Geospatial Energy and Life Cycle Assessment of Oscillating Water Column Systems (2018)

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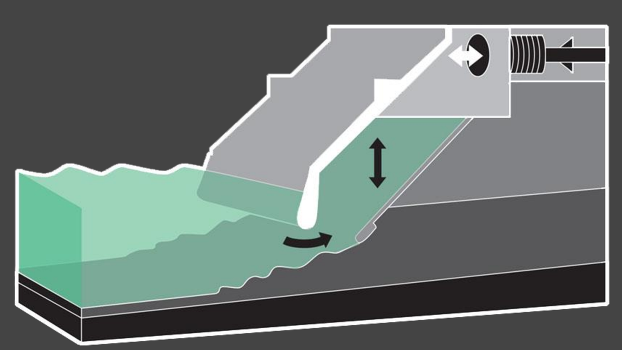
Introduction



Oscillating Water Column (OWC) systems generate electricity through harvesting the kinetic flow of air over a Wells turbine as the air enters and exits a concrete chamber. Air is compressed in the chamber as the encapsulated water column increases in height, thus inducing air flow from high to low pressure.

These renewable marine energy systems are not commonly employed even in regions of high energy generation potential. This study focused on quantifying both the geospatial generation potentials of OWCs and the environmental impacts that the manufacturing processes of optimally sized OWC chambers incur along the New England coastline.

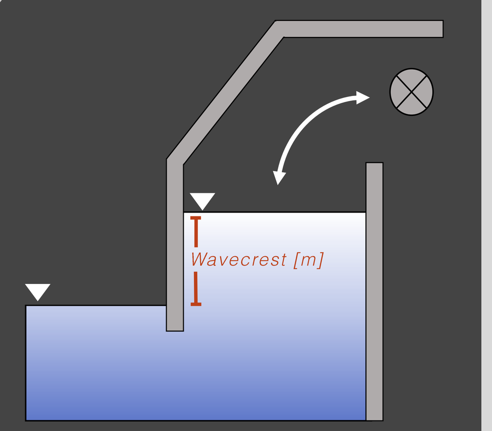
Calculating Wave Power

$$Energy = \frac{\rho g A^2}{2} \qquad A = \frac{H}{2} \qquad V_g = \frac{g}{2\omega} \qquad \omega = \frac{2\pi}{T}$$

$$Power = (Energy)(V_g) = \left(\frac{\rho g A^2}{2}\right)\left(\frac{gT}{4\pi}\right)$$

Gravitational Acceleration; Wave Period; Wave Height; Seawater Density

$$Power = \frac{\rho g^2 T H^2}{32\pi} \quad \text{units: } W/m$$

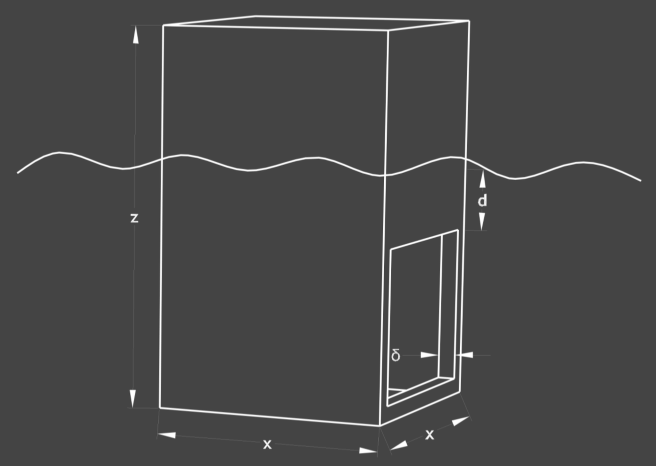


Optimized Chamber Volume

$$\Delta H = \frac{V_x A_d}{A_c} \qquad V_x = \frac{6356(Horsepower)}{pA} \qquad Horsepower = 1.34(Power)(H)$$

$$A_c = \frac{(6356)(1.34)(Power)(H)}{p\Delta H}$$

Chamber Cross-Sectional Area; Pressure



$$\text{Concrete Used} = (x^2 z\delta) - ((x - 2\delta)(|\tau| - d - \delta)\delta)$$

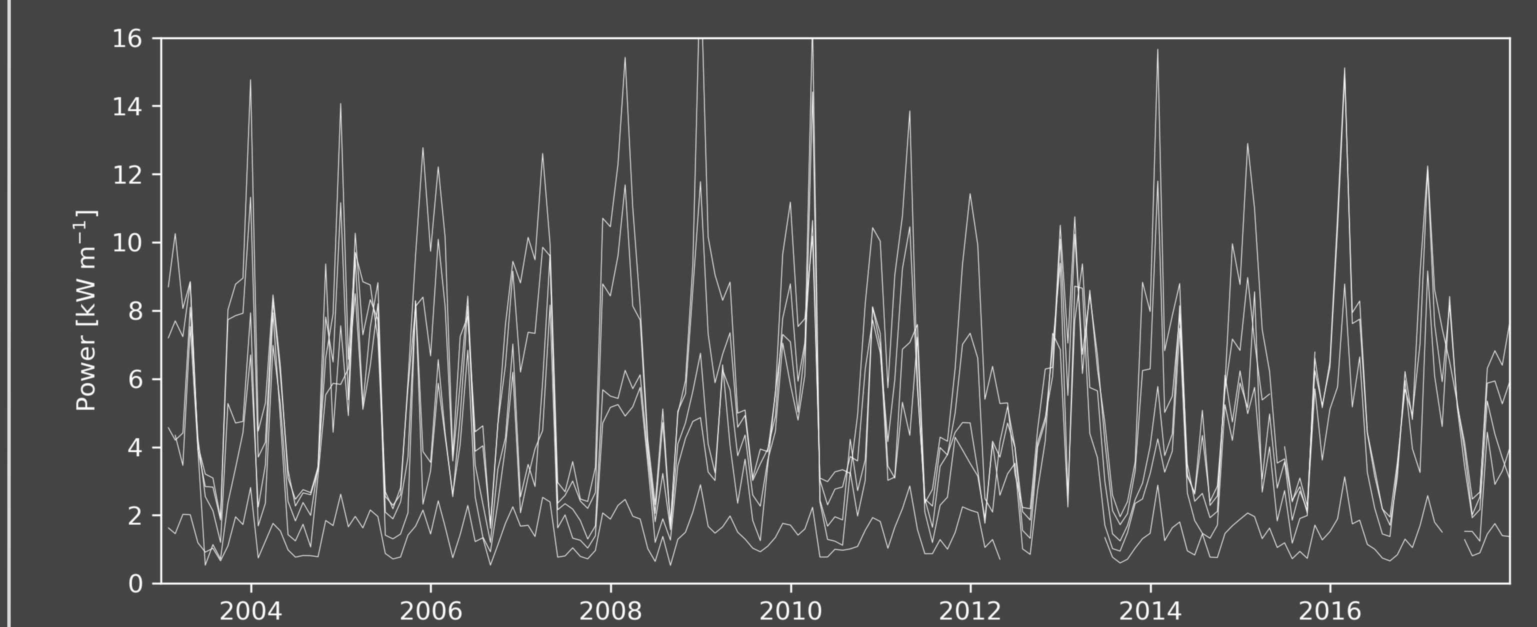
Chamber Cross-Sectional Area; Chamber Width; Chamber Height; Terrain Height; Chamber Draught Lip

Wave Power Interpolation

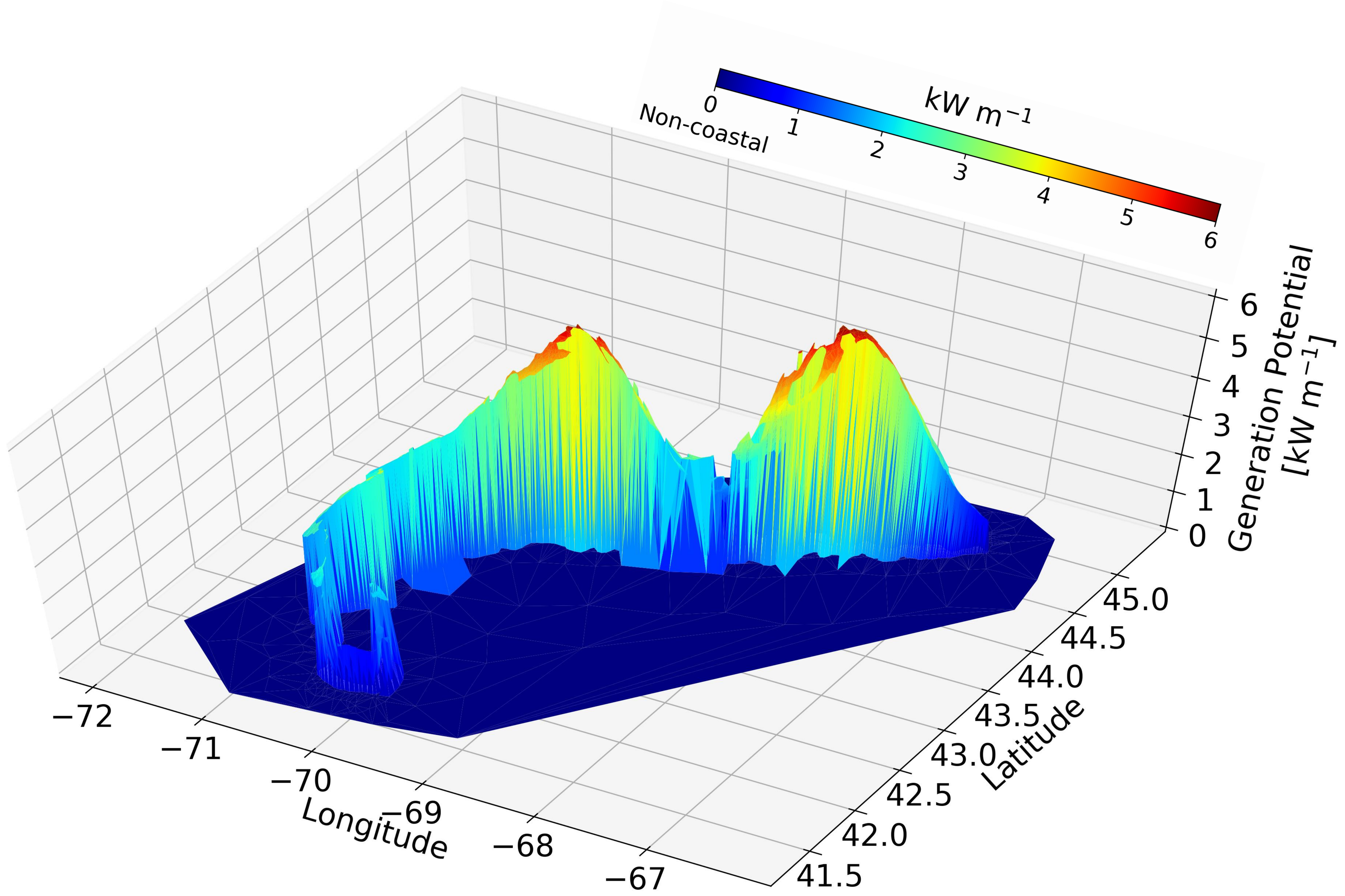
- Wave period and height data retrieved from five NOAA buoys for 2003-2017.
- Data averaged to monthly resolution and power was calculated using fixed turbine efficiency, $\eta = 59\%$.
- At every timestep, all five estimated wave power values were interpolated onto a meshgrid using a radial Gaussian interpolation function.

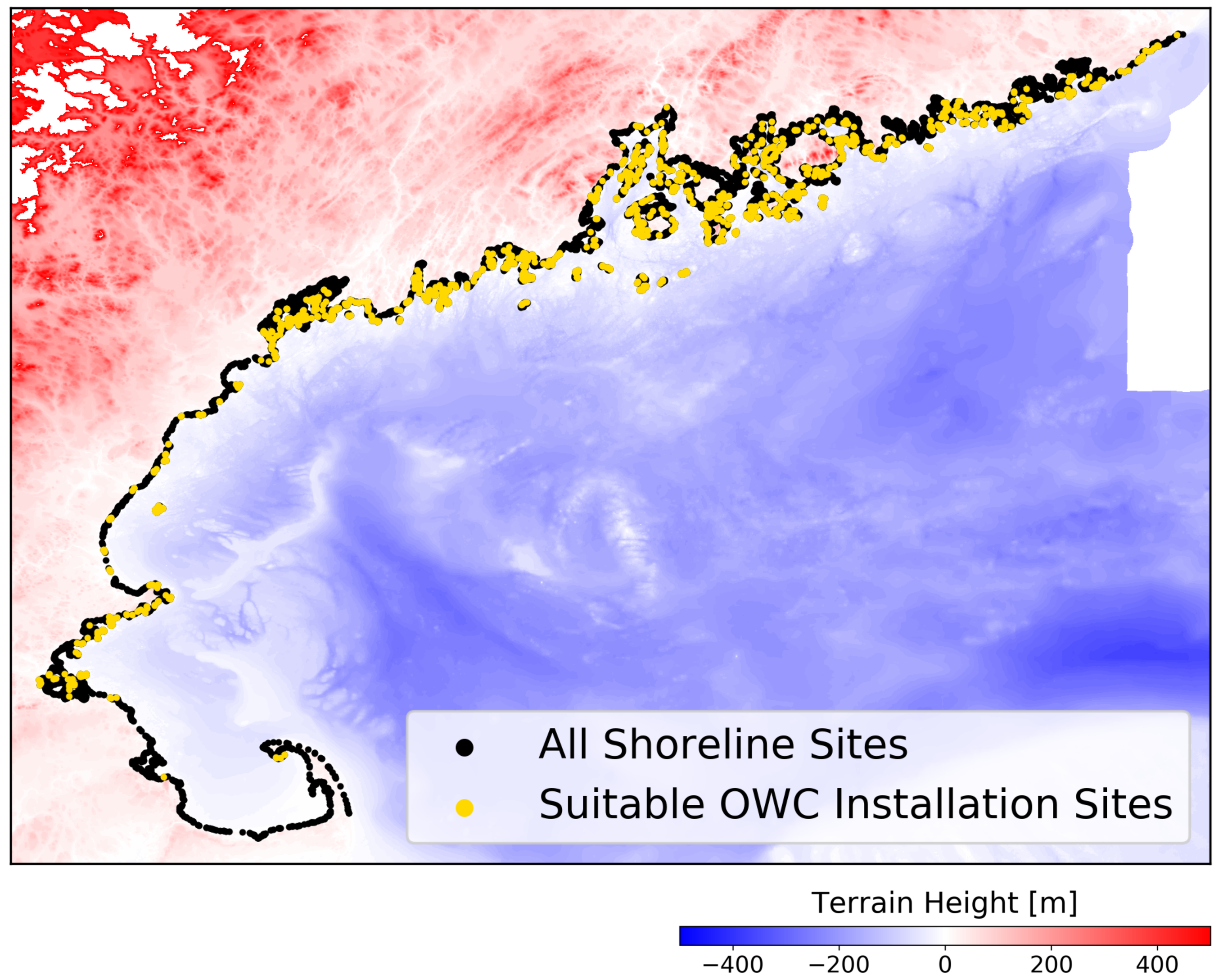
$$f(x,y,z) = e^{-\left(\frac{r(x,y)}{z\varepsilon}\right)^2}$$

- A matrix of power values was constructed for all 6,775 shoreline sites for 2003-2017.



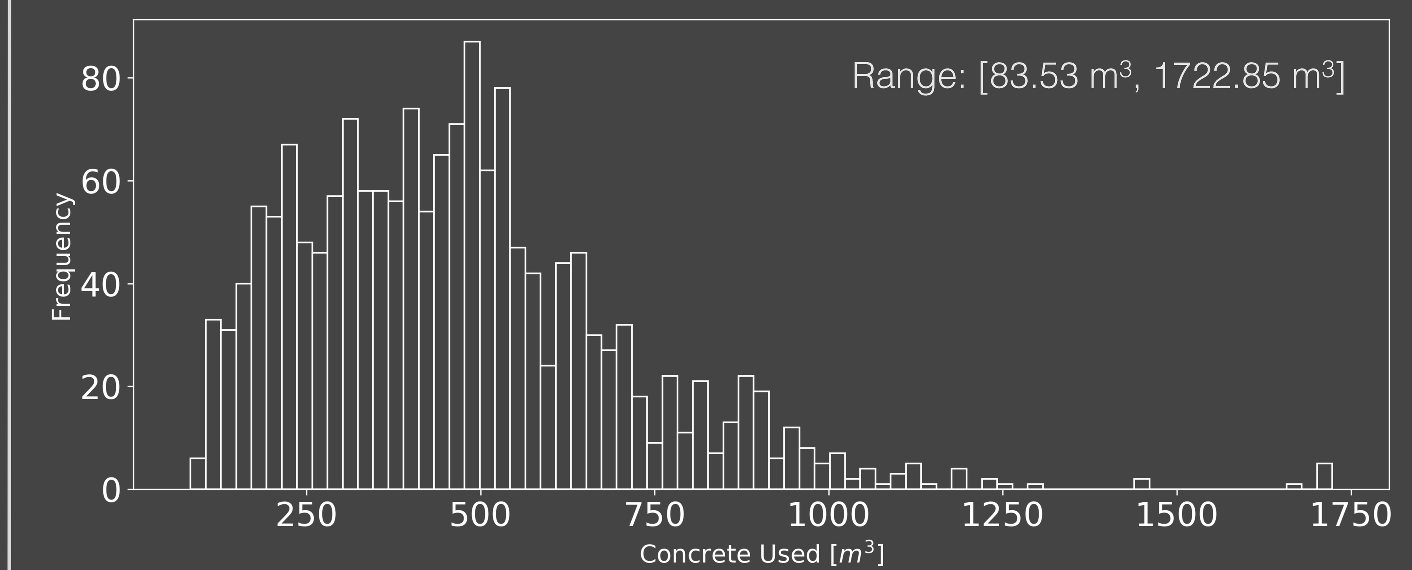
- Trimmed average (10%) was calculated across the temporal matrices to obtain the most realistic value of generation potential at each site.





Life Cycle Assessment

- 1,675 sites were suitable for installation; these sites were at least 7 m below sea level for 3.5 m chamber opening height and 3.5 m draught lip.
- Concrete usage per system was calculated from the optimized chamber sizes. Optimal chamber size is a function of energy generation potential.



- High variability in material consumption illustrates the importance of employing a Life Cycle Assessment in the next phase of this study.

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