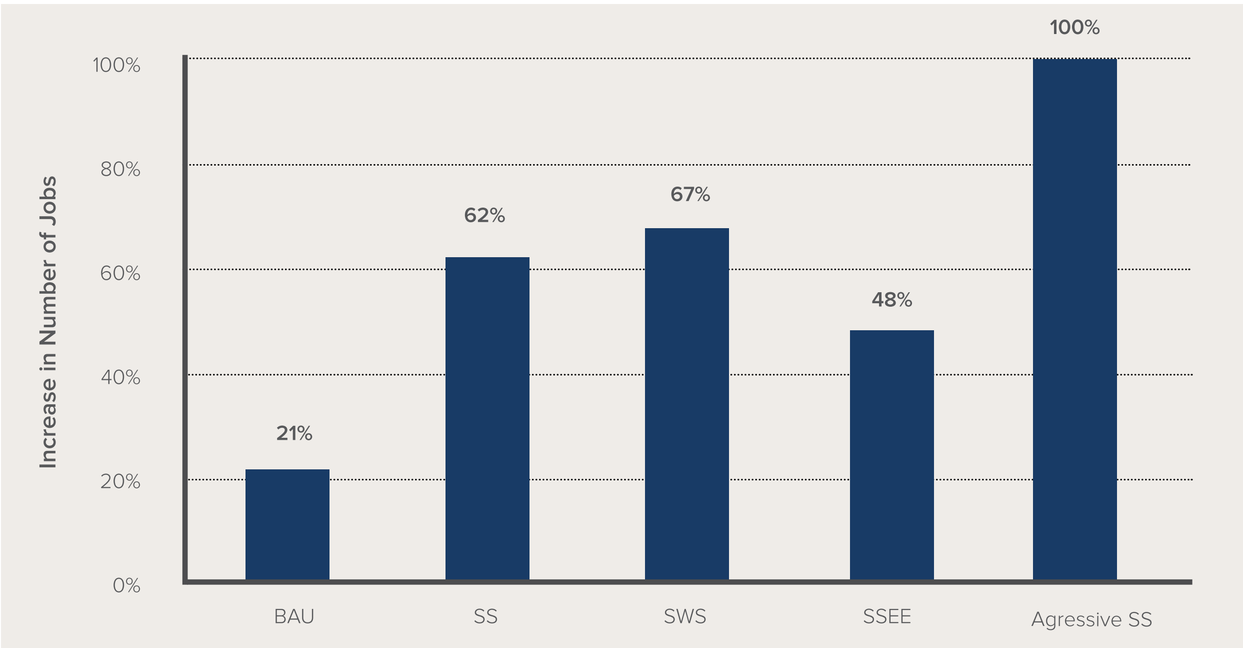


Figure 19 shows how well each scenario does in terms of its potential to create jobs compared to the highest performing scenario. Results from calculations confirm many of the trends observed by international organizations studying employment in the energy sector; scenarios with a higher renewable penetration have the highest potential for job creation. The Aggressive SS scenario has the largest potential for job creation due to the larger size of installed capacity developed. The number of construction jobs is far greater than the number of permanent jobs in all scenarios.

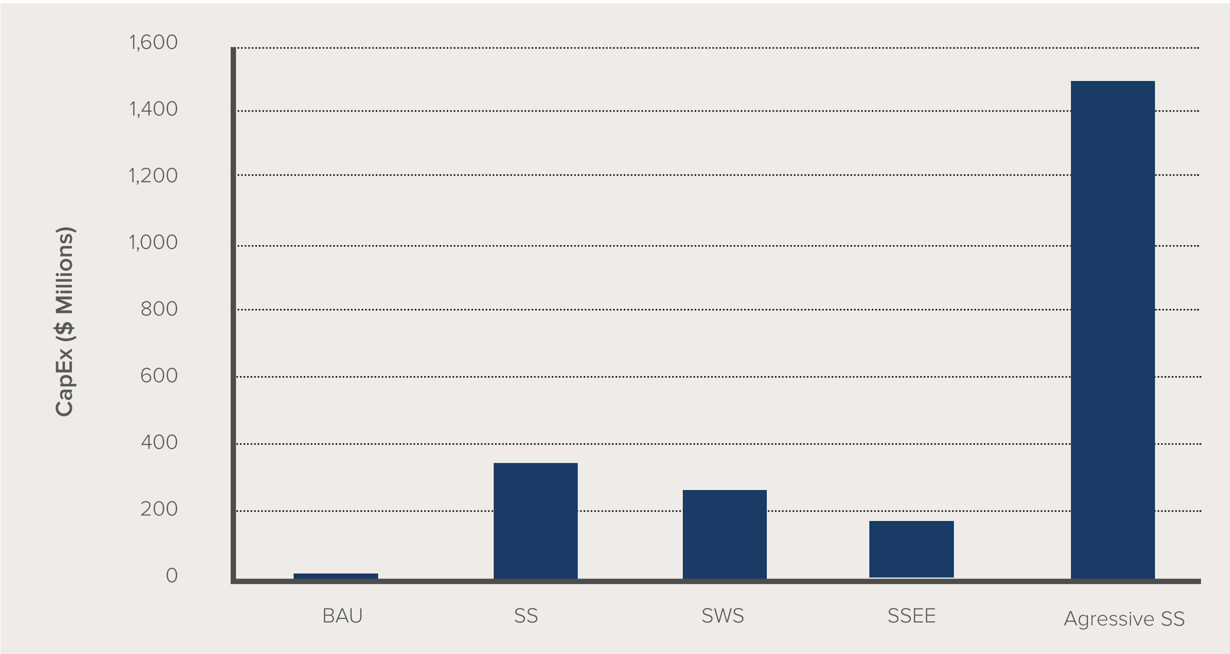
3.5.2 INCREASE IN INVESTMENTS

To test the objective of increasing investments in the country, the team calculated the total capital expenditure invested in each scenario. The results are shown in Figure 20. Scores were determined by assigning the scenario with the highest level of investment the highest score, and calculating scores for the other scenarios based on the percentage difference in investments compared to the maximum amount.

The renewable scenarios with higher levels of investment outperform the BAU scenario. The Aggressive SS receives the highest score due to the large investment required for a 10X expansion of installed capacity to reach 328 MW. The SS and SWS scenarios receive similar scores given similar levels of investments in new capacity installed. The SSEE scenario receives the lowest score out of all renewable scenarios due to the smaller required expansion in installed capacity to meet a smaller load because of an aggressive energy efficiency program.

FIGURE 20

CAPITAL EXPENDITURES FOR EACH SCENARIO



04 SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS

The team conducted sensitivity analysis to test the robustness of the R-NETS recommendations, exploring sensitivities with respect to the economically optimal size of technologies. Three sensitivity variables were tested: diesel fuel price, demand growth, and technology costs. The sensitivity analysis modified variables one at a time while holding all other inputs fixed to isolate the impact of changes to sensitivity variables. This section presents the sensitivity analysis for the SSEE scenario.

The results indicate that the optimal sizes of the technologies of the SSEE scenario are not significantly volatile under changing conditions for fuel price and technology costs. Alternatively, a 12 per cent increase in load size leads to a dramatic increase in the optimal size of storage. However, the high modularity and short lead time necessary to install storage, as well as solar PV, enables the BVI the flexibility to quickly increase technology sizes should load exceed expectations. The other sensitivity variables tested—fuel price and technology capital costs—do not affect the optimal technology sizes significantly.

Figure 21 shows the results of the sensitivity analysis. The bars in Figure 21 represent the percentage change in the optimal size of each technology when a sensitivity variable changes. For example, the second bar shows that if actual load is 16 per cent less than forecasted load, the optimal size for installed capacity of solar PV is around 80 per cent smaller than the recommended installed capacity. Alternatively, if actual load is 12 per cent higher than forecasted load, the optimal size for solar PV is around 60 per cent higher than the recommended size. Table 16 shows the assumptions used to carry out the sensitivity analysis for the SSEE scenario.

FIGURE 21

CHANGE IN ECONOMICALLY OPTIMAL SIZE OF TECHNOLOGIES UNDER CHANGING CONDITIONS, SSEE SCENARIO

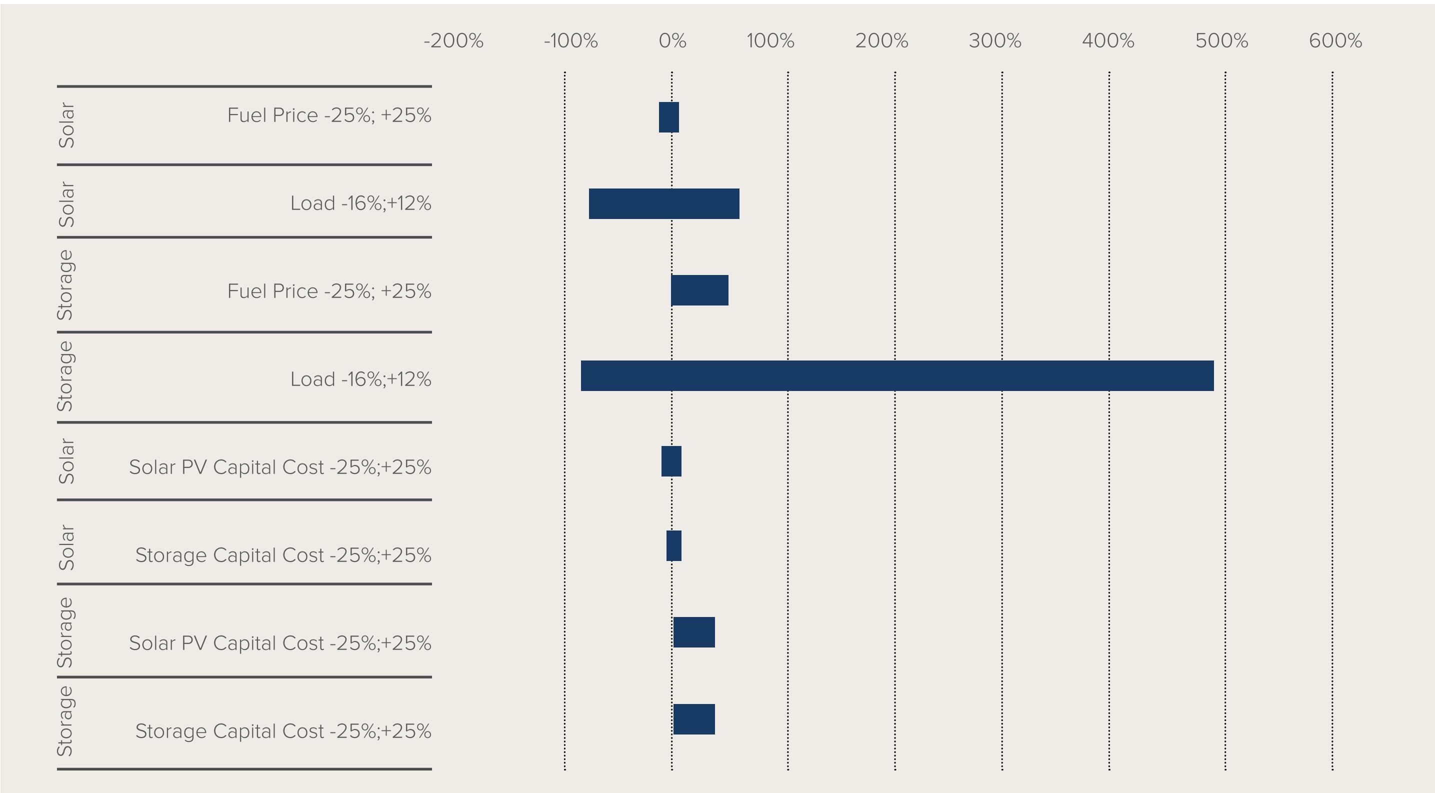


TABLE 16

ASSUMPTIONS FOR SENSITIVITY ANALYSIS, SEE SCENARIO

SENSITIVITY VARIABLE	BASELINE ASSUMPTION	HIGH-SENSITIVITY ASSUMPTION	LOW-SENSITIVITY ASSUMPTION
FUEL PRICE ($/LITRE)	0.579	0.720	0.434
PEAK LOAD (MW)	RENEWABLE SCENARIOS: 37 BAU SCENARIO: 39	39	29
SOLAR PV CAPITAL COST ($/KW)	2,192	2,740	1,644
STORAGE CAPITAL COST ($/KW)	900	1,125	675

05

RECOMMENDATIONS AND ACTION PLAN

RECOMMENDATIONS AND ACTION PLAN

The devastation caused by Hurricanes Irma and Maria offer an important window of opportunity to leapfrog from the current electricity system architecture characterized by centralized diesel generation transmitted through a highly vulnerable grid system to a 21st-century electrical grid characterized by high levels of decentralized renewable energy and energy efficiency. The R-NETS enables key decision makers to better understand the opportunity and options for the BVI to achieve the shared goals of stakeholders for the future electricity system. More importantly, the R-NETS results provide the BVI decision makers with a sequenced, prioritized, and flexible action plan designed to guide future investment decisions and transition to an electricity system that is resilient, reliable, low-cost, values environmental stewardship, and promotes job and industry creation.

The following section includes a set of recommendations and an action plan for immediate, medium, and long-term actions to accelerate the BVI's resilient energy transition.

5.1. RECOMMENDATIONS

The R-NETS recommends that the BVI pursue the following interventions:

5.1.1. AGGRESSIVELY PURSUE ENERGY EFFICIENCY

Energy efficiency (EE) is the lowest-cost individual resource option. Therefore, EE should be pursued through a targeted program to reduce loads by 10 per cent compared to BAU by 2023, and 20 per cent by 2037. The most common and effective interventions include replacing existing incandescent and CFL bulbs with LEDs, switching out inefficient refrigerators, and targeting the large loads at hotels with integrated lighting, cooling, and solar water heating strategies in a program supported by BVIEC. Pursuing EE would correlate to a direct cost savings to customers and mitigate the need to invest in additional generation in the future.

5.1.2. INVESTIGATE ENERGY STORAGE

Energy storage contributes to the reliability of the electricity system during normal operations, as well as the resiliency of the electricity system in response to external shocks. As the costs of implementing energy storage solutions have decreased significantly in recent years, it is now an accessible option and should be pursued in the BVI.

As demonstrated in the R-NETS results, energy storage will provide value to the BVI electricity system. A pilot project will allow BVI to see initial benefits, while gaining experience with the operation of this resource. This pilot project could be owned and operated by BVIEC (giving the utility full control over its use), or owned and operated by a third party with the services sold to BVIEC in support of the grid.

5.1.3. EXPEDITE REGULATORY CHANGES

Accelerating the deployment of EE and RE at scale requires regulatory change with a clear business case for the future role of the utility. A functioning electricity system requires a solvent utility to provide basic services such as system control, safety, reliability, and ensuring equitable benefits for all customers. Without proper mechanisms and new business opportunities in place to compensate BVIEC for incentivizing EE and distributed solar PV deployment, BVIEC's ability to remain solvent and effectively provide basic services could be compromised. The government and BVIEC should explore an EE cost recovery program, performance incentives, and/or lost margin recovery option, as well as investigate the deployment of electric vehicles as part of a new service BVIEC could provide to customers. BVIEC should also examine

innovative approaches to evolving its current business model. For example, BVIEC should establish a mechanism for recouping utility investments in RE to facilitate residents and businesses to produce their own electricity through rooftop solar PV while also contributing to the fixed costs of the electrical grid to benefit all customers.

5.1.4. INVESTIGATE NATIONAL WIND RESOURCE

The performance of the SWS scenario in the R-NETS indicates the potential for electricity generated from wind to provide benefit in the BVI's future electricity system. It is encouraging to know that the BVI Airports Authority measured wind speeds from January 2009 to December 2011 and found a good quality resource; however, these studies do not include the requisite level of detail to accurately determine the resource potential.

Determining if a wind project is considered commercially viable typically requires at least a year of detailed weather measurements. Wind measurement towers at the appropriate height (normally 80 meters) should be installed across multiple sites, including on Jost Van Dyke, to correlate and determine the wind resource, optimal sites for wind-power investment, and optimal turbine size. This will ensure the limited availability of land in Tortola and other islands in the BVI is optimized for wind-power deployment.

5.2. ACTION PLAN

The following action plan outlines specific immediate, medium, and long-term investment projects that the BVI should pursue given the outcomes of the R-NETS process.

IMMEDIATE ACTIONS

The specific projects are described here for immediate action. In addition, other projects may be proposed, and should be considered in terms of the BVI's shared priorities and the R-NETS recommendations.

5.2.1 LED STREET LIGHTING

Following Hurricanes Irma and Maria, there were virtually no remaining streetlights in the BVI; there is now an immediate opportunity to replace the damaged streetlights with efficient LED streetlights. BVIEC has completed a comprehensive tender process to select the optimal brand of LED luminaires to deploy, and the first shipment of luminaires is underway. Installation is scheduled for early 2018. Completing the installation of these LED streetlights will be a key first step in building back better following the storms, using low-cost and resilient EE as a resource.

5.2.2 COX HEATH SOLAR PROJECT

Studies to assess the feasibility of a proposed solar PV project in the Cox Heath area are underway. This utility-scale solar PV project, arranged as a power purchase agreement (PPA) in which BVIEC will purchase the generated electricity from a third party that owns the system, presents an ideal opportunity to implement the first large-scale solar project in the BVI. The insights gained during the project preparation phase, as well as the initial operation of the system, will provide value as additional projects are considered in the near term. Remaining project preparation requirements can be completed in Q2 2018.

5.2.3 GROUND-MOUNT AND ROOFTOP SOLAR PROJECT

From 2014 to early 2015, BVIEC began a tendering process for approximately 5 MW total of solar PV, distributed across both rooftop and ground-mounted locations, which attracted bids from four regional and international developers. When some of the land that was originally part of the process was no longer available, the smaller overall project size made the project less economically competitive. With today's solar PV prices (which have significantly decreased in recent years), there is an opportunity to begin a new tendering process for a consolidated solar PV installation across several sites in the BVI.

Project preparation will include identifying sites from the previous tender process that are still viable for solar PV, as well as identifying new sites that are less exposed to disaster risk using the SpatialEdge tool. Similar to the Cox Heath Solar Project, this project can be structured as a PPA where BVIEC purchases the electricity generated from the solar PV, and does not have to finance the cost of installing the system or be directly responsible for its continued operation and maintenance. Project preparation can be completed by Q2 2018, followed by a tender publication by Q3 2018.

MEDIUM TERM ACTIONS

5.2.4. SOLAR FOR SCHOOLS (AND GOVERNMENT BUILDINGS) PROJECT

Most public buildings—including schools and government buildings—were severely damaged or destroyed during Hurricane Irma, and require a full redesign and rebuild. This presents an opportunity to consider integrated EE and RE options in the design and construction process for these critical buildings. Identification of buildings to target will be a first key step; early indications of potential buildings of interest include the Elmore Stout High School and Seventh Adventist School in Road Town as well as the Central Administration Building. Project preparation will require utilizing expertise from whole-systems design experts, who can provide a consolidated recommendation on integrated EE options and RE potential that meet the needs of the BVI and these specific buildings. Project preparation can be completed in Q2 2018, with a tender publication by the end of Q2 2018.

5.2.5. PARAQUITA BAY INTEGRATED ENERGY PROJECT

The Paraquita Bay site in Tortola presents an opportunity for an integrated project spanning energy, water, and agriculture. As a first phase, adding solar PV on the site will reduce electricity costs for operating the water treatment and reverse osmosis plants. This first phase can be designed so that future phases harness the agricultural potential of the site, which can be seamlessly integrated into the site design.

The project will require tailored pre-investment studies—including a geotechnical analysis to determine the optimal type of solar PV foundation, an interconnection study to determine the optimal connection arrangement with the grid, and coordination with the Ministry of Natural Resources and Labour to understand long-term plans for the overall site and optimize sizing decisions for the solar PV project. In addition, coordination with the H. Lavity Stoutt Community College will be essential to integrate the needs and opportunities related to the curriculum with the first phases of the project. Project preparation can be completed in Q3 2018, with a tender publication by Q4 2018.

5.2.6. ANEGADA HYBRID MICROGRID PROJECT

The island of Anegada is not electrically connected to the rest of the BVI, and Anegada was not significantly impacted by the 2017 storms. Previous studies have shown the potential to convert the existing diesel electricity system to a hybrid microgrid containing solar PV, wind, diesel, and battery energy storage. With initial studies completed, final project preparations will include consolidating prior work and developing a detailed tender document specifying the optimal mix of technologies, while leaving room for bidders to submit their own tailored approaches for integration and control of the hybrid system. As part of this process, detailed evaluation will ensure the suitability of the proposed site in Anegada, and include requirements in the tender process to remove risks where possible in the construction and operation of the new resources. Two contract modalities could be pursued: an engineering, procurement, construction (EPC) contract with BVIEC as the owner and operator of the final microgrid, or a PPA contract with BVIEC purchasing electricity at an agreed-upon price from the owner and operator of the final installed microgrid. Project preparation can be completed by the end of Q2 2018, with a tender publication by Q3 2018.

LONG-TERM ACTIONS

5.2.7. ANEGADA GENERATION EXPANSION PROJECT

Pre-feasibility studies indicate that there is a potential to expand the Anegada hybrid microgrid to provide generating capacity well beyond Anegada's needs and to export excess power to other islands within the BVI via an undersea cable. To better understand this potential, detailed feasibility studies would need to be conducted—including site specific wind studies, land suitability for large scale RE infrastructure (i.e., geotechnical studies), cost analysis of laying an undersea cable, and operational and maintenance requirements given the remote location. The timetable for the completion of the required feasibility studies is contingent on the deployment of the Anegada hybrid microgrid project.

AP APPENDICES

APPENDICES

APPENDIX A: DEMAND FORECAST METHODOLOGY AND ASSUMPTIONS

The team forecasted total energy consumption each year over the forecast period for four customer classes: domestic, commercial, industrial, and street lighting. Annual autonomous consumption was estimated as the average consumption per customer multiplied by the number of customers in each customer class. Figure A1 provides an overview of how the components of the demand forecast model fit together.

The team predicted the demand by determining the relationships between two sets of variables: 1) growth in customer number as it corresponds to population growth, and 2) growth in average consumption as it corresponds to GDP per capita growth. For this analysis, the team used the concept of elasticity. Elasticity is a measure of how responsive one variable is to changes in another.

The forecast then accounts for other changes to electricity consumption in addition to autonomous growth. Forecasted consumption from customers that reconnect to the grid after the hurricane is included. Forecasted consumption from large projects projected to come on line during the next five years is also included, and the electricity demand saved by energy efficiency and distributed energy resources is subtracted. Table A1 shows the key assumptions used to forecast demand.

FIGURE A1

OVERVIEW OF THE BVI DEMAND FORECAST MODEL

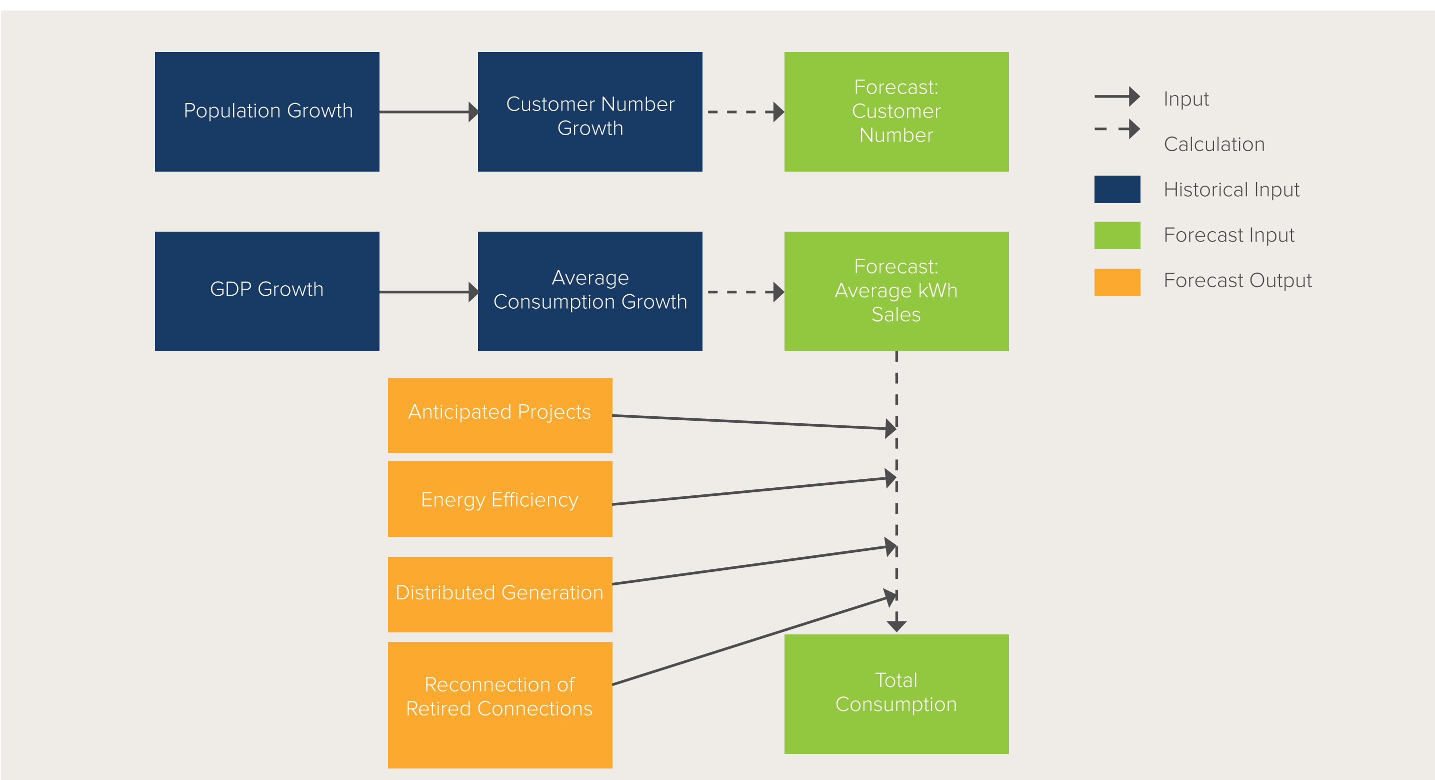


TABLE A1
KEY ASSUMPTIONS USED IN THE DEMAND FORECAST MODEL

ASSUMPTION	BASELINE	HIGH	LOW
GDP GROWTH 2018	-2.54%	-2.54%	-2.54%
AVERAGE ANNUAL GDP GROWTH 2019 TO 2023	3.34%	6.84%	2.01%
POPULATION ANNUAL GROWTH 2018 TO 2037	1.54%	2.50%	0.77%
ELECTRICITY T&D LOSSES (2023)	12%	12%	12%
BASELINE ENERGY EFFICIENCY SAVINGS COMPARED TO BAU 2023	10,510 MWh	12,380 MWh	9,486 MWh
AGGRESSIVE ENERGY EFFICIENCY SAVINGS COMPARED TO BAU 2023	24,976 MWh	27,919 MWh	20,857 MWh
SIZE OF INCIDENTAL DEMAND 2023 (INCLUDING RECONNECTION OF CUSTOMERS)	128,851 MWh	142,000 MWh	98,664 MWh
SCHEDULE OF RECONNECTION PERIOD	2018 to 2021	2018 to 2019	2018 to 2022
PERCENTAGE OF CUSTOMERS THAT RECONNECT AFTER HURRICANE IRMA	88%	95%	75%

APPENDIX B: SPATIALEDGE TOOL

To inform the R-NETS effort, the team reviewed the space available for solar PV in the BVI. To complete this assessment, RMI contracted NepCol International to establish a custom tool called SpatialEdge. The team at NepCol used geographic information system (GIS) data provided by the Department of Disaster Management, the Town and Country Planning Department, and BVIEC, along with publicly available data, to build SpatialEdge. This web-based software tool can be used to investigate individual roofs, parking lots, and plots of vacant land, as well as examine total potential across the BVI. The tool provides information on more than 13,000 potential sites, their size, susceptibility to landslides, and how much PV could potentially be installed. By filtering sites with the tool, this information can be aggregated at levels determined by the user. An overview of the potential PV capacity for rooftop, carport, and ground-mount installation is shown in Table B1.

In this assessment, solar PV potential is defined as the amount of space available (in m^2) multiplied by 130 W/

TABLE B1

SUMMARY OF SPACE AVAILABLE FOR SOLAR PV IN THE BVI, BEFORE FILTERING SITES

LOCATION	ROOFTOP SOLAR POTENTIAL (MW)	CARPORT SOLAR POTENTIAL (MW)	GROUND-MOUNT SOLAR POTENTIAL (MW)
TORTOLA	161	10	1,194
VIRGIN GORDA	43	2	372
JOST VAN DYKE	2	0	79
ANEGADA	4	0	168
TOTAL FOR BVI	213	12	1,813

m^2. The potential capacity calculated here represents the theoretical maximum, which will likely need to be reduced by partners to account for the following factors:

- **Shading:** The output of PV systems goes down significantly when whole panels or even individual cells are shaded. Other buildings, trees, obstructions on the roof itself, etc. need to be considered when siting a PV system to avoid any reduction in production from an installed system due to shading.
- **Structural issues:** PV panels add about 10 kg/m^2 of weight if attached to the roof, and even more weight when using a ballasted system. Not all roofs may be sturdy enough to support this amount of additional weight.
- **Building age:** The age of some roofs may also make it inadvisable to install a new PV system, as PV systems are designed for a 25+ year life. Replacing a roof that has PV installed adds cost and time to remove and re-site the solar, and therefore placing solar on aging roofs is rarely recommended.
- **Roof orientation:** Steeply-sloped roofs that face north should be avoided due to their lower potential for electricity output.
- **Roof size:** Some of the buildings included in this analysis may be too small to cost-effectively install PV systems. While PV systems can be very small (a single panel, 250 W), there are economies of scale in design, installation, financing, etc. that result in larger systems generating better financial returns.
- **Policy limitations:** Modifying policy to set an overall system size limit for residential properties, regardless of their roof size, can limit the amount of distributed solar PV deployment.

The software tool developed for this analysis allows the user to apply certain filters to narrow down the number of sites. The available filters (some of which may be more useful when evaluating land for ground-mount systems) are:

- Roof size
- Landslide susceptibility
- Distance to grid
- Distance to road

Access to the full tool is available at http://bvisolar-analysis.spatialedge.net. To view the tool for the BVI, log-in information is required.

Figure B1 is a screenshot showing the main SpatialEdge page, with a view of the whole territory. On the left side of the screen, the user can select which island(s) to view. The total solar potential results on the right side of the screen will update to show the totals for only the portion of the map that is currently visible.

Along with selecting a specific island view, the user can use additional filters on the left side to view buildings within a certain size range, within certain distances from main roads, on land within certain slope ranges, varying liquefaction potential, and susceptibility to landslides.

Zooming in on a specific area allows the user to view individual buildings, parking lots, or land parcels, as shown in Figure B2. Clicking on a building brings up a summary box listing the rooftop size and potential for solar PV, as well as an estimate of the building's suitability for solar PV. A number was assigned for each of the suitability parameters (roof size, distance to roads, landslide susceptibility, etc.) to give an overall estimate of each building's suitability for solar PV. Each

FIGURE B1

MAIN SPATIALEDGE PAGE

building has a unique identification number, allowing for easy referencing of specific buildings between users of the tool.

The additional options on the left side, shown in Figure B3, allow the user to examine additional details within the tool. For example, the second option is the Datasets, which allows the user to view key infrastructure such as roads and electric lines, as well as landslide susceptibility areas, liquefaction potential, and slope maps.

Additional options on the left side show summary tables and charts of the results. An example of one of these charts is shown in Figure B4, displaying the number of rooftops broken down by location in terms of island, and the how many rooftops fall in each range for landslide potential.

The SpatialEdge tool allows the user to view the total space potential for solar PV in the BVI, and to filter the results based on several criteria.[vii] The tool can be utilized beyond the R-NETS to identify top potential sites for rooftop PV installations. Solar PV is included in many of the scenarios investigated as part of the R-NETS.

APPENDIX C: SUMMARY OF KEY MODELLING INPUTS

This appendix presents the key assumptions used in the least-cost model. These assumptions were based on data received from BVIEC. When data was unavailable for an input, the RMI technical team determined a reasonable assumption based on knowledge of similar systems in the region. Table C1 shows the key assumptions used in the least-cost model.

[vii] For questions or technical support on SpatialEdge, please contact Kaitlyn Bunker at kbunker@rmi.org.

FIGURE B2

EXAMPLE OF ZOOMING IN TO VIEW INDIVIDUAL BUILDINGS, PARKING LOTS, AND LAND PARCELS IN SPATIALEDGE

FIGURE B3

DATASETS AVAILABLE TO VIEW IN SPATIALEDGE

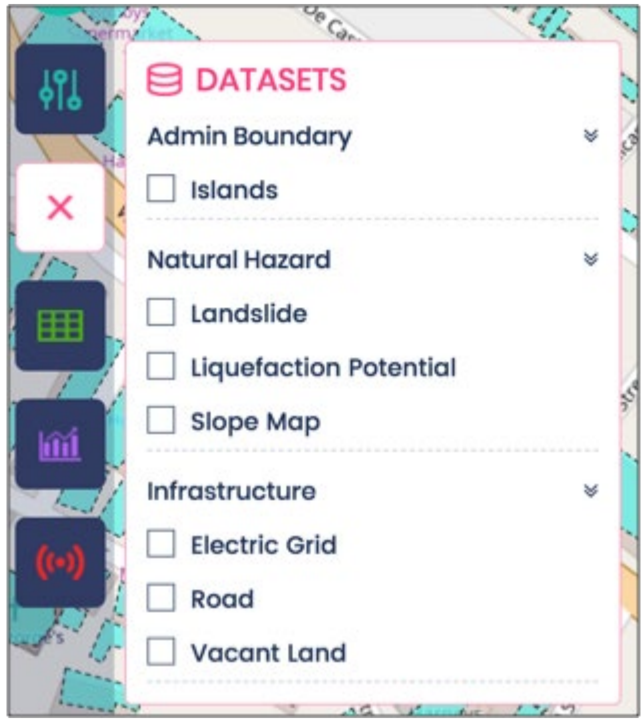


FIGURE B4

EXAMPLE SUMMARY CHARTS IN SPATIALEDGE

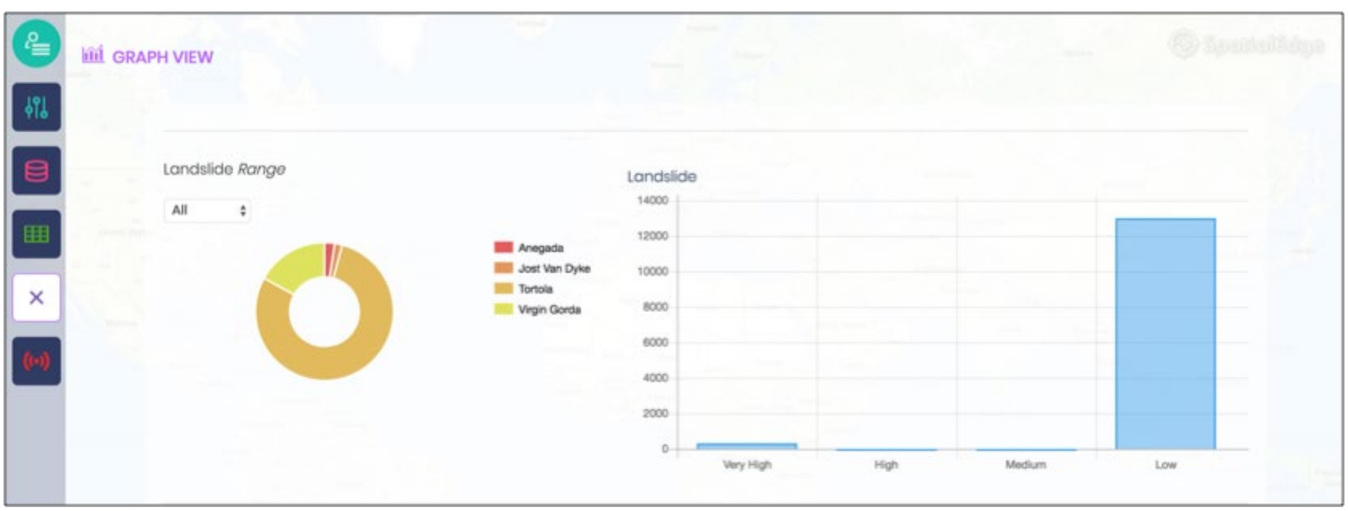


FIGURE C1

KEY ASSUMPTIONS USED IN LEAST-COST MODEL

KEY INPUT	ASSUMPTION
OPERATING RESERVE (%)	10% of current load 25% of solar output 50% of wind output
SYSTEM FIXED O&M COSTS (DIESEL-BASED SYSTEM) ($/Y)	40,435,195
SYSTEM FIXED O&M COSTS (RENEWABLE-BASED SYSTEM) ($/Y)	14,966,695
ENERGY EFFICIENCY UNIT COST ($/KWH)	0.074
SOLAR CAPITAL ($/KW)	2,192
SOLAR O&M COST ($/Y/KW)	12
STORAGE CAPITAL COST (INCLUDING CONVERTER) ($/KWH)	900
STORAGE O&M COST ($/Y)	10
WIND CAPITAL COST ($/275 KW TURBINE)	750,000
WIND O&M COST ($/Y/TURBINE)	13,750
DIESEL CAPITAL COST ($/KW)	500
DIESEL O&M COST ($/OP. HR)	0.016
DIESEL OVERHAUL COST ($/KW)	80
LIFETIME PER OVERHAUL (HRS)	48,000
FUEL PRICE ($/LITRE)	0.579
MINIMUM LOAD RATIO (%)	70

EN

ENDNOTES

ENDNOTES

[1] Conversation with Generation Engineer at Pockwood Pond power station in February 2018.

[2] NREL, Energy Snapshot BVI: Energy Transition Initiative, 2015

[3] BVIEC monthly downtime data 2011 to 2016

[4] Based on Energy Information Administration (EIA) long-term forecasts for diesel prices in the Annual Energy Outlook.

[5] NREL, *Distributed Energy Generation for Climate Resilience*. 2017. **https://www.nrel.gov/docs/fy17osti/68296.pdf**

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