Techno-Economic Study of Wind and Marine hydrokinetic turbines for electricity, hydrogen production, and water desalination

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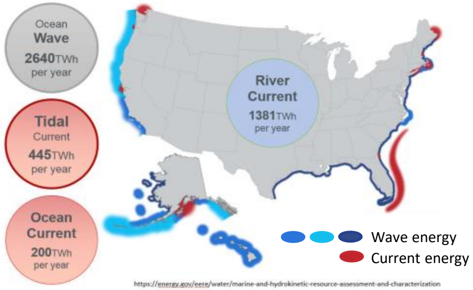
Motivation

- Exploring the renewable energy potential of the Atlantic Ocean
- Proposing a solution to improve North Carolina's island communities gride resiliency to withstand potentially disruptive events



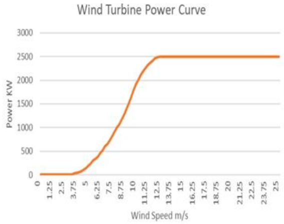
https://energy.gov/eere/water/marine-and-hydrokinetic-resource-assessment-and-characterization

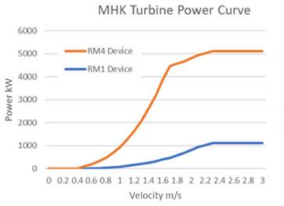
Research objectives

The study aims are to determine:

- The most cost-effective solution between offshore wind turbines and tidal power plants
- The most favorable location for the implementation of the tidal and current turbines (MHK) or off-shore wind turbines
- How to use the electricity produced to generate hydrogen, for what purpose and what are the associated costs

The following figure shows the electrical power output of the MHK depending on the ocean current speed:





Method

- Data are gathered from the NREL (Wind Toolkit), and NOAA databases.
- Wind, Tidal and current speeds are then analyzed for Eastern US Coast to determine the optimal plant location.
- Finally, the CAPEX and OPEX are calculated to determine the LCOE from the specifications of the location.

The equation used to calculate the LCOE is as follows:

$$\text{LCOE} = \frac{\text{Fixed Charge Rate} \times \text{Capital Cost} + \text{Fixed operating cost}}{\text{Annual Energy}} + \text{Variable Operating Cost}$$

	MHK Onshore ($/kW)	Wind Onshore ($/kW)	MHK Offshore ($/kW)	Wind offshore ($/kW)
Turbine capital cost	2403	775	5683	775
Balance of System	2907		3994	
Financial Costs	482		0	
CapEx total	**5792**	**4164**	**9677**	**5251**
OpEx; $/kW/yr	299		372	
FCR(%)	0.108%			

The components for LCOE calculation are calculated using NREL's System advisory model (SAM), using a GE 2.5MW wind turbine. The MHK data that is used in SAM comes from Sandia Lab's ocean current reference models for tidal (RM1) and ocean current turbines (RM4). The FCR used in both analysis is based on a 20-year project timeline.

Viable MHK energy production sites were found using NOAA databases including Tides and Currents database and Global Navy Coastal Ocean Model database. In a west coast survey. NCOM uses satellite water level measurements to create a grid model of ocean surface speeds. Tides and Currents uses a moored acoustic Doppler current profiler to measure real-time current speeds.

Of the analyzed locations, we selected an area in the Gulf Stream as having the highest potential ocean current resource using NCOM data. On the East Coast, we selected The cape cod canal as having favorable tidal current resource based on tidal current device power curve. We selected Southport NC as a location with the most favorable coastal location in NC based off Tides and Currents surveys

Results

The results of our study are summarized in the following tables, where the LCOE in $/kW is calculated using the System Advisory Model. Boxes that are yellow indicate price points where the price of MHK and Wind are Equal for the given location resource

Annual Energy Production	26349130	kwh	Cape Cod RI Analysis				
FOM ($/kW.year)	100	200	**300**	400	500	600	700
Overnight cost ($/kW)							
1000	$0.08	$0.12	$0.15	$0.19	$0.23	$0.27	$0.31
2000	$0.12	$0.16	$0.20	$0.23	$0.27	$0.31	$0.35
3000	$0.16	$0.20	$0.24	$0.27	$0.31	$0.35	$0.39
4000	$0.20	$0.24	$0.28	$0.32	$0.35	$0.39	$0.43
5000	$0.24	$0.28	$0.32	$0.36	$0.39	$0.43	$0.47
6000	$0.28	$0.32	$0.36	$0.40	$0.44	$0.47	$0.51
7000	$0.32	$0.36	$0.40	$0.44	$0.48	$0.51	$0.55

Annual Energy Production	6094335	kwh	Southport NC Analysis				
FOM ($/kW.year)	100	200	**300**	400	500	600	700
Overnight cost ($/kW)							
1000	$0.34	$0.51	$0.67	$0.83	$1.00	$1.16	$1.33
2000	$0.52	$0.68	$0.85	$1.01	$1.17	$1.34	$1.50
3000	$0.70	$0.86	$1.02	$1.19	$1.35	$1.52	$1.68
4000	$0.87	$1.04	$1.20	$1.37	$1.53	$1.69	$1.86
5000	$1.05	$1.21	$1.38	$1.54	$1.71	$1.87	$2.03
6000	$1.23	$1.39	$1.56	$1.72	$1.88	$2.05	$2.21
7000	$1.40	$1.57	$1.73	$1.90	$2.06	$2.23	$2.39

Annual Energy Production	249720000	kwh	Gulf stream Location				
FOM ($/kW.year)	100	200	300	**400**	500	600	700
Overnight cost ($/kW)							
1000	$0.01	$0.01	$0.02	$0.02	$0.02	$0.03	$0.03
2000	$0.01	$0.02	$0.02	$0.02	$0.03	$0.03	$0.04
3000	$0.02	$0.02	$0.02	$0.03	$0.03	$0.04	$0.04
4000	$0.02	$0.03	$0.03	$0.03	$0.04	$0.04	$0.05
5000	$0.03	$0.03	$0.03	$0.04	$0.04	$0.05	$0.05
6000	$0.03	$0.03	$0.04	$0.04	$0.05	$0.05	$0.05
7000	$0.03	$0.04	$0.04	$0.05	$0.05	$0.05	$0.06
8000	$0.04	$0.04	$0.05	$0.05	$0.05	$0.06	$0.06
9000	$0.04	$0.05	$0.05	$0.05	$0.06	$0.06	$0.07

Future work

Both LCOE will be used to calculate the levelized cost of hydrogen to know if it would be interesting to produce hydrogen from the generated electricity. Two cases of application will be studied:

- Hydrogen as fuel for NC Coastal ferry fleet
- Hydrogen as a means of electrical storage for grid resilience

Acknowledgement

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