Lake Superior as a Suitable Testing Ground? Wave Resource Analysis to Inform Coastal Infrastructure WEC Design for Global Adaptation

Gracie Bahr, Master of Science in Mechanical Engineering, University of Minnesota Duluth
Dr. Craig Hill, Assistant Professor, University of Minnesota Duluth

UNIVERSITY OF MINNESOTA DULUTH
Driven to Discover

The Great Lakes environment can be used as a testing ground to explore wave energy technologies as a source for renewable energy that can be adapted to locations worldwide

INTRODUCTION

Can the Great Lakes be used as a development and testing ground for WECs targeting deployment in other lower resource environments around the world? To begin exploring this, we use a case study from October 12 - 15, 2023, Park Point Beach, Duluth MN

Goal

- Gain an understanding of the available wave resources and the feasibility of a marine energy converter to be utilized in coastal communities

How

- Wave resource analyses on Park Point Beach buoy data during a common storm period from Oct. 12 - Oct. 15, 2023

Benefits of Coastline and Coastal Infrastructure Integrated WECs

- Create barriers protecting coastal environments across the Great Lakes
- Preserve coastlines and coastal infrastructure
- Resilient energy source for coastal communities

In Progress

- Accumulation of more extensive nearshore observation and model data sets for year-round wave climate to be analyzed

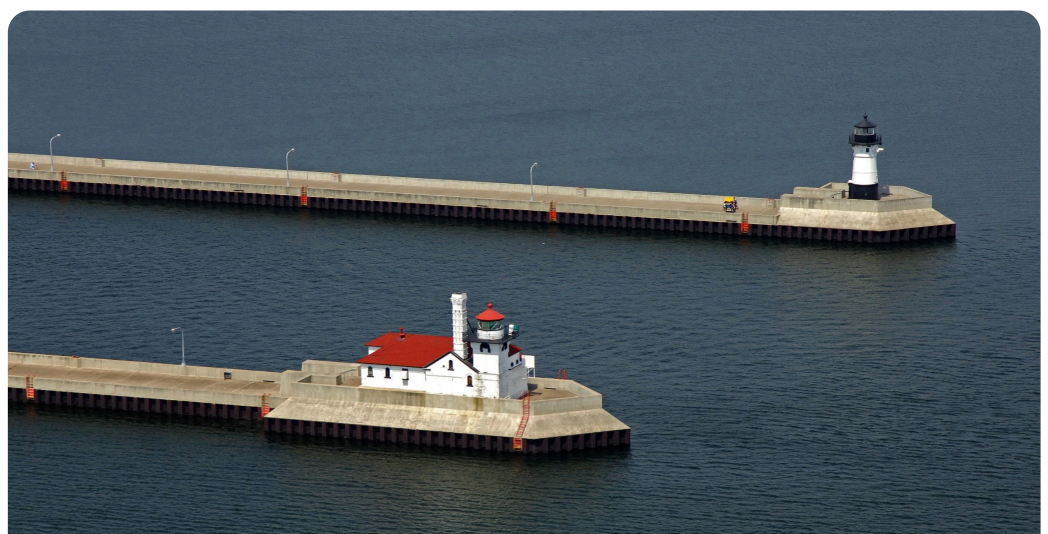
BACKGROUND

Powering the Blue Economy

- Sector of renewable energy that utilizes ocean resources sustainably, while preserving the ocean ecosystem
- Offshore power to support offshore activities
- Power for coastal communities

Integration of Marine Energy into the Blue Economy

- Power at sea: cost-effective alternative that decreases pollution and water contamination
- Resilient coastal communities: protecting shorelines, generate power, and create a robust and diverse power source even in extreme weather events



Seawall infrastructure on Lake Superior - Port of Duluth canal entrance

METHODS

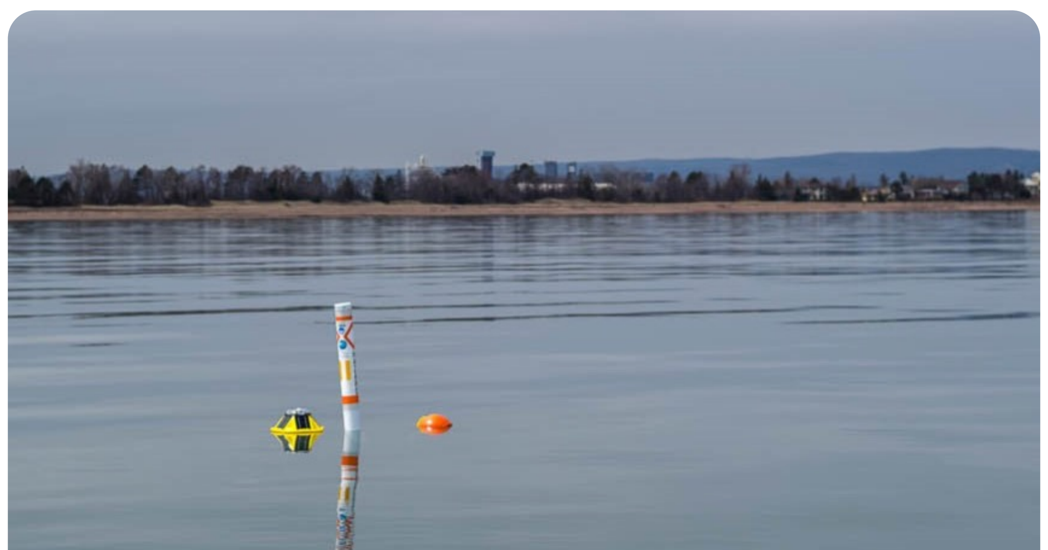
Use nearshore wave observations to:

- Calculate maximum available wave power and wave energy
- Inform designs for wave energy converters integrated into local infrastructure that fit energy production goals generated from nearshore waves on Lake Superior
- Adapt to locations on other Great Lakes and globally

Calculating wave power density:

- Buoy observations provide significant wave height (H_{m0}) and wave period (T_e) to enable calculating wave power density, J [W/m].

$$J = \frac{\rho g^2}{64\pi} H_{m0}^2 T_e$$



Spotter buoy deployed in 13m deep water – Park Point Beach House, Duluth, MN

RESULTS AND COMPARISONS

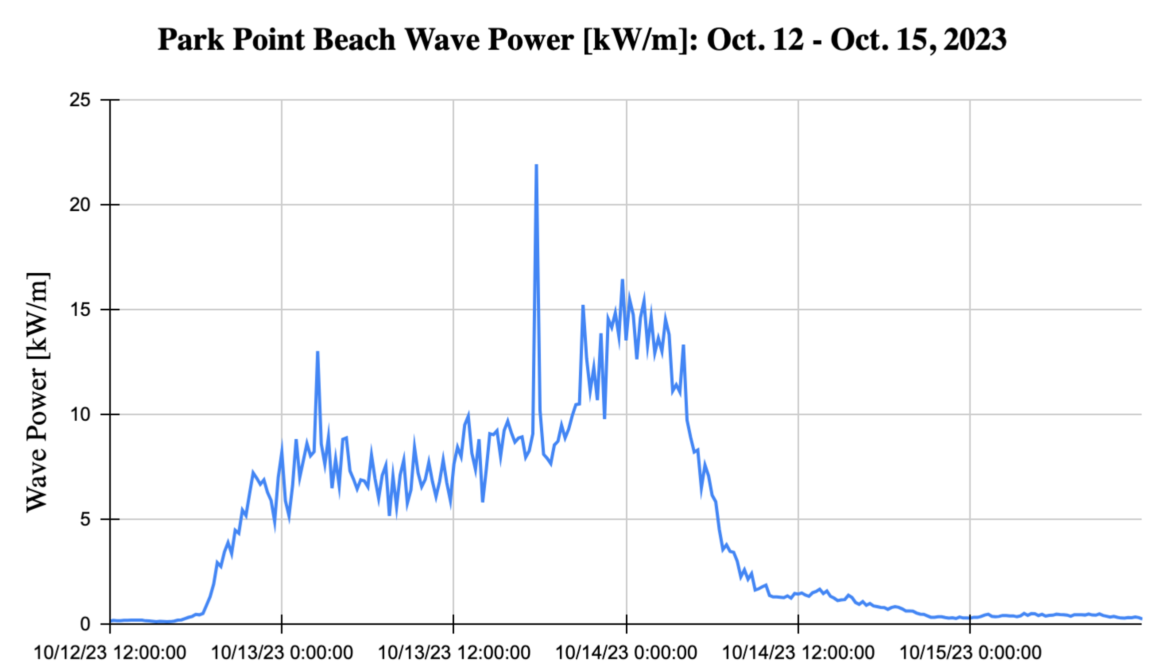


Figure 1. Park Point Beach Available Wave Power calculations for Oct. 12 - Oct. 15, 2023.

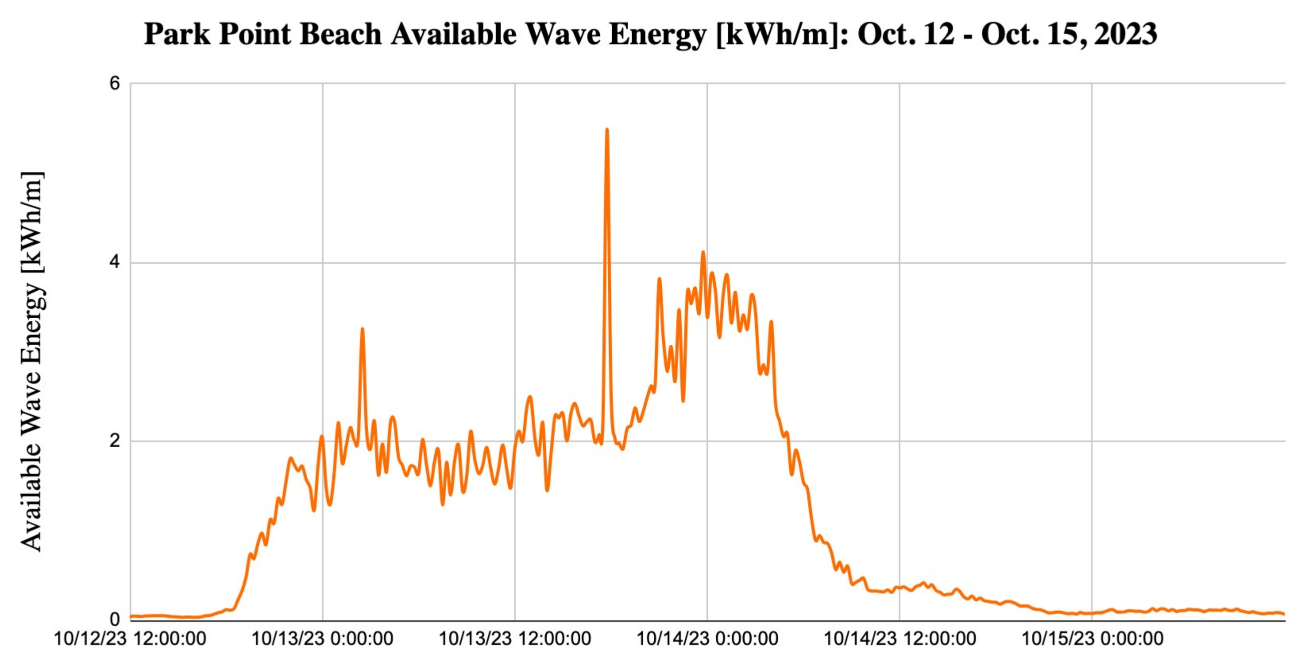


Figure 2. Park Point Beach Available Electrical Energy calculations for Oct. 12 - Oct. 15, 2023.

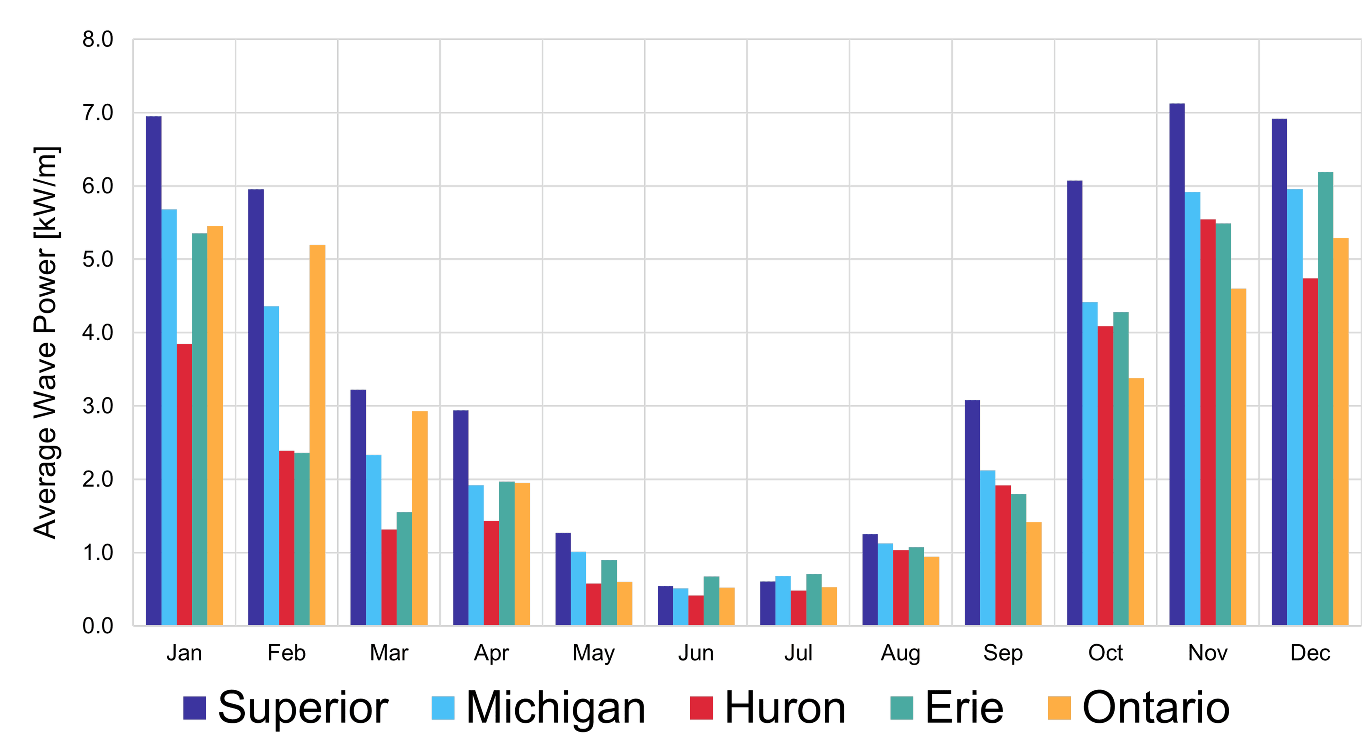


Figure 3. Maximum monthly average wave power during each month of the year for open water NDBC buoys across the Great Lakes. (Pheifer and Hill, 2024)

Key Results

Available Wave Power

- Instantaneous wave power per meter at 15 minutes intervals ranged from 0.13 kW/m to 21.94 kW/m (**Figure 1**)
- Available wave power per meter generated in each wave at 15 minutes intervals averaged ~4.67 kW/m, which is similar to previous studies comparing all five Great Lakes (**Figure 3**)
- Average wave power trends lower during the summer and higher during open water winter months, similar to other regions in the northern hemisphere (**Figure 3**)

Available Wave Energy

- Available wave energy per meter generated in 15 minutes intervals averaged ~1.17 kWh/m, with maximum values reaching above 4 kWh/m (**Figure 2**)
- Total wave energy per meter for the duration of Oct. 12th - Oct. 15th totaled ~337.66 kWh/m

COASTAL INFRASTRUCTURE WECs

Benefits of coastal infrastructure integrated WECs

- Shared infrastructure costs
- Maximize use of natural coastlines
- WEC stability improvement
- Ancillary benefits for tourism and recreation

Eco Wave Power infrastructure integrated wave energy array – Gibraltar

PUTTING ENERGY USE IN PERSPECTIVE

NDBC buoy SCOOP payload

- ~0.122 kWh per day (Copping et al., 2020)
- 1 buoy for 7.5 years

Marine Carbon Dioxide Removal (mCDR)

- 30 kWh per 1 ton of seaweed cultivation for biofuel (Cotter et al., 2020)
- 11 tons of seaweed cultivation for biofuel

Ocean Observation Systems

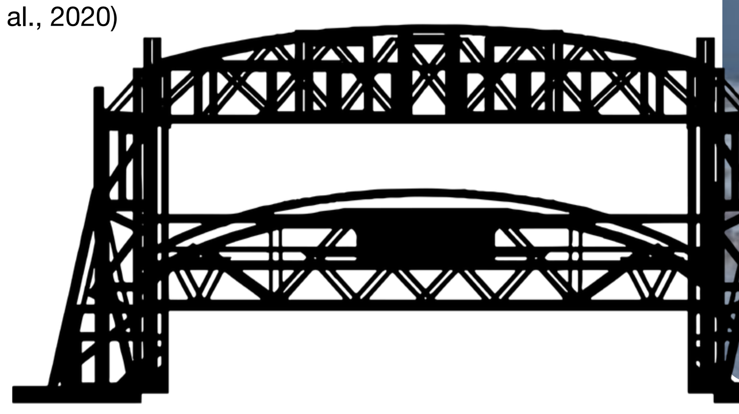
- HF Radar can draw up to 12 kWh/day (Cavagnaro et al., 2020)
- Expand observations or add new sensors

Duluth Lift Bridge

- ~589.3 kWh per day (MN Power)
- Over 12 hours

Electrical Vehicles

- Tesla: about 5 vehicles charged
- Chevrolet Bolt: about 29 - 44 vehicles charged



FUTURE DIRECTIONS

Project Direction

- In the process of gathering more extensive data for year-round wave analysis
- Inform designs for North Shore infrastructure integrated wave energy converters
- Filling energy needs of coastal communities
- Global adaptation focus for worldwide relevancy and implementation – scale waves and WEC operations to other environments

Potentials

- Diversify renewable energy
- Resilient power source
- Protecting coastlines
- Vast energy accessibility
- Powering the Duluth, MN community

Storm waves impacting coastal seawall infrastructure – Port of Duluth canal entrance

CONTACT

Gracie Bahr, bahr0080@umn.edu
Dr. Craig Hill, cshill@d.umn.edu

References

- Cavagnaro, R. J., Copping, A. E., Green, R., Greene, D., Jenne, S., Rose, D., & Overhus, D. (2020). Powering the blue economy: Progress exploring marine renewable energy integration with ocean observations. Marine Technology Society Journal, 54(6), 114-125.
- Copping, A. E., Green, R. E., Cavagnaro, R. J., Jenne, D. S., Greene, D., Martinez, J. J., & Yang, Y. (2020). "Powering the blue economy-ocean observing use cases report" (No. PNNL-29585). PNNL.
- Cotter, E., Cavagnaro, R., Copping, A., & Geerlofs, S. (2021, September). Powering Negative-Emissions Technologies with Marine Renewable Energy. In OCEANS 2021: San Diego–Porto (pp. 1-8). IEEE.

ACKNOWLEDGEMENTS

I would like to extend a huge thank you to my advisor, Dr. Craig Hill, for the introduction into a new passion and field of experience, and for the ongoing guidance, support, and collaboration in this research. I also want to extend my gratitude to my family and friends that have poured into my life and my work through continuously supporting, encouraging, and challenging me forward through every endeavor.