Offshore wind energy in the context of multiple ocean uses on the Bermuda Platform

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Background

Bermuda is a British island territory in the North Atlantic, and as a small, remote island, it is heavily dependent upon imported fossil fuels for electricity generation. In 2011, the Government of Bermuda established a set of renewable energy goals to increase its energy security and decrease per capita greenhouse gas emissions. Bermuda's consistent winds and sizable shallow sea bed, commonly known as the Bermuda Platform, make offshore wind energy an attractive option to meet its energy goals.

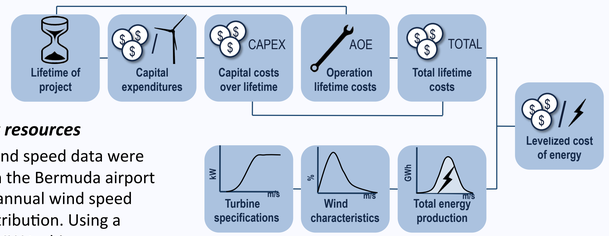
Offshore wind energy development will likely impact the multiple ocean uses and ecological features that occur on the Bermuda Platform. Minimizing these impacts necessitates the use of marine spatial planning to identify suitable locations for an offshore wind energy development.

Objectives

- ***Determine the economic viability*** of offshore wind energy with respect to Bermuda's current energy context
- ***Identify and characterize potential conflicts*** with ocean uses and ecological features
- ***Develop a spatial analysis model*** to identify potential locations for offshore wind farms with acceptable risk of impacts

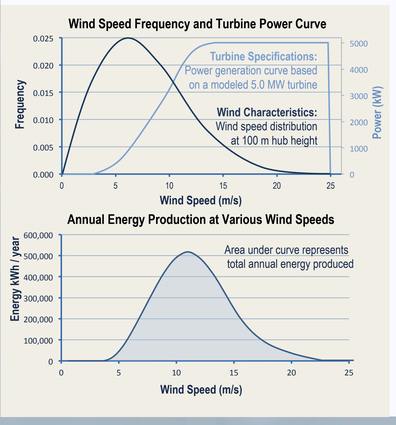
Wind energy model

We calculated the **Levelized Cost of Energy (LCOE)** in order to determine the economic viability of offshore wind energy. The LCOE is the price per unit energy from an energy project, and represents the minimum price that would be required in order for the developer to cover its costs over the lifetime of the project. Cost estimates for capital expenditures, annual operating expenses, and discount rate were obtained from a 2012 NREL study of offshore wind projects worldwide.



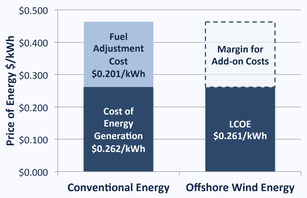
Wind energy resources

Six years of wind speed data were obtained from the Bermuda airport to model the annual wind speed frequency distribution. Using a modeled 5.0 MW turbine power curve, we estimated the total annual energy production for each turbine.



Economic viability of wind energy

We calculated a LCOE of $0.261/kWh, which is significantly lower than current energy prices in Bermuda. The actual consumer price of offshore wind energy will include add-on costs to account for power purchase agreement (PPA) obligations, intermittency mitigation, and regulatory compliance. The margin between the LCOE and current consumer energy prices leaves significant room for add-on costs while keeping energy prices at or below current rates.



Spatial analysis model

Suitability threshold analysis

The spatial analysis begins by defining suitability thresholds for all sectors of importance to create an overall map of sites that are deemed suitable for turbine placement.

Identify sectors of importance:

Commercial finfish & lobster fishery: Bermuda's commercial fisheries represent a small but socioeconomically important segment of the island's economy. These fisheries also support the tourism sector's high demand for consumption of local fish.

Recreational finfish & lobster fishery: Recreational fishing in Bermuda is a culturally significant and time-honored tradition. In recent years it has become an increasingly popular activity for the island's extensive tourism industry.

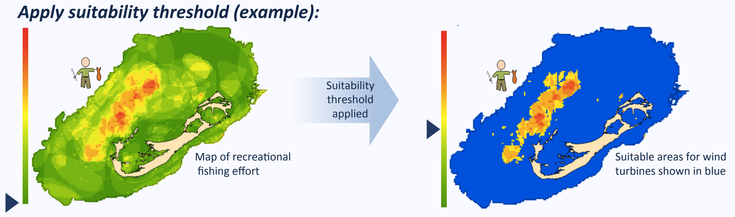
Seagrass: Bermuda's seagrass beds are important marine habitats because they provide nursery areas for juvenile fish, and are a key habitat for sea turtles. The five seagrass species found in Bermuda are protected by law.

Reefs: Bermuda's coral reefs support a diverse and productive ecosystem. The reefs are an attraction for visiting tourists, support Bermuda's fisheries, provide coastal protection for the island, and provide an opportunity for research and education.

Exclusion areas: Several sectors were identified as being 100% incompatible with the siting of offshore wind turbines. These areas have clearly defined boundaries and include the airport control area, shipping channels, marine protected areas, and important habitats for avian and fish species.

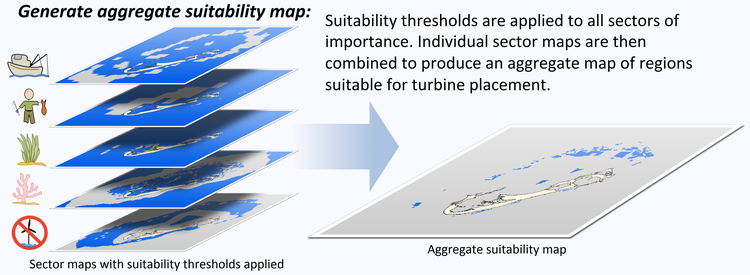
The suitability threshold is used to determine whether an area will be considered for, or excluded from the siting of offshore wind turbines based on the value of a sector at that location. The threshold could be set based on the preference to avoid risk of physical or economic impact from the placement of offshore wind turbines, and would likely need to be negotiated between stakeholders, energy developers, and decision makers.

Apply suitability threshold (example):



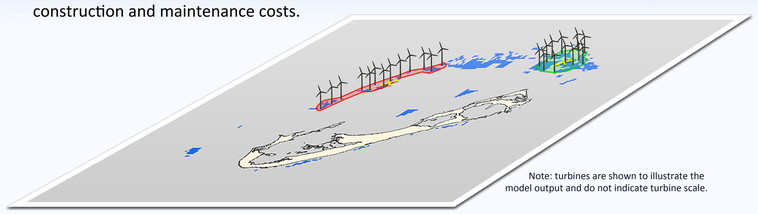
Generate aggregate suitability map:

Suitability thresholds are applied to all sectors of importance. Individual sector maps are then combined to produce an aggregate map of regions suitable for turbine placement.



Wind farm optimization algorithm

The wind farm optimization algorithm generates wind turbine placement scenarios that (a) meet specified generation capacity, (b) adhere to all suitability criteria, (c) maintain specified inter-turbine spacing, and (d) minimize the distance between turbines to reduce marginal construction and maintenance costs.

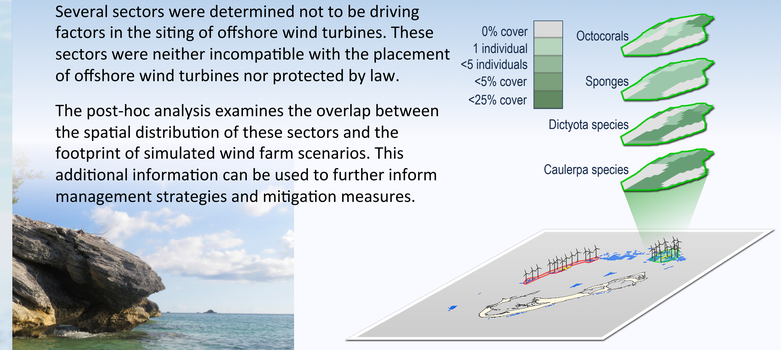


This figure shows two wind turbine placement scenarios simulating 100 MW wind farms centered on two different regions of the Bermuda Platform. The farm outlined in red shows a dispersed pattern of turbines, while the farm outlined in green shows a compact pattern.

Post-hoc analysis

Several sectors were determined not to be driving factors in the siting of offshore wind turbines. These sectors were neither incompatible with the placement of offshore wind turbines nor protected by law.

The post-hoc analysis examines the overlap between the spatial distribution of these sectors and the footprint of simulated wind farm scenarios. This additional information can be used to further inform management strategies and mitigation measures.



Conclusions

Offshore wind power is economically viable for Bermuda

The levelized cost of energy that we calculated is well below the current cost of energy paid by Bermuda energy consumers. Even with substantial add-ons to an offshore wind project's LCOE, it appears likely that the actual consumer cost of offshore wind energy will be equal to or less than current energy prices.

Stakeholder engagement is critical to successful offshore wind development planning

Offshore wind development poses some risk of impact to ecological, economic, or social values at all locations on the Bermuda Platform. Our spatial threshold model can facilitate negotiation between stakeholders, energy developers, and decision makers to determine acceptable thresholds of risk and to identify suitable locations for offshore wind energy development. Using this tool in a transparent and iterative way can build trust among stakeholders, thus increasing the likelihood of positive outcomes in the marine spatial planning process.

Viewshed impacts and risk to migratory birds should be considered in future models

Viewshed and avian impacts have often been identified as major concerns for offshore wind energy development. Explicit integration of viewshed criteria and migratory bird patterns into the spatial planning analysis would help to address these concerns.

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