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Island and Remote Grid Considerations for Marine Energy Development

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U.S. DEPARTMENT OF ENERGY BATTELLE

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Marine Energy Value on Islands and Remote Grids

Challenges

- Marine energy cannot compete with other resources exclusively on an energy/cost basis
- There are unique aspects of marine energy technologies that may provide competitive or unique benefits
  - Resource diversity and complementarity
  - Predictability
  - Address land constraints
  - Energy Security
  - Sustainability

Levelized Cost of Energy

- $30-50/MWh for PV
- $40-60/MWh for wind
- $250/MWh for tidal
- $350/MWh for wave

Source: Astariz et al. (2015)

Faroe Islands

Hawaiian Islands

Bermuda

Breadth of Value Streams

LOCATION

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)

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

Portfolio effects

- Improved geographic diversity of the generation portfolio: reduced system capacity and balancing requirements and a natural resiliency effect.

TIMING

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

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

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

SPECIAL APPLICATIONS

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)

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

- 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.

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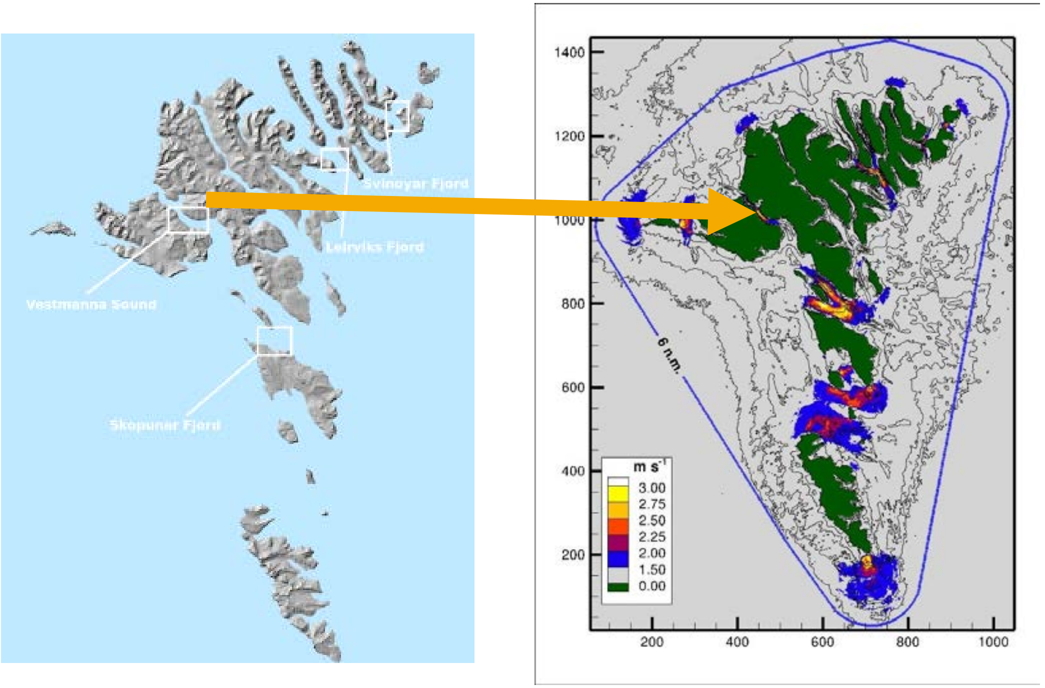
Faroe Islands

- 100% Renewable Energy Goal by 2030
    - Wind
    - Solar
    - Hydro
    - Storage (batteries and PSH)
    - Tidal energy: **Potential of 50-70 MW**



Tidal Pilot Project

- Collaboration between SEV (Faroe Islands Utility) and Minesto
- €2.5 million from European Commission's SME Instrument Program
- Two 100 kW Minesto tidal kites planned for installation: first early 2020 and second late 2020
- Power purchase agreement for delivery of energy

SEV

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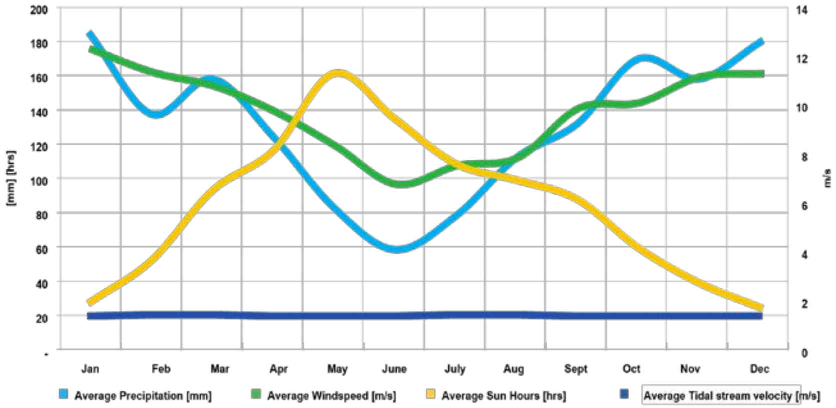
UNIVERSITY OF
THE FAROE ISLANDS

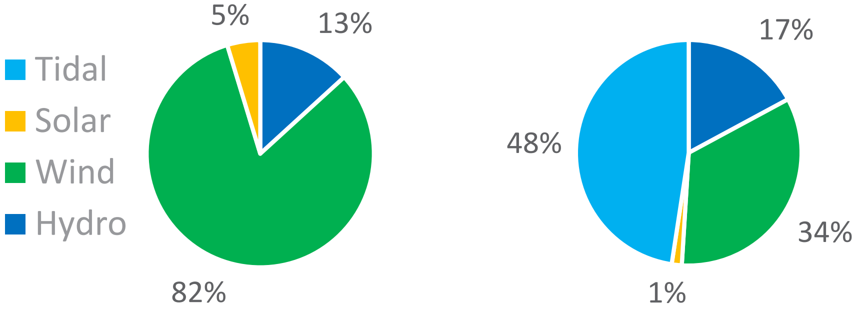
Source: SEV, Minesto

Resource Complementarity

Resource Complementarity: One or more resources aggregating to operate in harmony, resulting in increased resource balance.



Resource complementarity between different renewable technologies



Production in 2030: (left) without tidal; (right) with tidal

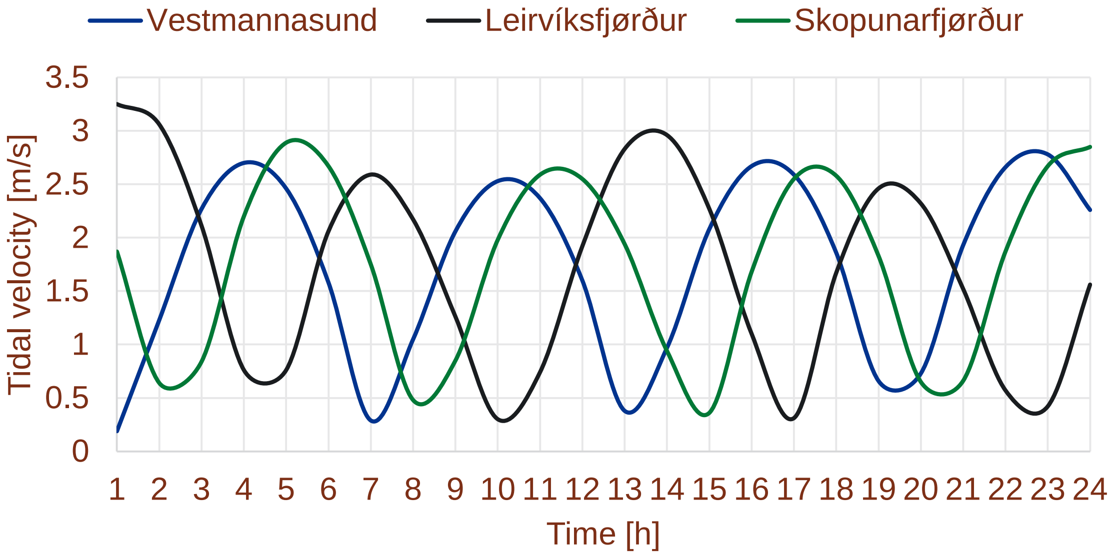
Additional Considerations in the Faroe Islands:

- Resource remains relatively steady month to month
- Tidal is available when other renewables are not
  - Low wind and rain in summer, low PV in winter
- Limited land for geographic diversity
  - Without tidal, significant season energy storage is needed
- Value for energy security and resiliency

Resource Complementarity

Resource Complementarity: One or more resources aggregating to operate in harmony, resulting in increased resource balance.

- Tidal energy can theoretically complement itself if significant phase diversity exists within proximity.



Tidal phase difference between straights in the Faroe Island chain

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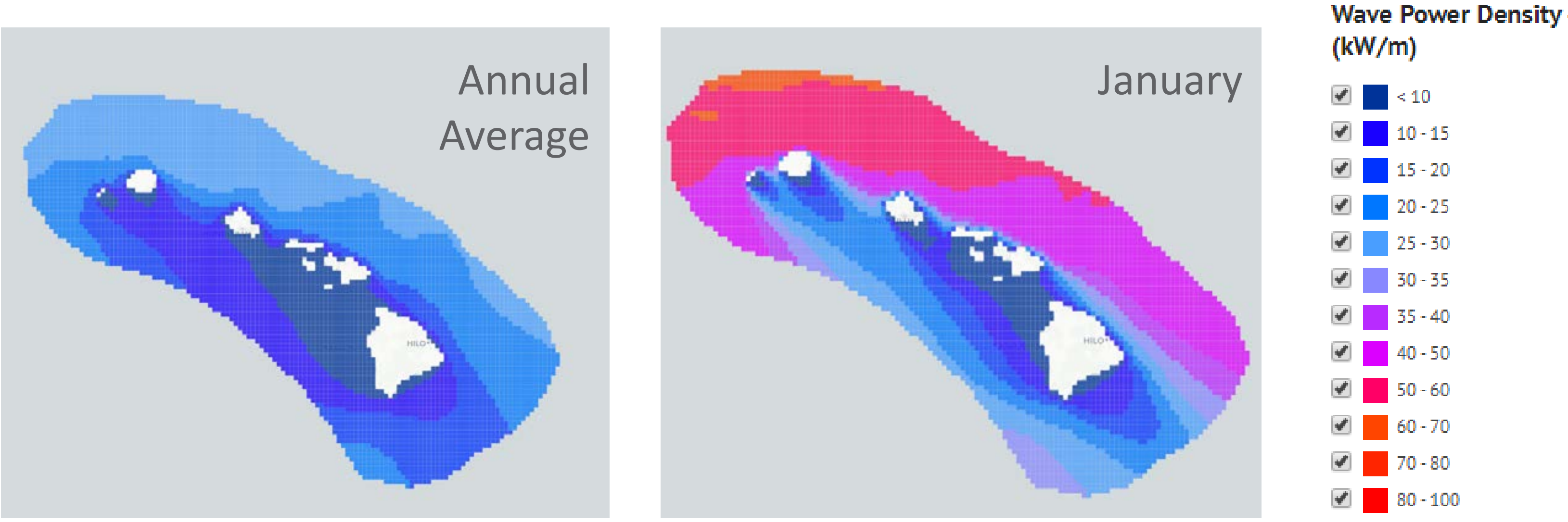
Hawaiian Islands

- 100% renewable energy goal by 2045
    - Installed a significant amount of solar PV
    - System has experienced issues:
        - ✓ Voltage issues on the distribution system
        - ✓ Frequency issues on the bulk system
- There is a strong potential for wave energy on Hawaii



Modeled wave energy power density: (left) annual average, (right) January.

Source: MHK Atlas, NREL

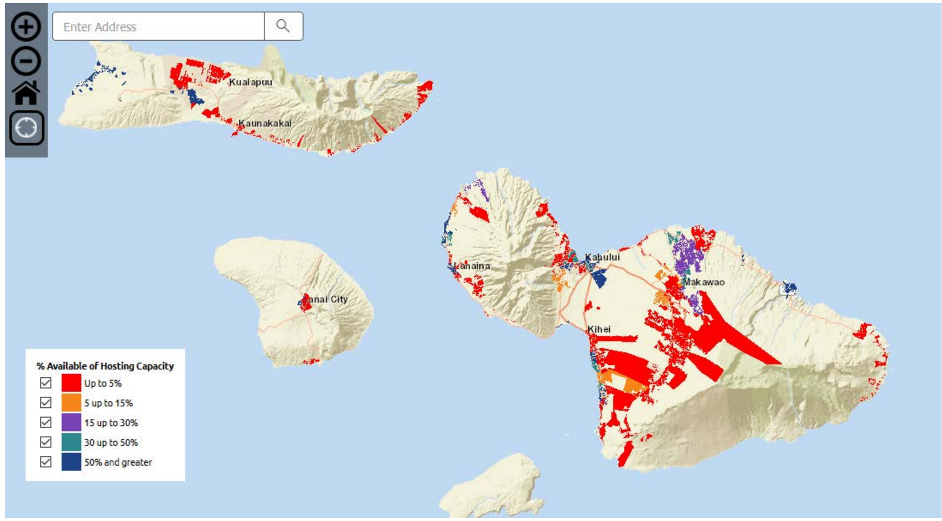
System Operations

Distribution System

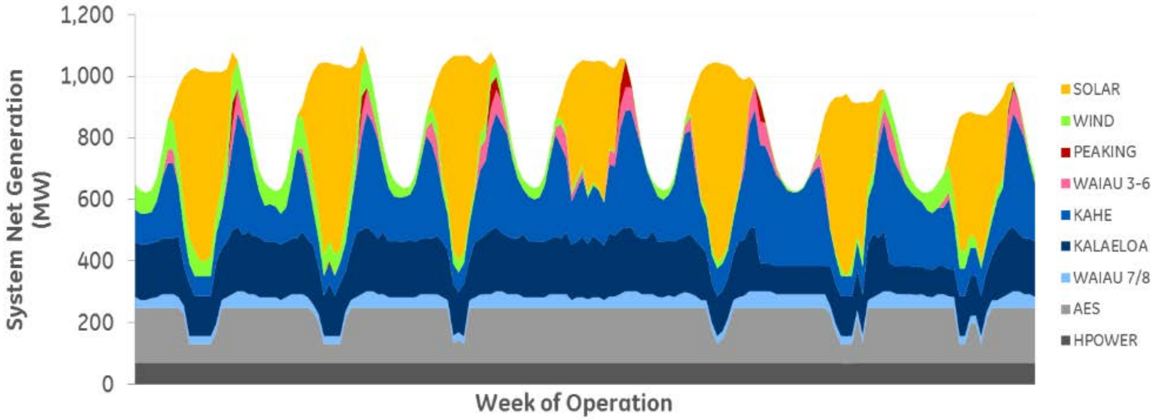
- Voltage issues due to PV deployment- PV hosting
- Interconnection and integration
  - Impacts of a wave deployment?
  - Strict utility interconnection requirements: frequency-watt response and reactive power

Bulk System

- Provision of reserves to maintain system frequency
  - Lack of resource diversity
    - Reliance on wind or solar and fossil units
- Operator challenges: meeting reserve needs
  - Heavily reliant on fossil resources to balance renewables, reluctant to rely on alternatives



Available PV (and DER) hosting capacity on the distribution system.

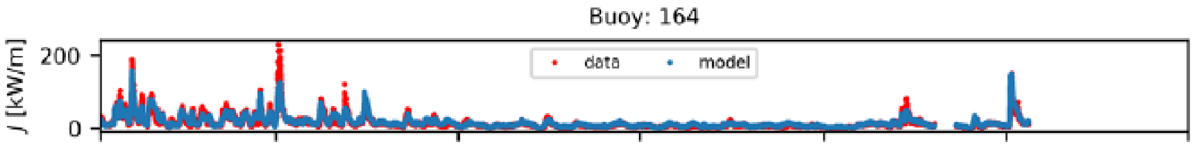


System generation profile for a typical week on Oahu.

Source: Hawaiian Electric, GE Power

Operational Implications

- Marine energy integration presents potential for benefits but also challenges
- Marine energy can provide:
    1. Relatively high capacity value and lower integration costs than alternatives
    2. Reduction in reserve requirements or even provision of reserves



Correlation between energy density for predicted output vs, buoy data in Hawaii.

Predictability of the resource can address operational planning imbalances: PNNL modeling shows the Hawaiian wave resource can be predicted.

Avoid negative impacts with:

- Integrated and external smoothing (mechanical/electrical storage)
- Smart inverters
- Arrayed deployment
- Site specific evaluation of load and other resources to ensure complementarity
    - Hawaii: Year round waves that peak in winter months <-> low solar in winter months with a relatively even load profile

Source: PNNL

Island of Bermuda: Land Use Constraints

- Bermuda is highly dependent on imported oil: nearly 100% of electricity
- Land constraints prevent onshore wind development and limit solar development
  - 15 MW maximum of solar, peak demand is 107 MW
- Resource assessments indicate significant wave potential and some tidal potential. Marine energy (wave & tidal) could complement offshore wind:
  - Resource diversity
  - Load and resource complementarity

Bermuda's 2009 Integrated Resource Plan selected a 20 MW commercial wave farm as one of its preferred projects

Image Source: NASA

Development Challenges

Bermuda's 2019 IRP Statement on Marine Energy

"Although it is acknowledged that marine generators, including wave and tidal generation technologies, have potential for the Bermuda context, **there was insufficient evidence of commercial operation in another jurisdiction at grid scale to justify their inclusion in this IRP**. A review of the international market for marine technologies also **revealed that the costs are currently too high to compete**."

Challenges

- Proving resource value
- Identifying investors who are willing to invest
- Utility structures and economic conditions

Experience with other emerging technologies in island and remote communities shows promise from:

- Green electricity mandates
- Encouraging private development
  - Contracting- PPAs
  - Permitting and siting
  - Public-private partnerships
- International aid funding

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Considerations for Marine Energy Development

These case studies demonstrate and establish value but **its quantification will be critical in supporting development.**

Benefits are site specific and depend on the resource. However, in the right situations, marine energy can:

1. Provide resource diversity, complementing other resources to achieve energy goals
2. Deliver a predictable and sustained resource that supports the grid
3. Provides a mechanism to avoid land constraints and deliver energy security and sustainability

This project is an ongoing effort to quantify these value streams through

- Avoided costs of alternate resources for balancing (overbuild of other renewables, energy storage deployment, etc.)
- System operating cost reductions
- Avoided fossil fuel costs (e.g. reliability and energy security)
- Reliability and resiliency

Thank you

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pnnl.gov/projects/marine-energy-grid-value