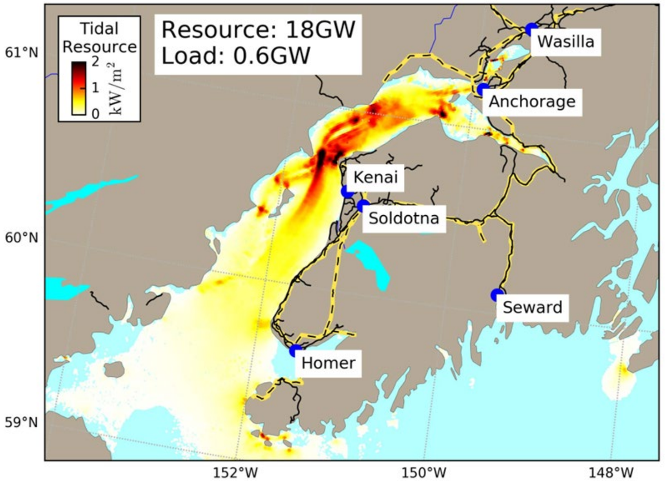
2.4.3.603 – Grid Value Proposition of Marine Energy



Dhruv Bhatnagar, Dr. Levi Kilcher, Dr. Ben McGilton

Pacific Northwest National Laboratory & Sandia National Laboratory

dhruv.bhatnagar@pnnl.gov,
levi.kilcher@nrel.gov, ben.mcgilton@nrel.gov

July 18, 2022

Project Overview

Project Summary

Pacific Northwest National Laboratory and the National Renewable Energy Laboratory, working with colleagues from Oregon State University, and the Pacific Ocean Energy Trust have together conducted several types of analyses to identify an illustrated value proposition for marine energy resources. This effort provides a fresh framework for evaluating electric system benefits based on marine energy's attributes and provides a preliminary analysis to illustrate and quantify those benefits, considering the early stage of technology development. To become commercially successful, the sector needs to explain why it can provide a unique contribution beyond energy decarbonization, which is otherwise readily available from other renewable resources at lower costs.

Intended Outcomes

- Documentable activities: incorporation of ME in system/resource planning (e.g. IRPs), proposed projects, MRE adoption, etc.
- Documentable usage of analysis outcomes by technology developers
- Documentable usage of analysis methods and outcomes by regulatory bodies (e.g., PUC evaluating an IRP that includes MRE)
- Documentable usage of analysis methods and outcome by standard generating bodies as a background material (e.g., IEEE amending interconnection standards to include potential MRE impacts)
- Informing DOE WPTO planning and funding allocation for the marine energy program

Project Information

Principal Investigator(s)

- Dr. Levi Kilcher, Dr. Ben McGilton
- Dhruv Bhatnagar, Dr. Jan Alam, Rebecca O'Neil

Project Partners/Subs

- Bryson Robertson, Oregon State University
- Homer Electric Association
- Georgia Tech Research Corp
- Jason Busch, Pacific Ocean Energy Trust

Project Status

Ongoing (Merit-Reviewed)

Project Duration

- 10/1/2018
- 9/30/2023

Total Costed (FY19–FY21)

$1.35M

Project Objectives: Relevance

Relevance to Program Goals: This project aims to identify the potential value that marine energy devices present to different parts of the electric system: deployments to capture value and near-term opportunities. This is a value-first approach to identify, evaluate, and measure characteristics of marine energy that may offer unique or competitive benefits to the electric grid.

- **Foundational R&D:**
  - Direct device performance improvements, cost reductions and develop new capabilities informed by grid needs and what the marine energy resource can provide
- **Technology Specific Validation:**
  - Consider existing devices and identify their limitations in delivering value to the electric grid (beyond LCOE); consider grid integration and operations of devices
  - Identify and consider locations for deployment and potential uses to support international standards development; interface with other technology sectors and international collaborators
- **Data Access & Analytics:**
  - Grid value focused effort improved understanding and access of marine energy to technology & project developers (marine and other renewables), regulators, utilities, independent power producers and other energy stakeholders
  - Local community focus provides near term opportunities to leverage marine energy for resilience, address environmental and equity considerations

Project Objectives: Approach

Challenges

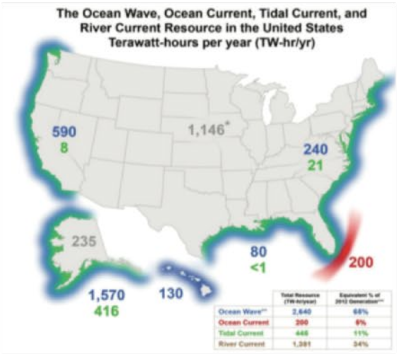
- Marine energy technology is at an early stage
- Costs are high, device designs widespread
- Not proven as grid assets: technical capabilities, characteristics and reliability not well known

Approach

- Look beyond the financial environment for individual devices on typical energy-revenue and capital-cost bases (LCOE or $/kW); *rather:* **what conditions, and to what degree there could be greater grid value in developing marine energy?**
- Consider the question of resource value from a holistic and illustrative perspective: identify, evaluate, and measure characteristics of marine energy that may offer unique benefits to the electric grid
- Synthesize studies and develop a basis for a grid value proposition that is device agnostic. This aids in clear identification of the benefits and values that the marine energy industry can offer. **A high tide raises all boats.**

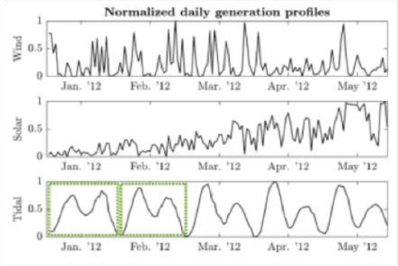
LOCATION

The benefits associated with marine energy resources being an offshore resource.



TIMING

The benefits associated with the forecastability, predictability, seasonality and load and resource correlation of marine generation.



SPECIAL APPLICATIONS

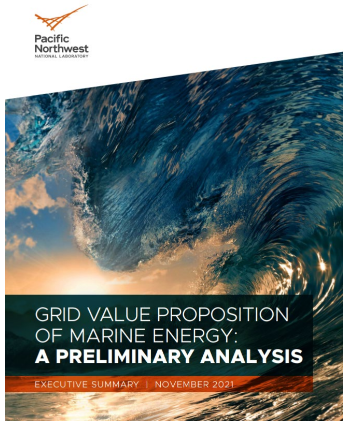
The benefits associated with the ability of marine energy resources to provide services in unique contexts.

1. Identify and classify the landscape of marine energy attributes and value
2. Develop an analytical framework
3. **Use illustrative value propositions and case studies to shed light on this value**

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- Technical reports and journal articles in various venues
  - Technical analysis approaches and models to consider marine energy deployment in different environments



- Presentations to and engagement with marine energy industry stakeholders
- Presentations to engagement with electric industry stakeholders: utilities, state energy offices, PUCs etc.

Intended Outcomes:

- Documentable activities: incorporation of ME in system/resource planning (e.g. IRPs), proposed projects, ME adoption, etc.
- Documentable usage of analysis outcomes by technology developers
- Documentable usage of analysis methods and outcomes by regulatory bodies (e.g., PUC evaluating an IRP that includes ME)
- Documentable usage of analysis methods and outcome by standard generating bodies as a background material (e.g., IEEE amending interconnection standards to include potential MRE impacts)
- Informing DOE WPTO planning and funding allocation for the ME program

Project Timeline

FY 2019

WPTO Progress Review

Published Literature Review

Published Analytical Approach

FY 2020

FY 2021

- Multi-lab effort with each lab taking a separate approach toward outcomes
  - PNNL: Illustrative value propositions
  - NREL: Case study of potential deployments
- Key Risks
  - Technology diversity; alignment of execution with goals; collaboration, data availability, abstraction in results

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1,350K	0K	$1,350K

FY18	FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Costed	Total Costed
$100K	$599K	$440K	$115K	$1,250K

100k carryover into FY21 merit reviewed continuation lab research

End-User Engagement and Dissemination

Stakeholder Dissemination and End-User Engagement

- Identified Beneficiaries: electric industry; marine energy industry, regulatory bodies and state agencies, WPTO
- Engagement with End-Users
  - **Marine Energy Council**: mid-project and final results
  - Marine energy industry: mid-project feedback and final results
    - Briefings to the National Hydropower Association (2020 & 2021)
    - Engagement and collaboration in several IEA-OES Workshops
    - Direct technology developer engagements
    - Conferences: 2019, 2020, 2021, 2022 Ocean Renewable Energy; 2019 Hydrovision; 2019 Oceans; 2020 Pan American Marine Energy; 2020, 2021 European Wave and Tidal Energy; ICOE 2021
  - Utility industry: mid-project and final results
    - Utility Integrated Resource Plan *Report*
    - Direct Engagement: OPALCo, National Grid, SnoPUD, Portland General, Puget Sound, CAISO, CEC, BPA, Utility Webinar to Northwest Utilities and National Grid, Northwest Public Power Association
    - Developed strong relationship with HEA and Railbelt operators
    - Conferences: IEEE PES Innovative Smart Grid Technologies, IEEE PES General Meeting; Alaska Sustainable Energy
  - Diverse stakeholder advisory group composed of ME industry, utility industry, state agencies and regulators, clean energy NGOs

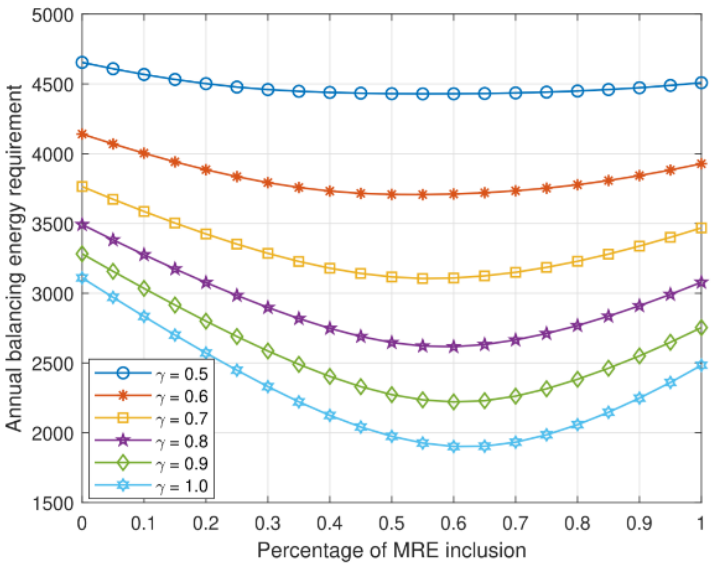
Performance: Accomplishments and Progress

- **Project Reports**
  - Grid Value Proposition of Marine Energy (summary report, November 2021)
  - Grid Value Proposition of Marine Energy: Executive Summary Brochure and Flyer (Nov 2021)
  - Review of Marine Renewable Energy in Integrated Resource Plans (December 2020)
  - Analytical Approach (September 2019)
  - Literature Review (July 2019)
- **Chapter** on "Economics of Power Generation from Tides and Waves" for The Palgrave Handbook of International Energy Economics
- **Peer Reviewed Articles**
  - "Evaluating the Potential for Tidal Phase Diversity to Produce Smoother Power Profiles," Journal of Marine Science and Engineering, April 2020
  - "Timing Value Characterization of Marine Energy Resources for Bulk Grid Operations," Applied Energy, 2021
  - "Evaluating the Resilience Benefits of Marine Energy in Microgrids," EWTEC, September 2021
- **PNNL Webpage** on Understanding the Grid Value Proposition of Marine Renewable Energy https://www.pnnl.gov/projects/marine-energy-grid-value

Progress: Complementarity and Diversity

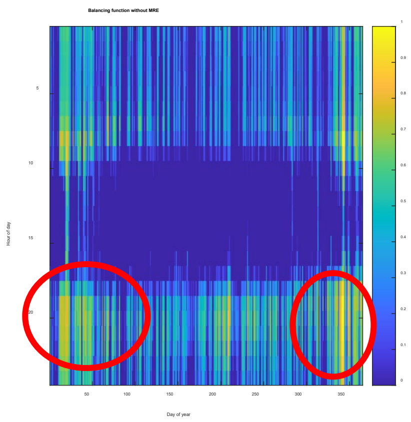
Marine energy can provide important complementarity and diversity within a portfolio of renewable resources:

- Marine energy has a higher **load carrying capacity**, a measure of a resource's ability to generate electricity when the grid is likely to experience energy shortfalls, relative to solar and wind generation
- The added diversity of using marine energy reduces the need for balancing resources to meet electricity needs by up to 20%. This directly manifests in **cost savings to the system at large**
- Deploying marine energy in a clean grid **reduces the need to build energy storage capacity to ensure system reliability by up to 40%**

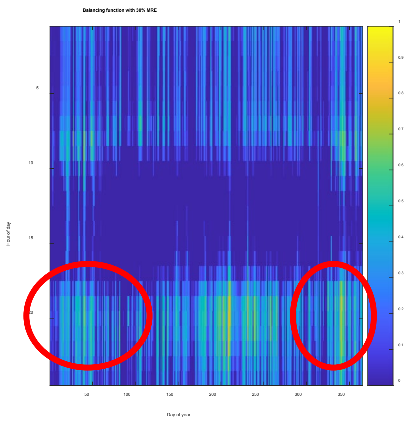


When generation resources are compared at a site, marine energy production adds resource diversity to the generation mix, bringing down balancing needs. The y-axis is balancing requirements in megawatts and the x-axis represents added levels of marine energy to an equal portfolio of wind and solar. γ represents the proportion of renewable energy, with the balance assumed to be fossil.

Balancing energy: variability mapping



without MRE

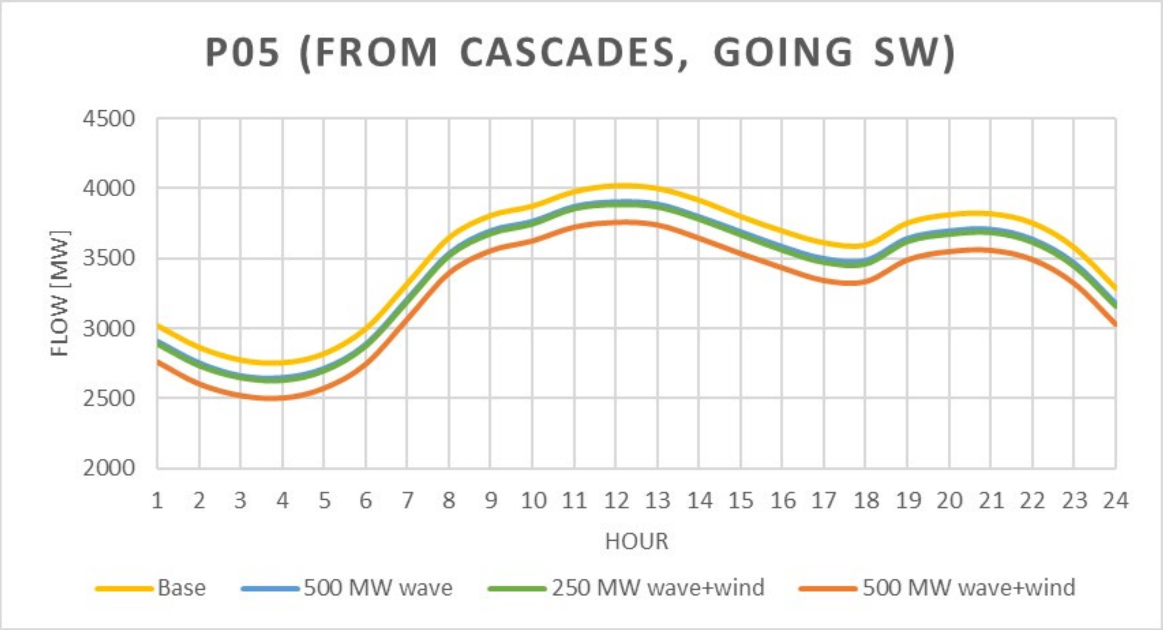


with MRE

Progress: Serving Coastal Loads

Marine energy resources can help serve coastal loads where more than 40% of our population resides:

- Deploying marine energy can reduce transmission buildout needed to meet clean energy goals and provide increased reliability and resiliency
- Increasing amounts of marine energy fulfills local energy needs and provides energy to regional loads, reducing transmission utilization and reliance on imports.
- On average, a 500 MW deployment of wave on the coast opens 200 MW of east to west transmission capacity at peak hours (Oregon)
  - This additional transmission capacity can then be used to deliver more renewable generation on both western and eastern coasts.



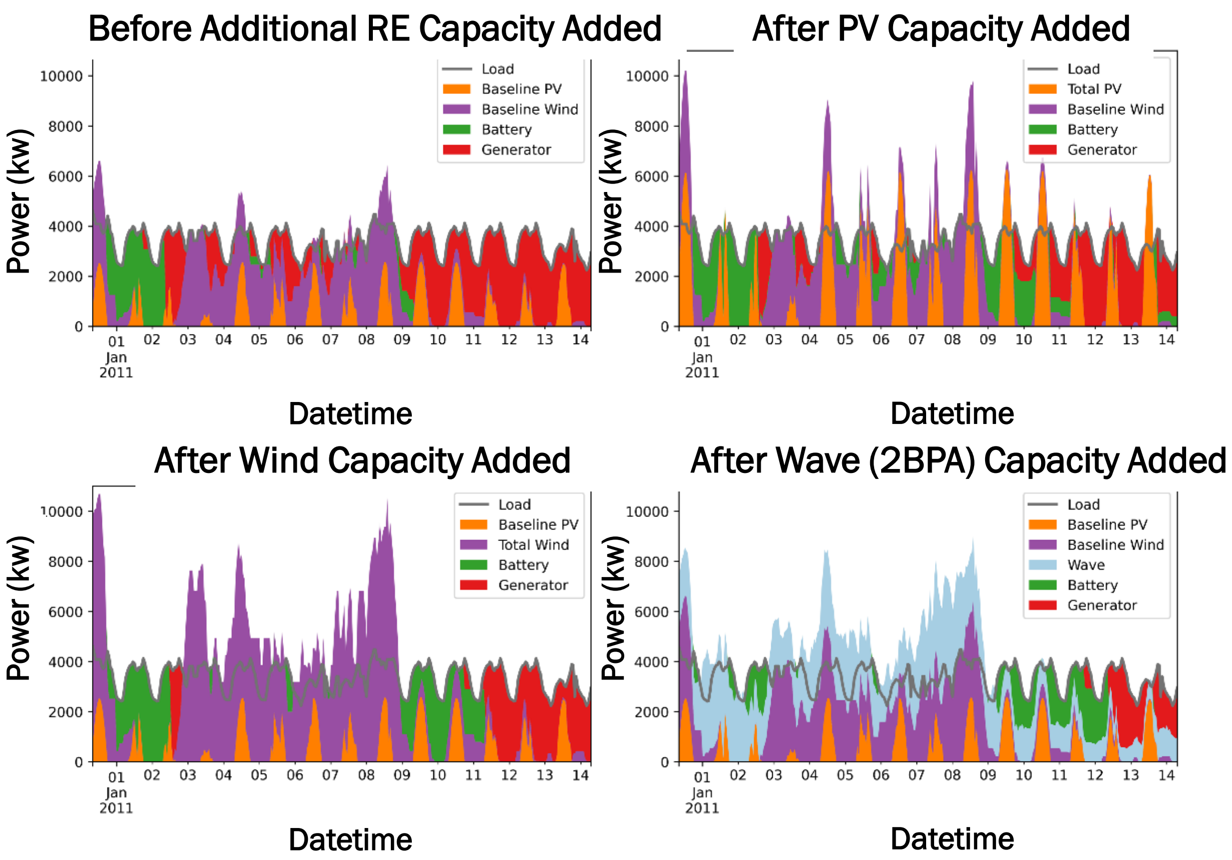
Impacts to hourly average flows from wave and wind integration on Western Electricity Coordinating Council Path 05; positive direction flow is west. The base case is the Western Interconnect in 2028 as modeled by the Western Electricity Coordinating Council. Wave and wind cases represent an equal amount of each resource (i.e., 250 MW of each or 500 MW of each).

Progress: Small Grids - Marine Energy as a Component of Microgrids

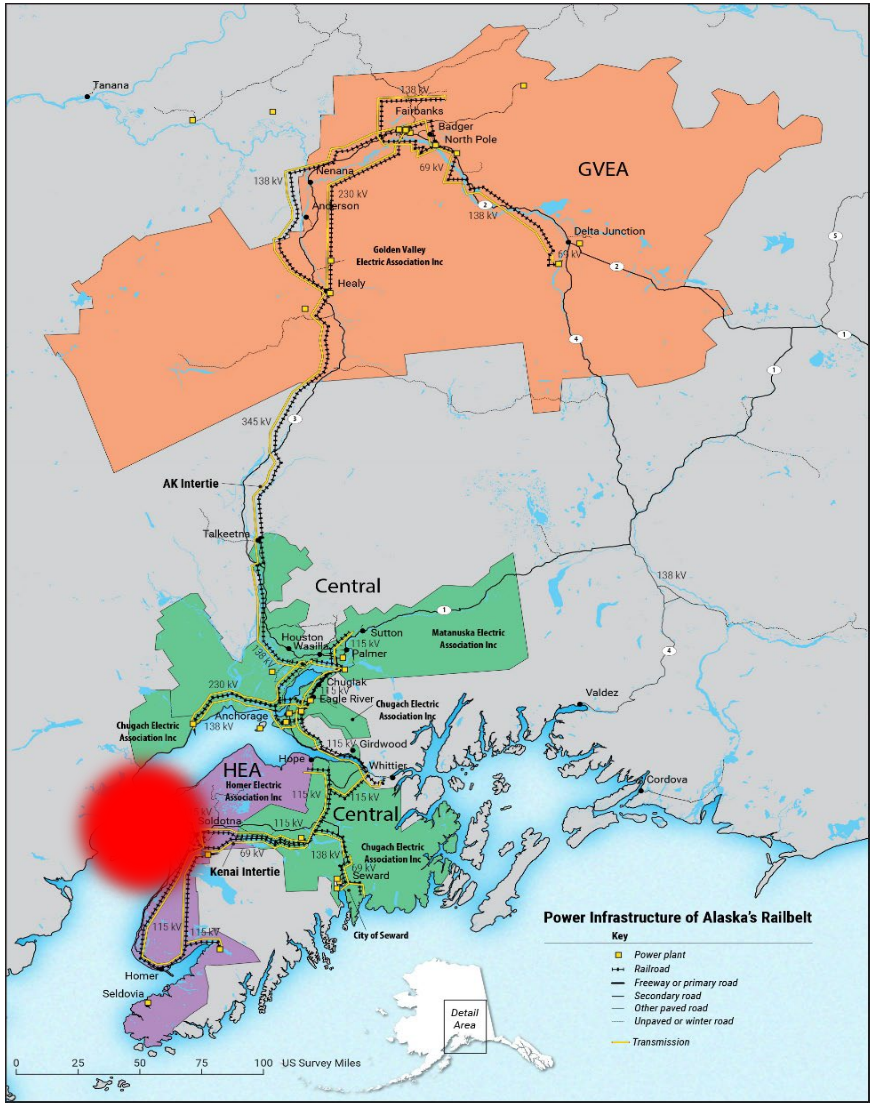
Marine energy resources can help reduce the reliance on imported fuels for small, island and remote grids, while supporting local energy system reliability. Incorporating new wave resources to meet a 100% emissions free target on the Hawaiian island of Molokai provides:

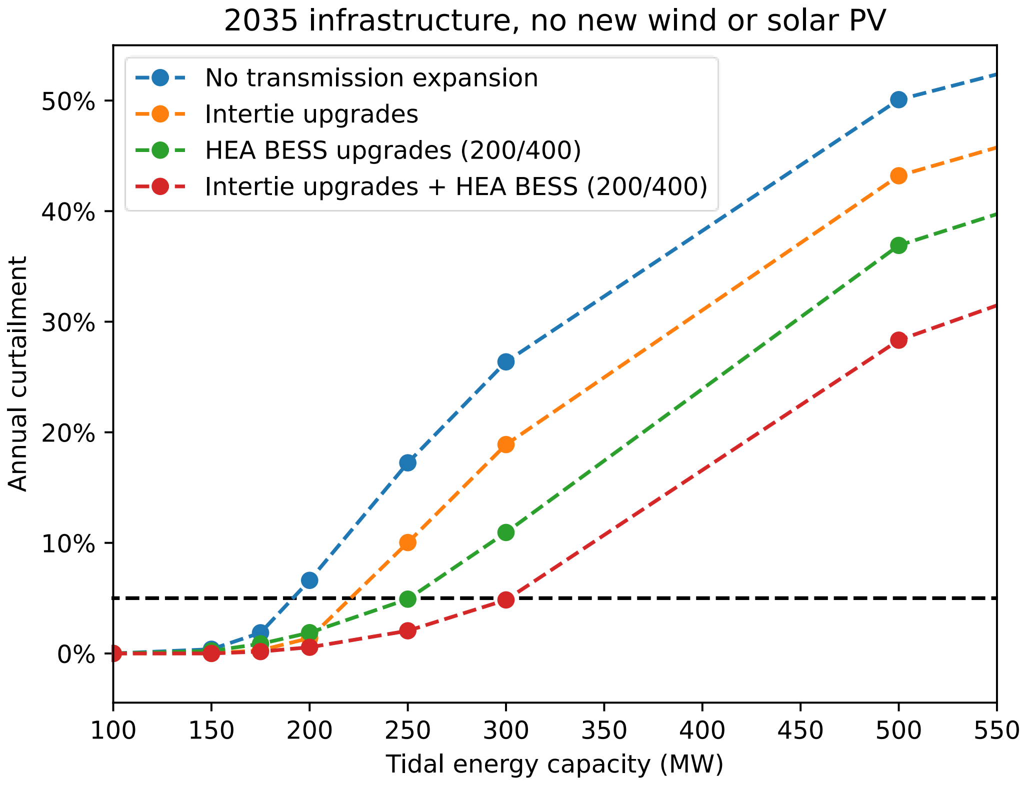
- Added resource **diversity,** which means **less wave capacity than solar capacity is required to meet the same energy need** (about 15-47% less)
- Increased **predictability reduces the amount of energy storage** needed by 17% (reducing system costs and land use)
- Reduced wave **variability cuts down the balancing energy needed to deliver reliable electricity** and the use of fossil fuels to do so by over 50%; and **improves system resilience** (by 30-90% per scenario)

Hourly resource dispatch for a single scenario



Progress: Cook Inlet Tidal Energy Integration Study





- Largest U.S. Tidal Resource (18GW)
- *Opportunity to contribute to 2035 goals*
- Planned grid upgrades: doubles market!
- *Future market:* hydrogen production for export!

NREL Future Work

Near Term Tasks

- Complete the Cook Inlet Study focusing on key value metrics and disseminate results
- Complete a Capacity Expansion Model of the Florida Coast Region including large scale ocean current energy in the renewable's portfolio

Proposed Future Work

- A Capacity Expansion Model of the Cook Inlet would be very beneficial in optimizing the balance of renewables in the energy portfolio and would be a powerful decision support tool for near- and medium-term energy infrastructure buildout planning

PNNL Future Work

Continued work on the Grid Value Proposition of Marine Energy: 3-year focus on the following:

1. High renewables environments: the value of ME in future 80-90% clean energy grids
2. Energy storage and microgrids: integration, benefits and designs
3. Equity and local communities: direct community engagement

Grid Integration of Marine Energy (GIMRE) at PNNL Sequim

Q&A