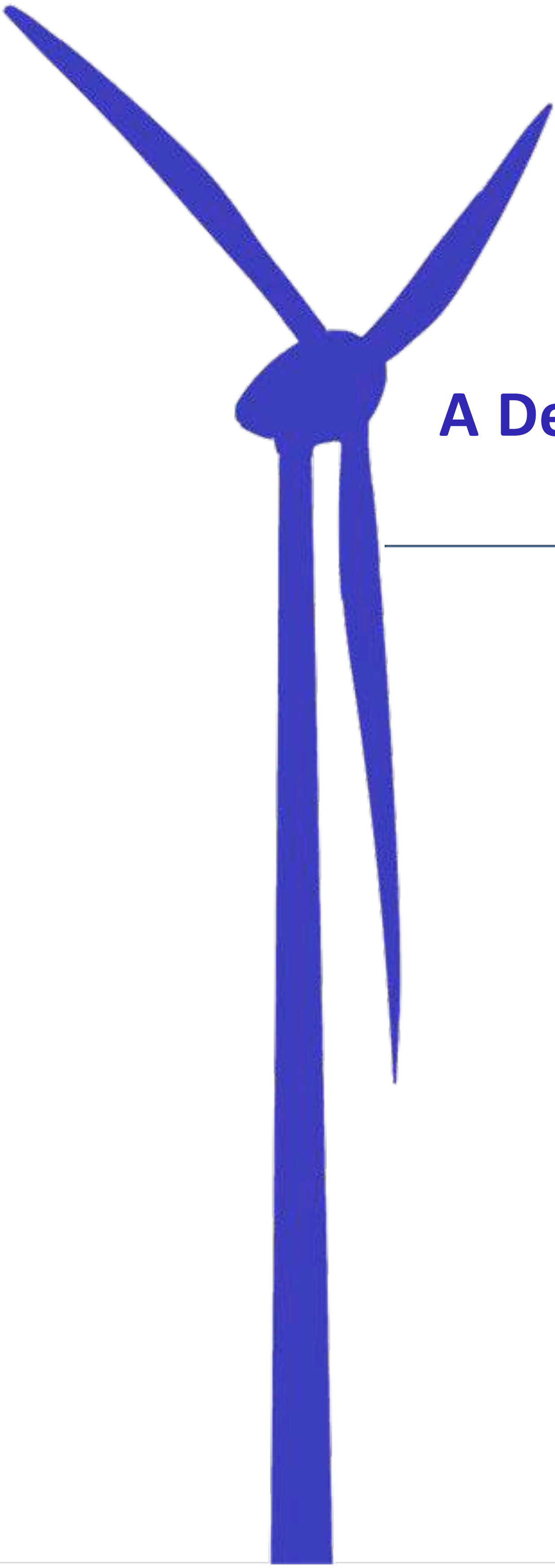

A Desktop Study of the Wind Resource in Barbados

Next Steps to Develop the Island's Wind Sector

April 2017

Department of Computer science, Maths and Physics
The University of the West Indies
Faculty of Science & Technology
Cave Hill Campus
Bridgetown
BARBADOS

Author: Dr Thomas Rogers

Department of Computer Science, Maths and Physics
Faculty of Science & Technology
Cave Hill Campus
The University of the West Indies
Bridgetown
St Michael
Barbados
Email: thomas.rogers@cavehill.uwi.edu

April 2017

Table of contents

1 Key findings

This report outlines the results of a desktop study into the technical wind energy potential for the island of Barbados, and suggests next steps for developing this resource. The key findings are as follows:

- Given the excellent resources on the island, utility-scale wind turbines are the cheapest way to generate electricity in Barbados. With economies-of-scale being most attractive for larger wind turbines and larger installed capacities.

- Seven potential wind zones are identified, yielding 64km^2 of land available for utility-scale wind turbine deployment. It is recommended that these zones be considered for inclusion in the future Physical Development Plan.

- Hypothetically, there is enough land available in these zones for Barbados to generate nearly twice its current electricity demand solely from wind energy (472MW). Hohmeyer's 2014 study of a 100% renewable Barbados required 200MW of wind.

- A review of current wind turbine planning consideration is required if this resource is to be effectively developed. Section 6.2 discusses suggested planning changes in a social, environmental and economic context.

- A detailed, investment-grade wind measurement campaign is required in order to identify suitable wind turbines, wind farm sites, provide accurate proof for financing, and to assist in the formation of attractive Feed-in Tariffs for wind. Working with overseas wind resource experts, the author has produced a detailed proposal for such a campaign, which includes developing local expertise for replicating wind measurement campaigns throughout the eastern Caribbean.

- There is a need to create a detailed wind strategy, whereby all wind sites are developed as one, thereby reducing duplication of resources and enabling optimum cost savings for the island's population. The creation of a wind energy stakeholder group, involving Government, local communities and the utility will help ensure support at every level for the development of the island's plentiful wind resource.

An outline of the suggested steps for developing the wind sector in Barbados is provided in Section 6.

2 Overview

This report provides a prefeasibility assessment of the wind energy capacity for Barbados, and suggests recommendations as to how this resource can be realised. It has been produced in order to help raise awareness of the impact that wind energy can have on energy costs, and to highlight the key issues around modern day wind energy.

Following Olav Hohmeyer's 100% renewable energy strategy report for Barbados, and subsequent discussions with the Island's various stakeholders, including farmers, its utility company, businesses, and government departments, it was evident that an investigation into the wind resource was an important next step in developing the wind energy sector. This report presents the results of an initial desktop study into the technical wind energy potential, with the anticipation that it will lead to a more detailed, investment-grade wind study. More specifically, this report:

- Estimates the maximum installed wind energy potential for the Island.
- Identifies the best locations for 200MW of wind identified in Hohmeyer's 100% renewable Barbados paper.[Error! Bookmark not defined.]
- Provides a basic economic analysis of wind turbine deployment.
- Reviews Barbados's wind turbine planning guidelines and describes planning changes that would help exploit the island's wind energy resource.
- Highlights the need for a local ownership model — the most beneficial for Barbados's economy.

Areas that meet the current wind turbine setback requirements are first identified, yielding a total potential area of 64km^2. Seven zones are identified, yielding a maximum installed potential of 472MW of 2MW wind turbines. 17 years of wind speed data from Grantley Adams International Airport (GAIA) is used to produce a wind resource map for the whole island, and the expected energy yield for each zone is calculated. The total expected yield is shown to be 1,473GWh/year, more than Barbados's annual electricity demand (~950GWh/year).

3 Methodology

The design of a wind farm is usually a compromise between high-energy yields, easy access, electrical grid integration, permitting, and commercial viability. Careful consideration of a substantial number of factors is typically required to reach the best designs and consequently the majority of wind farm developers use dedicated software tools. This study used EMD's industry software package, WindPRO 3.0[1]. WindPRO is a wind farm analysis package and has online access to worldwide wind datasets, surface roughness data, and topography data, as well as a catalogue of all of the main wind turbines on the market today. With this information the software is able to offer a substantial range of outputs, capable of aiding the whole wind farm planning process, including:

- Energy yield prediction
- Financial modelling
- Electrical integration modelling
- Noise maps
- Shadow flicker maps
- Photomontages/animation

The wind speed, topography and surface roughness datasets used for this study are presented in Table 1. The output from the software is very much dependent upon the quality of the data that is entered. The accuracy of the weather data and surface roughness data should be improved if a more precise assessment of the wind resource is to be determined. The weather data can be improved by performing a high quality, island-wide 1+ year wind measurement campaign (see Section 6.1), whilst the accuracy of the surface roughness can be improved by the provision of accurate land-use GIS maps (see Section 6.1). The topographical data is sourced from the U.S. Geological Survey's Radar Topography Mission and has a resolution of 1-arc second. Although this could also be improved, its accuracy is sufficient for the scale covered in this assessment.

Table 1. Input data for wind resource modelling of Barbados.

Weather data	3-hr wind speed and direction at 10m above ground level from Grantley Adams International Airport [1999 to 2016]
Topographical data	1-degree contour data from Shuttle Radar Satellite data, GeoCover satellite images.
Surface roughness data	300m x 300m roughness data from European Space Agency satellite imagery.
Wind turbine selection	2MW Enercon E-70[2] with a hub height of 75m

1 - EMD WindPRO 3.0 software: http://www.emd.dk/windpro/
2 - Enercon E-70 technical data: http://www.enercon.de/en/products/ep-2/e-70/

3.1 Wind turbine selection

Economies-of-scale determine that the cost-of-electricity from wind energy generally decreases as the size of the wind turbines increases, leading to the recognition that the largest possible wind turbines should be deployed. This is probably more imperative for small islands like Barbados, given that there are limited locations where wind turbines can be installed. In other words – don't waste valuable wind turbine land on small (<1MW) wind turbines. This observation is further evident in Figure 1, which shows one 2MW wind turbine and seven 275kW Vergnet wind turbines. The single 2MW wind turbine will generate more electricity than all seven of the smaller capacity Vergnet units combined, and will have a lesser visual impact on the landscape. Figure 2 also reinforces the value in selecting the largest possible wind turbines, with the installed cost per kW capacity falling substantially for the larger wind turbines, resulting in lower electricity costs for the consumer.

Figure 1. Photomontage of agricultural land in St Lucy, Barbados, highlighting the need for fewer larger wind turbines rather than many small wind turbines.

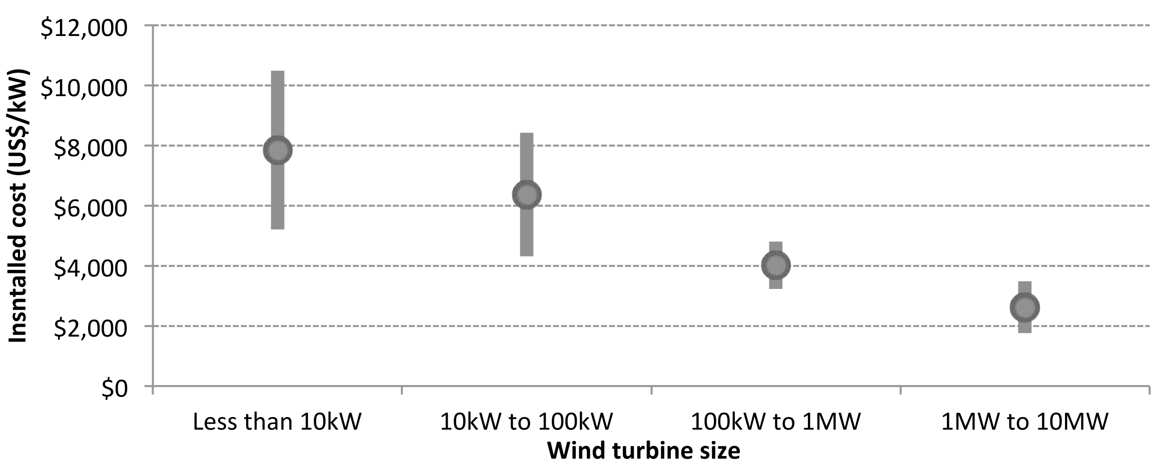

Figure 2. Installed cost for different sized wind turbines – mean and standard deviation (Source: USDOE, 2015)[3]

[3] - US Department of Energy – Levelised cost of Energy (LCOE) https://energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf

For an island like Barbados, the maximum size of wind turbine will likely depend upon two key logistical factors:

1. **Cranage** – To install the wind turbines, cranes will be required that can reach above the hub-height of the wind turbine and are able to operate safely at remote locations.

2. **Transportation** – The turbine towers can generally be transported in sections. However, wind turbine blades invariably have to be transported whole. This leads to difficulties if roads leading to wind sites are narrow with tight corners. It is for this reason that a detailed transport survey would be a necessary next step (see Section 6.5).

The local utility, Barbados Light and Power Ltd., has performed a transport survey for their proposed 10MW wind farm site at Lamberts East in the Parish of St Lucy and expect the largest sized wind turbine that they can install to be ~2MW. This corroborates conversations with other wind energy experts and is the reason that this study uses a 2MW rated wind turbine (Figure 3). However, it should be noted that economies-of-scale dictate that it would be possible to use larger wind turbines (as large as 3MW) if a higher installed capacity target is identified. In other words, if Barbados decided to target the upper end of the ~200MW of wind identified in Hohmeyer's study, it may make sense to invest in the transport infrastructure (road widening/straightening) and cranage, needed to install the larger wind turbines.

The worldwide wind turbine market is growing annually and there are a number of manufacturers of high quality, marine-rated, 2MW wind turbines now available. The German manufacturer, Enercon, was chosen for this study given that their Enercon E-70 2MW wind turbine is well suited for sites in coastal areas with high wind conditions. In reality, companies like Enercon and the other utility-scale wind turbine manufacturers will only become interested in selling to smaller markets, like Barbados, if a large order is sought (>30MW). This is just one reason why it would make good sense if an island-wide wind energy strategy were developed (see Section 6.3).

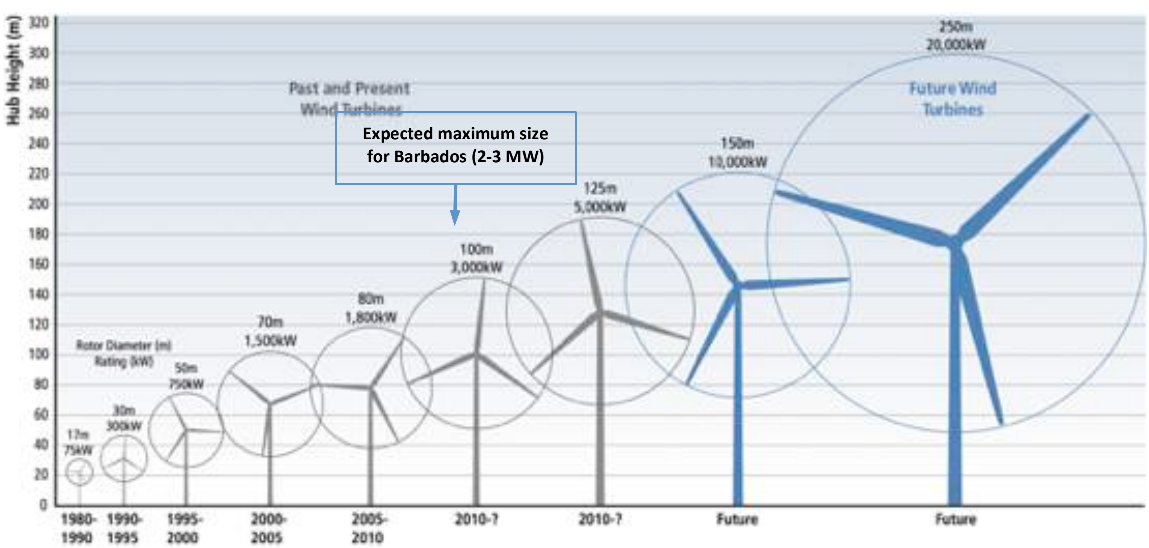

Figure 3. Historical growth in the size of wind turbines (Source: NREL)

3.2 Wind farm siting

A key part of this study was determining the potential locations for utility-scale (>1MW) wind turbines. The existing Physical Development Plan identifies four wind energy sites; Upper Salmonds, Lamberts and Lamberts East in St. Lucy, and Bissex Hill in St. Joseph (the locations of which are shown in Figure 4). All together, these sites might be expected to yield an installed capacity of around 40MW. However, the island has a large amount of relatively flat, rural, sugarcane land on its exposed North, East and South coastlines. This land is ideally suited for wind turbine installation. The exploration of these potential sites, or 'zones', is the subject of this section of the report.

When determining wind farm locations, the main consideration was the existing planning setbacks. The Barbados Town and Country Development Planning Office stipulates that wind turbines should be:

1. 1.5 times their height away from any roads and buildings,
2. A minimum of 350m away from the landowners' boundary, and
3. The wind turbine sound level should be below 45dB(A) at the nearest dwelling.

The second guideline has a significant impact on the maximum installed capacity and would require reviewing if Barbados wished to exploits its wind resources (see Section 6.2). As no property boundary information was available publicly, this survey ignores the setbacks from property boundaries and focuses on distance from residential dwellings, buildings and roads.

With respect to noise emissions, the planning guidelines adhere to World Health Organisation (WHO) rules governing the noise impact from wind turbines. Noise emissions change from turbine to turbine, so a conservatively high boundary limit of 350m was used in this study – in order to meet the 45dB(A) limit the Enercon 2MW wind turbine could be realistically installed within 300m of a residential dwelling. Section 6.2 discusses noise emissions in more detail and gives recommendations for updating the planning guidelines.

Adhering to setback rules 1 and 3 (above), satellite imagery was used to determine the open, rural locations available for wind turbines. This process was followed up with site visits. Figure 4 shows the areas where wind turbines could be installed and still meet the 1st and 3rd planning guidelines listed above. This was not an exhaustive search as only larger areas were of interest. There are smaller areas where wind turbines could also be installed, including the Bissex Hill site identified in the current Physical Development Plan (Figure 4). Section 6.2 discusses 'white mapping', a more precise GIS approach to determining wind zones.

Seven potential wind energy zones are identified, including the open agricultural land in the North of St. Lucy, and around Mount Gay, stretching down into St. Peter. The St. Andrew parish has good potential in the North and down by the flatter coastline. However, installing on the steeper slopes of St. Andrew would likely be inadvisable from a geological and foundation perspective. St. John and the agricultural land on top of Hackletons Cliff provide good wind turbine locations, along with farmland in St Phillip and Christchurch, and into the St George valley. St Phillip and Christchurch are interesting given the Woodborne oil field and the fact that there are already certain guidelines about proximity of the oil wellheads to dwellings.

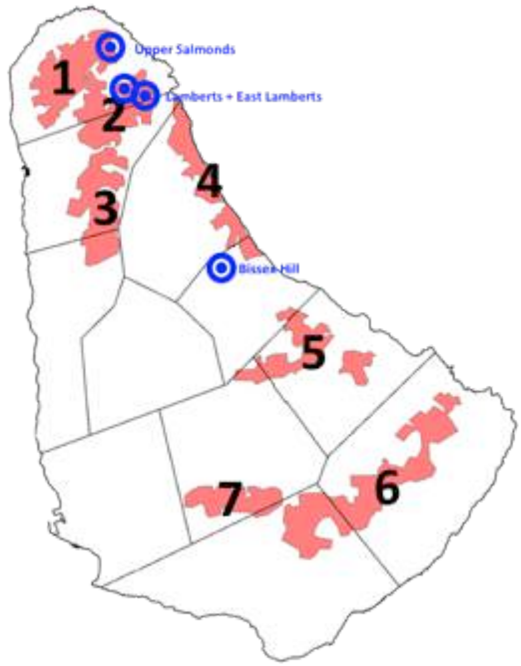

Figure 4. The seven wind zones identified in this study (and four existing development sites from the current PDP).

Given the importance of wind in providing a cheap and reliable source of electricity for Barbados, it is recommended that all seven of these zones be incorporated into future planning considerations. The reason being, given wind turbine noise setbacks, permitting just one dwelling to be built in any one of these wind zones could drastically reduce the area available for wind energy — by at least 38 hectares, or ~100 acres (further discussed in Section 6.2).

3.3 Wind farm layout

Once the seven zones in Figure 4 were determined, the next step was to establish how many wind turbines could be installed in each zone. There are several factors to consider when performing this task. Wind turbines operating in close proximity will impact the operation of their downwind and neighbouring wind turbines. A key element of wind farm layout design is keeping wind turbine spacing to a minimum whilst also minimising wake losses. The appropriate spacing for wind turbines is strongly dependent on the nature of the terrain and the wind-rose[4] at a site, in particular the prevailing wind direction (see Figure 5). If turbines are spaced closer than 5 rotor diameters together in a prevailing wind direction, it is possible that unacceptably high wake losses will result. For areas with predominantly unidirectional wind roses, like Barbados, greater distances between turbines in the prevailing wind direction are necessary, whilst tighter spacing perpendicular to the prevailing wind direction will prove to be more productive. For this study a row spacing of seven rotor diameters and an in-row spacing of four rotor diameters was used. Tighter in-row spacing may well be possible however this would require consultation and approval from the wind turbine supplier if warranty arrangements are not to be affected.

Table 2 provides information on each of the seven zones, including the area, the expected installed wind capacity and the expected annual energy yield for wind turbines installed in each

[4] - **Note:** A wind rose is a diagram showing which directions the wind blows from on average, and how strongly it blows.

zone (discussed in Section 5). Results show that roughly 15% of the island is available for wind farm development. Only a small fraction of this will be required for installing the wind turbines – including the base of the wind turbine, access roads and other infrastructure, only 5% of a wind farm involves a change of land use, meaning that livestock and arable farming can continue all the way up to the base of wind turbines.

Table 2. Area, installed capacity and yield for zones identified in Figure 4.

Zone	Area *(km^2)*	Installed capacity *(MW)*	Annual yield *(GWh)*
1	9.4	68	218.1
2	9.2	66	218.0
3	9.4	60	193.1
4	7.0	68	245.5
5	7.9	54	166.7
6	16.2	116	301.1
7	5.2	40	94.7
	64.2 km^2	**472 MW**	**1,437.3 GWh**

4 The wind resource

4.1 Wind statistics

The WindPRO software is able to provide a useful insight into the Barbados wind resource. By way of an example, Figure 5 shows the wind speed distribution for wind speeds in Zone 4 – in short showing the probability that the wind speed will be a certain value. The wind speed distribution for Barbados indicates that the island receives broadly constant and predictable wind speeds, which is to be expected given its exposure to the North Atlantic Trade Winds. The wind energy rose supports this assertion, indicating that any wind turbine installed on the island will point eastwards most of the time.

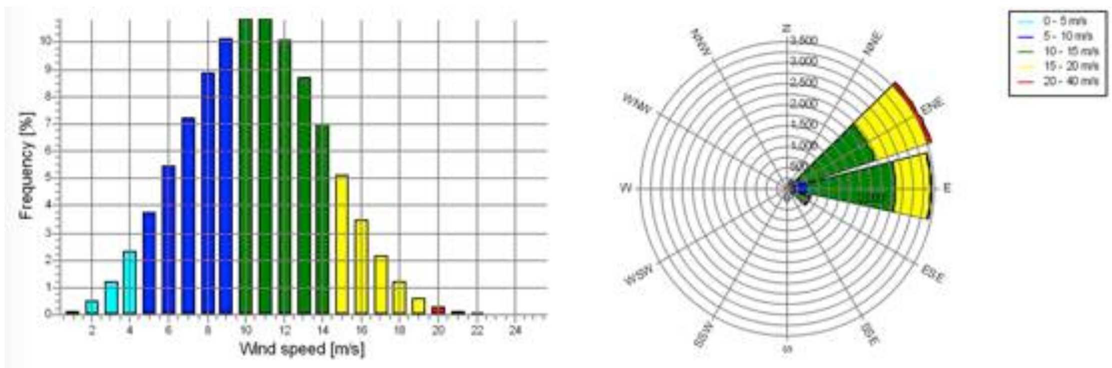

Figure 5. Typical Weibull distribution and wind energy rose for Barbados.

The wind speed in Barbados also shows a distinct diurnal pattern. Figure 6 shows the average hourly output of a wind turbine over the course of 24 hours. This Figure also shows how electricity demand typically changes in Barbados (known as the Demand Curve). We can see that as people wake up in the morning, electricity demand increases, peaking during the middle of the day when the cooling demand is at its highest. There is a second peak in the evening when people return home and turn on their lights and cook their evening meals, etc. Demand then falls during the nighttime. Interestingly, even in the middle of the night, when most people are asleep, the demand is still more than 50% of its peak demand.

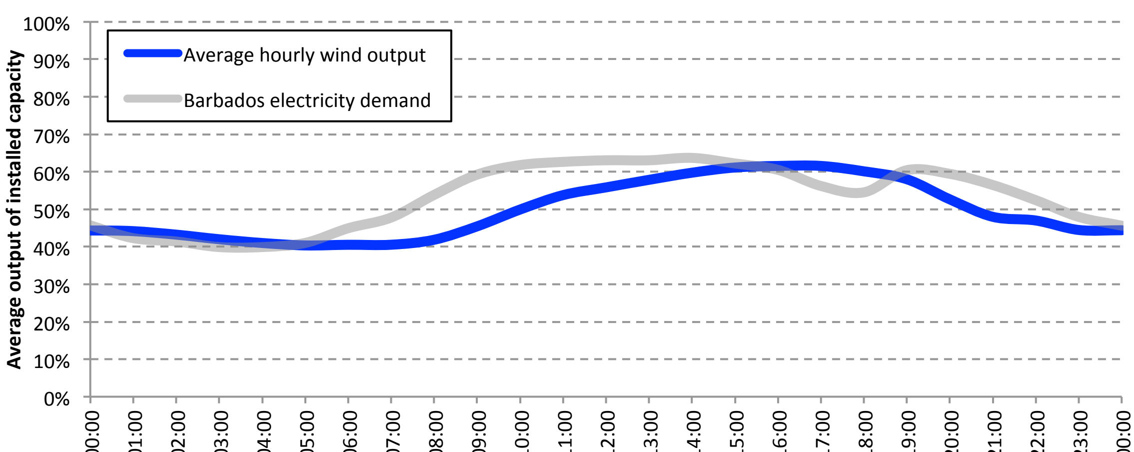

Figure 6. Expected average hourly wind capacity output for Barbados along with the country's typical daily demand curve.

Although wind speeds may be broadly constant and predictable on an hourly and daily basis, as with studies of other Caribbean islands, wind production in Barbados will vary between a strong wind year and a weak wind year. Figure 7 shows how the annual average wind speed varies. There is a clear difference between a strong and a weak wind year and this will have an impact on wind energy yield. Figure 8 shows how the annual average energy yield for a wind turbine installed in Barbados might vary each year from a thirteen year average. Together, Figure 7 and Figure 8 indicate that for a weak wind year (2011) there will be almost a 25% reduction in the long-term average annual energy yield. As compared with a strong wind year (2015), where there was a 30% increase in the long-term average annual energy yield.

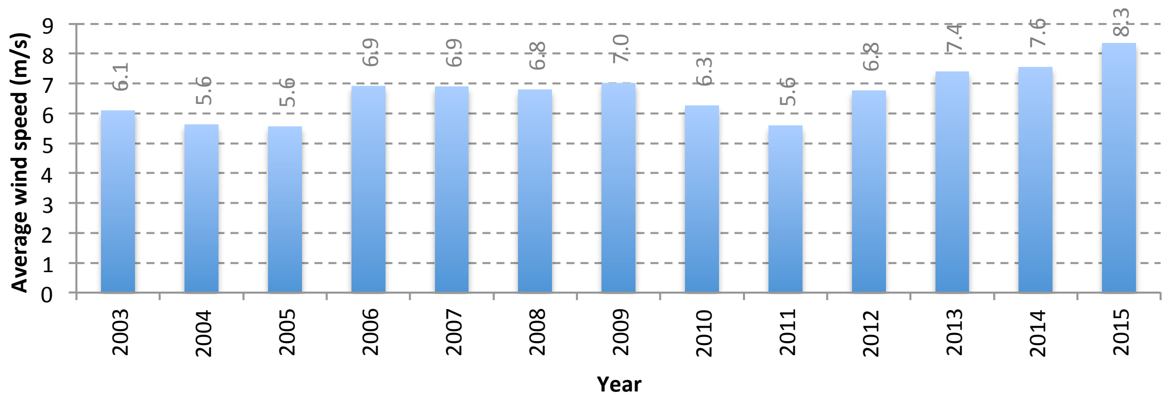

Figure 7. Annual average wind speeds for Grantley Adams International Airport (at 10m above ground level).

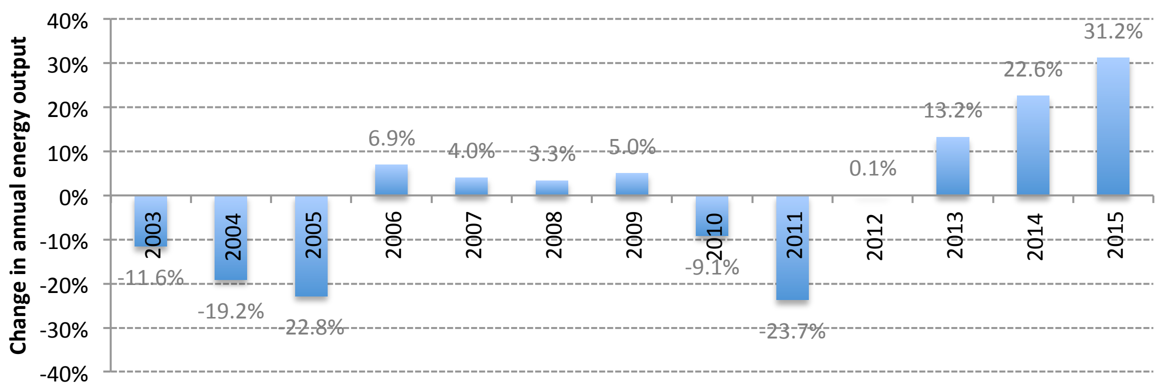

Figure 8. Predicted yearly change in energy output from 13-year average for a wind turbine installed in Barbados.

4.2 Impact of hurricanes

Engineering advancements mean that modern, utility-scale wind turbines are better able to cope with any risk from hurricanes. If quality wind turbines are sourced, and there is close communication with the wind turbine supplier/manufacturer, a hurricane's impact should be minimal. A more important factor is to consider surrounding objects that could become airborne during high wind speeds and damage wind turbines. There are several examples of wind farms installed in tropical locations, where the impact of hurricanes must be considered. One Caribbean example is the 38.7MW Wigton wind farm in Jamaica (Figure 9), which has survived two hurricanes with minimal damage (Category 4 and Category 5)[5]. The US National Renewable Energy Laboratory reports that for US waters, several hurricanes have already exceeded wind class Ia with wind speeds above the 70m/s (156mph), and efforts are now being made to improve standards, which will benefit Caribbean islands in hurricane zones.

Figure 9. The 38.7MW Wigton wind farm in Jamaica (Source: CIPORE[5]).

4.3 Wind resource map

Figure 10 shows the wind resource map for Barbados. It gives the average wind speeds at a height of 65m above ground level. Whilst viewing the map, it is important to consider its accuracy. Unlike solar resource, which varies by only a small amount over the whole island, wind speeds are greatly impacted by local obstacles. The wind speed map presented here will be greatly improved by a detailed wind measurement campaign and a more detailed assessment of the surface roughness data. However, this wind resource map helps to improve on previous knowledge, and allows for the identification of expected windier locations and a basic calculation of the expected annual wind energy yield.

Examining the resource map in more details, all along the north of the island and down the east coast, and around the corner into the south of the island, there are average wind speeds over 8-9m/s, which is excellent for utility scale wind. Wind farm developers generally investigate areas above 7m/s (light blue areas). There are even some locations, such as on top of Hackleton's cliff, along the ridge of the Scotland district and around Lamberts in the parish of St. Lucy, with wind speeds above 9-10m/s (which, given speed up effects is better than undisturbed offshore locations). On average, wind farms in other parts of the world will typically generate their rated capacity output for 20% to 40% of the time (known as the 'capacity factor'). The windier locations in Barbados would provide capacity factors of over 60%, on a par with some of the best wind sites in the world.

5 - Wigton wind farm experience: http://www.cipore.org/wp-content/files/wigton_windfarm_panel_presentation.pdf

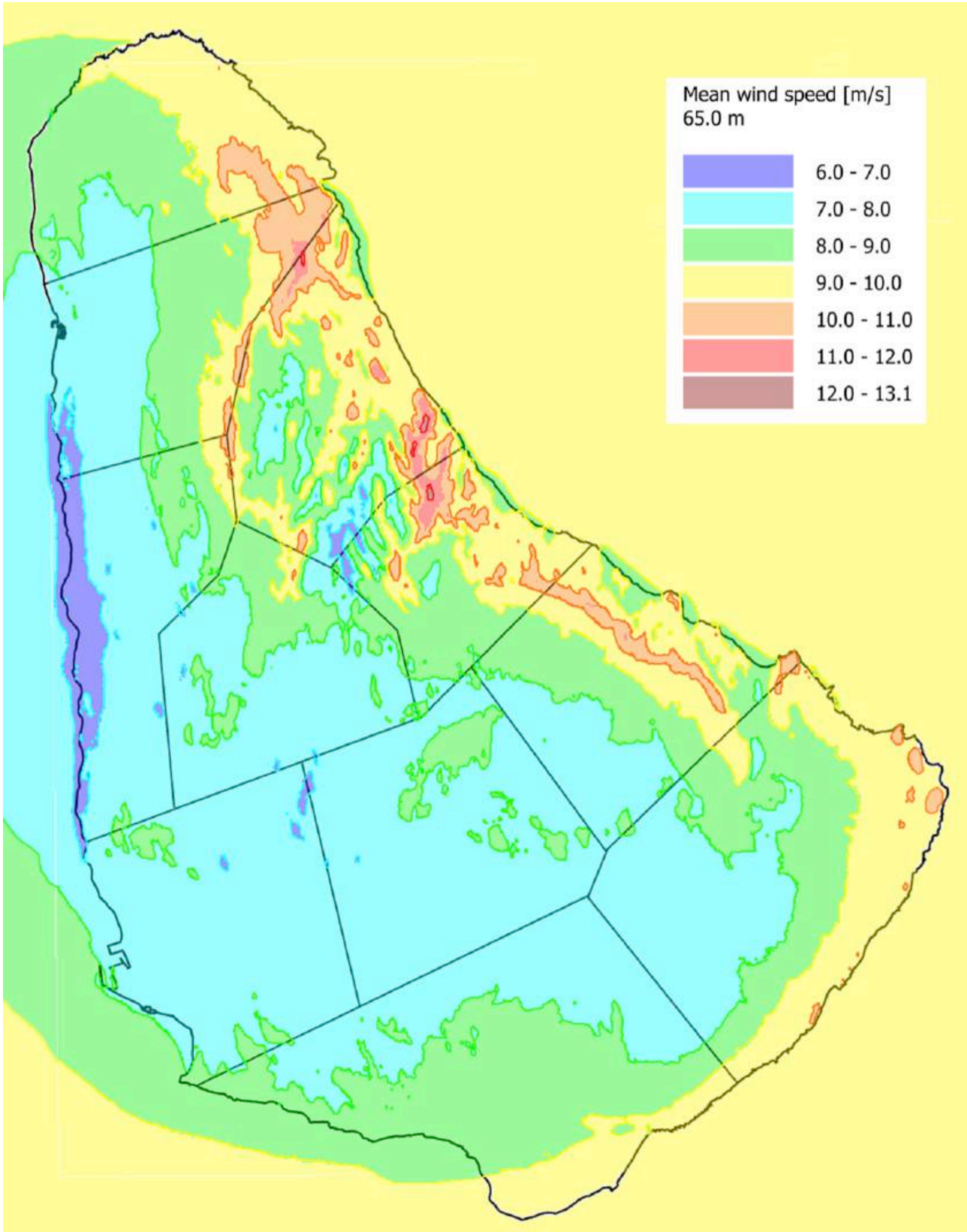

Figure 10. Wind resource map for the island of Barbados.

5 Expected yields

The total expected energy yield for 2MW Enercon wind turbines installed at all of the wind zones is 1,437 GWh/year. This is based on the 17 years of wind data collected at Grantley Adams International Airport and includes a 10% reduction in output due to typical wind farm operation and maintenance schedules. The WindPRO software is able to take array losses into consideration and these are characterised by a respectable park efficiency value of 96.1% (also included in the result).[6] Table 2 shows the expected outputs of each of the seven zones outlined in this study.

Figure 11 shows the outlines of the seven wind zones, along with the expected capacity factor contours for an Enercon E-70 wind turbine. The figure suggests that the eastern parts of each zone should be the first areas identified for wind development. In particular Zones 4, 2, 1 and 5 (in that order), then zones 3, 6 and 7. The Figure also indicates that the current wind turbine sites from the existing Physical Development Plan are located at good wind locations with expected capacity factors of ~50%.

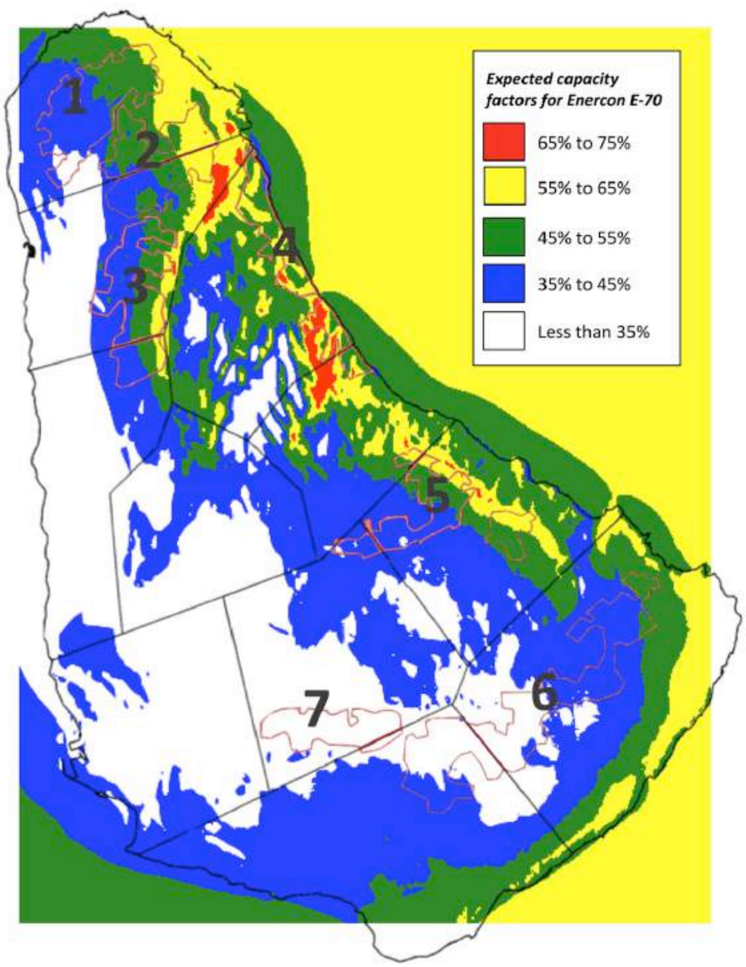

Figure 11. Identified wind zones with overlay of expected capacity factors for an Enercon E-70 wind turbine.

6 - Array losses: the wake of one wind turbine impacts the resource of a downwind wind turbine.

6 The next steps

Results of this desktop study show the wind resource in Barbados to be attractive for development. Given the wind resource is so high, and with installed costs for wind turbines currently around $2,200/kW, this would equate to a potential levelized cost of energy between BB$0.05/kWh and BB$0.12/kWh[7]. The following sections discuss the suggested next steps to be considered if Barbados is to tap into this indigenous and sustainable energy resource.

6.1 Detailed wind measurement campaign

A detailed wind measurement campaign is an important first step. A wind study was conducted for the island in the 1980s and although detailed at the time, modern measurement techniques are able to provide a far clearer picture of a wind resource. Also, land-use changes since the 1980s may have affected some of its findings.

Today, wind measurement campaigns collect 10-minute average wind speed measurements from at least three heights up to 150m above ground level (with modern LiDAR units able to measure at multiple heights up to 200m). They also monitor wind direction, turbulence, temperature, relative humidity and air pressure. Ideally, data is collected for at least 1-year. For Barbados, it is recommended that measurements are take from each of the seven identified wind energy zones. This data will then serve to identify the best wind turbines for the local conditions, and provide proof to investors and money lending institutions that any wind farm projects have sound and returnable futures. Detailed wind measurements will also allow the regulator to set Feed-in Tariffs that will ensure all parties — investors and consumers —benefit from the deployment of wind turbines. Part of this measurement campaign should include a consultancy to produce a detailed surface roughness map of the island, which will further increase the accuracy of the wind resource map.

6.2 Updating the planning guidelines for wind turbines

Planning guidelines will play an important role in realising the wind resource potential of the island. There are a number of areas to be addressed, including:

- **A review of the 350m setback rule:** the current planning guidelines need relaxing if an appreciable amount of wind capacity is to be installed. In particular the requirement that wind turbines should be a minimum of 350m from the landowner's boundary. This requirement severely restricts the maximum installed capacity in each of the zones identified in this study, and it is therefore recommended that this guideline be altered to read "a minimum of 350m away from residential dwellings" (with the 350m distance open for discussion). If the island's wind is considered to be a valuable resource for the island, just like its water or its oil, then it is evident that agricultural land should be set aside for the deployment of wind turbines. The introduction of wind zones will also help restrict future urban sprawl, and will have no impact on any of the island's existing groundwater protection zones.

- **Shadow flicker:** This is where the shadow of the rotating blades falls upon a building's windows, leading to discomfort for the building's occupants. It is more of an issue in higher latitudes where, for large parts of the year, the sun is low in the sky. In the tropics, shadow flicker is seldom a problem and can easily be overcome by programming

7 - CAPEX = BB$3,450,000/MW, OPEX = BB$138,000/year, Cost of capital = 10% and lifetime = 30 years.

wind turbines not to operate for the limited amount of time each year during which shadow flicker may occur. It is understood that shadow flicker is not presently included in the Barbados planning guidelines, but recommend that it is in order to discourage negative experiences from the installation of wind turbines.

- **Noise limits:** Any possible changes in sound levels from nearby wind turbines are of great concern to local residents. The current guideline uses the World Health Organisation recommendation for noise setbacks of a maximum sound level of 45dB(A) at the nearest residential dwelling. This is sufficient for future planning guidelines. Once a utility-scale wind turbine is installed on the island, it would be worth performing a noise study as local climatic conditions may impact receiver sound levels. This sound-level study should run for at least one year to account for the expected variation in background noise during the different seasons and associated vegetation cover. It is worth noting that background sound levels are being recorded at property neighbouring the proposed 10MW wind farm at Lamberts East, and anecdotal evidence suggests that the background sound-levels have never dropped below 55dB(A). Given the high levels of background noise on the island (whistling frogs, cicadas, road traffic and wind blowing through vegetation), this is perhaps not so surprising.

- **Aviation:** It is understood that the existing radar system for Grantley Adams International Airport would restrict the installation of wind turbines in many of the zones identified in this study. The reason for this being that the moving wind turbine blades will create a radar shadow, impeding safe observation of airplane traffic. It is also understood that a new, more sophisticated radar system is soon to be, or is being, installed on the island. This new radar system is able to omit the impact from the installation of wind turbines.

- **White mapping:** the basic analysis of this study to identify the seven potential wind zones would be greatly improved by the use of GIS data and associated software. Existing GIS files for the island should be used to more accurately identify potential wind zones. Shape files incorporating buildings (and their use, be they residential, commercial, farm buildings, etc.), property boundaries, the island's electricity grid (including maximum line loads), public roads, historic sites, recreational parks, etc. Using GIS software, this information can be queried and setbacks applied, to leave 'white' areas that meet the planning guideline requirements for wind turbine installation.

- **Local investment:** where possible, planning guidelines should provide additional insurance that only local investment in wind farms should be permitted, ensuring that the island's communities and economy fully benefit from this exceptional local resource. The next Section provides further detail on the need for local investment.

6.3 Setting up of a wind energy stakeholder group

The one overriding lesson from 30 years of wind power experience around the globe it is that in order for wind energy to be a success, all stakeholders must be involved with every step of the wind farm development process, and the local community *must* be involved in this process. This will likely need dedication, flexibility and constant communication between the various stakeholders, and perhaps will require Government leadership along the lines of the island's current offshore oil campaign. Along with the Government and its various ministries, key stakeholders will likely involve community groups, the Utility, TCDPO, GEED, FTC, ELPAC, local investment entities (credit unions, banks, etc.) and, of course, the landowners. There should be a strong focus on raising public awareness about the benefits of wind energy and creating a simple, transparent investment climate for local investors.

Another consideration for any wind farm development is a need for a wind energy strategy, which treats the island's wind energy development as one complete entity. Having numerous developments will lead to a duplication of work and increased spending. Given the limited installed potential, it would make sense for one body to be set up, involving the aforementioned stakeholder list, to oversee the island's wind energy sector. This way purchasing power will be increased, thereby helping to streamline the development process and ensuring that potential for cheap electricity prices is realised.

6.4 Detailed grid infrastructure survey

Any serious development of wind energy in Barbados will need close cooperation with the island utility. In their 2015 Wind and Solar Integration Study (BL&P 2015), the island's utility operator, Barbados Light & Power (BL&P) engaged the services of General Electric Energy Consultants to examine a number of renewable energy integration scenarios for the island and determined that 15MW of wind energy could be connected without any noticeable impact on the grid's operation. A similar study is required to assess the economic and technical requirements of the infrastructure upgrades required to exploit the island's wind resource.

6.5 Transport survey

A survey of the island's road networks is required to ascertain the maximum size of wind turbine that can be installed at each particular site. This comprises surveying the transport routes between the port and the intended wind farms sites. Wind turbine transportation is ordinarily performed during the nighttime to minimise any impact on traffic. It may also involve close coordination with the local utility, where power lines may have to be temporarily re-routed to allow high-loads to pass. Depending upon the size of the wind farm, this may include identifying roads that need resurfacing and widening – a potential benefit to the local community. Elsewhere, this process is usually performed in collaboration with local the transport ministry, with the wind farm helping to cover any investment costs for road upgrades. For the more remote sites, it may be necessary to explore other means of transporting wind turbine components to site, including landing the wind turbines on local beaches, or using heavy-lift helicopters.

7 References

Danish Wind Energy Association (DWEA). (2003). The Park Effect and Park Layout. [online] available from <http://windpower.org/en/knowledge/windpower_wiki.html>

BL&P (2015). Barbados Wind and Solar Integration Study – Executive Summary Report. Prepared for Barbados Light and Power Company Ltd (BL&P). Prepared by General Electric Energy Consulting. [onine] available from <http://www.blpc.com.bb/images/watts-new/Barbados%20Wind%20and%20Solar%20Integration%20Study%20-%20Exec%20Summary.pdf>

Hohmeyer, O.H. (2014) 'A 100% renewable Barbados and lower energy bills: A plan to change Barbados' power supply to 100% renewables and its possible benefits'. Center for Sustainable Energy Systems (ZNES) [online] available from http://brea.bb/wp-content/uploads/2016/09/100-percent-Renewables-for-Barbados-plan.pdf

NREL (2013). Development of Offshore Wind Recommended Practice for U.S. Waters. National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy13osti/57880.pdf

Schlez, W. Tindal, A. (2009). Wind Farm Siting and Layout Design. Garrad Hassan and Partners Ltd. http://www.wwindea.org/technology/ch02/en/2_4_2.html