*Analyzing Investments in NC Offshore Renewable Energy Under Uncertainty About Resource Availability and Hurricane Damage

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Abstract

This work investigates the use of stochastic programming in the portfolio optimization of offshore wind, wave and ocean current technology. We also use the stochastic programming technique in the context of a capacity expansion model, to help understand how the incorporation of hurricane damage scenarios can influence how the North Carolina energy system may evolve in the future and how the offshore energy technologies may be affected by that.

Project Flow Diagram

DATA BATCH 1

- **Historical wind** speed data from **NREL**, and wind energy conversion device costs/power curve for **GE Haliade 150-6MW.**
- **Historical significant wave height and period** from **WWIII**, and energy conversion device costs/power matrix for **Pelamis-1.5MW.**
- **Historical ocean current speed** from **HYCOM**, and energy conversion device costs/power matrix for **RM4-SANDIA.**
- **Historical electricity prices** from the **Federal Energy Regulatory Commission. Battery price estimates from NREL.**

Synthetic Time Series of Energy Generation: Python/TensorFlow Coding (Neural Networks)

Propose a methodology to create synthetic time series of energy generation for Wind, Wave, and Ocean Current

Challenges:
*Spatial dependence between energy resources.
*Temporal dependence.
*Large number of site locations in the NC coast.

Model:
A Deep Convolution Generative Adversarial Neural Network Model (Deep CNN-GANs) was proposed.

Stochastic Optimization Part 1: Python/Pyomo Coding and Mathematical Modeling

Propose a stochastic portfolio optimization model to minimize the risks of low energy generation scenarios (CVaR).

Model 1: Ignore CapEx and OpEx in the site selection. Focus on the energy resource only.

Model 2: Add CapEx and OpEx of Wind, Wave, and Ocean Current in Model 1.

Model 3: Add battery usage in Model 2.

Simulations Part 1

Model 1	Model 2	Model 3

Results I

Optimal site locations for offshore technologies considering resource variability and cost variability.

Stochastic Optimization Part 2: Capacity Expansion Model (TEMOA)

DATA BATCH 2

Create hurricane damage scenarios, based on historical data.

Historical hurricane speed data from **HAZUS, and technology location.**

Convert hurricane speed to damage using the technology **fragility curves.**

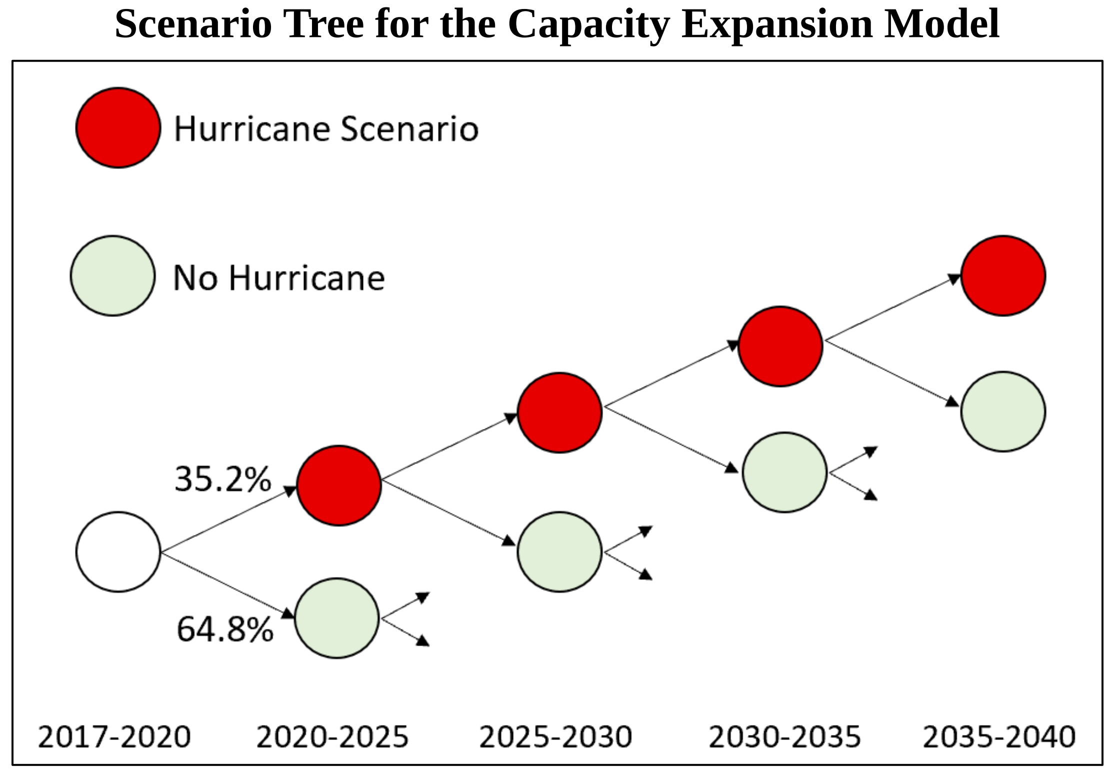
TEMOA Simulations (Simulations Part 2)

Run capacity expansion model of NC with ocean technology and hurricane damage

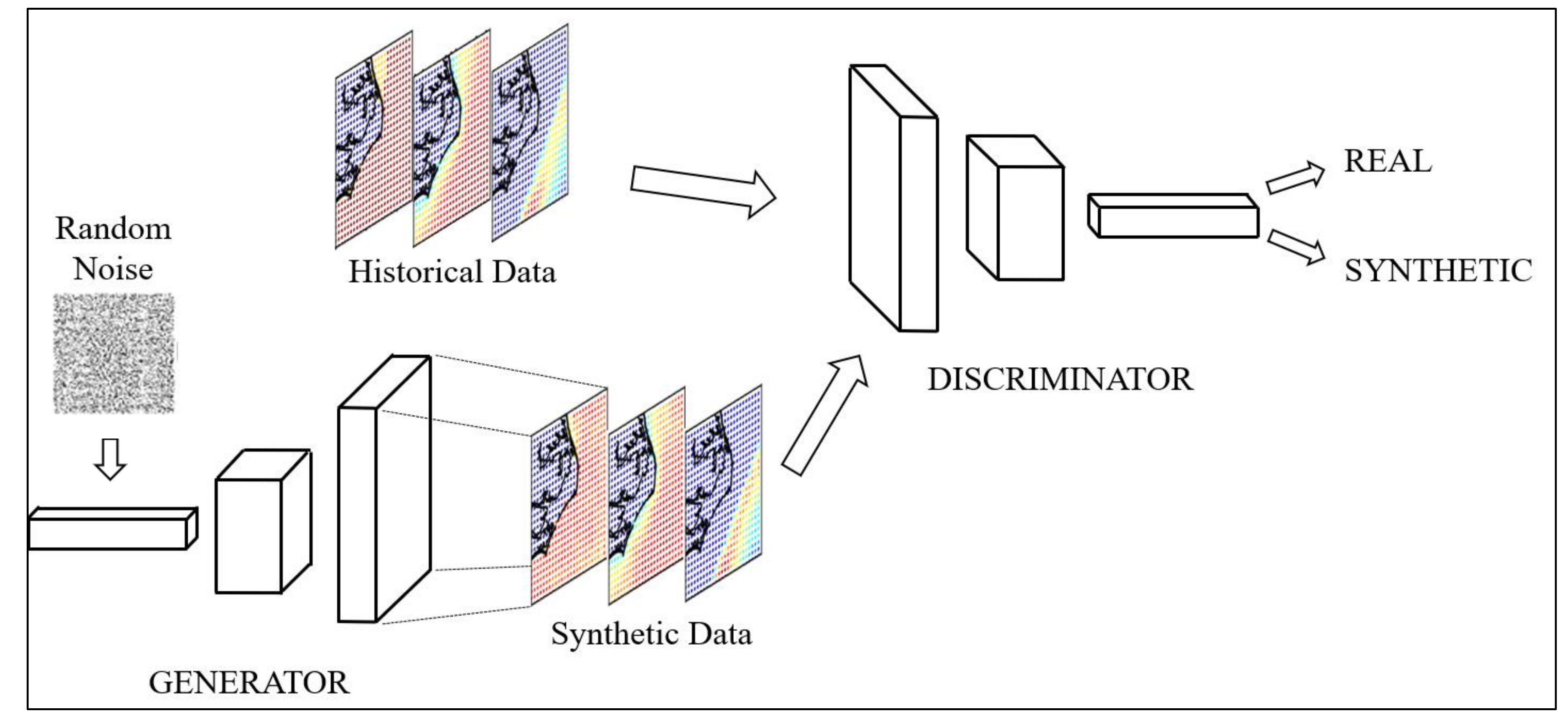
Results II

How the incorporation of hurricane damage scenarios influences the levels of offshore energy deployment.

Scenario Tree for the Capacity Expansion Model



Synthetic Time Series Generation



Stochastic Portfolio Optimization

Stochastic Model Without Storage (SP)

$$Min \sum_{i\in E}\sum_{j\in J_i} c_{i,j}\cdot y_{i,j} + \mathbb{E}\left[Q(Y,\zeta)\right] + \beta\ CVaR_{\alpha}(Y,\zeta) \qquad (1)$$

Frist Stage Constraints:

$$\sum_{j\in J_i} y_{i,j} = N_i \qquad \forall\, i \in E \qquad (2)$$

$$y_{i,j} \le n_{i,j} \qquad \forall\, i \in E, \forall\, j \in J_i \qquad (3)$$

$$\sum_{(i_k,j_k)\in D_{i,j}^{40km}} y_{(i_k,j_k)} \ge v_{i,j} \sum_{\ell\in E} N_\ell \qquad \forall\, i \in E, \forall\, j \in J_i \qquad (4)$$

$$\sum_{i\in E}\sum_{j\in J_i} v_{i,j} = 1 \qquad (5)$$

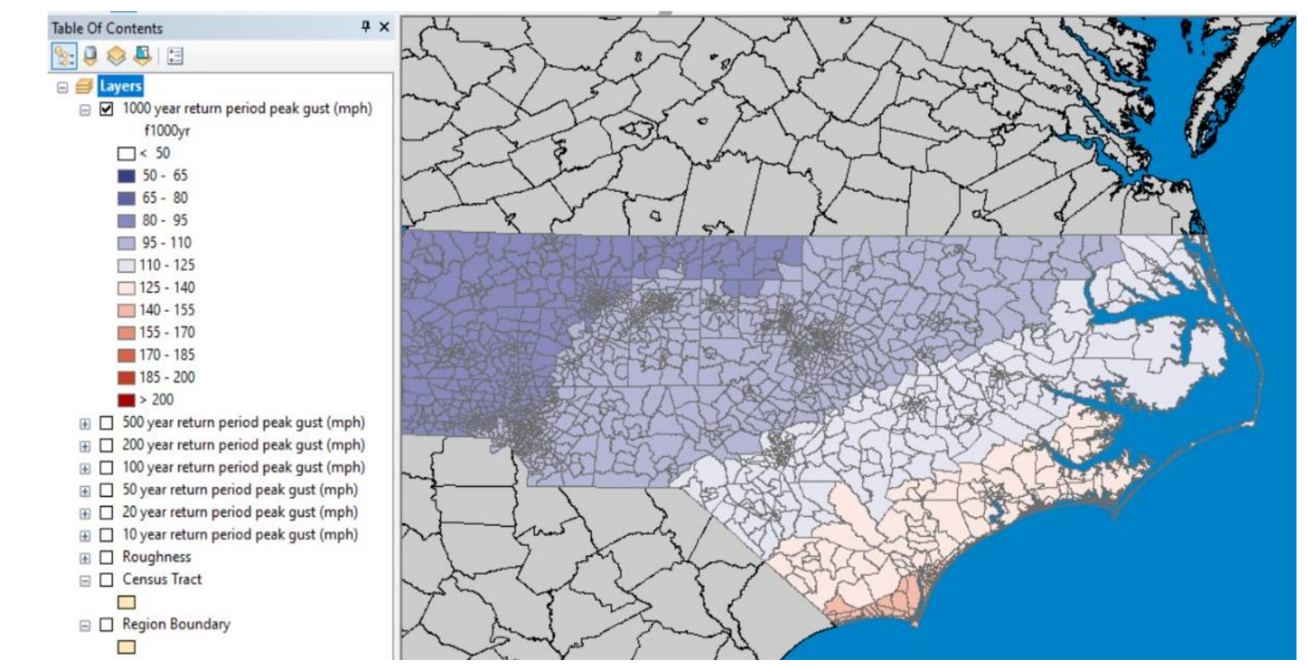
Second Stage Problem:

$$Q(Y,\zeta_s) \coloneqq Min\ -\sum_{t\in\{1,\dots,T\}} P_t\cdot EG_t \qquad (6)$$

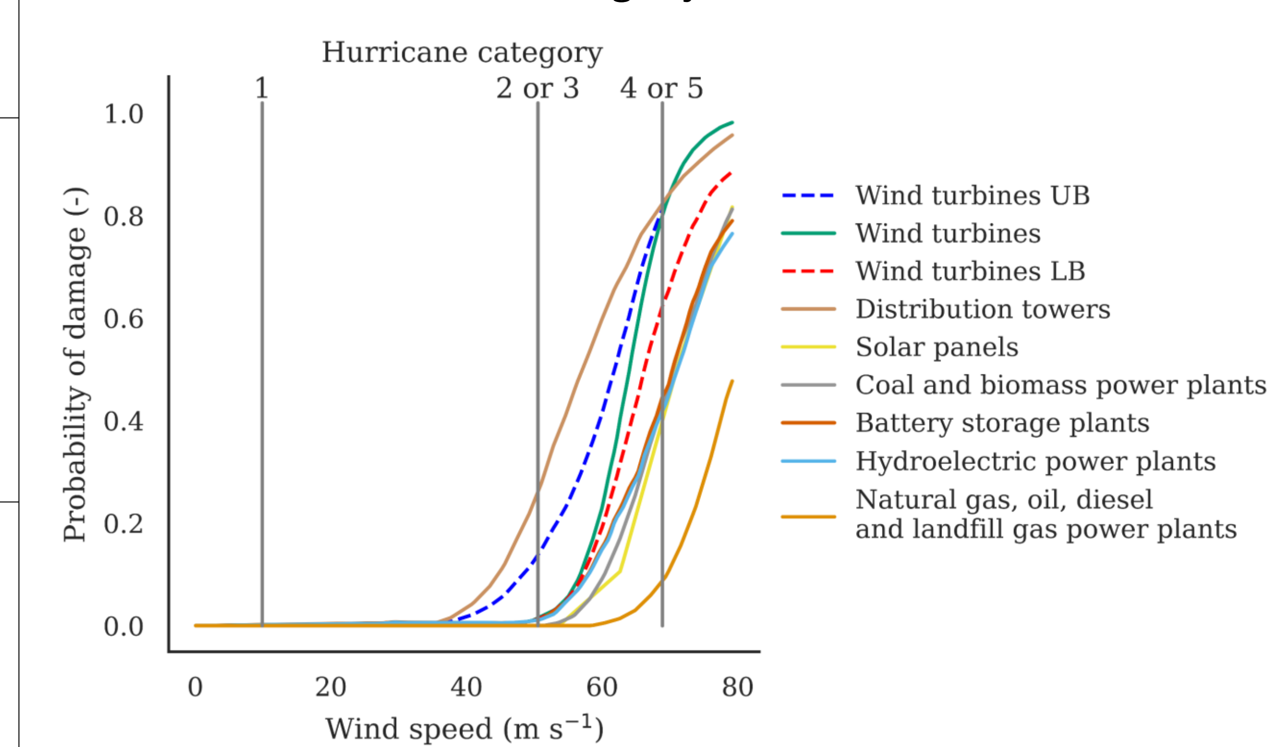
$$EG_t = \sum_{i\in E}\sum_{j\in J_i} e_{i,j,t}^{\zeta_s}\cdot y_{i,j} \qquad \forall\, t \in \{1,\dots,T\} \qquad (7)$$

Hurricane Damage Scenarios/Capacity Expansion Model

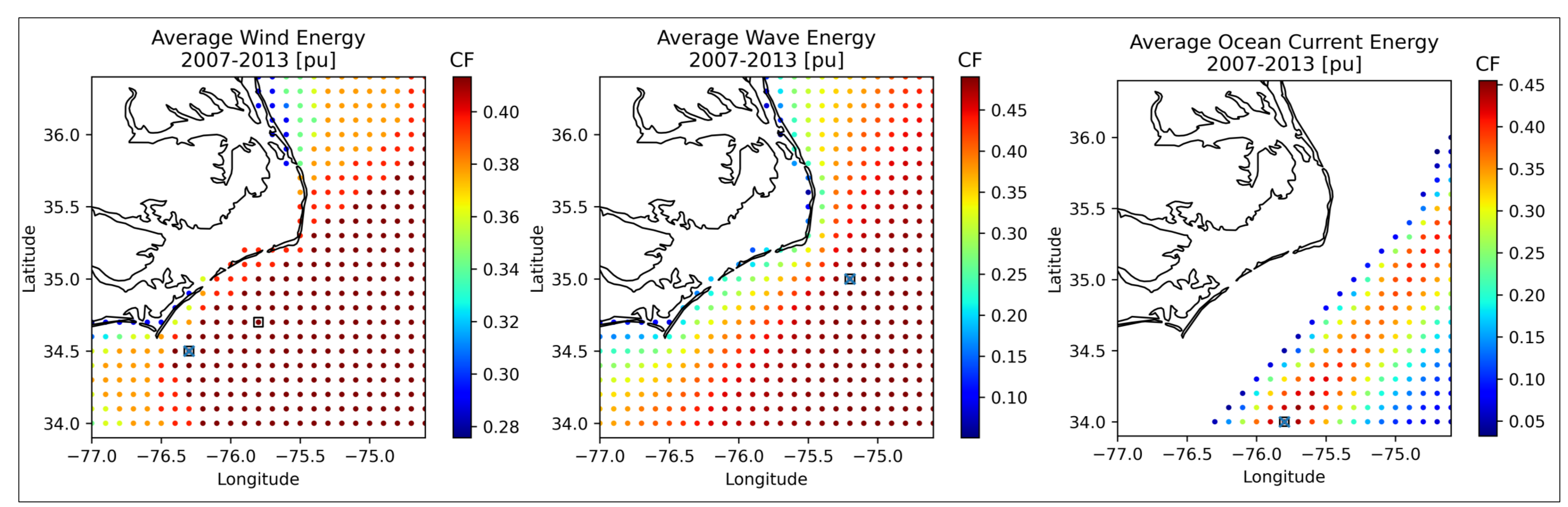
Historical Hurricane Data [1]



Fragility Curves



Preliminary Results For Model 1



References

[1] FEMA- Federal Emergency Management Agency (2021). Hazus Hurricane Model Technical Manual.

[2] TEMOA Github. DukeTerritory. Access at: https://github.com/TemoaProject/data. Last access May, 2021.

[3] J. A. Bennett, C. N. Trevisan, J. F. DeCarolis, C. Ortiz-Garcia, M. Perez-Lugo, B. T. Etienne, and A. F. Clarens. Extending energy system modeling to include extreme weather risks and application to hurricane events in Puerto Rico. Nature Energy, 2021.

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