DEVELOPING THE SAINT LUCIA ENERGY ROADMAP

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ABOUT US

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. In 2014, RMI merged with Carbon War Room (CWR), whose business-led market interventions advance a low-carbon economy. The combined organization has offices in Basalt and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

The Clinton Climate Initiative, launched by the Clinton Foundation in 2006, has committed to working with island nations around the world to create and advance diesel replacement solutions with support from the Government of Norway. Since 2012, CCI has signed MOUs with 25 island nations and formed a strategic partnership with partners including Rocky Mountain Institute-Carbon War Room and IRENA. CCI has helped generate over 63,000 MWh of clean energy annually in the Caribbean and East African Islands. CCI's Islands Energy program sees significant value in establishing a whole-systems approach for island nations to transition from fossil fuel-based to low-carbon economies.

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INTRODUCTION TO SAINT LUCIA

Saint Lucia is an island nation in the volcanic island arc of the Lesser Antilles of the Caribbean archipelago. Home to 183,600 people, Saint Lucia has an average gross domestic product (GDP) per capita of US$7,762.[1]

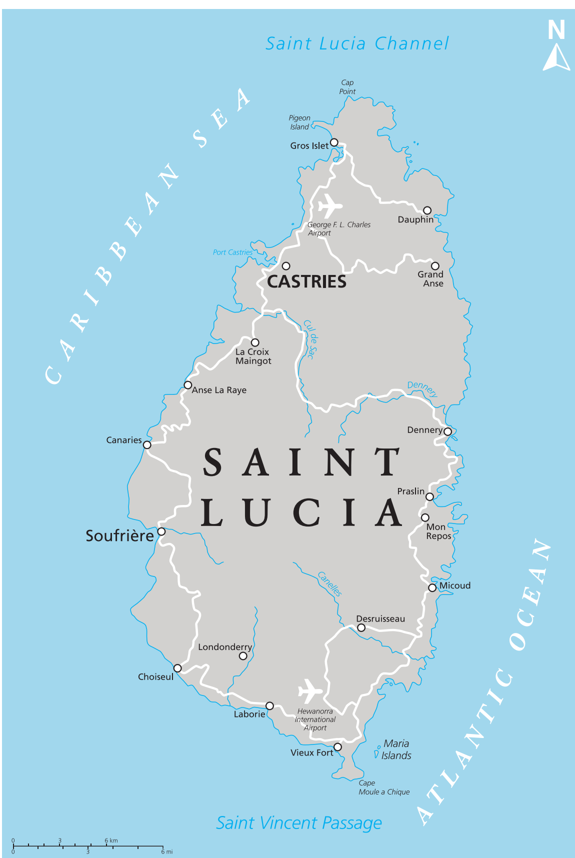
The island's economy relies heavily on tourism, which has recently supplanted agriculture (mainly bananas) as the primary driver of the economy. More than 300,000 tourists visit the island each year. Like all small island developing states (SIDS), Saint Lucia is particularly vulnerable to the impacts of climate change.

[1] World Bank Data, 2015. Although Saint Lucia uses the Eastern Caribbean Dollar, all currency in this document is reported in U.S. dollars.

ELECTRICITY IN SAINT LUCIA

Economic growth in Saint Lucia is dependent on reliable access to electricity. However, like the majority of island nations, the residents and businesses of Saint Lucia pay high costs for electricity due to the island's reliance on imported diesel for electricity generation.[2] The average price of electricity peaked in 2014 at $0.38/kilowatt hour (kWh), placing a burden on citizens and the national economy. Not only is electricity expensive, but its cost fluctuates due to volatile global oil markets.

The Government of Saint Lucia (GoSL), as well as the national electric utility, St. Lucia Electricity Services Limited (LUCELEC), identified a need and an opportunity to improve the resiliency and cost-effectiveness of the electricity sector using indigenous resources.



THE NATIONAL ENERGY TRANSITION STRATEGY

Falling costs of renewable energy technologies and initiatives to address climate change have caused governments in the Caribbean region to challenge the status quo of a monopolistic, diesel-based, government-regulated electric utility. One narrative in the region describes a future of reduced rates from competition in the electricity sector along with high levels of decentralized renewables. However, the electricity grid is a complex system built upon decades of careful investment, and equitably serves all customers. The GoSL recognized the need to understand the fundamentals of the energy system to make informed decisions regarding the future of its regulatory framework.

Recognizing that LUCELEC provides reliable and efficient electricity service, the GoSL stated that a successful change or evolution of the sector could not happen without the collaboration of the incumbent utility. Together, the parties agreed that what was needed to create a sustainable, reliable, cost-effective, and equitable electricity service was not a piecemeal approach to renewable energy investment, but rather a comprehensive long-term plan. This goal set the stage for the National Energy Transition Strategy (NETS)—a plan developed jointly by the GoSL and LUCELEC, informed by independent analysis from international partners and feedback from the public. This collaboration sets an example of proactive leadership and purposeful planning of Saint Lucia's future energy system, based on fundamental techno-economic principles to reduce the uncertainty associated with transition to a diversified energy portfolio.

[2] Although at the time of this writing (a period of historically low oil prices), the average price of electricity in Saint Lucia is $0.27/kWh, a high reliance on diesel means that price volatility and future high prices are certain.

EXECUTIVE SUMMARY

Seeking independent and objective analysis, the GoSL and LUCELEC approached Rocky Mountain Institute-Carbon War Room (RMI-CWR) and Clinton Climate Initiative (CCI) Islands Energy Program to lead the process as independent facilitators and energy experts, supported by DNV GL, a consulting engineering firm. The effort began with the signing of a joint agreement in January 2016.

To inform the NETS, the parties created an integrated resource plan (IRP), the first for the country. IRPs assess supply and demand-side options and select a set of resources that meet expected electrical demands in the most cost-effective manner. Traditionally, IRPs are commissioned by an electricity regulator, performed by the utility, and scoped within the existing regulatory environment. In Saint Lucia, the unique collaborative approach by the GoSL and LUCELEC aimed to balance the needs of all stakeholders. Partners jointly identified goals of grid reliability, cost containment, and energy independence for the future system.

The NETS built upon the fundamental analytical principles of an IRP to model the costs of various future energy portfolios, which could reliably meet the electrical demand over a 20-year timeframe. The analysis explored resource options ranging from traditional thermal power plants to more innovative sources of supply—namely solar, wind, and geothermal—as well as demand-side management and energy efficiency to contain or reduce costs of the electricity system.

To structure the analysis, the analytical team pursued four sequential activities:

1. Build a fact base of the current system.
2. Examine future scenarios, including energy options and ownership structures.
3. Develop the long-term plan.
4. Explore policy options and business model implications.

RESULTS

The NETS analysis built on a foundation of technical and economic models, frequent stakeholder engagement, and input and consensus at all decision points. The team incorporated up-to-date energy and cost estimates from the current 3 MW Hewanorra International Airport solar project, the Dennery Bay wind project, and the Soufriere geothermal project, all of which are currently under development.

This techno-economic analysis resulted in a roadmap with a combination of energy investments that achieves the objectives of maintained or improved reliability, cost containment, and energy independence. For near- to medium-term planning, the analysis determined the optimal scale, grid connection points, ownership modalities, and financial structures to be pursued in Saint Lucia's energy transition. In the more immediate term, the NETS presents a five-year plan of cost-effective energy efficiency programs, renewable energy, and energy storage investments, as well as the necessary regulatory changes to set Saint Lucia on the pathway to meet its energy transition goals.

[3] To ensure the provision of reliable power, utilities ensure electricity supply always exceeds demand. This approach leads to reserves: both immediately available "operating reserves" (also called "spinning reserves") and "supplemental reserves" that can be brought online quickly.

KEY FINDINGS OF THE NETS INCLUDE:

- The economically optimal system is a portfolio of solar, wind, energy storage, energy efficiency, and existing diesel generation. These investments would reduce diesel expenditures by 42 percent and carbon emissions by 40 percent by the year 2025. Alternative optimal scenarios further reduce imported fossil fuels by including geothermal energy if secured at the right power purchase agreement (PPA) price point;
- Existing diesel generation should continue to play a role to meet reserve requirements and maintain system reliability;[3]
- A higher degree of utility ownership leads to lower customer rates; and
- Energy efficiency is a low-cost resource and the optimal route to minimize system costs once enabling policy is in place.

The NETS revealed that lower-cost systems, where all stakeholders' interests are met, are possible through an energy transition. Energy efficiency and energy storage play an increasing role in the evolving grid as renewable energy penetration levels increase over time. Most importantly, LUCELEC, the nation's utility and high-skill employer, can remain financially viable with new renewable assets and can develop new programs for energy efficiency with regulatory incentives.

The NETS results provide a solid pathway for the GoSL and LUCELEC to understand the price points at which investments and PPAs should occur, to build a strong case to attract financing, and to better position themselves to negotiate with developers. The NETS facilitates the development of legislation and a regulatory framework, which can create new, previously unexplored opportunities.

CONCLUSION

Developing a National Energy Transition Strategy requires focused, adaptive, and visionary leadership. Through the support of LUCELEC and the GoSL, the NETS charts a pathway toward a future Saint Lucian energy system—one of lower cost, continued reliability, and increased energy independence. This vision applies specifically to Saint Lucia, but the process and findings apply across the Caribbean region and build upon specific projects currently underway.
The leadership of all parties in Saint Lucia provides a guiding light for other island communities seeking an energy transition, and the multi-stakeholder approach shows the power of collaboration.

Millions of dollars have been spent on island nations to help them select, analyze, and finance cost-effective energy solutions. Millions more are earmarked to ensure these systems are compatible with combating climate change. The results of the NETS process demonstrate that comprehensive planning combined with projects to capture the opportunity are a more powerful approach to helping islands transition their energy systems than projects alone. The approach can be scaled to many island nations with the support of the donor community and a willingness of those engaged in the process to create national energy strategies that will benefit these islands for years to come. Lastly, the process provides guidance to aid agencies, project developers, and efficiency companies, allowing them to put their efforts to best effect.

The RMI-CWR and CCI collaboration demonstrates that bringing together the right level of collaboration can very quickly deliver real results. Reproducing the approach in other islands around the globe can help steer millions of dollars into de-risked renewable energy projects and infrastructure improvements to provide the highest impact for each dollar invested and accelerate the transition to sustainable and cost-effective energy systems.

01 CONTEXT

CONTEXT

Today, Saint Lucia receives highly efficient power generation, and has a reliable grid due to the continued efforts of the Government of Saint Lucia (GoSL) and LUCELEC, the island's vertically integrated electric utility company. LUCELEC is the sole provider of electricity, supplying reliable power to 67,000 customers as well as the more than 300,000 tourists that visit the island each year. The current electricity system runs ten prime movers (diesel generators) located at Cul de Sac, after which power moves through two rings of seven transmission substations and 33 distribution-level feeders. The GoSL aims to reduce price volatility of electricity, diversify the energy mix, and utilize local sustainable energy sources.

Caribbean islands in general are blessed with an abundance of natural resources that can be harnessed with proven technologies (solar PV, wind generation, geothermal energy, etc.) at increasingly lower capital and operating costs. Taking into account that the electricity sector is interwoven and complex, each generation asset impacts the wider network. Evaluating projects and technologies in a vacuum yields incomplete answers. Determining the optimal least-cost solution requires an integrated approach that takes into account the interaction of all components (spanning supply side to demand side) on the system.

Long-term planning supports effective decision making from electric utilities, and as new opportunities emerge, the importance of planning grows. Historically, as electricity demand increases, Caribbean utilities respond by installing more diesel generators. However, the inclusion of renewables—both centralized and decentralized—in the electric power system requires an in-depth understanding of how diesel and renewable energy systems will interact to meet demand. Investments in energy infrastructure require significant capital, so thorough due diligence and planning are necessary. Integrated resource plans (IRPs) provide a framework for investment by considering numerous supply and demand options and selecting an integrated set of resources that meet expected needs in the most cost-effective way.

The NETS is underpinned by the IRP but goes well beyond the scope normally embodied in the IRP methodology. The NETS embodies an umbrella of analyses, including economic, technical, and policy-impact assessments as well as analyses of the effect on the utility business model, the impact on tariffs, the potential for reduced price volatility, and the impact on the environment. The core analytical models were derived from a typical IRP process. To fully understand the challenges and opportunities of an island-wide energy transition, the techno-economic results needed to be assessed under the prevailing policy regime and ownership models. The NETS added a further layer of analysis by modeling alternative regulatory regimes and utility business models to truly understand the opportunities that can be made economically attractive. This analysis was projected through the next 20 years, yielding implications both for the electricity system and more broadly for the country.

The implications of the energy transition span the national economy. The reliability and cost-effectiveness of the electricity supply supports the tourism sector, the main industry in Saint Lucia. The tourism industry is based on the beauty of the natural environment, cost competitiveness, the quality of the service industry, and the quality of the amenities. Cheaper electricity can lay the foundation for more attractive pricing with respect to competing holiday destinations. Economic objectives formed an additional rationale for the NETS—to seek to enhance the Saint Lucia economy and create an enabling environment for future economic growth (including and beyond tourism), while reducing physical and economic exposure and vulnerability to fossil fuel prices and extreme weather. Islands are particularly vulnerable to the impacts of climate change, creating urgency to demonstrate leadership in combating climate change through emissions reductions.

As part of the Paris Agreement, the GoSL set ambitious goals outlined in its Nationally Determined Contributions (NDCs), which state that Saint Lucia aims to reduce greenhouse gases by 23 percent

CONTEXT

by 2030. International obligations and renewable energy objectives can be met—but this requires deploying capital. Careful planning and national, regional, and international support will lead to the best allocation and greatest reduction of required capital. The NETS ensured that the economics made sense, first and foremost.

Throughout the Caribbean region, many governments are exploring whether the introduction of competition in the electricity sector will reduce electricity rates and help meet national emissions reductions goals. As illustrated below, high renewable energy targets sometimes conflict with the ability to serve customers reliably and at lowest cost. This analysis prioritized reliability as the essential criteria, with cost reduction as a second objective, and ultimately calibrated the lowest-cost systems with their ability to meet Saint Lucia's international commitments.

02 PROCESS

PROCESS

Traditional IRPs are commissioned by utilities and typically focus on solutions viable in the current regulatory regime. The NETS, building upon the standard IRP methodology, followed a participatory and collaborative approach, engaging all relevant stakeholders in the energy sector to form a cohesive solution looking broadly at future potential.

STAKEHOLDERS

A key component of the NETS included identifying stakeholders early and engaging them at every stage of the process. Stakeholders included multiple ministries and agencies within the GoSL, including the Ministry of Finance; planning and development agencies; and primarily, the Renewable Energy Division of the Department of Sustainable Development.

LUCELEC provides one of the most reliable and cost-effective electricity services in the region. As the ongoing operator of the electricity system, LUCELEC shares responsibility for implementing the national energy priorities. At the onset of the IRP, the GoSL stated that the Saint Lucia Energy Transition could not occur without meaningful collaboration and participation from LUCELEC.

The Islands Energy Program, LUCELEC, and the GoSL solicited participation at public meetings hosted by the GoSL. After each meeting, the team provided an online feedback form to gather additional input and feedback.

After being established in January 2016, the National Utilities Regulatory Commission (NURC) became a stakeholder during the NETS process. The NURC, as the national electricity and water regulator, is the authoritative body tasked with ensuring economic regulation of Saint Lucia's energy and water sectors, setting tariffs, ensuring compliance, and protecting consumers. The NETS team prioritized meeting with NURC at the earliest opportunity to inform it of the scope of the NETS. The NURC's participation minimized isolated analyses and redundancy of work, and further promoted a collaborative and complementary approach to developing the evolving national electricity strategy.

TEAM

Throughout the process, GoSL and LUCELEC provided oversight and guidance to direct the technical team, comprised of RMI-CWR, CCI, DNV GL, and HOMER Energy. The RMI-CWR and CCI Islands Energy Program bring technical acumen, project management, and facilitation skills, while being independently funded and technology-neutral. DNV GL's team of energy engineers supported the NETS process as a key technical partner, providing guidance throughout the process and performing critical technical analyses.

THE IMPORTANCE OF INDEPENDENT IRP ASSESSMENTS

Governments and utilities, along with the general public, often have competing desires or vested interests. An independent IRP avoids biases by providing an objective analysis of all viable resources. By bringing together all stakeholders and seeking only to ensure a successful pursuit of national objectives, an independent approach serves the public interest.

GOALS

A clear and effective project requires setting well-defined and achievable goals at the start. The establishment of primary objectives aligned partners around the forthcoming analysis, articulated the perspectives of each stakeholder, and ensured that the right questions were being prioritized and addressed.

The three primary goals of the NETS, listed in order of importance as agreed on by LUCELEC and the GoSL, are:

- Maintained or improved reliability
- Cost containment
- Energy independence (including environmental protection)

PROCESS

Based on the goals of the NETS, the most important questions to be answered were:

1. Would electricity generation from any portfolios of new generation assets in Saint Lucia be more cost-effective than current diesel generation?
2. What resource combination provides the best value to the people of Saint Lucia?
3. What are the impacts on rates?
4. Who should own any new assets?
5. Are there alternative regulations that can create new economic opportunities?

To answer these questions, the analysis had to be governed by well-defined and measurable metrics (displayed in Figure 1 below).

FIGURE 1
OBJECTIVES, GOALS, AND METRICS FOR NETS PROCESS

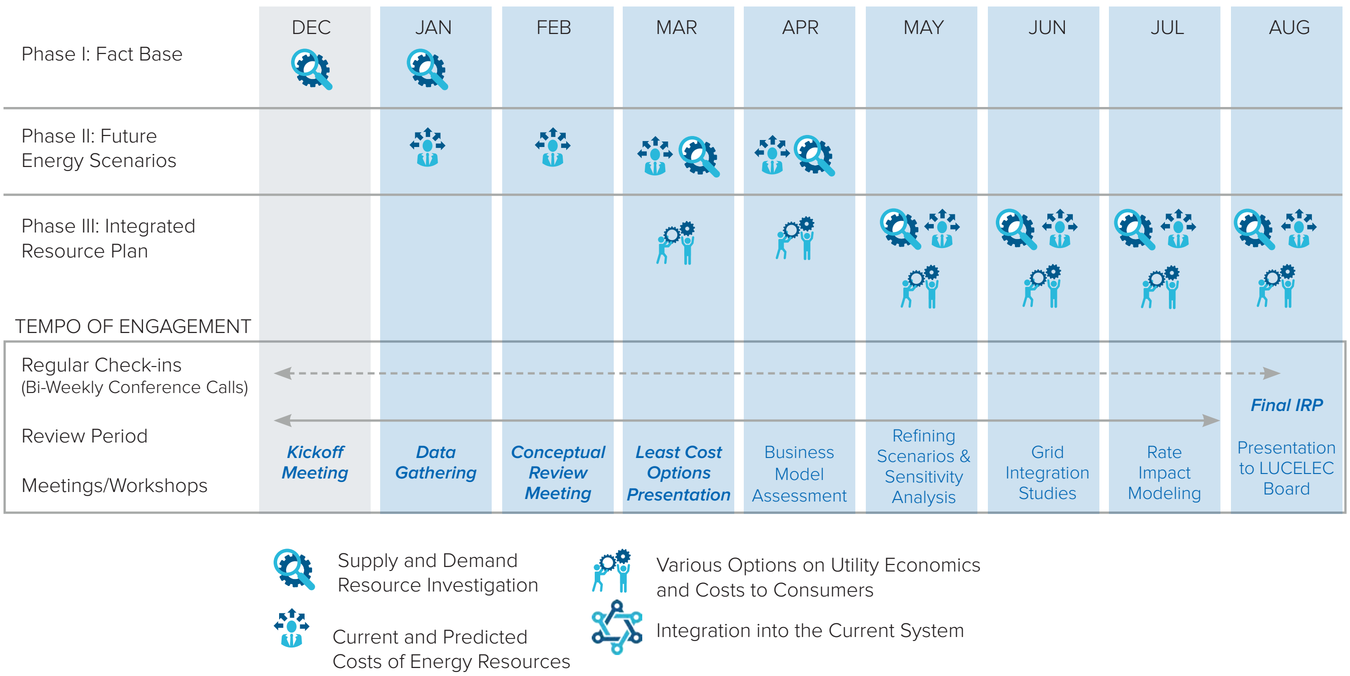
Objective	Goal	Measurements
1. Reliability	Achieve lower-than-historical Saint Lucia outage duration and frequency	• System Averaged Interruption Duration Index (SAIDI) and System Averaged Interruption Frequency Index (SAIFI) • Availability (expressed in a percentage, such as 99.99%) • Cost of unserved load (also part of cost containment)
2. Cost containment	Reduce total customer cost	• Average annual rate per customer class (ECD per kWh, averaged over a year, projected into the future) • Total customer bill (inclusive of usage)
	Improve cost effectiveness of energy supply	• Levelized cost of energy (ECD per kWh) – expressed both in generation and in transmission and distribution components • Losses from the transmission and distribution system
	Ensure financial viability of the utility	• Profit margin and EBITDA (earnings before interest, taxes, depreciation, and amortization) • Return on equity (average over a five-year future projection) • Other metrics
	Reduce impact of fuel volatility on customers	• Total cost of hedge program (ECD per quarter) • Month-to-month predicted change in customer bills (percentage change) • Correlation between global fuel prices and customer bills
3. Energy independence	Ensure achievement of renewable energy targets	• Renewable energy penetration target achieved (measure either in energy or capacity)
	Reduce reliance on vulnerable resources	• Percentage of electrical infrastructure vulnerable to natural disaster • Estimated days to restore electrical service after hurricane
	Increase energy diversity	• Annual kWh generated from any single generation source

TIMELINE

The primary analysis for the NETS process took place from January to August 2016. Monthly meetings were held with key government and LUCELEC representatives. Biweekly, multi-stakeholder calls let the analytical team update all parties on the progress of the analysis and seek inputs and ideas as the IRP unfolded (see Figure 2 below).

FIGURE 2

NETS TIMELINE



03 METHODOLOGY

METHODOLOGY

DATA GATHERING AND BASELINE SETTING

Effective and accurate technical analysis requires robust data. The team incorporated previously completed feasibility studies, resource assessments, strategy documents, and infrastructure expansion plans into the analyses. These studies provided the analytical team with an understanding of the energy vision for Saint Lucia and essential baseline data.

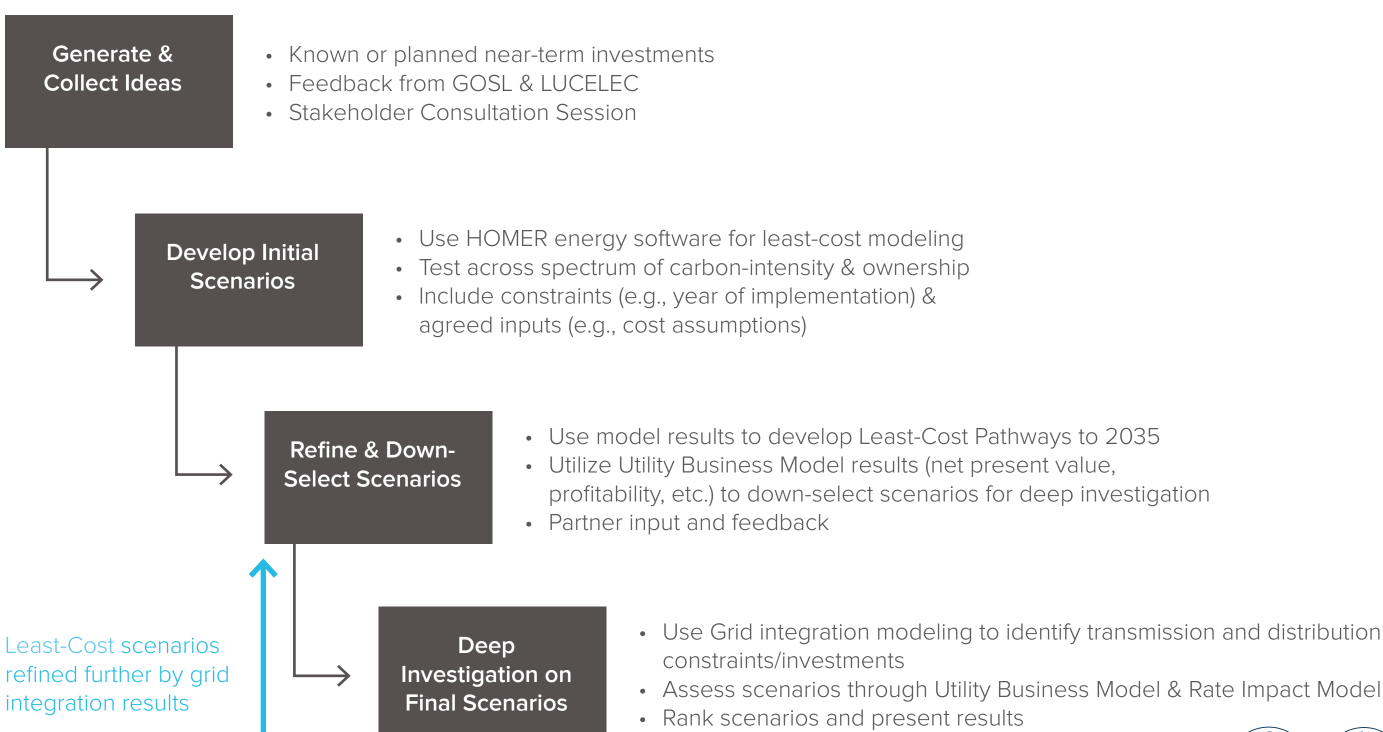
To initiate the analyses, the Islands Energy Program needed to understand the operations of the electricity system as well as the national economic framework. The accuracy of the resulting outputs is directly proportional to the level of detail and precision of these inputs. Accurately modeling the recent past and present situation allowed a high level of confidence in models that are projected over the next 20 years.

INSIGHT INTO THE OPERATION OF THE ELECTRICITY SYSTEM WAS PROVIDED BY:

- LUCELEC's forecast of load growth by feeder
- Generator-specific generation and performance data
- Operational information and schedules
- Forecasted maintenance for various assets
- Historical and expected capital costs
- Typical debt and equity splits for financing
- Rate-setting procedures
- Proposed rate-recovery structure for Independent Power Producers (IPPs)
- Many more

As the baseline emerged, the team moved into a series of analyses, each building upon the preceding, as outlined in the diagram below:

FIGURE 3
ANALYSIS PROCESS



METHODOLOGY

LOAD FORECASTING

Load forecasting provides the foundation of all long-term utility-planning efforts. Load forecasting identifies the magnitude of the demand from today through the next 20 years and provides a multi-aspect characterization of the load profile. Forecasts present the total energy or the number of customer-purchased kilowatt-hours, while also projecting annual peak demand.[4] It is traditionally the responsibility of the utility to meet these peaks when they are expected to occur in the future; thus, predicting the peak ensures proper planning for future procurement of adequate generation capacity (i.e., the total power of the generating assets).

Load forecasts, based on both near-term developments (such as hotels and large commercial buildings) and long-term economic growth projections, projected a steady increase in electricity usage and peak demand with a total projected increase of 33 percent in the coming 20 years. The load forecasts showed that new generation assets would be required in 2023 to meet loads and reserve requirements.

DEMAND-SIDE MODELING

Regulators and utilities globally have used demand side management (DSM) to reduce peak demand, defer generation and transmission and distribution (T&D) investments, and benefit consumers by reducing electricity consumption. Some common examples of DSM include;

- Energy efficiency: using less energy to perform the same task;
- Demand response: reducing demand on the customer side in order to respond to an event or condition within the electricity system; and
- Load shifting: not reducing overall energy use, but shifting the time of use to an off-peak period.

The analytical process for Saint Lucia focused on customer-based energy efficiency, specifically retrofits and equipment upgrades to reduce end-use energy consumption for residential, commercial, and hotel customers as the most cost-effective energy strategy for Saint Lucia.

Energy efficiency is commonly considered "low-hanging fruit" because it is often available at lower costs than adding new generation of any type. However, the operation of energy efficiency programs requires a programmatic approach and dedicated staff. To determine the potential for energy efficiency, the analytical team assessed consumer behavior in upgrading energy-using equipment based on assumptions of future financial incentives.
The team found significant opportunity to reduce energy consumption, while providing the same or greater level of comfort. For example, the assessment found that with hotels consuming 20 percent of the electricity of the country, and more than 60 percent of that electricity being used to provide lighting and cooling, hotel energy use could be decreased by 7 to 10 percent, at half the cost of powering that load with diesel generation.

SUPPLY-SIDE MODELING

Supply-side management involves choosing energy resources and operating them in the most cost-effective manner. In continental and island electricity

[4] Peak demand is the total, instantaneous, maximum magnitude of power that is required by customers in a given year.

grids, stakeholders increasingly consider a range of generation sources from traditional thermal generation (e.g., diesel, coal, natural gas, nuclear) to renewable (e.g., solar, wind, geothermal, etc.). The Islands Energy Program assessed all supply options, while examining different ownership structures and considering existing assets and fossil fuel expansion plans. The team explored the associated benefits and drawbacks of a spectrum of alternative fuels ranging from heavy fuel oil to natural gas combustion.[5] Of the fossil fuel-only options considered, two scenarios were selected to be modeled in further detail: 1) the business-as-usual case of diesel only, projected for the next 20 years; and 2) an addition of natural gas, procured with a long-term purchase agreement, over this same timeframe.

To assess renewable energy options, the team performed resource assessments to provide a theoretical maximum potential for energy generation for modeling. For example, by examining satellite imagery, LIDAR studies, and parcel maps, the team identified a range of potential solar sites across the island. These resource assessments established a technical limit for generation from alternative sources independent of costs.

The NETS team, in collaboration with the GoSL, LUCELEC, and DNV GL, decided on distinct pathways, or scenarios, to analyze the impact of generation mixes on the grid and the economic impact to ratepayers. Scenarios provide a structure to test a variety of alternative approaches to achieving the objectives of the IRP.

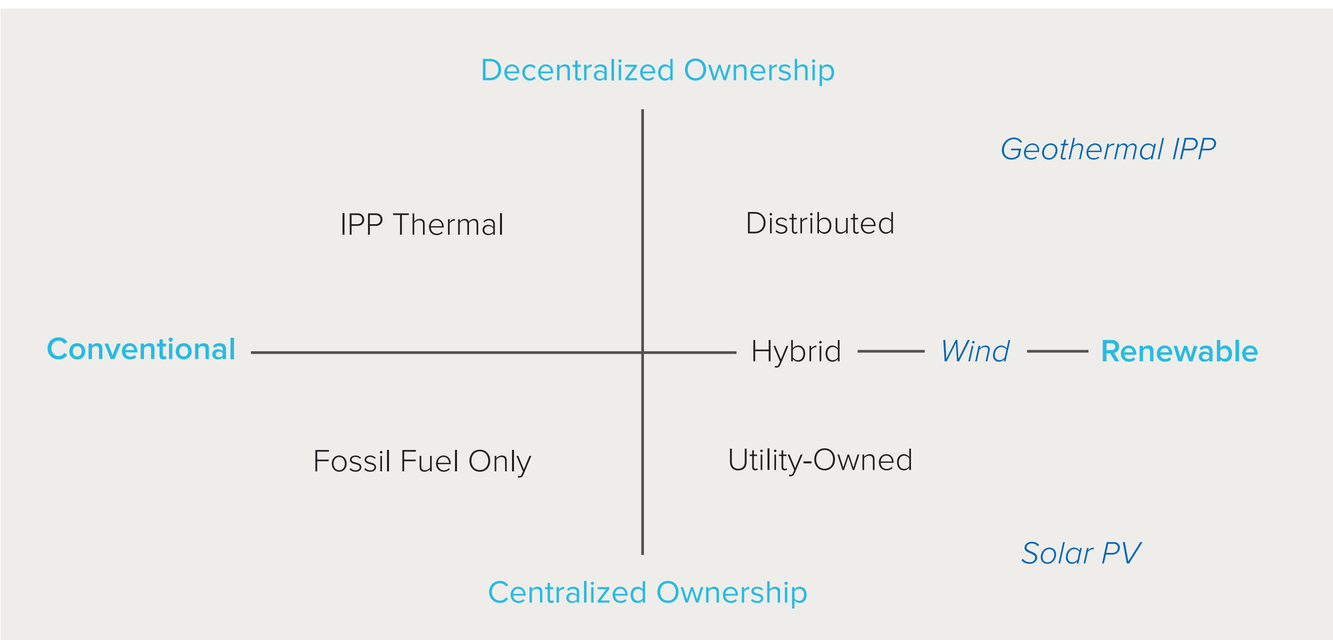
These scenarios test two dimensions:

1) the ownership of the assets, and, by extension, the financing and costs to the system; and

2) the carbon emission intensity, which is a proxy for the degree of energy independence for Saint Lucia (see Figure 4 below).

FIGURE 4

SCENARIO STRUCTURE



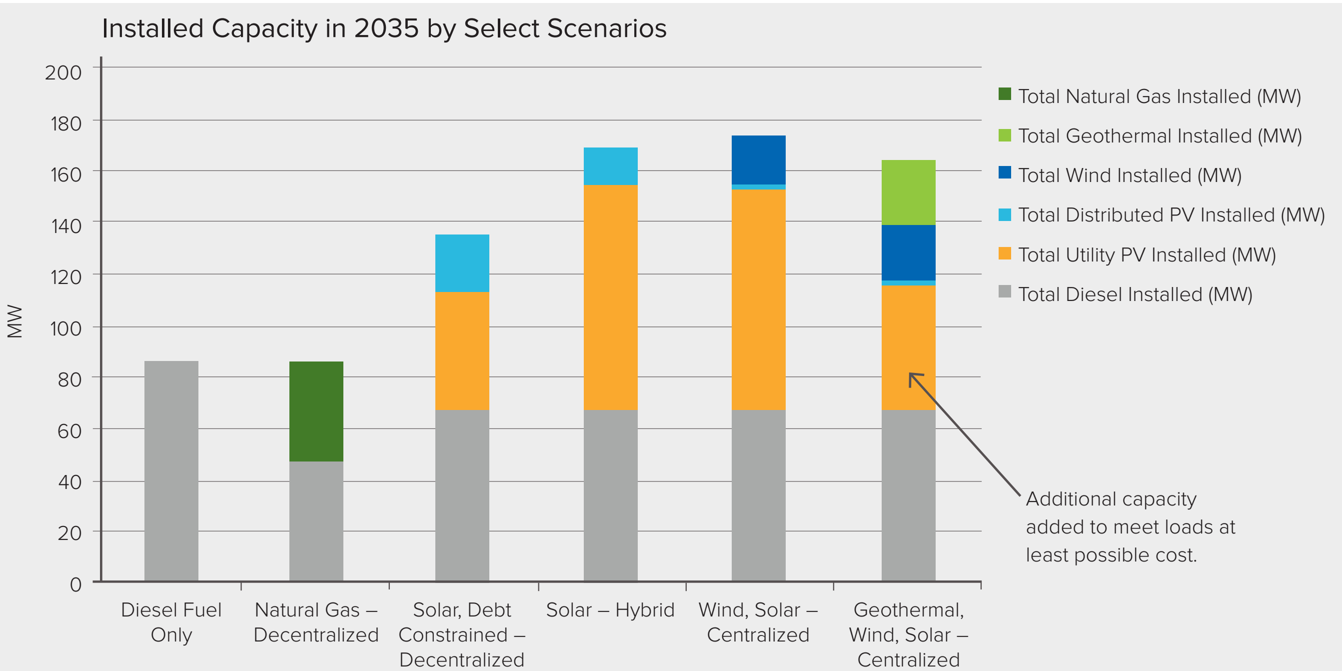
[5] Heavy fuel oil is what remains of crude oil after gasoline and distillate fuel oils are extracted. It is an alternative to the diesel commonly used in island electricity systems.

METHODOLOGY

FIGURE 5
SELECT SCENARIO DESCRIPTIONS

Scenario	2025 Renewable Penetration (by energy)	Description (in 2025)
Diesel Fuel Only (Reference Case)	0%	Continued diesel, new diesel installed in 2023 (12.4 MW)
Natural Gas – Decentralized	0%	Natural gas (40 MW) from retrofits and diesel (46.3 MW w/new 12.4 MW installed in 2023)
Solar, Debt Constrained – Decentralized	18%	Solar (47 MW, 60% owned by LUCELEC), storage (16 MWh), and diesel
Solar – Hybrid	33.1%	Solar (54 MW, 80% owned by LUCELEC), storage (18 MWh), and diesel
Wind, Solar – Centralized	38.9%	Solar (54 MW), wind (18 MW), storage (27 MWh), and diesel – Optimal rate reduction
Geothermal, Wind, Solar – Centralized	75.3%	Solar (23 MW), wind (12 MW), geothermal (30 MW), storage (19 MWh), and diesel

FIGURE 6
INSTALLED CAPACITY BY SCENARIO



All scenarios meet loads (projected 2035 load and interim years) at all hours of the year, including reserve margin

These scenarios are detailed further in Figures 5 and 6.

Over the course of this IRP, the Islands Energy Program collaborated with LUCELEC on a request for proposal (RFP) for a 3 MW solar project near the Hewanorra International Airport. This process revealed true costs for land, logistics, duties, taxes, and permits required for developing a renewable energy project. The collaboration on this project established a new standard for low-cost solar in the region, and provided Saint Lucia-specific data that was incorporated into the models to realistically reflect implementation timelines and costs.

ENERGY OPTIMIZATION

To perform detailed energy projections, the team utilized software from HOMER Energy.[6] HOMER's optimization and sensitivity analysis allows evaluation of the economic and technical feasibility of many technology options, accounting for technology costs, electric load, and energy resource availability. For a given electricity demand (i.e., load), HOMER compares the cost-of-energy supply for each scenario and provides an hourly dispatch of the most cost-effective set of generation resources. The estimated timeframes for implementation of solar, wind, geothermal, and storage were established with stakeholder input. The phased implementation of renewable energy capacity was input into HOMER so that the energy generation from any particular generation source did not exceed what was realistically possible given project development timeframes.

HOMER provides an economic filter for generated scenarios, while also testing how each scenario would operate by completing an hourly dispatch of all resources for a one-year simulation, ensuring both load and operating reserve requirements are met hourly.

TRANSMISSION AND DISTRIBUTION STUDIES

DNV GL completed transmission and distribution (T&D) grid integration studies for each generation scenario. The studies were performed to determine infrastructure limitations on power flow within the system and any upgrades required for new generation resources to ensure system safety and reliability under all potential operating conditions. These studies began by examining the physical infrastructure of the T&D system, including modeling the geo-referenced T&D lines, substations, and other system electrical components. The T&D infrastructure on Saint Lucia needs to be sized accordingly to handle not just larger current flows, but also multidirectional flows as distributed generation comes online.[7]

Grid integration studies also tested the resilience and the ability of the system to recover when large generators go offline. When one generator goes down, the remaining generators need to quickly compensate for the shortfall in generation. This compensation is required to maintain the fine balance between generation and consumption, and ultimately, to maintain grid reliability and integrity.

The transmission and distribution studies revealed the grid can remain reliable under a variety of scenarios; however, adding increased levels of renewable energy would likely require electricity storage to maintain system stability. The studies show that even high levels of distributed generation require no additional infrastructure upgrades in the coming ten years, presuming battery storage is tactically installed. The levels of electricity storage found to be economical for the system provide sufficient instantaneous reserve capacity to address any generator outages in the coming 20 years, with issues only beginning to emerge with the 2035 load and generation conditions.

[6] HOMER Energy is an energy modeling software that recommends least-cost generation portfolios to meet forecasted loads.

[7] Under certain conditions, distributed generation can create reverse power flow within a distribution-level circuit, causing potential dangers and operational concerns.

METHODOLOGY

UTILITY BUSINESS MODEL

The utility business model examines the implications of future energy investments on both LUCELEC and the ratepayer. Information reviewed included financial reports, annual filings, and national energy regulations. The utility business model was tailored to reflect the current and future operations of LUCELEC and to assess each scenario's ability to meet the cost objectives of the IRP.

The utility business model incorporated costs for installation, operation, and maintenance of the alternative generation options required to provide electricity to customers through a variety of financing options. For example, the financial structure required for a 12 MW wind plant whose energy is sold through a PPA differs from that plant under direct LUCELEC ownership. Similarly, seeking financing for a solar project is significantly different from finding funding for a new diesel generator. Each scenario reflects a different ownership structure as well as different technologies to forecast revenues, costs, and customer rates.

04 RESULTS

RESULTS

TECHNO-ECONOMIC OPPORTUNITY

The NETS process seeks the best interest of the customer, which depends on the financial viability of the utility as it continues to operate a reliable electricity system. Relatively high electricity costs in Saint Lucia ($0.27/kWh average as of September 2016) result in energy bills that can be a large portion of Saint Lucians' average incomes. Rates are dependent on the cost of service; therefore, with the right policies and rate-recovery mechanisms in place, reducing system costs can lead to reduced rates. Ultimately, the NETS process found a potential win-win solution that continued utility profitability while stabilizing and eventually reducing customer rates.

Technologies were initially assessed individually, on a levelized cost of energy (LCOE) basis, providing a preliminary indication of their cost competitiveness. The results are presented below:

FIRM RESOURCES[8]

- Solar-plus-storage is cost-competitive at oil prices of $50 per barrel.
- Diesel infrastructure is already in place and provides a firm resource but is vulnerable to volatile oil market prices.
- Entering a PPA for geothermal at the maximum considered price makes economic sense only when the price of oil exceeds $72 per barrel and remains at or above that level for the term of the agreement. There is scope for this price to be lower, at a point that competes with today's cost of generation, but this hinges on concessional financing and the success of exploratory drilling.

VARIABLE RESOURCES[9]

- Energy efficiency is the cheapest route to a least-cost solution. Energy efficiency is competitive with diesel at almost all feasible oil prices, competing at costs as low as $5 per barrel.
- Solar (without storage) is competitive with today's oil prices of $27 per barrel and above.
- A PPA for wind energy at the proposed price is competitive with oil prices at $75 per barrel.
- When LUCELEC owns and operates wind power generation, it becomes competitive at $46 per barrel.

Of the proposed technologies, the most cost-effective measures are:

A) Energy Efficiency:

- Opportunities exist in lighting, refrigeration, air-conditioning, and water heating to save approximately 0.5 percent of electricity sales per year, growing to avoid 11 percent of annual sales by 2024 at a levelized cost of $0.03 per kWh saved. Under the existing and proposed regulations, LUCELEC would require compensation from the NURC to pursue energy efficiency, as neither rate regime provides an incentive to LUCELEC.

B) Solar:

- A total of 20 MW installed within eight years leads to a system-wide LCOE reduction of approximately 7 percent.

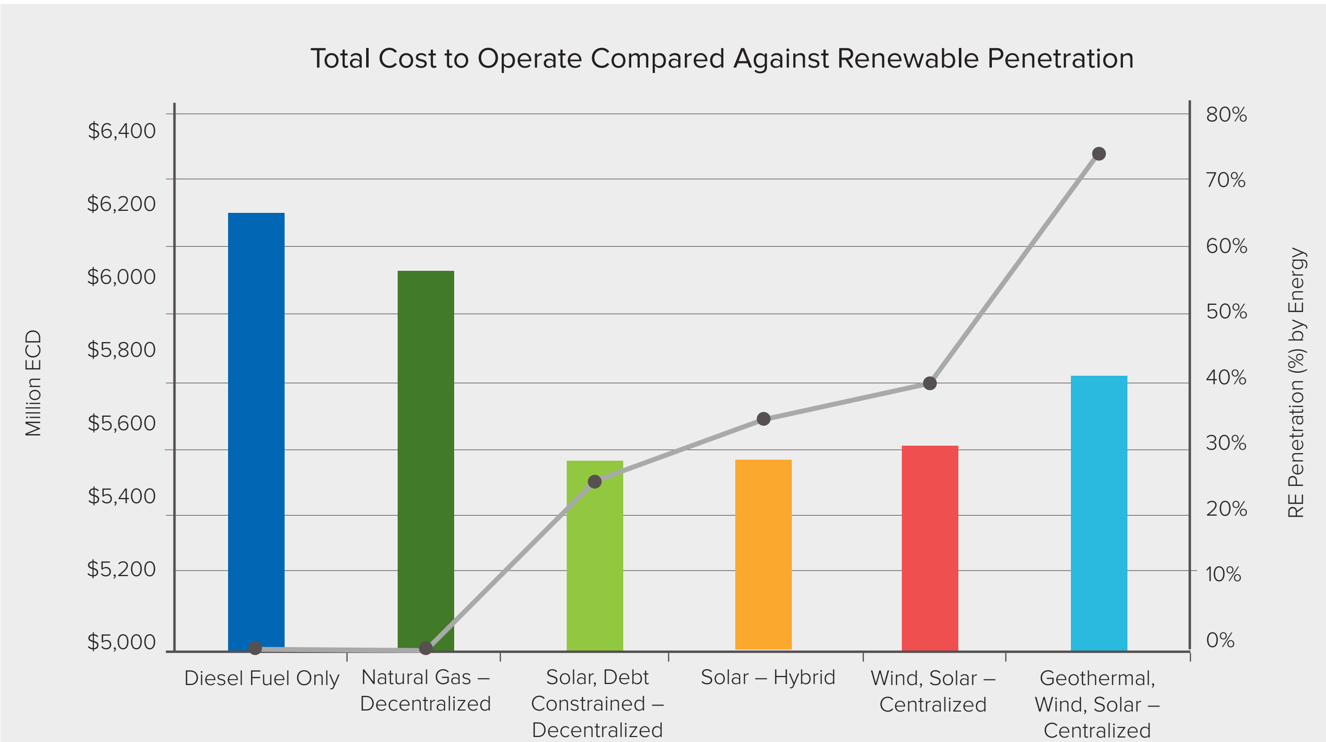
[8] Firm resources, such as diesel generation and geothermal, are power generation assets that provide electricity on-demand (barring any lack of fuel or technical failures).

[9] Variable resources, such as wind and solar, are power generation assets whose production fluctuates due to extrinsic factors such as wind speed or solar irradiation.

While the above measures were determined to be beneficial on their own, interactive electrical grids require techno-economic analysis looking at the entire system through a multi-asset scenario-based lens instead of individual system additions. Results show a number of potential scenarios that offer benefit when compared against a diesel-only base case, as illustrated in Figure 7 below.

FIGURE 7

COST TO OPERATE AND RENEWABLE PENETRATION BY SCENARIO



The scenario offering the greatest economic benefit to Saint Lucia consists of up to 31 MW of solar photovoltaics,[10] 12 MW of wind capacity (owned by LUCELEC), 14 MWh of storage (providing a maximum of 42 MW of instantaneous power), and energy efficiency displacing 11 percent of the load by 2025. Because geothermal development is in a preliminary stage, it is too early to definitively conclude whether geothermal plays a role in the least-cost Optimal Scenario. With concessional financing, proven resources, and effective system integration, geothermal up to 30 MW could be an effective electricity-producing asset, providing valuable base-load generation and allowing the country to reach renewable energy penetration in excess of 75 percent. The geothermal production-well test results and the availability of concessional financing are critical in determining whether the resource can be accessed at or below economically advantageous price points.

[10] Includes already installed solar PV

RESULTS

Economic modeling indicates that the 20-year incremental capital costs of the plan described above are $630 million and overall societal value (NPV) is $210 million, making a strong investment case for Saint Lucia and LUCELEC.

STRATEGIC PATHWAYS TOWARD ACHIEVING THE NETS OBJECTIVES

Transitioning to a high degree of energy independence and a low-carbon system is a gradual process that requires significant investments. A multi-stakeholder solution can be successfully achieved when all stakeholders understand the complexities, trade-offs, and challenges.

Enabling Energy Efficiency

In Saint Lucia, there is prime opportunity for lowering customer demand while maintaining the benefits customers currently receive from their electricity usage. Simply stated, investment in energy-efficient technologies allows the same quality of life with lower energy consumption. This opportunity is considered to be "low-hanging fruit," provided legislation allows a compensatory mechanism to account for the reduction in sales, since LUCELEC's annual revenue is currently based on the number of kilowatt-hours sold. At present, the more energy the customers use, the more LUCELEC earns. While the revenue increases with more electricity sales, so does the cost to generate and operate the system. The cheapest way to minimize operating costs is to generate fewer units of energy while not sacrificing any provided service at the customer end.

Enabling tariff structures can decouple revenues from sales. In these structures, the utility is guaranteed financial viability with reduced sales. Furthermore, lower consumption reduces line losses and lengthens the time between maintenance cycles, resulting in added savings. Coupled with a facilitating regulatory regime, energy-efficient technologies can be introduced in Saint Lucia to reduce system costs, resulting in lower rates to the consumers.

"No Regrets" Investments

Energy efficiency will likely be implemented gradually. In the near term, investments in some renewable energy projects add long-term benefit to the system. However, energy projects occur at different scales. Systems on the kilowatt (kW) scale may be a preferred choice for homeowners and businesses. Larger projects, such as geothermal, require significant due diligence, major upfront capital costs, large-scale development, and long lead times. With geothermal potentially providing in excess of 50 percent of future electricity generation, installing other forms of renewables earlier creates competition and potential overproduction. This leads to the question: will investing in small-scale projects with shorter lead times erode the economics of longer-term investments?

To assess the question above, the team closely examined both the technical and economic implications of installing near-term renewable energy. Based on power flow analysis, different feeders would be able to handle even high amounts of distributed generation without requiring costly upgrades. When geothermal is added to the mix, similarly high amounts of distributed generation operate effectively as part of the overall mix. To examine economics, different scenarios, including solar and geothermal, were assessed. The team determined that even presuming 30 MW of geothermal capacity, up to 20 MW of solar PV (utility scale and distributed) offers additional value to the system versus continued diesel generation.

Adding more solar through distributed generation offers advantages, but risks burdening ratepayers with the cost of operating the electricity system. LUCELEC piloted a net-metering program in 2009 to understand the impact of customer-owned and sited solar PV in terms of cost, grid operations, and safety.

Under this program, the self-generator receives a unit credit for exported energy that is equal to the cost of purchasing (not producing) electricity from the grid. With increased uptake, the system becomes inequitable as the increased unit costs of operating the system can shift to remaining customers who are not self-generating. The cost associated with each customer's connection to the grid, whether or not he or she self-generates, should be charged fairly and accordingly. A further study is required to determine the appropriate compensation and caps for self-generation.

Once the technical limitations of the grid are well understood by the NURC and LUCELEC, and a robust self-generation regulation is in place, customer participation poses minimal threat to the operation of the grid. In fact, there can be advantages. A well-regulated distributed system should include minimum power quality requirements of the customer-installed equipment to ensure system safety and reliability. Additionally, monitoring the electricity flow through each feeder to ensure that it is below the capacity of the connected substation would be of utmost importance and would allow LUCELEC to target specific feeders for incentives and upgrades. Robust distributed energy infrastructure can offset the benefit of reduced line losses (as the generation is closer to the load) and potentially defer costly transmission and distribution investments.

On-Going Role of Diesel

Diesel generators will continue to play a part in meeting demand in all scenarios for various levels of baseload, reserves, and grid stability, albeit at reduced volumes as renewable energy comes online. Diesel generation provides critical reserve capacity and grid stability benefits. In the short term, reserves are most effectively provided using diesel, since the infrastructure is already in place and diesel provides valuable load-following capabilities.[11] In coming years, the current three oldest generators can be phased out, and renewable generation can provide enough energy that an additional generator will not be required in 2023 to meet reliability criteria.

With increased renewables penetration, storage (i.e., batteries) is recommended to support diesel generation in providing reserves and stability to the grid.

[11] Diesel fuel cost in 2016 averaged approximately $0.45 per liter, with expected increases up to $0.57 per liter by 2025, according to futures markets and EIA projections.

RESULTS

Alternative Thermal Options: Natural Gas

The NETS team also examined a scenario in which 50 percent of the installed capacity shifts to natural gas as the fuel source for existing generators (through retrofits).

Natural gas has long been promised as an alternative generation option. At certain price points, it can reduce the total cost to operate the system compared to diesel. However, the cost of establishing the required natural gas infrastructure on the scale required for Saint Lucia is uncertain, since few relevant case studies exist. **Providing natural gas to LUCELEC's Cul De Sac power station at competitive price points requires regional cooperation to attract the benefits of economies of scale and cost-competitive long-term contracts.**

For natural gas to provide an economically superior alternative for energy generation, the following conditions must exist:

- All-in gas costs must fall below $15/million British thermal units (mmBTu) and preferably below $12/mmBTu to outcompete renewable energy technologies.
- LUCELEC would need to sequence the retrofitting of four of its generators to accommodate natural gas, with each retrofit costing approximately $1,400/kW ($43 million in total).

Natural gas prices and diesel prices are volatile and unpredictable. The magnitude and direction of the price trends/movements may or may not correlate. In the event where they diverge, dual-function generators offer the flexibility to LUCELEC to generate from the more cost-effective fuel. However, natural gas suppliers seek long-term contracts at fixed volume to justify the transportation costs, reducing the agility in maneuvering between fuels.

Cost-Optimal Scenario

Analyses completed by the technical team revealed that solar can be cost-competitively introduced at both utility and residential/commercial scales. The team determined that up to 20 MW of solar can be deployed as a "no-regrets" strategy, and up to 28 MW of solar can be installed before significant infrastructure upgrades or investment in storage are needed.

Wind is also cost competitive at the scale currently being considered by LUCELEC; however the economics are significantly more attractive when LUCELEC owns and operates the wind assets (versus a PPA structure).

Geothermal is a baseload resource and provides a steady contribution of electricity to the grid. However, developing a geothermal project is a highly specialized, lengthy, and expensive process. Project development, ownership, and operation are best left to geothermal experts and, by extension, optimized via an IPP (independent power producer) arrangement. A range of geothermal power purchase agreement (PPA) prices are currently being negotiated. The final PPA price should be based on successful exploration and concessional financing. The lower end of the range of PPA prices being explored would likely allow geothermal to play a significant role in the cost-optimal scenario.

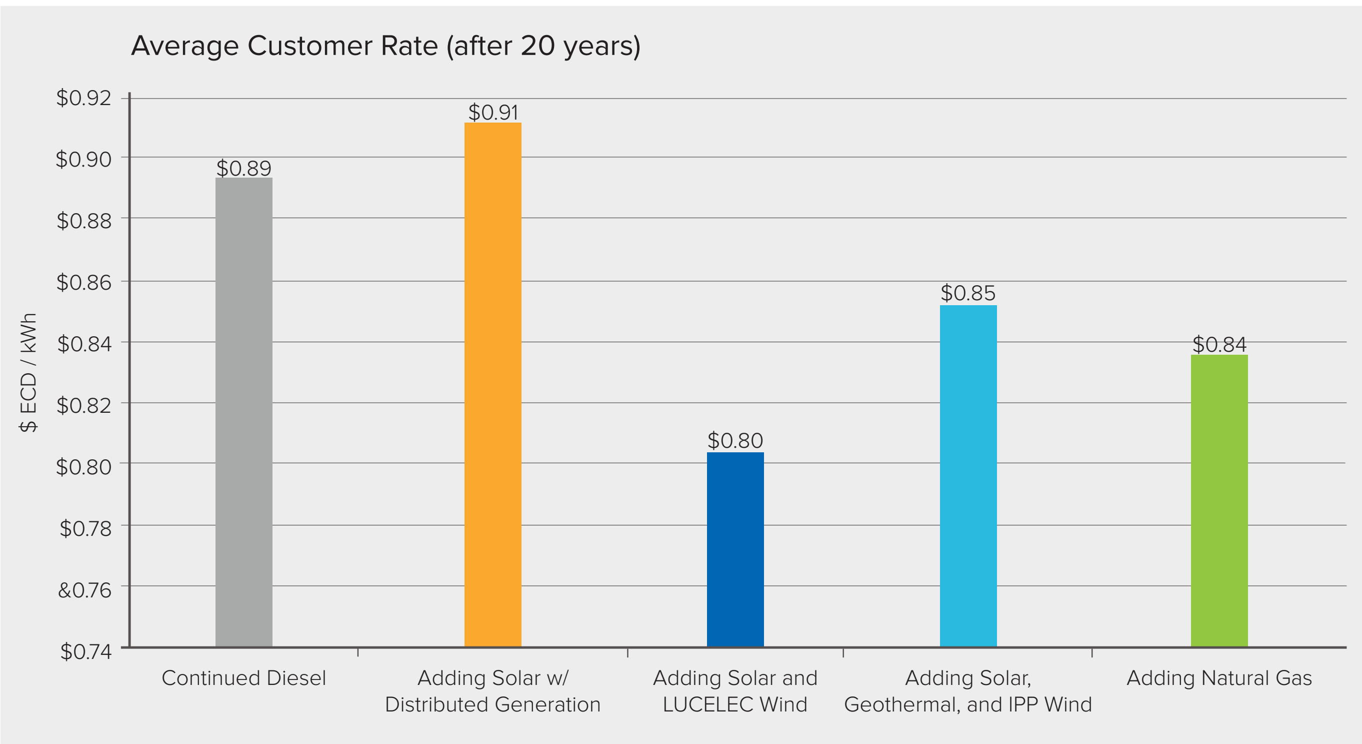
Storage plays a significant role as variable resources are added to the grid. Sufficient storage capacity can improve the economics of renewables by storing energy when it is generated in excess and releasing energy when needed, making previously non-dispatchable resources much more flexible. Additionally, battery storage systems are capable of providing multiple ancillary benefits such as frequency regulation and spinning and non-spinning reserves. These services are currently provided by the diesel generators. Storage can also provide an economic benefit in deferring transmission and distribution upgrades.

The team ranked the economic implications of each scenario based on the cost to generate electricity, the cost to operate the system, and the final cost to consumers. As seen in Figure 8 below, the economic results reveal that the Cost Optimal Scenario (i.e., the scenario that provides the lowest customer rates while reliably matching the load) includes a portfolio of technologies including wind, solar, storage, energy efficiency, and diesel.

Regulations have a significant influence on the technologies of choice, the scale of investments, and the ability for LUCELEC to invest. Having the right legislation in place is key when it comes to taking the IRP from concept to steel in the ground.

FIGURE 8

PROJECTED CUSTOMER RATES BY SCENARIO



RESULTS

POLICY, LEGISLATION, AND TARIFF REGULATIONS: ACHIEVING COST MINIMIZATION

Regulatory reform in Saint Lucia has begun. In January 2016, the GoSL passed an act enabling the NURC, and has since drafted an Electricity Supply Services bill and an Energy Efficiency bill. The NURC now has the responsibility for promoting economic efficiency of the energy sector by encouraging cost-effective energy investments to benefit both investors and consumers. Multi-stakeholder participation is key in formulating the right policy directives and the associated legislation and regulations.

For the recommendations of the IRP to become a reality, the enabling policy framework must be in place to incentivize the right investments at the right time, by the right owner, and at the right price. Saint Lucia has the opportunity to craft the enabling regulations to create low-cost, reliable, and secure electricity for the country.

LUCELEC is a well-run utility with a healthy financial record and is able to attract competitive lending rates to invest in upgrades and improvements for service. It is the responsibility of LUCELEC to maintain a reliable system with the least disruption possible. When an IPP fails to deliver power, LUCELEC must have reserves in place to compensate for the generators that have gone offline. IPPs on the system can, therefore, lead to redundant assets. Having reserves necessitates additional infrastructure requirements, which, in turn, add capital costs as well as operating and maintenance costs. The more control the utility has over the generating assets, the lower the investment in reserves needs to be in order to maintain system reliability. As stated earlier, the rhetoric in the Caribbean is one of introducing competition into the electricity markets. The Saint Lucia NETS shows how all stakeholders can benefit through an inclusive process involving the national utility and select customer and independent power producer participation.

When IPPs (whether renewable energy or conventional thermal) enter a small island market, especially where IPPs did not exist before, the cost of capital can be higher compared to the utility. This cost would then be passed on to the consumers through increased rates.

The results of the scenario modeling indicate that scenarios with the highest degree of utility ownership facilitated the lowest customer rates. Future policy directives should be focused on utility ownership, only enabling IPPs in cases where the latter adds more value and less risk to the system, such as in highly specialized ventures such as geothermal.

The least-cost system can be determined by analyzing the total cost to operate the system. However, a broader metric, the "revenue requirement," reflects the total income required to operate the system as well as earn a reasonable rate of return on invested capital. Under current Saint Lucia energy legislation, there is a band within which the internal rate-of-return must lie. Reducing the cost of operation (i.e., aiming for the least-cost solution to electricity supply) facilitates lower electricity rates for customers.

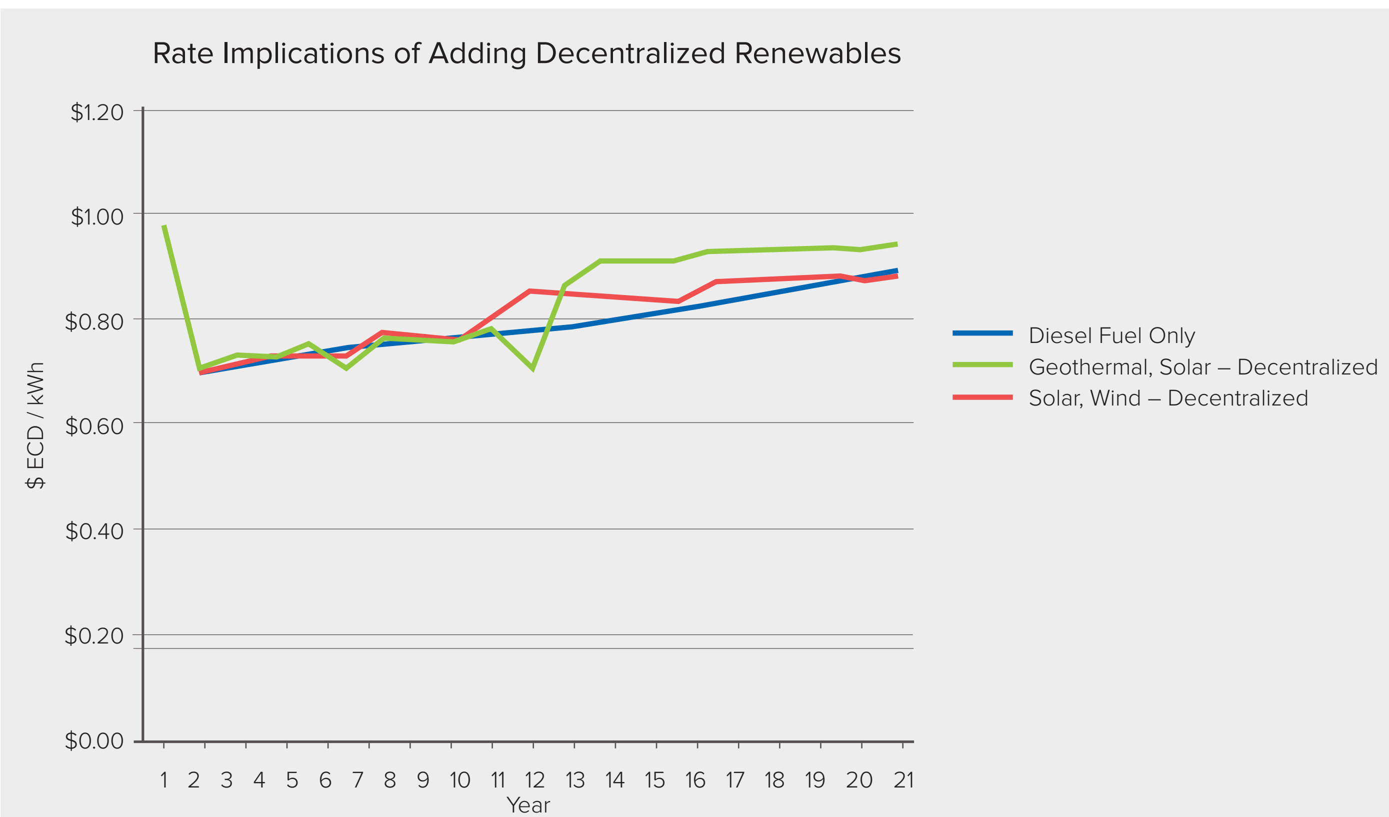
Under the present electricity tariff structure, LUCELEC recovers its revenue volumetrically. This means there is a direct relationship between the amount of units of energy sold and the revenue recovered by LUCELEC. Under this scheme, energy efficiency on the customer-side negatively impacts the utility's bottom line. However, there are alternative regulatory methods that encourage consumer energy efficiency while guaranteeing profitability to the utility. For example, decoupling sales from revenues (with performance guarantees) could achieve this outcome. This approach and others should be further assessed moving forward.

Under the prevailing tariff scheme, rates generally increase with time. When large IPPs come online under the current policy, rates are shown to initially decrease, then sharply increase. This phenomenon is termed "rate shock," where the utility initially takes a loss, and subsequently the rates adjust to return LUCELEC into the allowable rate-of-return band. Customers experience a sharp increase in rates, which is not desirable (see Figure 9 below).

The regulatory regime, as it exists today, allows for many elements of an energy transition but at the risk of rate shock. Alternative regulatory frameworks and rate regimes can create the enabling framework to incentivize the investments needed for an optimal energy transition to eventually stabilize and reduce rates to the consumer. In order to leverage the maximum benefit from indigenous, renewable resources, the underlying policy framework must be aligned, robust, and clear.

FIGURE 9

PROJECTED RATE BY YEAR WITH POTENTIAL RATE SHOCK



RESULTS

IMPLICATIONS OF THE RESULTS

These results, though focused on national implementation, will bring valuable benefits to the broader Caribbean energy community. The process clearly differentiates projects, examines interactions, and defines a path forward to maximize the benefits to all Saint Lucians. That same process can apply to other countries in the region.

By creating an integrated plan, future project development receives early de-risking, and allows all parties to work toward capacity targets and timelines. Both donors and project developers benefit from a streamlined project development process. The new national regulator, the NURC, received fact-based analysis that supports decision making about critical regulatory issues, such as customer generation and PPA arrangements. That process creates regulatory certainty. Lastly, the results of the process guide the donor community and development banks to allocate assistance and financing.

CONCLUSION

Prior to the NETS, there was a high level of uncertainty associated with new energy investments, which was hampering progress toward a resilient, sustainable, and lower cost energy portfolio. The NETS explored a wide variety of supply-side and demand-side options by evaluating scenarios representing various levels of ownership of generating assets and various levels of reliance on fossil fuels. These scenarios were tested for technical, economic, and implementation feasibility.

The NETS was based on a collaborative vision from the GoSL and LUCELEC. The Islands Energy Program, as an independent third party and process facilitator, built robust, comprehensive economic and technical models with stakeholder input.

The team incorporated realistic costs based on data extrapolated from renewable energy projects currently under development. The ensuing analysis identified opportunities that improve the Saint Lucian electricity supply while reducing the total cost to operate the system. The analysis shows that lower cost systems are indeed possible.

Energy efficiency and energy storage would play an increasing role in the evolving grid. The process highlighted that even though solar and wind are variable resources, they are not entirely unpredictable. The inherent uncertainty in energy production is mitigated by capping the installed capacity within limits specific to Saint Lucia, without adding significant operation costs and complexity. The well-designed and maintained Saint Lucia grid is well poised to embrace such investments. Thoughtful planning is essential to ensuring a successful evolution to a lower-carbon, lower-cost electricity sector.

Investments in alternative generation address the objectives set forth in the IRP, and have additional benefits such as climate change mitigation. Most importantly, LUCELEC can remain financially viable once the business model is adapted to the energy transition. Lastly, the NETS results provide a solid pathway for LUCELEC and the GoSL to understand the price points at which investments and PPAs should fall and put them in a better place to negotiate with developers, attract financing, and advance the right projects to benefit the country.

06 APPENDIX

APPENDIX A: GLOSSARY

BTU	British thermal units
DR	Demand response
DNV GL	Independent engineering firm
EE	Energy efficiency
GDP	Gross domestic product
HOMER	HOMER Energy, LLC
IPP	Independent power producer
IRP	Integrated resource plan
kV	Kilovolt (a unit of voltage, commonly used with T&D systems)
kW	Kilowatt (a unit of power). When used in units this is typically kW based on nameplate rating
kWh	Kilowatt-hours (a unit of energy). 1 kWh = 1000 Wh.
LED	Light-emitting diode (a lighting system type)
LCOE	Levelized cost of energy, a measurement of the cost of energy including lifetime and investment costs ($/kWh) - typically expressed in ECD / kWh in this report
LNG	Liquefied natural gas
LUCELEC	Saint Lucia Electricity Services Limited
MW	Megawatt (a unit of power = 1000 kW)
NETS	National Energy Transition Strategy
PPA	Power purchase agreement
PV	Photovoltaic, specifically solar generation
T&D	Transmission and distribution
Wh	Watt-hours (a unit of energy). 1 kWh = 1000 Wh

APPENDIX B: PROCESS INSIGHTS

The Islands Energy Program work in the Caribbean is funded by grants from the Dutch Postcode Lottery, the Norwegian Development Agency (NORAD), and the UNDP GEF. The Islands Energy Program is not funded by technology providers or developers. Project work is funded by agencies that seek to remove the hurdles encountered by island nations facing the multi-pronged challenge of maintaining an attractive and competitive tourism industry while also facing the challenges associated with climate change. The problem is compounded by the small grid size and the region's lack of experience in managing variable generation sources.

As process facilitators, the Islands Energy Program established a schedule of communication with LUCELEC and the GoSL. Monthly check-in trips to Saint Lucia were complemented by biweekly calls with representatives from the Energy Unit of the Ministry of Sustainable Development, Energy, Science, and Technology and LUCULEC's business development manager and system planning engineer. Communications were based on the developments in the analysis and results, with detailed agendas, spreadsheets, and results provided in advance for team review and discussion.

The NETS team is comprised of energy engineers and finance analysts from the United States, the Caribbean, and the United Kingdom, who have worked in the Caribbean region and internationally. As a result, from the start and throughout the NETS process, the team prioritized developing a deep understanding of the local context.

A key asset to the NETS team was hiring a local Saint Lucian as the National Project Coordinator. He proved invaluable for framing the local perspective as well as gathering data, verifying data, organizing public consultations, and keeping the momentum at a healthy pace.

An integrated resource plan is based on forecasts over a multi-year time frame, in this case, 20 years. As with all forecasts, there is expected to be some deviation of reality from the assumptions in this analysis. An IRP is a reflection of a snapshot in time. Thus, IRPs should be redone at regular intervals (three to five years), especially as the grid evolves.

Custom-built models were developed in HOMER, the utility business model is specific to LUCELEC, and the processes for the development and analysis of all inputs of these models plus the analysis of the results were shared with the GoSL and LUCELEC. The NETS team involved the LUCELEC engineers throughout the process. This process has been documented in detail for LUCELEC, the GoSL, and the NURC. The IRP process can thus be owned and managed to a higher proportion by LUCELEC in the future.

The energy transition requires careful consideration of equitable benefits for all citizens on the island. Consideration must be placed on avoiding a situation where residents self-generate electricity potentially leaving other customers to compensate for the increasing cost of grid services. The Islands Energy Program will work closely with the regulator, NURC, to ensure that robust and equitable decisions are made and that trade-offs and consequences are factored into the decision-making process going forward.

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