The Possibility of 100% Renewable Electricity by 2030: A Land Area Analysis

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Abstract

Barbados, a Caribbean island, has a goal of achieving 100% renewable energy electricity by 2030. In order to achieve that feat, it is estimated that about 600MW of renewable energy technologies would have to be installed [1]. With a land area of 431 square kilometres, it is questionable if there will be enough free land area to accommodate the predicted amount of technology [2]. With the total land area in mind, this research seeks to discover if there is enough area to achieve the 100% by 2030 goal without compromising pre-existing land used for agriculture, recreation and wildlife reserves. This goal will most likely be achieved through the use of solar and wind farms. There is some research to use ocean thermal energy conversion (OTEC) and off-shore wind, however the feasibility of it actually happening is not fully known. Barbados is in a unique position as the island cannot rely on hydroelectricity or geothermal energy, unlike many of its Caribbean counterparts. Currently, Barbados uses mostly fossil fuels alongside a 10MW solar farm and 5MW of battery storage from commercial generation. There has to be a major overhaul for this goal to happen in the next 10 years. Not only does Barbados have to worry about installing the necessary capacity, but there are a number of issues which arise, such as the opportunity cost of using the land for renewable technologies versus for purposes such as agriculture or tourism. The research will be undertaken by looking at the current data available from a variety of sources and previous studies done in Barbados and the wider world regarding Barbados' future and the standards being used by other global forces.

Key Words: Renewable Energy, Barbados

Introduction

Barbados is a small island located in the lesser Antilles in the Caribbean. The island was formed through underwater volcanic eruptions which broke away from the seafloor. Thus, it is not a mountainous island and has very few water sources outside of the underground water table and the surrounding ocean. The renewable energy possibilities are limited, as they cannot use geothermal or hydroelectric energy which tend to have a large energy yield. Instead, Barbados' main plan is to build their renewable capacity with solar panels, wind turbines and battery storage. Right now, Barbados' energy mix consists of a 10MW solar farm, 5 MW of battery storage and about 239 MW of engines which include steam, diesel and gas turbines [2]. Other projects in the works is a 10MW wind farm and a clean energy bridge, both of which should operate out of St. Lucy [3]. By 2030, however, the fossil fueled engines should no longer be in active operation. These projects have been coordinated and spearheaded by the current utility company, the Barbados Light and Power Co.; however, there are plans to demonopolize the sector, and other entities are being encouraged to invest in renewable energy for the island [4]. In addition to solar panels and onshore wind turbines, there are also discussions of utilizing floating wind turbines and ocean thermal energy conversion (OTEC). to add to the renewable energy capacity of the island. Aside from large scale investments, there are also 22MW of installed renewable capacity on private households and local

businesses according to the local electric company. According to the current government, the goal is to achieve 100% renewable electricity by 2030 [6]. Presently, with a peak load of about 170MW, it is estimated that they would require about 600MW of renewable energy power in order to have grid stability and the necessary reserves for inopportune environmental conditions [1, 2]. Alongside renewable energy technologies, there is also a need to have batteries to make up the load during the night/cloudy days and/or when there is less wind. With a land area of 431 square kilometres, there is concern that there isn't enough space to build the infrastructure needed to reach 600MW of energy capacity. For this to be successful, there has to be a cohesive effort by the government, the private sector and personal households to pool resources and electrify the country. The purpose of my research is to examine the needed renewable energy capacity and assess its feasibility, bearing in mind the land space, to achieve 100% by 2030.

Limitations of Study

In this study, I intend to look at the available land space and, based on current technologies and previous projects done in Barbados, analyze the feasibility of the 100% renewable electricity goal. I will be ignoring the price of installation and whether it would be possible for the island to afford the project, as well as technologies that are not fully developed yet. Additionally, it will be assumed that all the land area that is free and seemingly available is licensed and suitable for building renewable energy technologies. There were no site visits done in order to determine the suitability of each land area found. I will not be assessing the contributions through rooftop solar panels, which was estimated to potentially contribute 280 MW of solar power [6]. This study will take into account the land space currently used for agriculture, recreational use and wildlife reserves and how possible it would be to use the available land space and ocean capacity. In the study, only appreciable land areas will be considered (greater than an acre). The research will analyze the combination of solar, wind and battery storage needed to accomplish the 100% goal.

Research Methodology

The research was carried out through utilization of prior data from studies of the available land space in Barbados through surveying and prior projects. Most of the data has been obtained from the local utility company, the Barbados Light and Power Co. Additionally, the use of Google Maps also supplemented getting estimates of the land area and the locations which have large open spaces. Moreover, there was information drawn from peer-reviewed articles from various databases and sources. The research was based mostly on current research regarding renewable energy technologies and batteries in order to estimate the land space needed to fulfill the required electricity capacity in the year 2030. This approach was chosen as I believe it is the best way to obtain accurate information to determine the possibility of Barbados' renewable energy plans

Discussion/ Data Analysis

Land Availability

Barbados is a Caribbean island formed from the collision of the Caribbean and Atlantic plates along with a volcanic eruption. As such, there are few rivers or streams that can be found on the island. Barbados has a land area of 431 square kilometres. Currently, this land area is used in a variety of ways including commercial, residential and agricultural uses, as well as for renewable energy technologies. The available land area is located mostly in the northern part of the island, whereas the majority of the population resides in the south. Using Google Earth, one is able to see the available land area and estimate the measurements (see burgundy areas in Figure 1). In 2016, agriculture comprised about 23.3% of Barbados' land space which is roughly 100 square kilometers [7].

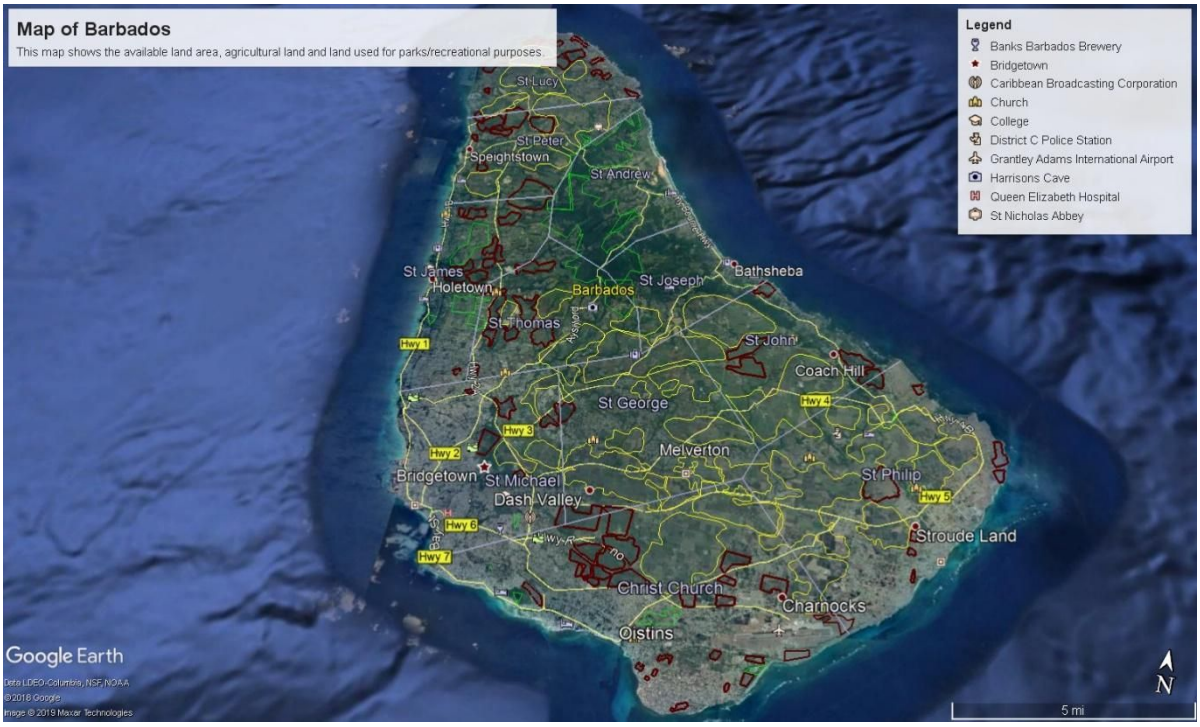

Figure 1: Map of Barbados highlighting the available land area, areas used for agriculture and areas used for parks/recreation.

Through the use of Google Earth, one is able to see the free land space and make educated guesses as to where the agriculture (highlighted with yellow), forest reserves and recreational activities (highlighted in green), e.g. golf courses, are located through the geography and the visual of the land area. For example, one could identify plantation fields through how the plots of land are arranged in a certain area. With Google Earth, and a previous study, it was roughly estimated that about 30.9 km^2 of land is available for renewable energy use around the island. These land areas are scattered throughout different parts of the island and encompass different characteristics. In the study, 83 different areas of land were identified across the island ranging from 2.34 acres to 570 acres. Of these 83 different areas, it will be assumed that there will be a mix of wind and solar energy. Due to the terrain, not all of the land will be suitable for renewable energy use; however, in order to assess the space, site visits would have to be done. Additionally, necessary infrastructure, such as substations and additional connections, may have to be

built for certain areas in order to accommodate the production and account for the distance between the connections.

Renewable Energy Necessity

According to [8], it is estimated that Barbados will have an annual energy consumption of 1350 GWh. When calculated, this results in a required capacity of 150 MW of power per day, with a total installed capacity of 600MW - which includes the back-up capacity - for a stable grid. Additionally, there needs to be about 30% or 180MW of battery storage to serve the country during cloudy days, night or low wind speeds [1]. This 600 MW figure accommodates for fluctuations in production from renewable sources. For example, with 200MW of installed PV, on a sunny day the entire island could be powered at peak load from solar power alone. However, on a cloudy day the power output of PV will drastically decrease, and this deficiency could then be made up by the installed capacity of other renewable sources.

Renewable Energy Models

Solar Energy

To calculate the potential solar capacity, the ratio of 4 acres per megawatt was implemented [9]. Using this estimation, about 2400 acres of land is needed for enough solar power capacity. In our estimation, there is about 30 km^2 or 7,646.47 acres of available land with potential production of about 1,911.62 MW. This amount is very rough as some land areas may not be suitable for this use. However, this figure is more than three times the necessary energy needed. Therefore, there is some room for deciding which combination of land area would give the greatest yield and be the most efficient and feasible to put the solar panels. If the land areas that were close to the grid (which also could be accommodated) are the only ones considered, there would be about 82.74 MW of solar energy. As such, in order to achieve fully renewable electrification, there is a need for improvements in the infrastructure and grid network around the island in order to support going 100% renewable. To accomplish this feat, the grid network needs to be more extensive and there have to be adjustments to the load connections.

Wind Energy

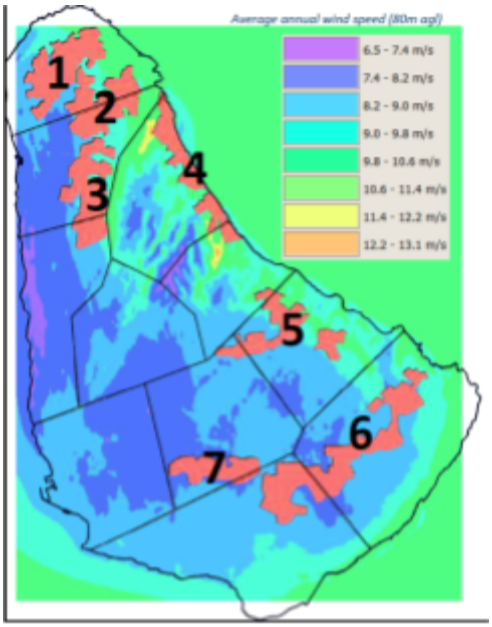

Figure 2: Study showing average annual wind speeds throughout Barbados

For wind, a prior study was utilized, which highlighted key areas on the island for wind development (see figure 2) [6]. The areas numbered and in a reddish hue are the areas that were considered the best for wind energy development. The study and the free land space were compared and of the 83 areas, only 12 areas were suitable. It was estimated that a necessary land area of 20 - 47 acres per MW of wind would be necessary. There is a range due to the different sizes/capacity of turbines available and the set-back requirements in a country. The upper boundary of the range was calculated, using the premise of a 2 MW turbine, due to the regulation that it has to be 350 m from the nearest property line and the area per turbine was calculated using the area of a circle with a radius of 350 m [10]. The same could be done for the lower boundary; however, if the turbine has a larger capacity, there would be less area per megawatt in this case. Thus, it was calculated that between 49.25 MW (47 acres/MW) and 115.74 MW (20 acres/MW) of wind energy potential is available and does not include the 10 MW which is to be developed in Lamberts, St Lucy. Wind energy presents many issues with installation on the island. The road networks and bridges were not built to necessarily accommodate the weight and size of a wind turbine. Also, the country does not readily have the necessary manpower for the maintenance and installation of these technologies. Therefore, initiatives could be done to train people to be skilled as a wind turbine technician, as the Wigton Wind Farm in Mandeville, Jamaica could be likened to a Caribbean example of a wind farm and used as a training ground.

Mixed Renewable Technology

In this model, there is a mixture of wind and solar energy. The land areas that are suitable for wind energy will be used for wind, and all the rest of the land areas will have solar energy on it. In this model, roughly between 1382.17 MW and 1448.66 MW of renewable energy potential. These figures are still at least 2 times more than the necessary renewable energy capacity in order for the island to stay electrified.

Battery Storage

As aforementioned, there needs to be 180 MW of battery storage located around the island, or roughly 30% of the total installed power capacity [1]. There will have to be batteries available which have the ability to discharge quickly during peak times, as well as discharge relatively slowly overnight. Batteries are also an important asset during the night and during cloudy days. Efforts for battery storage will be a combination of private storage (for example, the Tesla Power Wall), utility efforts and third-party initiatives. Battery storage will play an integral part in the 100% renewable initiative and be used to regulate the frequency and stability of the grid. Batteries stabilize the grid through fulfilling dips in the energy produced by, for example, solar panels when the day becomes overcast which allows for the maintenance of the frequency. Currently, batteries are being used in St. Lucy that are charged by the grid,

but discharge once the frequency drops to 49.88Hz from the stipulated 50Hz. These batteries have assisted tremendously during peak times to fulfill a spike in the load.

Possibility of Microgrids

Microgrids could increasingly become an integral part of the Barbados power grid. Microgrids are a small-scaled version of standard grids and supply one or a small group of consumers with power [11]. Microgrids can be isolated or connected to the grid. In the Barbados power grid, it is most likely that most of the microgrids made will be interconnected. Microgrids supply the island with grid stability as they are able to supply power to consumers in times of grid failure or natural disaster. It is anticipated that the usage of microgrids would be concentrated in large power consumers such as hotels, and the main hospital. Microgrids are an emerging technology that could provide a useful service in Barbados.

Utilizing Land Space

There are a variety of ways in which land is used in Barbados and will continue to evolve in the future. Currently, the land area is protected, used for agriculture or recreational activities such as golf. Using up the land space for renewable energy alone would not be the most effective use of the land. Therefore, there are multiple ways in which the land area could be used alongside the renewable energy technologies.

In the case of solar panels, the land underneath the panels could be used for agriculture, i.e. grow low-lying crops which require shade such as peppers, cilantro, etc [12]. Additionally, other uses for agriculture include grazing of sheep around the panels which keep the grass low, as well as providing food for the livestock. Another use of solar panels would be in car parks which would provide shade for cars and allow for the multipurpose use of space in such a small island.

For wind energy, the free land space can be used for agriculture up to the base of the wind turbine [13]. Through the multipurpose use of the land space, economic growth could be stimulated through subsidies and governmental efforts to encourage the stimulation of the agriculture sector.

Possible Issues with 100% Renewable

As a small island, Barbados' grid is not the most stable even now when using fossil fuels. Therefore, there have to be additional measures implemented to ensure grid stability. Grid stability would most likely be achieved through the use of batteries, which would assist in the short-comings of the system. Additionally, to become 100% renewable through the use of solar and wind only is a costly endeavour and will require a large number of investors and/or heightened debt to the Barbadian government. Currently, there are discussions regarding de-monopolizing the energy sector, which adds more complications over ownership, costs and overall maintenance and responsibility of the grid and its various sections [4].

With more energy infrastructure being built, there will be a need for new and/or improved substations around the island. The substations currently will not be able to accommodate the capacity needed for the 600MW of power mandated. These projects would pose a significant expense and may take some time to come to fruition. In order to accomplish the goal by 2030, there will have to be a lot done in a short period of time.

Land is a vital part of human life. It is used for many purposes such as living, agriculture, recreation, etc. Through building the necessary infrastructure for the 100% by 2030 goal, Barbados is essentially giving up at least 2400 acres of their free land space which could be utilized for increased agriculture or property development. As a densely populated country, the land area might be extremely useful for additional development to house the growing population. Nonetheless, if the land was to be used for agriculture instead there are ways in which crops could be grown and the renewable energy technologies cohabit the area. The decision on the type and height of crops would have to be thoughtfully made if using solar energy.

Nonetheless, the land is not spared by natural disasters. Barbados, although not frequently, has the potential of being hit by a hurricane. Through using solar in particular, Barbados becomes vulnerable to a major loss in their generation capacity in the case of a category 4 or 5 hurricane. Other island's PV systems have been decimated by hurricanes of that strength, and it is unsure of what can be done to prevent the destruction of the PV systems, but preventative methods are put into place such as properly torqueing and double nutting the panels to the base [14]. Wind energy systems are reportedly supposed to be able to withstand a category 4 or 5 hurricane [6].
The above highlights some of the main issues associated with going 100% renewable. There is a possibility that the issues highlighted could be overcome with intentional planning and understanding of the different situations at hand and/or the goals trying to be achieved for the area of land.

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Conclusion

The Barbados 100% by 2030 goal is feasible in theory. It is evident that there is enough potential land space to provide more than double the amount of power needed regardless of the model chosen. With solar panels alone, there is a potential of roughly 1900MW and for mixed wind and solar, the potential ranges from about 1300MW to 1450MW, and both are appreciably greater than the necessary 600MW [1]. This research does not include rooftop PV and/or its potential which would contribute more to the total production of Barbados. However, there are still many issues that are at hand such as the licensing that the land has, financing and ensuring that the infrastructure will be able to withstand natural disasters. Although there is an opportunity cost in developing such infrastructure, there can be multipurpose usage of the land, ranging from agriculture to car parks. Also, there are other factors to explore such as battery storage and microgrid development throughout the island. Improvements to this study could include the rooftop PV and analyzing the overall power potential from that source, as well as, looking at the land areas of those identified which are licensed to be used for renewable development. Nonetheless, the feat will have to be a cohesive effort from all stakeholders on the island. With the right policies, regulations and availability of funds, the 2030 goal may just become a reality.

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