Barbados Action Plan for IRRP

Action Plan and Roadmap – Final Report

Prepared by:

acelerex

1 Broadway, 14th Floor,
Cambridge, MA 02142

Prepared for:

Ministry of Energy and Business Development

PRIDE AND INDUSTRY

ENERGY DIVISION

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1	Draft Report	Acelerex	05/01/2022
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1. Executive Summary

This action plan and roadmap document identifies the key actions to guide the implementation of the approved recommendations under the Integrated Resource and Resiliency Plan (IRRP) to achieve the transition to renewable energy given scenario 3 within the IRRP. The roadmap and action plans are built on the efforts of previous projects and activities to establish a comprehensive plan for Barbados. A kick-off meeting was held on Jan. 31st, 2022 with the participation of the Ministry of Energy and Business Development (Ministry) and Acelerex. A stakeholder engagement workshop was held on March 9-11th, 2022 in Barbados with the participation of Ministry, BLPC, GEED, ELPAC, FTC, BREA, and academia. A comprehensive report on the internal and external environmental analysis after the engagement workshop was prepared using a collaborative approach, which included several interviews and consultations.

The Government of Barbados is committed to promoting sustainable energy practices both on the supply side, mainly using renewable energy sources, and on the demand side, by encouraging energy efficiency and energy conservation as a means of reducing the country's dependency on fossil fuels, enhancing security and stability in energy supply, improving the economy's competitiveness, and achieving greater environmental sustainability. Barbados has the Barbados National Energy Policy (BNEP) to achieve the 100% renewable energy and carbon-neutral island-state transformational goals by 2030.

1.1 Key actions

These recommended actions were validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration.

- BLPC Licenses Executed.

- The **storage policy** should be finalized including the time-of-use rates, storage FiT programs, procurement methods, and stacked services regulations to support the growth of cost-effective storage and vehicle-to-grid (V2G) deployment.

- **Power Purchase Agreement** (PPA) for stand-alone and hybrid systems should be standardized for renewables and storage additions.

- The **grid modernization plan** should be prepared by BLPC

- The **expected number of applications/licenses/connections/inspections** should be forecasted on a regular basis with respect to the capacity addition expectations in IRRP Scenario 3.

- **Three proposed information dashboards** should be updated regularly to track, analyse, and display historical, current, and forecasted data of grid operations in Barbados.

- **Distribution hosting capacity** should be tracked and analysed by BLPC based on the real conditions of the grid.

- **Pilot projects for storage services and V2G technologies** should be supported to assess options for new technologies of energy storage systems, and vehicle-to-grid charging stations. Pilots for new technologies enhance the understanding of technology, integration, customer behaviour, and societal benefits, as well as help, increased the adoption, and usage of electric transportation and clean energy.

- The FIT program alone will not accomplish the BNEP goals by 2030. Large-scale energy projects are necessary. Implementation of a **competitive procurement process** supports the competitive bidding, economies of scale, and the best pricing with larger project procurements to meet the goals given the time deadlines, the land constraints, and the identified retirement of the current baseload fossil fuel units on the grid.

- High renewable penetration in the generation mix requires new processes and methodologies for operational planning. **Updates on the supply capacity and reserve requirement calculation process/methodologies** would be important to operate a high renewable embedded power system. The proposed process and methodologies are not an activity currently undertaken by BLPC.

- **Sustainable Energy course(s)** should be incorporated into the syllabus of the Samuel Jackman Prescod Institute of Technology, the University of the West Indies, Barbados Community College.

- **Streamline IRRP Process –** the IRRP process for Barbados is periodically updated every few years and takes around a year to update where the IRRP process needs to be stream lined and updated more often given the 2030 BNEP goals, where a simplified annual update would be more suitable.

1.2 Key areas for resource

Some of the recommended actions given above require resources for the successful implementation of the action.

- **The number of applications & licenses** are forecasted to continue to increase the workload of the Ministry. It is expected to reach more than 700 per year in the next couple of years. The increased number of applications & licenses also require dedicated human resources at the Ministry.

- The number of **connections** will continue to increase the workload of the responsible system operator - BLPC. This requires dedicated human resources at the responsible system operator.

- The number of **inspections** will continue to increase the workload of the Government Electrical Engineering Department (GEED). This requires dedicated human resources at the GEED.

- **A clean energy communication coordinator** at the Ministry may have the resources and the authority to follow the progress of the communication & engagement plan.

1.3 Key areas for budget allocation

Some of the recommended actions given above require a budget allocation for the successful implementation of the action.

- The **pilot projects** are categorized under distributed generation & storage, virtual power plant, and vehicle-to-grid technologies, stacked services, and rate structures. These pilots require small-scale procurement of new technologies such as li-ion batteries, solar panels, V2G technology embedded electric vehicle chargers, high-power DC vehicle chargers, etc. These pilots also require software program licenses to fully investigate the benefit of such technologies.

- Funding opportunities should be created as a part of the **education strategy** to support the educational contribution to the achievement of the Barbados National Energy Policy.

- Funding opportunities should be created as a part of the **communication strategy** to organize seminars/webinars, and regular communication workshops and to engage in traditional and social (digital) media.

- Budget and resourcing review for Ministry, GEED, BLPC for applications, licenses, inspections, and connections.

- **Keeping the three dashboards updated** is important for public and investor engagement. Budget allocation is needed to have enough digital systems for the sustainability of the dashboards.

2. Introduction

Barbados has the Barbados National Energy Policy (BNEP) to achieve the 100% renewable energy and carbon-neutral island-state transformational goals by 2030. Several sectors of the energy economy that were identified inter alia in completing the BNEP are related to the electricity: renewable energy supply, energy efficiency, infrastructure, and environment. As a leading country in the Caribbean, the recent development of the local solar photovoltaic (PV) industry and the burgeoning electric vehicle market in Barbados are encouraging.

The Integrated Resource & Resiliency Plan for Barbados (IRRP) was finalized by Mott Macdonald in 2021. The objective of the IRRP for the electricity sub-sector in Barbados was to establish the required planning decisions for the short, medium, and long-term. The IRRP utilized the multicriteria planning approach consistent with the framework identified under the BNEP 2019-2030. The BNEP and the IRRP not only identify long-term outcomes and the strategy to follow but also provide a necessary basis for continuous monitoring of changes in the sustainable energy transition program.

This report – The Action Plan and Roadmap to implement the IRRP - outlines the roadmap and action plan to enable the strategy establishment to grow until it reaches the long-term vision framed in the BNEP. The identified actions are based on the risk and barrier determinations of previous reports about Barbados and the Stakeholders' Engagement Workshop held on March 9-11, 2022.

3. Roadmap & Action Plan

The implementation steps consist of several building blocks, that is, these building blocks constitute the strategy. These blocks will be knitted together with several actions that will enable the strategy establishment to grow until it reaches the long-term vision framed in the BNEP. The list of required tasks is given in Table 1. The tasks/actions are detailed with their objectives, descriptions, timeline, priority, dependencies, and responsible party/organisation. The timeline is divided into quarters of a year. The priority rank is classified into P1, P2, and P3 where P1 has the highest priority.

Table 1: Roadmap: List of Required Tasks, Timeline, and Priorities

Task #	Required tasks/actions	Objectives	Description	Timeline	Priority Rank	Dependencies	Responsible Party/Organization
1	Action Plan and Roadmap	- Critical milestones - Recommended actions - Goals	Identifies the key actions to guide the implementation of the approved recommendations under the Integrated Resource and Resiliency Plan (IRRP) to achieve the transition to renewable energy given scenario 3 within the IRRP.	Q2 2022	P1	None	Ministry
2	Forecast of connected systems	- Workload of the shareholders until 2030	Based on the historical capacity per connections data, the total number of connections expected to be completed until 2030 is forecasted for each year with respect to the capacity addition expectations in IRRP Scenario 3	Q2 2022	P1	None	BLPC
3	Storage Policy	- support the growth of cost-effective ○ storage and - V2G deployment	To finalize the pilot projects, time-of-use rates, storage FIT programs, procurement method, and stacked services regulations.	Q3 2022	P1	None	Ministry, FTC
4	Dashboards	- Track - Analyze - Display historical, current, and forecast data of grid operations in Barbados.	- Barbados Grid Operational Dashboard - Ministry Renewable Energy License Dashboard -BLPC Renewable Energy Connections Dashboard	Q3 2022	P2	None	Ministry
5	Standard PPA	- Streamline process for Independent Power Producers, BLPC, Ministry and FTC	Power Purchase Agreement (PPA) for systems can be standardized to lower the uncertainty on the return of investment for renewable and storage additions.	Q3 2022	P2	None	Ministry, FTC
6	Execution of BLPC License agreement	- Facilitates market design for independent power producers or storage providers	Facilitates independent power producers for generation or storage providers, enables market design for independent producers with single buyer system	Q3 2022	P1	None	Ministry

Table 1: Roadmap: List of Required Tasks, Timeline, and Priorities

Task #	Required tasks/actions	Objectives	Description	Timeline	Priority Rank	Dependencies	Responsible Party/Organization
7	Legal and Regulatory Reforms	- stable - predictable regulatory framework	All proposed changes in the action plan regulation need to be implemented in a way that minimizes the impact on already existing actors.	Q4 2022	P2	Storage policy	Ministry
8	Distribution Hosting Capacity	- track - analyze the real conditions on the grid.	Hosting capacity is the amount of distributed energy resources that can be added to the distribution system before control changes or system upgrades are required to integrate additional capacity safely and reliably.	Q4 2022	P3	None	BLPC
9	Application & Licensing Processing Bandwidth	- Prepare the human resources - Decrease the processing time	The increased renewable integration for both rooftop & utility-scale solar and wind increases the number of applications and licensing by Ministry.	Q4 2022	P2	Forecast of connected systems	Ministry
10	Implementation of Utility Licenses Requirements	- Implement new market design	Data reporting, grid modernization plan, accounting unbundling, dispatch code, separating dispatch from T&D and sales	2023-2024	P2	The license agreement	BLPC
11	Grid Modernization Plan	- modern grid infrastructure - digitalization - modernization.	The system operator has responsibility for the grid modernization plan, but this can be done with assistance from a consultant.	Q1 2023	P1	The license agreement	BLPC

12	Pilots for Storage Services and V2G	- assess options of new technologies
		  ○ energy storage systems
		  ○ vehicle-to-grid charging stations
		- evaluate benefits and costs.
			Pilots for new technologies enhance the understanding of technology, integration, customer behaviour, and societal benefits, as well as help, increased the adoption, and usage of electric transportation and clean energy.	Q1 2023	P2	None	Ministry & BLPC

Table 1: Roadmap: List of Required Tasks, Timeline, and Priorities

Task #	Required tasks/actions	Objectives	Description	Timeline	Priority Rank	Dependencies	Responsible Party/Organization
13	Competitive Procurement Process	- Competitive bidding - market opportunity - economies of scale - the best pricing with larger project procurements - meet the goal	The FIT program alone will not accomplish the BNEP goals for 100% renewable energy and decarbonization of the power sector by 2030. Large-scale energy projects are necessary given the time deadlines, the land constraints, and the identified retirement of the current baseload fossil fuel units on the grid.	Q1 2023	P2	None	Ministry

14	Update Process & Methodologies	- Update the process or
		- methodologies of the calculation of
		  o ICR,
		  o PRM,
		  o operational reserves
		  o ELCC
			Update the process or methodologies of the calculation of Installed Capacity Requirement (ICR), planning reserve margin (PRM), operational reserves, or Effective Load-Carrying Capacity (ELCC) that are not an activity currently undertaken by BLPC.	Q1 2023	P3	The license agreement	BLPC

15	Connection Processing Bandwidth	- Prepare the human resources - Decrease the processing time	The increased renewable integration for both rooftop & utility-scale solar and wind increases the number of connections by BLPC.	Q2 2023	P2	Forecast of connected systems	BLPC
16	Inspection Processing Bandwidth	- Prepare the human resources - Decrease the processing time	The increased renewable integration for both rooftop & utility-scale solar and wind increases the number of inspections by GEED.	Q2 2023	P2	Forecast of connected systems	GEED

3.1 Forecast of Efforts Required & Processing Bandwidth

Barbados has commenced its transition from an economy powered by fossil fuel to one that is powered by renewable energy. A forecast of additional capacity by year is prepared plan for the workload of applications, licenses, inspections, and connections. Based on the analysis of connection dates and sizes of 59.6 MW-AC of distributed, customer-owned, grid-connected solar PV, the total capacity has increased significantly after 2019 as shown in Figure 1.

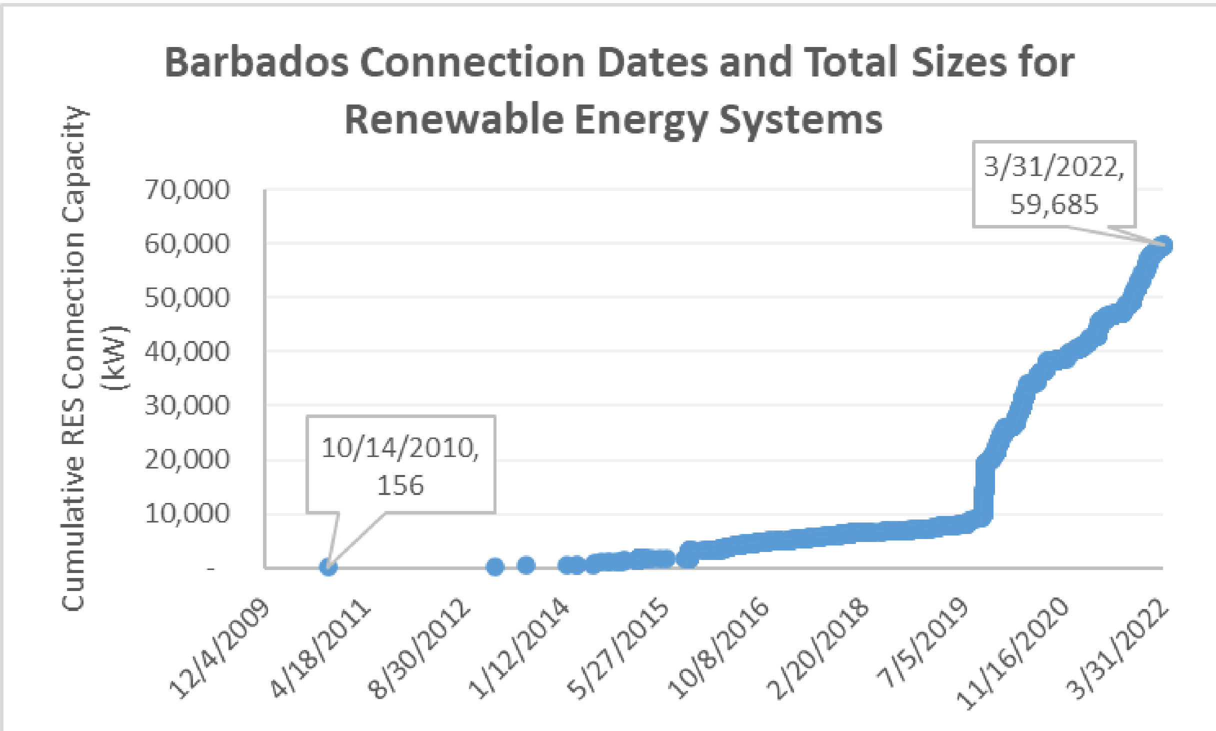


Figure 1: Barbados Connection Dates and Total Size of Solar Capacity

Source: BLPC

In the last 10 years, the highest capacity by connection is 1,000 kW. The average capacity per connection; however, is 30 kW within the last 4 years. The annual maximum and minimum capacity by connections are illustrated in Figure 2.

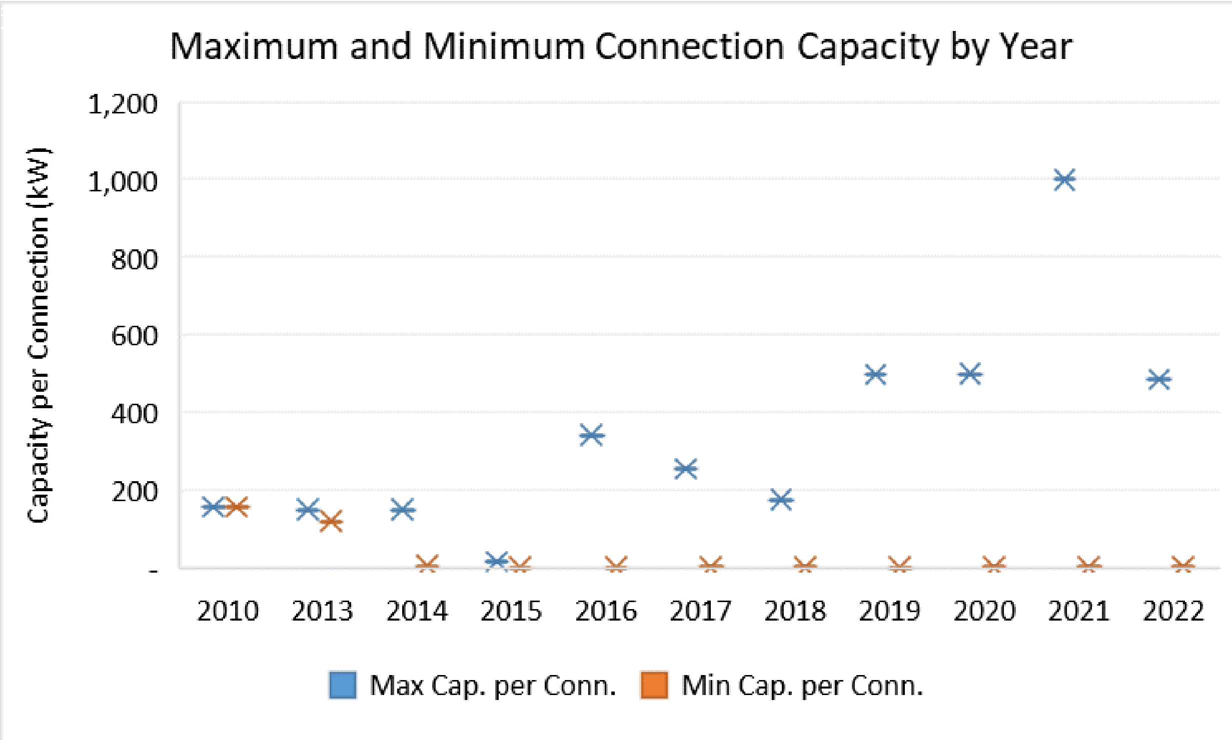


Figure 2: Maximum and minimum connection capacity by year

Source: BLPC

Each distributed, customer-owned, grid-connected solar PV creates a workload for shareholders at a different level. Based on the last 10 years of data, the number of connections per year reached 723 in 2020 at the highest. The total number of connections is 2,639 with a total solar capacity of 59.6 MW in the last 10 years. The historical connections workload by year for solar rooftop systems and the cumulative solar generation capacity that they provide is given in Figure 3.

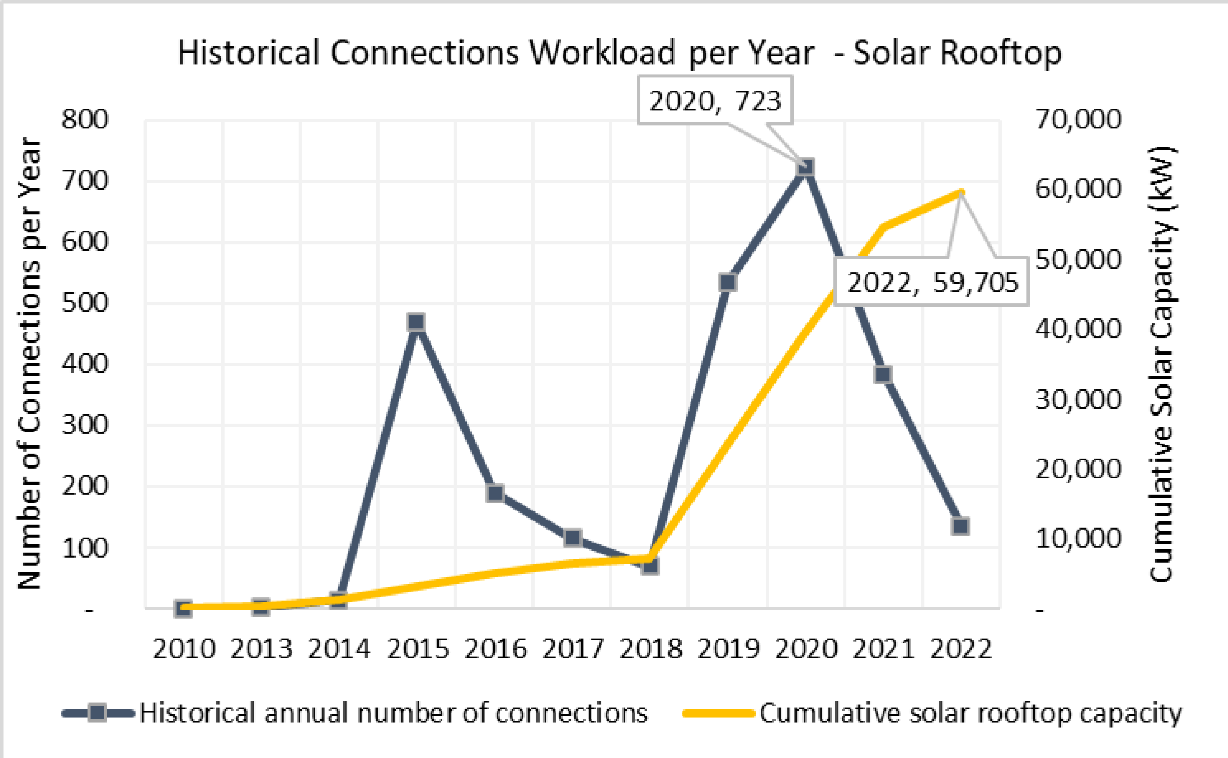


Figure 3: Historical connections workload per year – Solar rooftop

Source: BLPC, Chart: Acelerex

The historical number of applications (connections) by year for solar rooftop systems is given in

Table 2: Historical Number of Connections by year – Solar Rooftop and Solar Utility Scale

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022*
Solar Rooftop	2	14	469	190	116	69	535	723	384	136

Source: BLPC

The IRRP capacity addition schedule and the average capacity by a connection from the historical connections data are used to better understand the workload – processing bandwidth – for the next years. The total solar capacity was evaluated in three categories in the IRRP Scenario 3:

- Solar rooftop
- Solar utility-scale
- Solar thermal

The cumulative expected capacity by year by solar category in IRRP Scenario 3 is given in Table 3. The total solar rooftop capacity is expected to reach up to 100MW in 2030. The total utility-scale solar is expected to reach 180MW, solar thermal to 60MW.

Table 3: Cumulative Capacity by year – IRRP Scenario 3

Category	2022	2023	2024	2025	2026	2027	2028	2029	2030
Solar Rooftop*	56.47	68.07	77.6	84.1	89.55	93.98	96.37	98.76	100.13
Solar Utility Scale	20	40	60	80	100	120	140	160	180
Solar Thermal	0	0	0	20	40	40	40	40	60

* The capacity includes the fading impact of solar rooftop

Based on the analysis of the connection of 59.6 MW-AC of distributed, customer-owned, grid-connected solar PV – provided by BLPC- an assumption of 15kW per application (hence the connection) on average is made to forecast the application processing bandwidth for the solar rooftop applications. The historical and expected number of connections by year and the total solar capacity (including the current capacity and the expected solar rooftop capacity additions) are illustrated in Figure 4.

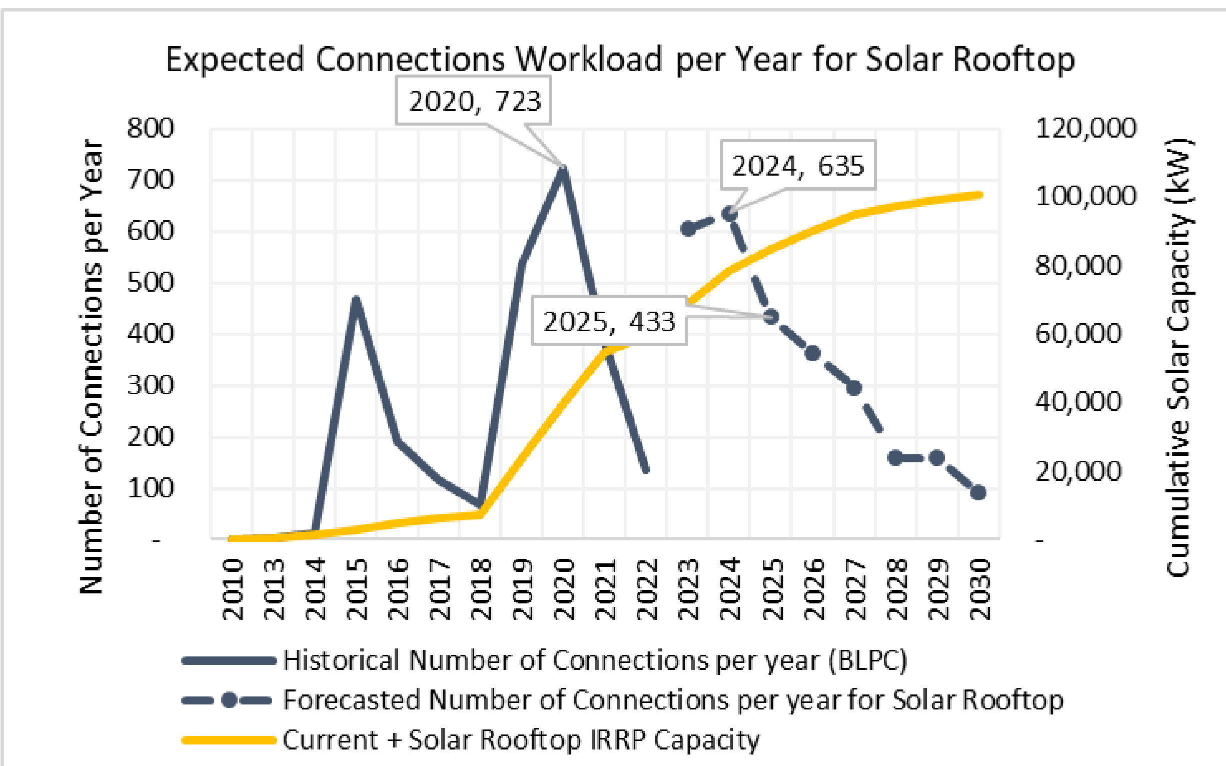


Figure 4: Expected connections workload per year – solar rooftop

Source: BLPC, Acelerex, Chart: Acelerex

For the utility-scale solar system additions, an assumption of 250 kW per application (hence the connection) on average is made to forecast the application processing bandwidth for the utility-scale solar applications. For 20MW of annual capacity additions by the utility-scale solar systems, where up to 80 new applications per year are expected as the application & licensing workload.

The expected number of applications (connections) by year for solar rooftop systems and solar utility-scale systems is given in Table 4.

Table 4: Expected Number of Applications by year – Solar Rooftop and Solar Utility Scale

	2023	2024	2025	2026	2027	2028	2029	2030
Solar Rooftop*	605	635	433	363	295	159	159	91
Solar Utility Scale**	80	80	80	80	80	80	80	80

* an assumption of 15kWp per application

* an assumption of 250kWp per application

The list of actions on the forecast of efforts required validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration is given in Table 5.

Table 5: List of Actions on Forecast of Efforts Required

#	Actions	Responsible Shareholder
1	Development of an indicative forecast of connected systems covering a minimum 5-year time frame, fully aligned with the goals and policy direction published by the Ministry.	BLPC, Ministry
2	Complete an IRP every year	Ministry

3.2 Storage Policy

Based on the IRRP report by Mott Macdonald and the Barbados Clean Energy Storage and EV Policy report by Acelerex, the advanced capability of energy storage is a must to achieve an ambitious clean energy future for Barbados. The large-scale storage implementation is needed in a short period in Barbados; therefore, the shareholders and the potential investors need to comprehend the legal and regulatory perspective of the Barbados storage policy. Some shareholders believe that to achieve such large-scale storage deployment there needs to be a comprehensive policy-based initiative that supports the procurement and deployment strategy within the required timeframe.

3.3 Dashboards

A dashboard is an information management tool used to track, analyse, and display key performance indicators, metrics, and data points. Barbados can use a dashboard to monitor the overall status of sustainable energy transition goals. Behind the scenes, a dashboard connects to the files, attachments, services, and APIs. A dashboard transforms the raw data into something human-readable. It can aggregate data from multiple data sources. Instead of sifting through columns or rows in a spreadsheet, one can analyse the data in a table, line chart, bubble chart, bar chart, etc.

The following three dashboards are identified to be developed:

- Barbados Grid Operational Dashboard
- Ministry Renewable Energy License Dashboard
- BLPC Renewable Energy Connections Dashboard

The Barbados Grid Operational Dashboard is the information management tool used to track, analyse, and display historical, current, and forecast data of grid operations in Barbados. The dashboard mainly focuses on the technical development trend of the grid under several engineering-related metrics. These metrics are categorized under 4 topics, one of which is renewable energy generation monitoring. The list of recommended actions on renewable energy generation monitoring validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration is given in Table 6.

Table 6: List of Actions on Renewable Energy Generation Monitoring

#	Actions	Responsible Shareholder
1	The BLPC should develop prediction modules for renewable generation systems: - Day Ahead Monitored Solar Production Prediction - Day Ahead Monitored Wind Production Prediction	BLPC
2	The BLPC should update the BLPC Renewable Energy Connections Dashboard and its databases regularly based on the technical information detailed in the associated report.	BLPC

3.4 Legal and Regulatory Reforms

Stakeholder management can be the main consideration in completing the administrative phases of the energy transition in Barbados. Improper stakeholder management can complicate not only the early stages of the projects but also the day-to-day operation. A process for collaborative activation of the implementations should be prepared by the Ministry.

One of the main obstacles identified to renewables integration is the lack of legal and regulatory reforms. A stable and predictable regulatory framework would help shareholders to lower the financial risks and to increase the effort on the energy transition. The reforms should be compatible with the goals of IRRP and the policies in the BNEP and should be based on the grid principle of:

- grid investments should not hinder or discourage renewable development,
- renewable development should also understand how the grid evolves and spreads.

While it has always been true that governments play a critical role in the economy when they drive decisions about standards, today's rapidly changing, and technology-dependent business environment has made the role of the government in technology standardization even more important. If the standard successfully creates network externalities and is cost-effective, the standard can diffuse to other nations. Then companies enjoy the benefits of being developers or early adopters and can use their domestic market to develop subsequent technologies and test marketing strategies to export to other countries. They have the advantage of being able to innovate and move the market to the next generation of technology before later adopters can catch up. End-users in the countries that adopt the technology earlier enjoy benefits as well, with lower prices and a greater variety of products or services.

A clear distinction between large and small renewable projects should be made. The procedures should not be the same for both types because the owner profile is quite different. Simplification of licensing procedures which may even be costless for the project owner should be evaluated for small projects, especially residential applications. Increasing project data transparency is important for large projects so developers can have full site information when bidding on a project. Last but not least, the development of a standard power purchase agreement (PPA) for large projects is essential for the financial reliability of renewable integration.

To achieve the goal of simplifying and better coordinating project licensing procedures, grid access, and connectivity issues should definitely not be overlooked. This point has its own classification, as it is identified internationally as one of the main barriers to continued renewable penetration.

3.5 Distribution Hosting Capacity

Distributed energy resources (DER) refer to often smaller generation units that are located on the consumer's side of the meter. Examples of DER are rooftop solar photovoltaic units, small-scale wind turbines, and battery storage. The list of recommended actions on distributed energy resources validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration is given in Table 7.

Table 7: List of Actions on Distributed Energy Resources

#	Actions	Responsible Shareholder
1	The BLPC should regularly track the distribution hosting capacity and provide the information transparently to the public.	BLPC
2	To monitor the real-time system conditions of renewable energy generation, the followings should be digitally tracked through AMI or estimation by the BLPC, but the coverage should be expanded to all renewable generators to fully capture the real-time system conditions: - 24 hr. monitored solar production - 24 hr. monitored wind production - 24 hr. curtailment of solar and wind production	Ministry, BLPC

3.6 Grid modernization plan

In order to achieve a sustainable, reliable, and safe electricity grid with 100% renewable resources, the grid infrastructure should be supported with digitalization and modernization. Many items are in progress already for modernization in Barbados. From a grid modernization perspective, the main AMI deployment is complete along with the communication backbone by end of 2021. Moreover, three projects are also currently processing. These are distribution automation with intelligent switches at the feeder level, pilot distribution equipment monitoring (DEM), and battery energy storage systems for grid support procurement proposals.

Barbados has engaged in grid modernization in the last decade, yet a forward look is needed to support the large-scale renewable integration into the grid. The system operator has responsibility for the grid modernization plan but this can be done with assistance from a consultant, starting with a TOR. The grid modernization plan needs to represent a change in methodology for reliability assessment on the grid from joint probability to Expected Load Carrying Capability methodology.

Table 8: List of Actions on Grid Modernization Plan

#	Actions	Responsible Shareholder
1	The BLPC should regularly develop and update its current reporting activities on current network capacity by: • Changes from the previous version and the reason for these changes; • The amount of production already in operation and the production that has been pre-licensed and/or signed a connection contract; • The most important reasons for restricting production and developments or plans to correct these restrictions	BLPC
2	Following international good practices in MV network planning, as this topic is still very much talked about around the world.	BLPC
3	The BLPC should include in its operation and planning processes: • the appropriateness of voltage control in the MV network; • Intensification of R&D for due diligence of the MV network protection system and research of new ways of network protection, surveillance, and control in case of significant DG	BLPC

3.7 Pilots for Storage Services and V2G

Pilot projects are needed to support the learning curve of the clean energy transition in Barbados. The pilot projects will assess options to integrate new technologies such as energy storage systems and vehicle-to-grid charging stations and evaluate the associated benefits and costs. The goal of pilot projects is to understand how the use of technology can provide services when managed in grid operations. The pilots will help understand the return of investment on resiliency-related investments and advanced customer offerings. Pilots for these new technologies enhance the understanding of technology, integration, customer behaviour, and societal benefits, as well as help, increased the adoption, and usage of electric transportation and clean energy.

Distribution planning methodologies are still under in-depth study and are expected to be subject to different changes (intranational community) in the coming years; it is recommended that pilot projects be established with principles applicable to Barbados's situation.

The pilot projects should help inform the approach for pricing and paying for services. They should also be targeted for:

- repeatability,
- commercially viability,
- matching funds or in-kind contributions,

- public webpage of the project,
- maximization of participation of BLPC, Investors, Ministry, Developers, Academia, end-users, and other entities.

The political and academic support for such pilot projects is essential to disseminate the project findings to a wide range of communities.

Table 9: List of Actions on Pilots for Storage Services and V2G

#	Actions	Responsible Shareholder
1	Actively implementing pilot projects to test the new technologies	Ministry, BLPC

3.7.1 Pilot project suggestions

The pilot projects are categorized under distributed generation & storage, virtual power plant, and vehicle-to-grid technologies, stacked services, and rate structures.

Distributed Energy Generation & Storage Pilot Projects: Behind-the-meter energy generation & storage solutions will be at customer scale assets (1-100kW). The pilot program tests the need for and benefits of integrated generation & storage, and how to determine early adapter of the new technologies. It will evaluate storage operating strategies coordinated with other distributed energy resource assets. The pilot will also evaluate the impact on and support system reliability measures.

This pilot should be implemented in multiple sites with single system control behind the meter with solar, battery energy storage system, electric vehicle charger components, and possibly controllable demand.

Virtual Power Plant or Aggregator Pilot Projects: This group of pilot projects will explore a variety of virtual power plant (VPP) options along with resultant benefits and costs. The VPP pilot consists of distributed energy resources, energy storage systems, and electric vehicle chargers. It can test the use and control of VPP infrastructure as an integrated asset to the utility.

Vehicle-to-Grid Pilot Projects: This group of pilot projects will evaluate the integration, benefits, and costs of EV charging infrastructure. The pilots will cover home EV charging stations, public charging infrastructure (third-party and utility-owned), and vehicle-to-grid (V2G) capable technological assets. The projects will test the need for and benefits of integrated deployment, hardware, software, and grid integration of EV charging infrastructure. During the pilot, customer behaviour can be analysed and the impact on greater adoption of EVs can be evaluated.

Stacked Services: The stacked services approach in which the energy storage systems can provide more than one service during the day is a technically viable approach to lower the total capacity requirement of storage in the power system. The coincidence of two services required at the same time is lower for some services such as peak shaving and renewable curtailment reduction. While the storage units are required for renewable curtailment reduction service generally during the noon, the peak shaving service is required around the evening in Barbados. Therefore, the same physical storage unit can indeed provide these services; therefore, increasing the capacity factor of the investments. The stacked services pilot project will show BLPC managing stacked services by providing capacity and adding monitoring, analysing, and reporting skills.

Rate Structures Pilot Program: The rate structures for the participants of pilot projects can be different than the usual customers. For example, evaluation of time of use rates for charging behaviour impacts or testing pricing influence on the use of EV charging options is applicable. Testing of pricing models relative to grid support, load management, and reliability can be applied to energy storage system pilots.

3.8 Competitive Procurement Process

The Barbados Competitive Procurement and Licence Process report by LHA Ventures and Acelerex, explains that the licence processing times will impede the adoption of a higher volume of clean energy systems. The report identifies seven key blockers that are needed to be resolved in order to process higher volumes of applications; some of which are also discussed in this report in associated sections. Moreover, the report also suggests 34 recommended actions validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration.

3.9 Update Process & Methodologies

The following sections are the proposed process or methodologies going forward. The calculation of Installed Capacity Requirement (ICR), planning reserve margin (PRM), operational reserves, or Effective Load-Carrying Capacity (ELCC) are not an activity currently undertaken by BLPC as an input for the proposed procurement process.

3.9.1 Capacity requirement

Every year, the BLPC calculates the Installed Capacity Requirement (ICR) which is the firm capacity for the next three years, and the ICR is used as the basis of capacity procurements. The ICR is calculated based on the net peak demand forecast and the assumptions made on the planning reserve margin (PRM). The associated equation is given below.

$$ICR = Net\ peak\ demand + Planning\ reserve\ margin$$

On a yearly basis, the BLPC calculates the PRM for the next three years and it is used as an input to the ICR calculation. The PRM calculation considers the supply risk outages, maintenance, and intermittency of the generators. On a yearly basis, on the other hand, the BLPC also calculates net peak demand and Net energy for the next three years, and these are used as a part of the ICR calculation as well as for input to the procurement process.

3.9.2 Operational Reserve Requirement

Another input for the procurement process is the operational reserve requirement. On a yearly basis, the BLPC calculates the operational reserve requirements for the next three years and this calculation is used for input to the procurement process as well.

The inputs of the operational reserve calculation are as follow:

- Net Demand Prediction Errors
- Supply Prediction Errors
- Loss of largest unit
- Others

The outputs of the operational reserve calculation, on the other hand, are as follows:

- Duration of Reserves
- Amount of Reserves

3.9.3 Capacity Credit

A capacity credit per project is needed as a solar project with one hour of storage has different load carrying capability than a solar project with 4 hrs of storage. As part of the connection process, BLPC should calculate the capacity credit using Effective Load-Carrying Capacity (ELCC) subject to network constraints for each new project and reports the projects' ELCC credit as part of the interconnection application process and supplements it with AC time-series power flow.

An example of ELCC for the capacity value of solar, wind, and storage is given in a Canada-based distribution system operator's IRP study. The study can be found online at the following link:

https://irp.nspower.ca/files/key-documents/final-irp-report/NS-Power-IRP-Appendices-A-N.pdf

Also, the followings are resources for ELCC of distributed solar and grid-scale systems of solar or wind from various entities:

Source 1: PJM Effective Load Carrying Capability (ELCC) Review Part II

Source 2: NERC – Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning

Source 3: ISONE Installed Capacity Requirement

3.9.4 Capacity Pricing

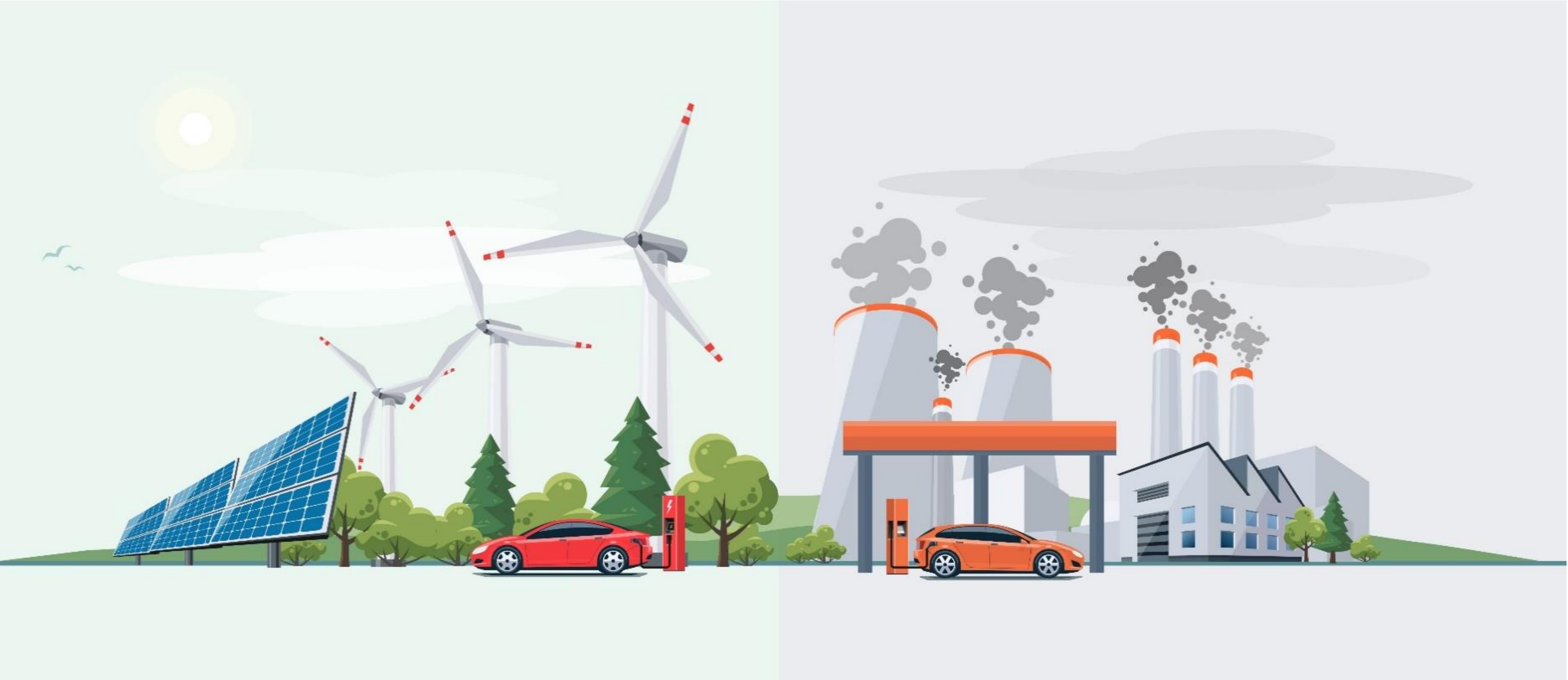
A fair playing field of capacity payments needs to be set of capacity credit and capacity price because the capacity of renewables and storage carries different amounts of peak load depending on the duration of the storage. The issue of fixed capacity price in PPA over the duration of the project is that the fixed capacity price in PPA over the life of PPA presents the risk of overpaying or underpaying for capacity. Thus a capacity demand curve methodology likely should be adopted with capacity lock-ins of 7 years to 10 years and then after the lock-in period the capacity price is calculated as diminishing between a capacity shortage price of 1.5x Net CONE to zero capacity value at 1.2x ICR. Net CONE is the cost of new entry (CONE) less variable revenues of energy and services (Net) and Installed Capacity Requirement is the peak demand plus the planning reserve margin.

3.9.5 Net Capacity Payments

The net capacity payments should be different for renewables, thermal generators, and storage systems. The net capacity payment is calculated by subtracting the energy payment and the service payments from the capacity payments. The capacity payment is calculated by the capacity times the capacity price times the capacity value. The equation is given below.

$$\begin{aligned} &Net\ Capacity\ Payment \\ &\quad = Capacity * capacity\ price * Capacity\ Value - energy\ payments \\ &\quad - services\ payments \end{aligned}$$

For renewable systems, the net capacity payment should be calculated by deducting the energy payment received by the renewable system. Therefore, the total payment to a renewable system will be the energy payment and the net capacity payment. However, the storage systems should receive services payment and the net capacity payment.



4. Blockers & Risks

A blocker is anything that prevents progress from occurring within a project or plan. A blocker can be internal or external. They generally require immediate attention to resolve. Based on the discussions at the Stakeholder Engagement Workshop, the blockers can be treated under three categories:

- Market-wide blockers
- Blockers of less than 10MW system integration
- Blockers of greater than 10MW system integration

4.1 Market-wide Blockers

Barbados will see a considerable diversification of its energy mix in the next decade, in particular through the growth of renewable electricity generation. Barbados should ensure that policies are in place to bolster transparency and short- and long-term predictability in the market. The list of key market-wide blockers validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration is given below.

- Signature of utility licenses,
- Lack of forward-looking forecast of ICR, Net Peak Demand, Net Energy, and operational reserves,

- Failure or delays in the energy transition/implementation plan,
- Uncertainty on the storage policy,
- Delay of anticipated legal and regulatory reforms and tasks,
- Low FiT allocation capacity by year (Current allocation 58MW installed, 62MW Approved but not connected. Total 120MW)

4.2 Blockers of less than 10MW system integration

The small and medium-scale renewable energy capacity additions will play a critical role in achieving 100% sustainable energy generation in Barbados. The simplified (less paperwork) or premium processes (i.e. feedback from ELPAC for license process) for such systems will increase the attraction of the investment. Decreased operational complexity and increased financial predictability are also important factors for the integration of less than 10 MW systems. The list of key blockers validated through discussion with various stakeholders or specific suggestions made by stakeholders that merit consideration is given below.

- Lack of pilots for storage services and V2G
- Uncertainty on Power Purchase Agreement (PPA) for 1-10 MW systems
- Consistently low distribution hosting capacity
- Failure to prepare the final version of the Grid Modernization Plan
- Low connection processing bandwidth
- Hardship on license applications
- Outdated operational dashboards

4.3 Blockers of greater than 10MW system integration

One of the main drivers of the rapid increase in renewable energy capacity that Barbados will see in the next decade will undoubtedly be large-scale capacity investments. Considering the financial size of such projects and the intensive labor required for their realization,

- tender processes with uncertain methods,
- uncertainties in the purchase guarantee or power purchase agreement,

- and the shortcomings in capacity credit may cause large-scale renewable energy and storage projects to slow down.

4.4 Supply security & generation retirements

The concept of "energy supply security" refers to the ability to reach an existing energy source, rather than the depletion of potential sources. The availability of energy sources, especially renewable, is critical. A more positive development for the security of supply is that Barbados is actively working towards curbing its energy consumption and increasing its energy savings, as well as promoting and incentivising the use of renewable energy sources, which have a positive impact on the security of supply by reducing dependence on imported fossil fuels. Many renewable energy sources are locally generated (e.g. wind, solar) if such production is incentivised or commercially viable (e.g. biofuels). However, during the transition period until the grid reaches the 100% renewable scenario, the retirement schedule of the existing generators (as suggested in the IRRP) should be carefully reviewed and immediate actions should be taken in case the expectations on the firm capacity additions are not achieved on time.

The IRRP has accelerated retirement assumptions with respect to schedule over the study horizon. However, there is variance between the schedules of the new license regime and the 2021 IRRP Report. The IRRP retires Units D11-D13 in 2024-2025. Schedule A retires the LSD plant, D10-D13 in 2028. The concern arises should the waste to energy plant not come online (or other firm capacities) as replacement firm capacity within either timeframe. If the replacement firm capacity is not secured, the IRRP retirement schedule needs to be extended.

5. Carbon Emission

Carbon dioxide is a colourless gas formed during the combustion of any material containing carbon. All energy production using combustion emits carbon dioxide. This includes driving vehicles, electricity production, heating, etc.

5.1 IPCC Guidelines for National Greenhouse Gas Inventories

The 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines) provide a technically sound methodological basis for national greenhouse gas inventories. To maintain the scientific validity of the 2006 IPCC Guidelines, certain refinements were required, and a task force finalized the refinements in 2019. The new methodology report to refine the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, was carried out by the Task Force on National Greenhouse Gas Inventories (TFI) in accordance with the decision taken at the 44th Session of IPCC in Bangkok, Thailand, in October 2016. It is titled “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories” The 2019 Refinement was presented for adoption and acceptance during the 49th Session of IPCC in Kyoto, Japan, in May 2019. The 2019 Refinement does not revise the 2006 IPCC Guidelines, but updates, supplements, and/or elaborates the 2006 IPCC Guidelines where gaps or out-of-date science have been identified. It will not replace the 2006 IPCC Guidelines and should be used in conjunction with the 2006 IPCC Guidelines.

5.2 Reference year

The Government of Barbados has long been an advocate of developing renewable sources of energy. The Barbados Light and Power Company (BLPC), with the approval of the Fair-Trading Commission (FTC) and technical support from the Inter-American Development Bank, introduced the Renewable Energy Rider initiative in 2010. This initiative allows customers to connect to the grid and sell any excess electricity generated from renewable sources to BLPC. Therefore, 2010 is selected as the reference year that such sustainable energy-related actions have started in Barbados. During the following several years of the IRRP implementation, CO_2 emission metrics will be tracked with respect to the CO_2 emission levels in 2010 in Barbados.

5.3 Metrics

The CO_2 emission-related metrics are followed under two categories:

- Historical (real)
- Future (projections)

Historical Year CO_2 Reductions: To track the improvement of the CO_2 reduction goal, a historical year fuel burn will be used in accordance with the IPCC calculation methodology to calculate a historical year's CO_2 emissions and the difference between the reference year.

Historical Year Fuel Reductions: To track the reduction in the amount of fuel burned for electricity, a historical year fuel burn will be used in accordance with the IPCC methodology. The reduction will be reported as the difference from the reference year.

Future Year CO_2 Reductions: To predict the future year CO2 emission, a production cost IRP model of Barbados can be used to simulate the amount of fuel burned. Then the IPCC calculation methodology will be adopted for estimated CO_2 emission. The reduction can be calculated as the difference with the reference year.

Future Year Fuel Reductions: To predict the future year fuel burn, a production cost IRP model of Barbados can be used to simulate the amount of fuel burn for the electricity sector. Then the future year fuel reduction can be calculated as the difference from the reference year.

5.4 IRP model of Barbados

The Integrated Resource Plan (IRP) model framework for planning future policies combines a capacity optimization (alternative analysis) phase with a production cost phase. By combining the capacity planning model and the production cost model, it is possible to inform policy and regulatory decisions as well as for informing utility decisions. This model was prepared to look at energy storage expansion and can be extended to be used for other types of technologies and technology evaluations or policy futures to investigate the combined impact of capacity expansion and short-run marginal cost. The modelling consists of two phases:

1. **Alternative Analysis**, to determine the expansion of storage and peaker plants
2. **Production Cost**, including annual, short-term, and real-time optimization, to determine the dispatch of the storage and peaker plants and associated prices

The alternative analysis (AA) phase takes as inputs capital costs and operational costs of current assets and future assets to run the grid, as well as new technologies assumptions, and performs cost minimization. The capacity optimization phase determines the MW size of new generation technologies as well as energy storage. The objective function of the capacity optimization modelling minimizes the production cost and the capital cost of the system. An annual optimization is performed over each year of the study horizon.

The production cost (PC) phase is responsible for optimizing to find the lowest-cost system dispatch and corresponding energy prices. The hourly production cost phase simulates hourly dispatch schedules and solves for the least-cost dispatch (in MWh) of the energy storage sized in the AA phase with respect to the variable costs of current and future assets.

6. Capacity Targets

The objective of the IRRP for the electricity sector in Barbados was to establish the required planning decisions for the short, medium, and long-term, and ultimately develop the Ministry's capacity to undertake the IRRP process. The IRRP utilized the multicriteria planning approach consistent with the framework identified under the BNEP 2019-2030. The development of the IRRP was undertaken with the support of the Inter-American Development Bank (IADB) via their consultant, Mott McDonald.

The IRRP is a result of a comprehensive process that includes resource options evaluation, demand forecast, storage option evaluation, generation planning options under three different scenarios, transmission planning, and multi-criteria assessment. After the evaluation process of different scenarios and that the BNEP has a fundamental goal of establishing 100% renewable energy by 2030, Ministry concluded that Scenario 3 should be employed to achieve the sectoral goal as it removes the greatest amount of carbon emissions, it impacts on the multi-criteria was on par with the other criteria generally, and that the levelized cost of energy was not materially difference to the other scenarios.

6.1 Resource Options Evaluation

The resource option evaluation considered the levelised costs of generation (LCOE), the land requirements, and the resource pattern. The evaluation with respect to generation considered technologies such as conventional generation, solar (photovoltaics and concentrated), wind, and bioenergy (biomass, bio-diesel, landfill gas, and waste-to-energy). Figure 5 shows the installed capacity mix and a peak load of Scenario 3. The expected capacity of all generation options and batteries are represented in different colours.

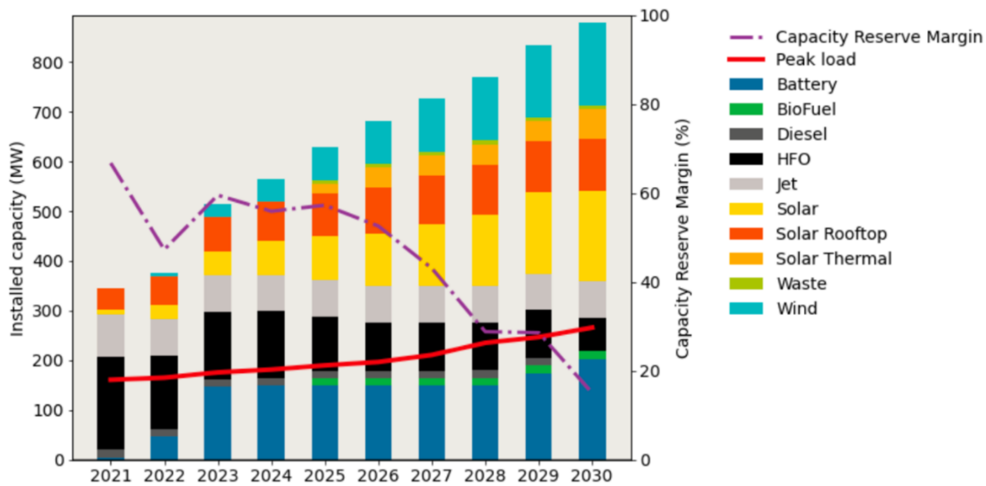


Figure 5: Scenario 3 – Installed capacity mix and peak load

Source: Integrated Resource & Resiliency Plan for Barbados

6.2 Demand Forecast

As stated in the IRRP report, Barbados's future power demand will be closely linked to economic drivers within the existing economy and will also be influenced by the electrification of new sectors currently served by fossil fuels, most notably the road transport sector. The power demand from 2020 until 2030 will continue to be mainly driven by the commercial and residential sectors, with EV having a significant share from 2030 to 2040. Three scenarios were then advanced - Base, High, Low up to 2040. The Base scenario demand initially rises slowly to reach 1049 GWh in 2025 and then more rapidly to reach 1277 GWh in 2030 and almost 1500 GWh by 2040. The High scenario sees demand growth accelerating through the 2020s to reach 1670 GWh in 2030 before growth decelerates in the 2030s to reach 1776 GWh in 2040. The Low scenario sees demand falling slightly before slowly recovering from 2025 onwards to reach 899 GWh in 2030 and 1003 GWh in 2040.

6.3 Storage Option Evaluation

The IRRP report indicated that currently, Li-Ion battery storage is the only mature and proven technology that can cover the whole range of required storage applications. This may change as technology development advances and feasibility studies shed more light on the options available to Barbados. In the near term, for bulk storage applications, Hydro Pumped Storage could be a competitive option, and in the future also Flow Batteries, CAES, and thermal storage may become suitable options. However, the IRRP report stressed that from a resiliency and transmission network perspective, modular and distributed solutions would be preferred, which currently leaves only Li-Ion battery storage as an option. This is because it:

- Optimises the use of the existing network capacity with less overloading and reduced transmission losses; and
- Supports islanding by balancing generation and loads that are diversified across the island.

The IRRP report posited that the clear alternatives for Barbados are utility-scale battery storage systems (10-30 MW) that are distributed across the island as well as distributed home energy storage (thousands of small-scale systems in the kW range).

The centrality of required investments in stationary storage and V2G technologies is observable in a simple simulation of how a typical daily supply-demand balance in Barbados is expected to evolve over the coming decade. First, the increased installed capacity of renewables – driven especially by the plentiful supply of solar resources in Barbados – lowers the net demand required to be supplied by BLPC. In some cases (during peak hours) the net demand that should be satisfied by the dispatchable resources becomes non-positive, creating a surplus of power that is expected to expand dramatically as more solar capacity is installed between now and 2030. This phenomenon is generally referred to as the "duck curve," a name that originated in California, a region that experiences similar solar conditions to Barbados.

The Barbados "duck curve" with net demand to be supplied by dispatchable resources for future years is illustrated in Figure 6. The conditions of the "duck curve" require ramping up of power to stabilize the grid and also cause curtailment risks. If such conditions are not addressed, they not only create reliability issues but also can result in substantial economic losses for power generators. These conditions are, however, suitably addressed by investments in stationary storage and V2G technologies, which then act as a natural balancing mechanism by providing a demand outlet for the excess supply of solar power during peak periods.

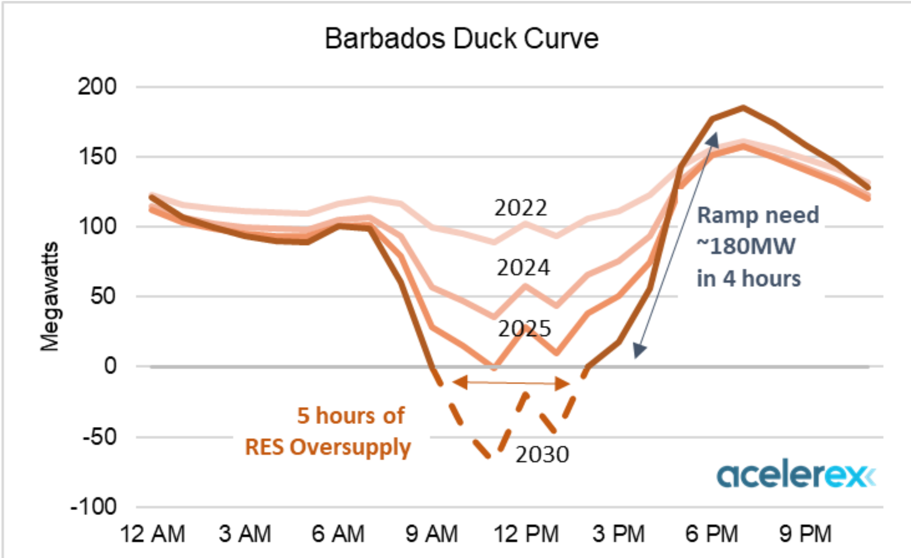


Figure 6: Barbados Duck Curve (2022-2030)

Source: BLPC, Acelerex Chart: Acelerex

6.4 Generation Planning

Scenario 3 is a Forced Firm Renewable Scenario with carbon cost internalised (FRES) - Policy intervention implemented via a carbon price. The carbon price is internalised into build and dispatch decisions.

The undiscounted cumulative investment over the study horizon needed to achieve Scenario 3 was estimated at BDS$2.59 billion. This is a reduction in the cost initially projected in the BNEP which takes into consideration the reducing cost of the technology. The average emission under Scenario 3 stood at 275,789 tonnes/year.

Figure 7 below shows the generation mix for Scenario 3. By 2030 the generation mix is 2% fossil fuels, 4% firm renewables (waste – 1%, biodiesel – 3%), 31% wind, 38% solar PV, 14% CSP, and 9% BESS.

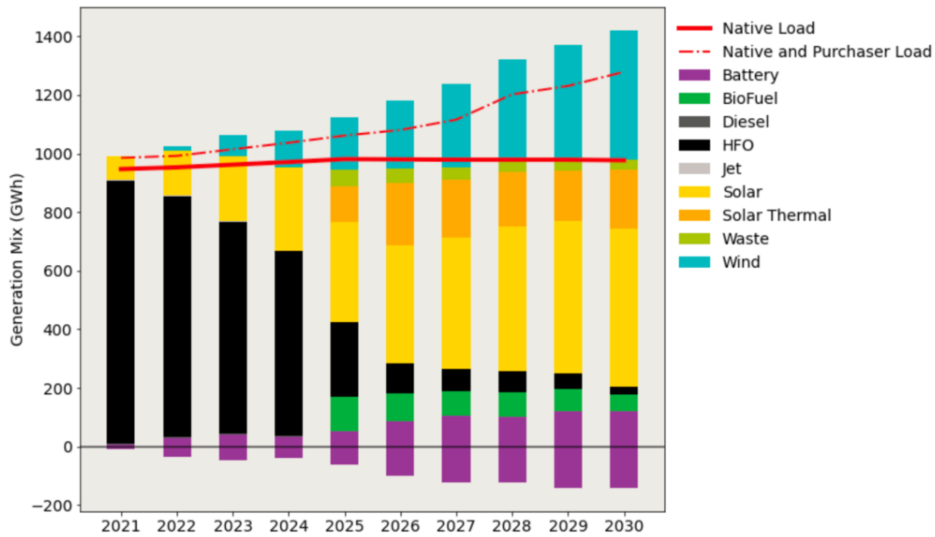


Figure 7: Scenario 3 – Generation mix

Source: Integrated Resource & Resiliency Plan for Barbados

An example of distributed rooftop solar is explained here to make it easier to visualize the amount of capacity to be added. With an average of 2.5kW installed solar capacity per roof, the implementation of panels to 50,000 houses in Barbados reaches the cumulative solar capacity of 125MW. With an assumption of 260kWh per month (~14% capacity factor) solar energy generation by each house, the total energy production is 13 GWh per month and approximately 156 GWh per annum.

Figure 8 shows the annual new resources required for Barbados which adds up to 294MW of solar resources, 166MW of wind resources, and 280MW of storage by 2030. The size requirements in MW represent the output power capability. The amount of storage required year-by-year as indicated in the figure and the table below is technology-independent. Due to the fact that the round-trip efficiency of different storage technologies varies, if a specific storage technology is selected then the losses will have to be factored into the energy amount required. The losses associated with specific technologies have an impact on the energy component of the storage, not the power component.

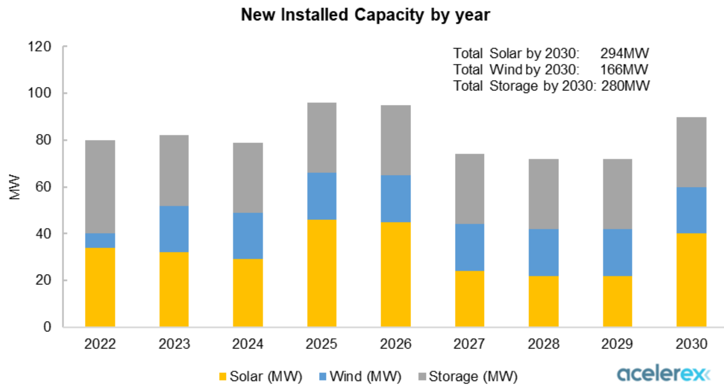


Figure 8: Annual New Installed Renewables & Storage Capacity

The cumulative total of renewable and storage resources by year is given in Table 10. They will start replacing the existing fossil fuel generators and eventually generate and store electricity without carbon emissions.

Table 10: Total Installed Renewables & Storage Capacity by Year

Expansion (MW)	2022	2023	2024	2025	2026	2027	2028	2029	2030
Solar (MW)	34	66	95	141	186	210	232	254	294
Wind (MW)	6	26	46	66	86	106	126	146	166
Biomass (MW)	0	0	0	20	20	20	20	20	20
Waste to Energy (MW)	0	0	0	8	8	8	8	8	8
Landfill Gas (MW)	0	0	0	5	5	5	5	5	5
Storage (MW)	40	70	100	130	160	190	220	250	280
Storage (MWh)	160	280	400	520	640	760	880	1,000	1,120

6.5 Multi-Criteria Assessment (MCA)

The IRRP study recognising that the BNEP was predicated on the multi-criteria approach, the IRRP also evaluated a holistic ranking of generation planning scenarios, as Barbados transitions to a more sustainable electricity system. Based on the agreed criteria with the stakeholders, where scenario cost and land use are assigned the highest importance.

7. Terminology

#	Acronyms	Full Terminology
1	AA	Alternative Analysis
2	BNEP	Barbados National Energy Policy
3	BLPC	Barbados Light and Power Company
4	DEM	Distribution equipment monitoring
5	DER	Distributed energy resources
6	ELCC	Effective load carrying capacity
7	ELPAC	Electric Light and Power Advisory Committee
8	EV	Electric vehicle
9	FIT	Feed-in tariff
10	FRES	Forced Firm Renewable Scenario with carbon cost internalised
11	FTC	Fair-Trading Commission
12	IADB	Inter-American Development Bank
13	ICR	Installed capacity requirement
14	IRP	Integrated Resource Plan
15	IRRP	Integrated resource and resilience plan
16	IPCC	Intergovernmental Panel on Climate Change
17	kW	Kilowatts
18	LCOE	Levelized costs of generation
19	MCA	Multi Criteria Assessment
20	Ministry	Ministry of Energy and Business Development
21	MW	Megawatts
22	MWh	Megawatt-hours
23	RFP	Request for proposal
24	PC	Production Cost
25	PPA	Power purchase agreement
26	PRM	Planning reserve margin
27	TFI	Task Force on National Greenhouse Gas Inventories
28	TOR	Terms of reference
29	VPP	Virtual power plant
30	V2G	Vehicle to Grid technology