Understanding the Grid Value of Marine Energy Resources

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Additional benefits from systems integration of marine renewables

IEA-OES Workshop, December 16 2019

PNNL is operated by Battelle for the U.S. Department of Energy

PNNL-SA-150090

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Marine Energy Grid Value

Project Goals

The primary goals of this project are to provide data and supporting analysis that will:

- Enable the marine energy industry to articulate additional value to potential investors and customers
- Allow system planners, utilities and decision makers to have information to evaluate marine energy when considering a suite of available generating resources
- Guide the technology investments made at the US Department of Energy toward improving marine energy performance where it is likely to have competitive or unique value

Partnerships

- **NREL:** Partner laboratory, wave energy technology and modeling simulation
- **POET:** Advisory committee convener, industry liaison

NREL Transforming ENERGY

poet PACIFIC OCEAN ENERGY TRUST

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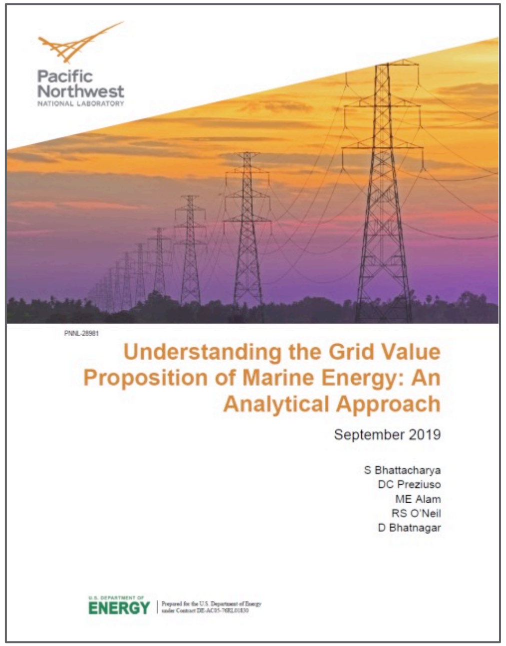
Project Design / Workproducts

- Funded by the US Department of Energy Water Power Technologies Office (EERE) into 2021

Task 1:	Task 2:	Task 3:	Task 4:	Task 5:
• Analytical Approach	• Literature Review	• Case Studies	• Grid Services Selection and Metrics Development	• Stakeholder Engagement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PNNL-28981

Understanding the Grid Value Proposition of Marine Energy: An Analytical Approach

September 2019

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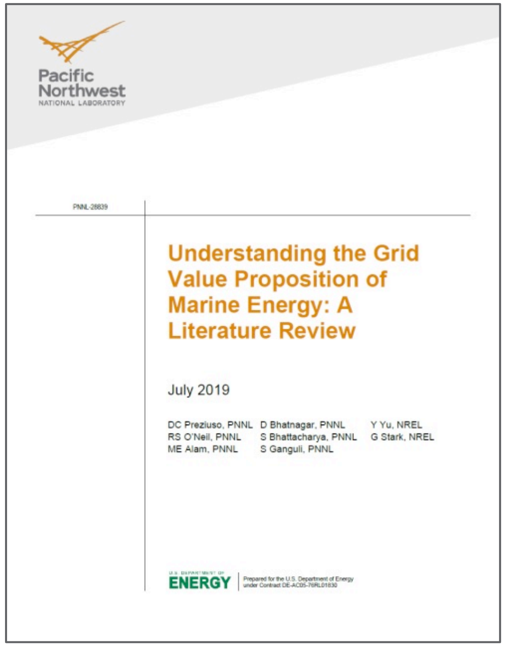
ENERGY | Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830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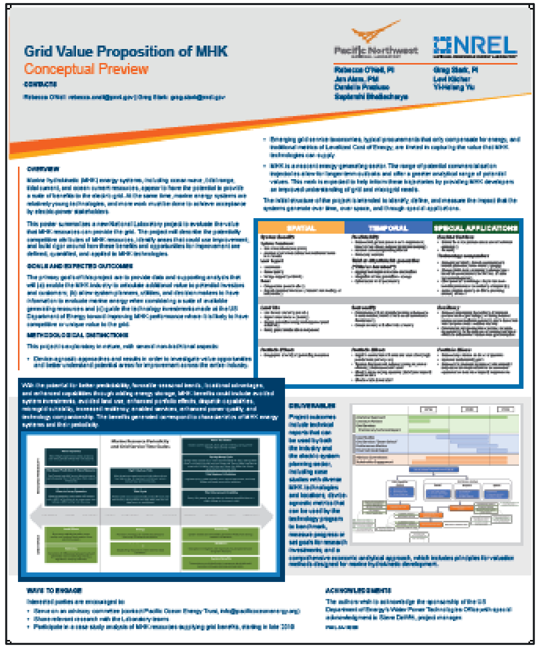
PNNL-28839

Understanding the Grid Value Proposition of Marine Energy: A Literature Review

July 2019

DC Preziuso, PNNL; RS O'Neil, PNNL; ME Alam, PNNL; D Bhatnagar, PNNL; S Bhattacharya, PNNL; S Ganguli, PNNL; Y Yu, NREL; G Stark, NREL

ENERGY | Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830



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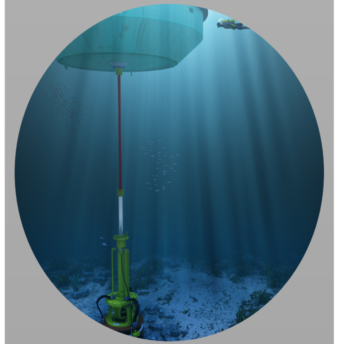
A Chain of Technical Work

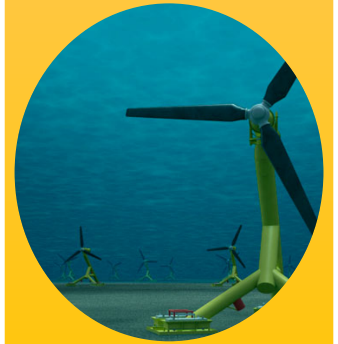
RESOURCES

- Wave
- Tidal Current
- Ocean Current



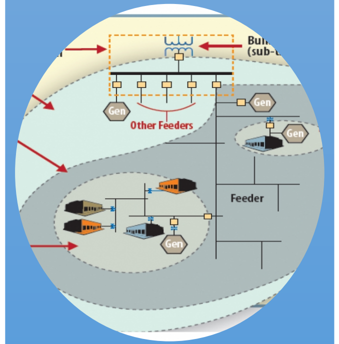
DEVICES

- Variation in Energy Capture
- Variation in Technology
- Interactions with the Marine Environment



ARRAYS

- Interactions
- Aggregation
- Export



INTEGRATION

- Storage
- Microgrids
- Interconnection

DISTRIBUTION SYSTEM

- Local Effects and Investment Deferral
- Electric Loads
- Resiliency

TRANSMISSION / GRID

- Energy, Capacity and Ancillary Services
- Timing
- Spatial Distribution

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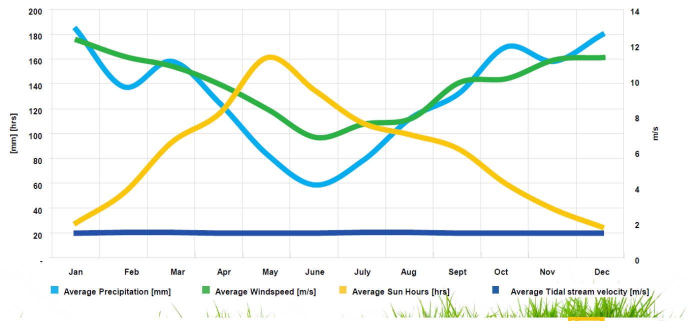
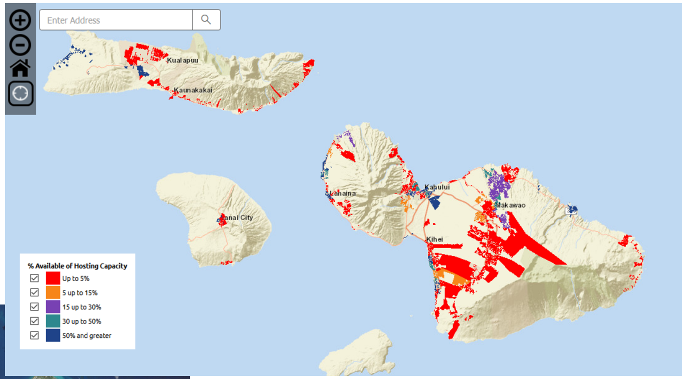
LOCATION	TIMING	SPECIAL APPLICATIONS
System Benefits System Investments • MRE as non-wires alternatives (NWA) • Avoided or deferred distribution and transmission investments Local support • Local load and balancing needs • Power quality and voltage support (volt/VAR) Power Flow • Reduced congestion (coastal cities and transmission corridors) • Remote system improvements (avoided line losses and transmission and distribution loading)	*Predictability* • Reduced integration requirements and associated costs: reduction in reserve requirements, needs for gas/hydro ramping • Enhanced market participation: bid accuracy, qualification, scheduling certainty, penalty avoidance, extended time window for decision making in forward markets *Seasonality* • Coincidence with load • Complementary with other resource availability	*Enabled services* • MRE as a behind the meter resource (customer and grid benefits) • Storage for flexibility and dispatchability • Microgrid suitability: coastal, remote communities and islands (e.g. Barbados, Faroe Islands, Igiugig) • Improvement in performance of other technologies (symbiotic benefits)
Land Use • Increased energy density of coastal land • Avoided opportunity cost of land use for energy generation • Provision of energy in areas where there is low to no availability (dense, remote and island regions) • Address policy goals for intra-BA development	*Scheduled / dispatchable generation ("Tidal as baseload")* • Aggregation: resource diversity offset to create a "baseload" profile • Dispatchability and participation in markets with storage • Optimization of generation with storage	*Resiliency* • Reduced vulnerability to electricity disruptions. • Reduced reliance on conventional backup generation and risk from fuel availability and price volatility. • Avoidance of sustained effects to critical infrastructure from grid disruption as a microgrid resource, in combination with microgrids, or as a backup generation resource. • Systemwide and localized black start
Portfolio effects • Improved geographic diversity of the generation portfolio: reduced system capacity and balancing requirements and a natural resiliency effect.	*Portfolio effects* • Negative correlation with wind and solar at very high penetrations (e.g. winter peak) • Thermal improvements: displacement, reduced cycling, improved efficiency, and reduced emissions • Effective load carrying capability (ELCC) and capacity credits for MRE • Reduction in system costs, capacity and balancing requirements with an integrated portfolio • System reliability improvements: effects on LOLE and LOLP	*Portfolio effects* • MRE modularity and array-based development allows for as-needed expansion, reducing financing risk, up-front costs and ongoing operations and maintenance costs. • Reduced dependence on diesel and natural gas production and delivery infrastructure. • Improvements to meeting environmental and sustainability goals.

Island Grids



Resource complementarity



Marine energy resources present several possible benefits to island grids

- Resource complementarity to other variable renewable generation – tidal in Faroe Islands 100% RE by 2030
- As a predictable resource MRE may require a fraction of associated integration costs and support the integration of other resources – Hawaii is facing significant voltage and reserve impacts from PV
- Land use: land is limited on islands, MRE can provide a key offshore energy source – Bermuda has no land for onshore wind and limited land for solar development

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Image Sources: SEV (Faroe), Hawaiian Electric, NASA

Tidal Phase Diversity

- Evaluating clusters of tidal resource phasing to explore more uniform aggregated generating profiles (mitigating rather than amplifying production extremity)
- Uniformity, especially in concert with predictability, can increase grid value
- Aggregation delivery mechanism model on the rise
- Completed a first order analysis around the US using the M2 constituent and are now exploring the full tidal time series

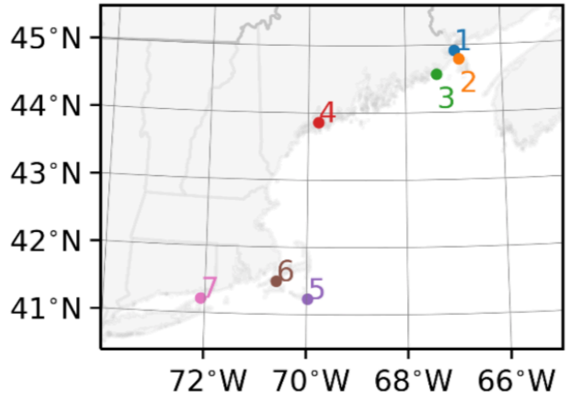


Fig. 3 Representative locations selected for the Northeast region.

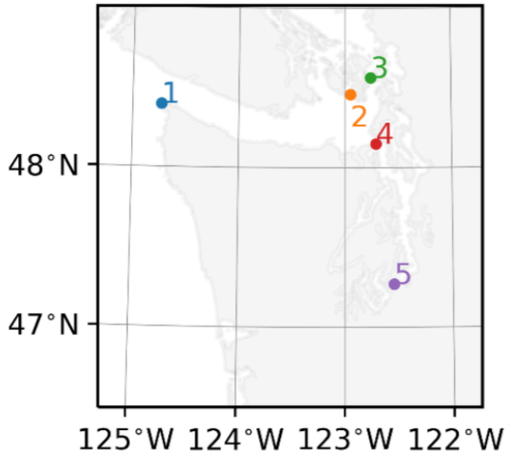


Fig. 4 Representative locations selected for the Salish Sea, Washington region.

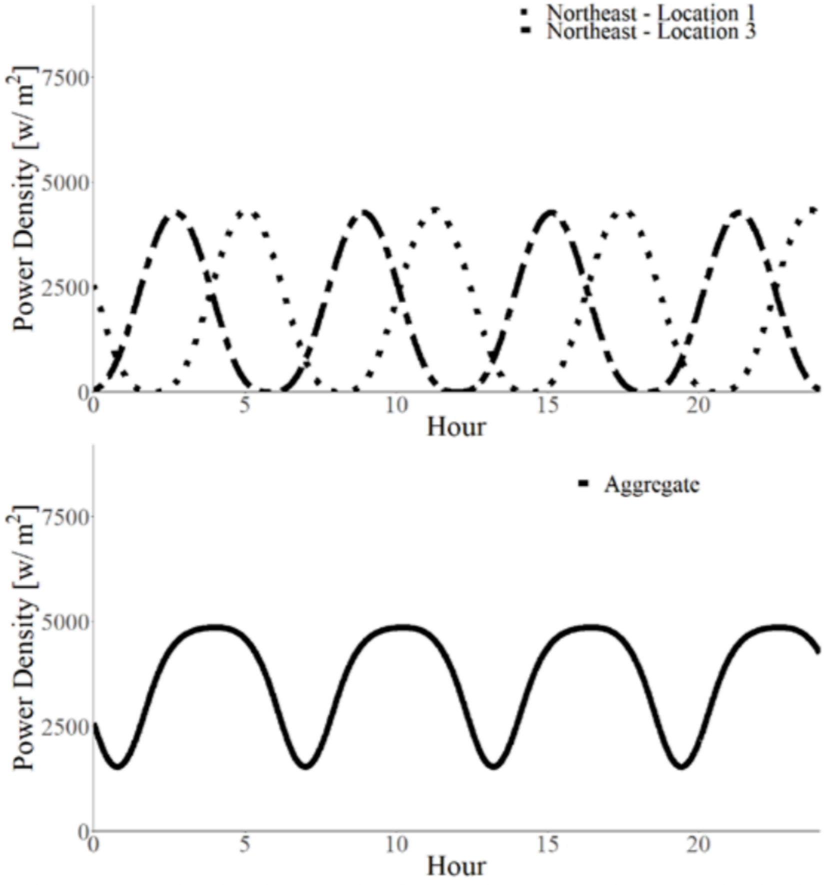
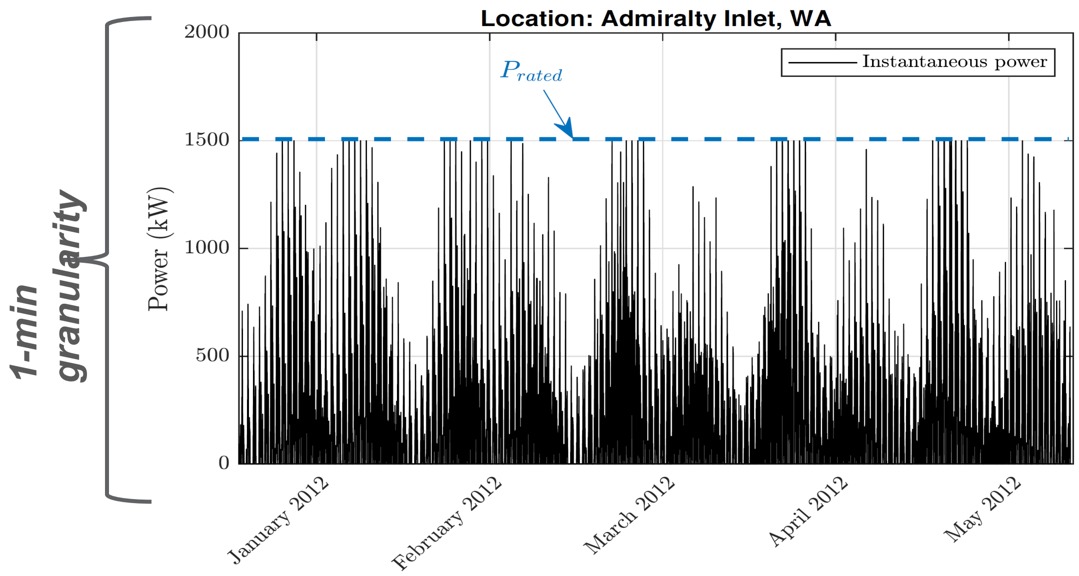
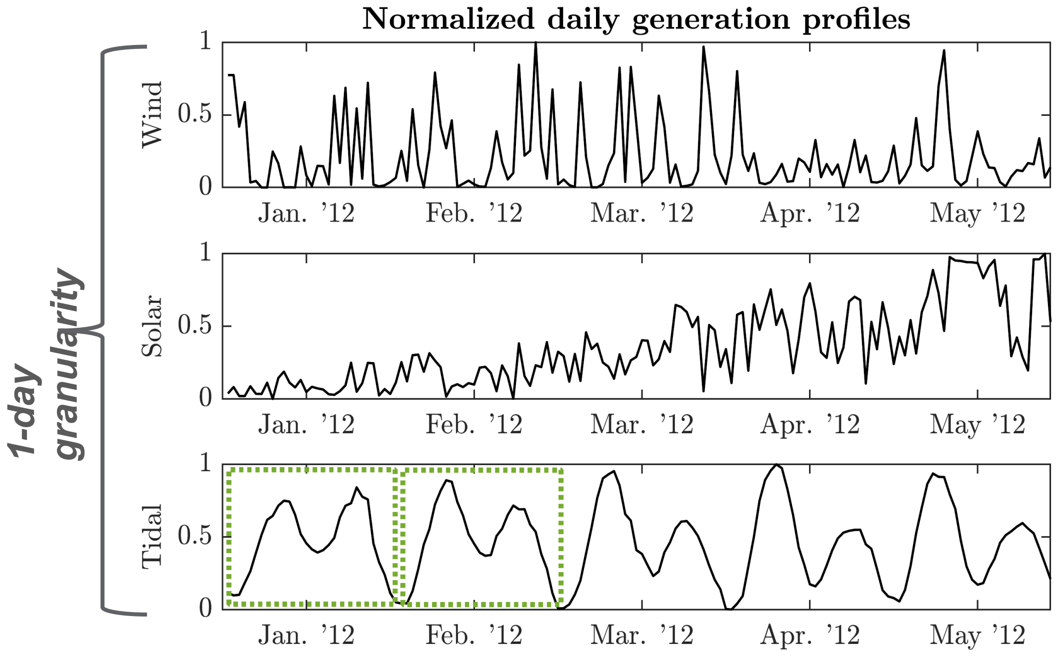


Fig. 5 Power density times series for Northeast Locations 1 and 3 (top) and the aggregate power density time series (bottom) for one day.

Measuring Predictability

- We can use approximate entropy (time-series statistical measure) as a quantitative representation of randomness to predictability
- This permits comparison of resources over various time-horizons and an estimation of grid value in capacity, reduced reserves, and resource selection.





Partnership opportunities

- Website: https://www.pnnl.gov/projects/marine-energy-grid-value
- Technical collaboration: journal publications, case studies
- Advisory collaboration: participate in advisory committee
- Conferences upcoming--
  - PAMEC- Pan-American Marine Energy Conference in San Jose, Costa Rica | January 26-28,2020
  - ICOE- May 2020 in Washington DC
  - IEEE ECCE- October 2020 in Detroit MI
- Powering the Blue Economy, Resilient Coastal Communities
  - PBE focus on community demands, technical needs and requirements, physical integration and device design
  - Grid value in terms of reliable, economic and resilient electricity delivery to coastal operations and loads

Contact Information

PNNL main team composition

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Thank you

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